Water Quality Management Plan

2025/September

Version 1

Table of contents

Chapter 1 Preamble

This document compiles the following materials produced under the “The Project on Capacity Development of KUKL to Improve Overall Water Supply Service in Kathmandu Valley”.

- List of Standard Operating Procedures (SOPs) for WTP O&M and Water Quality Management
- WTP maintenance plan
- Water quality monitoring plan for WTP process control, Service reservoir monitoring and Tap water monitoring
- Risks Anticipated in Water Treatment Plant O&M and Their Management Policies
- Coordination among KUKL water quality concerning departments based on the PDCA cycle

This document constitutes the Water Quality Management Plan within KUKL.

We hope that this document will be referred by KUKL and fruits of “The Project on Capacity Development of KUKL to Improve Overall Water Supply Service in Kathmandu Valley” will be utilized continuously in KUKL.

Sep.25/2025

JICA Expert team

.

Chapter 2 SOP List

This chapter shows a list of Standard Operating Procedures (SOPs) for the operational management of water treatment plants and associated water quality measurements.

When performing each task, refer to the SOP to ensure that operations are conducted correctly and properly.

The latest SOPs are available from the following web page.

Ref: http://www.kukl-jica.sakura.ne.jp/nrw.html

2.1 SOP list for WTP O&M

Table 2.1 SOPs on WTP O&M

WTP	Title
Mahankalchaur	SOP Mahankalchaur WTP - Integrated Version
	SOP Mahankalchaur WTP - Overview
	SOP Mahankalchaur WTP – Flocculation / Sedimentation
	SOP Mahankalchaur WTP - Rapid Filtration
	SOP Mahankalchaur WTP - Chemical
Bode	SOP Bode WTP - Integrated Version
	SOP Bode WTP - Overview
	SOP Bode WTP – Flocculation / Sedimentation
	SOP Bode WTP - Rapid Filtration
	SOP Bode WTP - Chemical
Bansbari	SOP Bansbari WTP - Integrated Version
	SOP Bansbari WTP - Overview
	SOP Bansbari WTP – Flocculation / Sedimentation
	SOP Bansbari WTP - Rapid Filtration
	SOP Bansbari WTP - Chemical
New Sundarijal	SOP New Sundarijal WTP - Integrated Version

2.2 SOP list for Water quality monitoring

Table 2.2 SOPs on water quality monitoring

No.	Title
1	Sampling and Preservation
2	Turbidity
3	Turbidity Monitoring for Branch Office
4	pH (Mahankalchaur Laboratory)
5	pH Measurement (Bansbari Laboratory)
6	Electrical Conductivity (EC)
7	Multiparameter (pH, EC)
8	EC Meter (Bansbari Laboratory)
9	Total Iron
10	Total Ammonia
11	Total Hardness
12	Total Chloride
13	Total Alkalinity
14	Residual Chlorine Meter (HACH DR300)
15	Residual Chlorine Meter (Palin TEST PTH027)
16	Residual Chlorine Meter (Pocket Photometer, Branch water quality monitoring)
17	Multiple Tube Fermentation for Total Coliforms
18	Membrane Filter Method for Coliforms and Escherichia Coli
19	Jar Test
20	Chlorine Demand Test

Chapter 3 WTP O&M Plan

This chapter outlines the fundamental aspects of WTP O&M, including the desludging, backwashing, and chlorination. For the operation of WTP, refer to the SOP for each WTP.

3.1 Management of operations (General provisions)

Pay attention to changes in water quality (Turbidity) during the purification process and operate accordingly.

Common matters in the management of WTP operations are outlined below.

Table 3.1 Basic operations according to changes in water quality (turbidity)

Treatment process	Response to Increased Turbidity
Raw water	✓ Increase in flocculant injection rate. ✓ Should an extreme rise in turbidity be observed, stop water intake.
Pre-sedimentation water	✓ Adjustment of coagulant injection rate, lime injection rate, and pH adjustment. ✓ Implementation of desludging.
Pre-filtration water	✓ Review the coagulation-sedimentation process to reduce turbidity loading to the sand filters. ✓ Monitor contamination levels on the surface of the sand filter beds and perform backwashing as required.
Clear water	✓ Water supply halt. ✓ Investigate the operational status of the coagulation-sedimentation process and sand filtration process to identify and resolve issues in water purification operations.

3.2 Maintenance during normal operation

3.2.1 Mahankalchaur WTP

(1) Desludging

The sections where desludging operations are conducted and the monthly frequency of desludging are shown below.

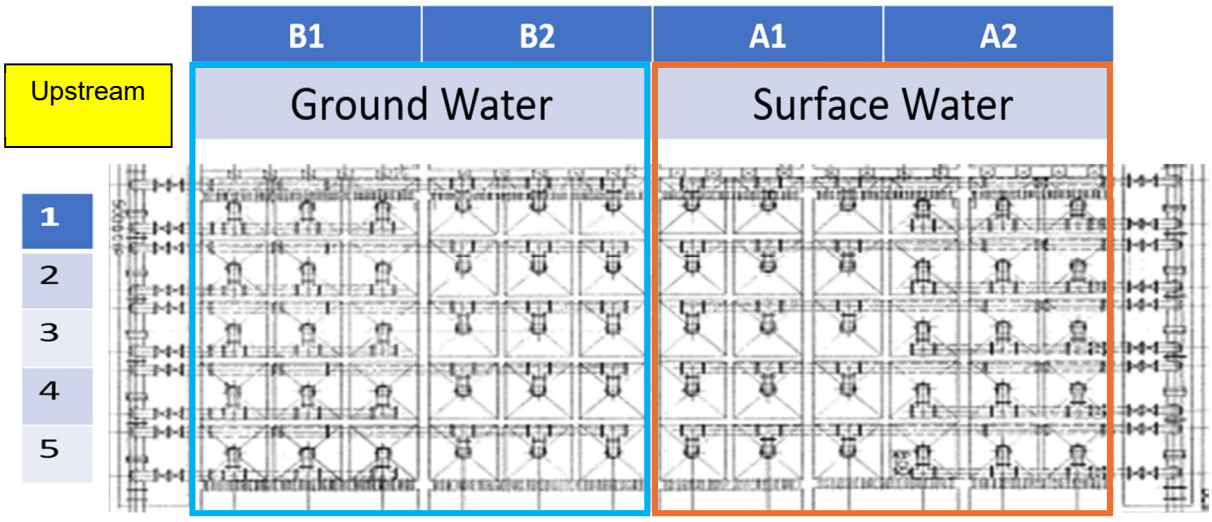

Figure 3.1 Section division of the sedimentation tank in the desludging operations

Table 3.2 Desludging Schedule (Desludging / Month: As of 2082/4)

Lane	B1	B2	A1	A2
1	4	4	4	4
2	4	4	4	4
3	4	4	4	4
4	4	4	4	4
5	4	4	4	4
Total	20	20	20	20

Note: The frequency of deluding should be determined as appropriate, considering changes in the in the quality of the sedimented water (turbidity).

(2) Backwash

The sections where backwashing operations are conducted and the monthly frequency of backwashing are shown below.

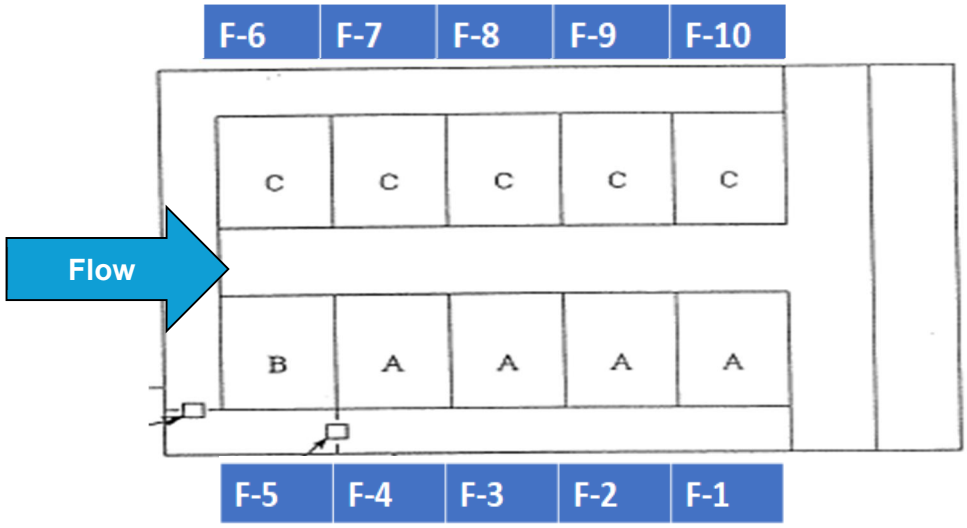

Figure 3.2 Section division of the sand filtration tank in the backwashing operations

Table 3.3 Backwashing Schedule (Backwashing / Month: As of 2082/4)

F-6	F-7	F-8	F-9	F-10
12	12	12	13	14
F-5	**F-4**	**F-3**	**F-2**	**F-1**
13	13	13	12	13

Note: The frequency of backwashing should be determined as appropriate, considering changes in the head increase of the filtration tank and changes in the quality of the filtered water (turbidity).

(3) Water quality target value

Efforts should be made to maintain the following water quality at the outlet of WTP (Clear water tank).

Table 3.4 Target water quality in the clear water tank

Item	Target value
Clearness	Turbidity < 5 NTU
Biological safety	Free residual chlorine 1.0 mg/L

3.2.2 Bansbari WTP

(1) Desludging

The sections where desludging operations are conducted and the monthly frequency of desludging are shown below.

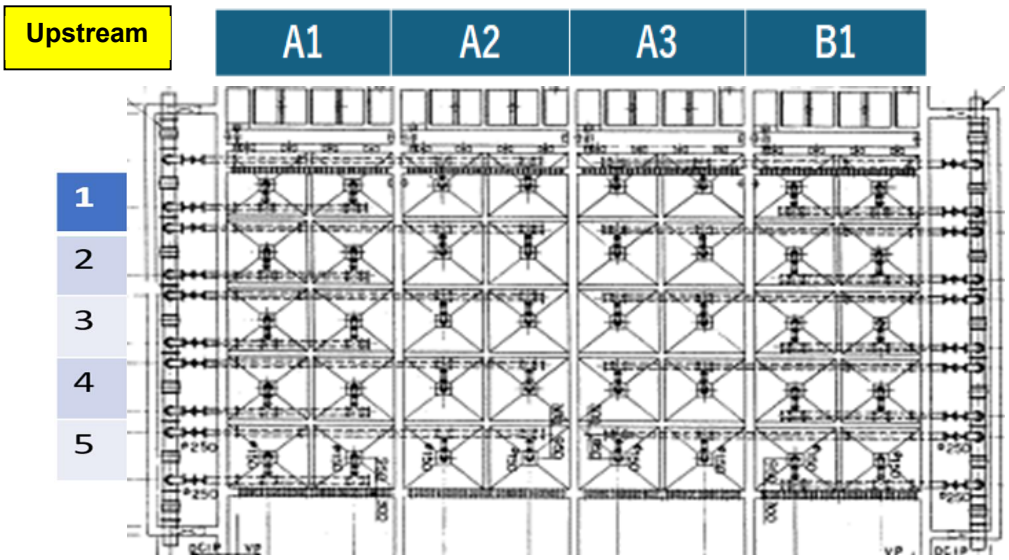

Figure 3.3 Section division of the sedimentation tank in the desludging operations

Table 3.5 Desludging Schedule (Desludging / Month: As of 2082/4)

Lane	A1	A2	A3	B1
1	3	3	3	3
2	3	3	3	3
3	3	3	3	3
4	3	3	3	3
5	3	3	3	3
Total	15	15	15	15

Note: The frequency of deluding should be determined as appropriate, considering changes in the in the quality of the sedimented water (turbidity).

(2) Backwash

The sections where backwashing operations are conducted and the monthly frequency of backwashing are shown below.

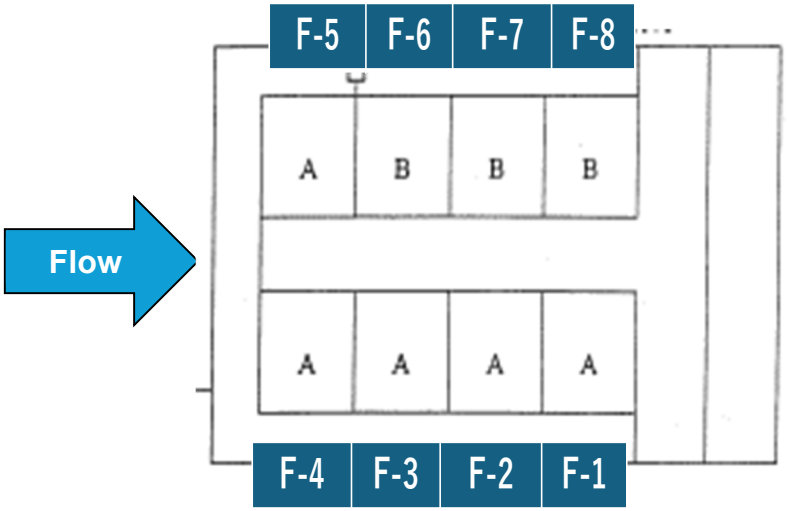

Figure 3.4 Section division of the sand filtration tank in the backwashing operations

Table 3.6 Backwashing Schedule (Backwashing / Month: As of 2082/4)

F-5	F-6	F-7	F-8
5	8	9	10
F-4	**F-3**	**F-2**	**F-1**
4	4	6	5

Note: The frequency of backwashing should be determined as appropriate, considering changes in the head increase of the filtration tank and changes in the quality of the filtered water (turbidity).

(3) Water quality target value

Efforts should be made to maintain the following water quality at the outlet of WTP (Clear water tank).

Table 3.7 Target water quality in the clear water tank

Item	Target value
Clearness	Turbidity < 5 NTU
Biological safety	Free residual chlorine 1.0 mg/L

3.2.3 Bode WTP

(1) Desludging

The sections where desludging operations are conducted and the monthly frequency of desludging are shown below.

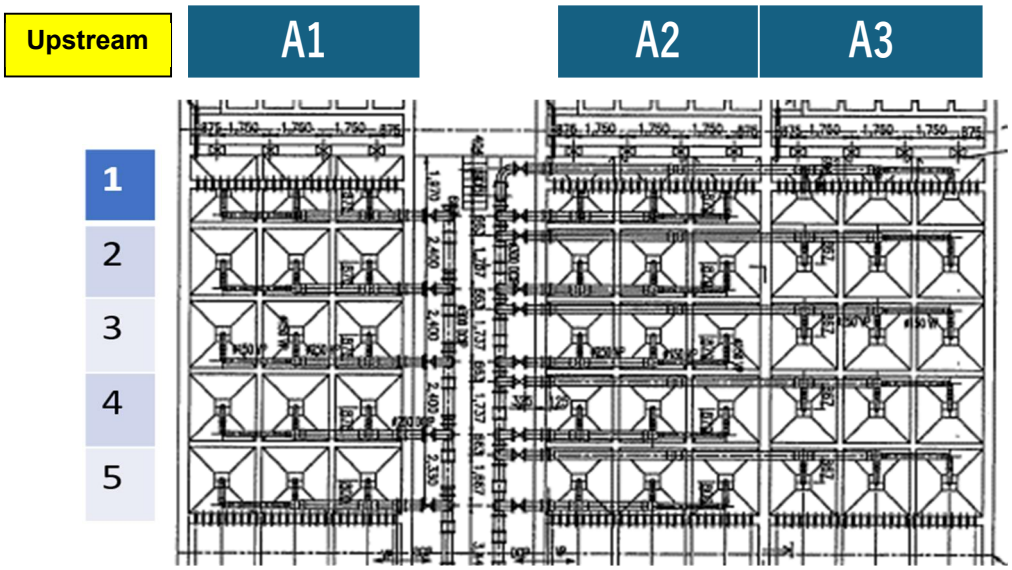

Figure 3.5 Section division of the sedimentation tank in the desludging operations

Table 3.8 Desludging Schedule (Desludging / Month: As of 2082/4)

Lane	A1	A2	A3
1	3	3	3
2	3	2	3
3	2	3	3
4	3	2	3
5	3	2	2
Total	14	12	14

Note: The frequency of deluding should be determined as appropriate, considering changes in the in the quality of the sedimented water (turbidity).

(2) Backwash

The sections where backwashing operations are conducted and the monthly frequency of backwashing are shown below.

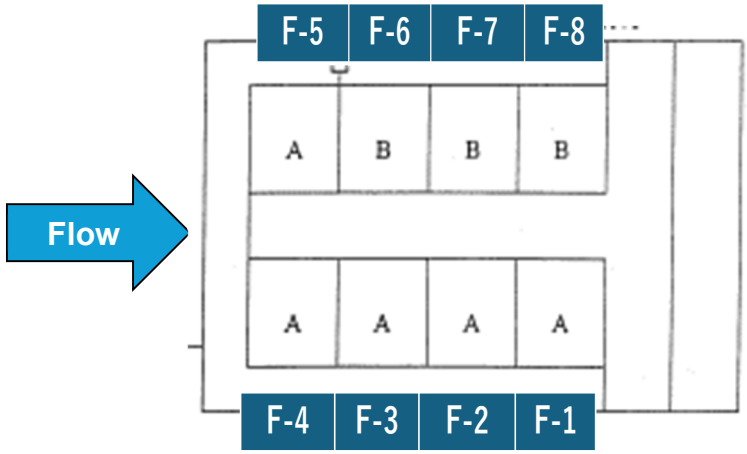

Figure 3.6 Section division of the sand filtration tank in the backwashing operations

Table 3.9 Backwashing Schedule (Backwashing / Month: As of 2082/4)

F-5	F-6	F-7	F-8
21	25	36	28
F-4	**F-3**	**F-2**	**F-1**
14	14	15	27

Note: The frequency of backwashing should be determined as appropriate, considering changes in the head increase of the filtration tank and changes in the quality of the filtered water (turbidity).

(3) Water quality target value

Efforts should be made to maintain the following water quality at the outlet of WTP (Clear water tank).

Table 3.10 Target water quality in the clear water tank

Item	Target value
Clearness	Turbidity < 5 NTU
Biological safety	Combined residual chlorine 1.0 mg/L

Note: At Bode WTP, it is estimated that free residual chlorine is hardly retained due to the influence of ammonia in the raw water. As ammonia removal is not achieved under current operational conditions, disinfection capacity must be secured through combined residual chlorine.

3.2.4 New Sundarijal WTP

(1) Desludging

The sections where desludging operations are carried out and the monthly frequency of desludging are shown below.

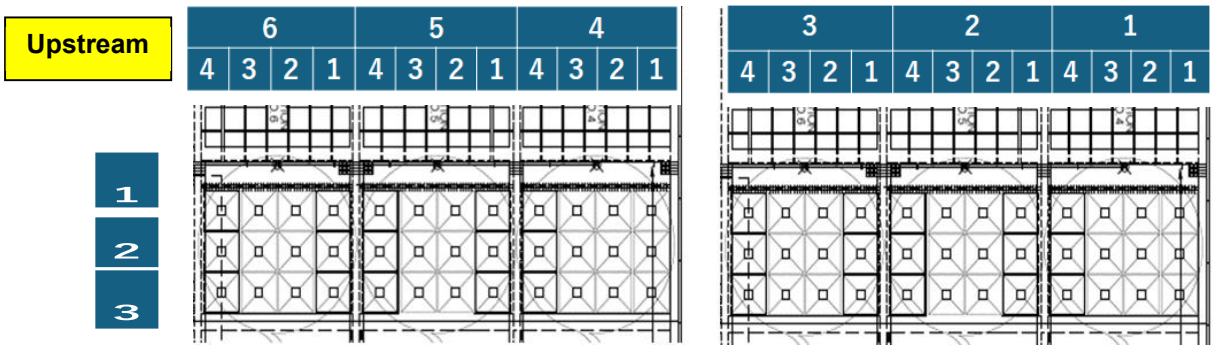

Figure 3.10 Section division of the sedimentation tank in the desludging operations

Table 3.11 Desludging Schedule (Desludging / Month: As of 2082/4)

Lane	6	5	4	3	2	1
1	5	5	6	6	6	6
2	5	5	6	6	6	6
3	5	5	6	6	6	6
Total	15	15	18	18	18	18

Note: The frequency of deluding should be determined as appropriate, considering changes in the in the quality of the sedimented water (turbidity).

(2) Backwash

The sections where backwashing operations are carried out and the monthly frequency of backwashing are shown below.

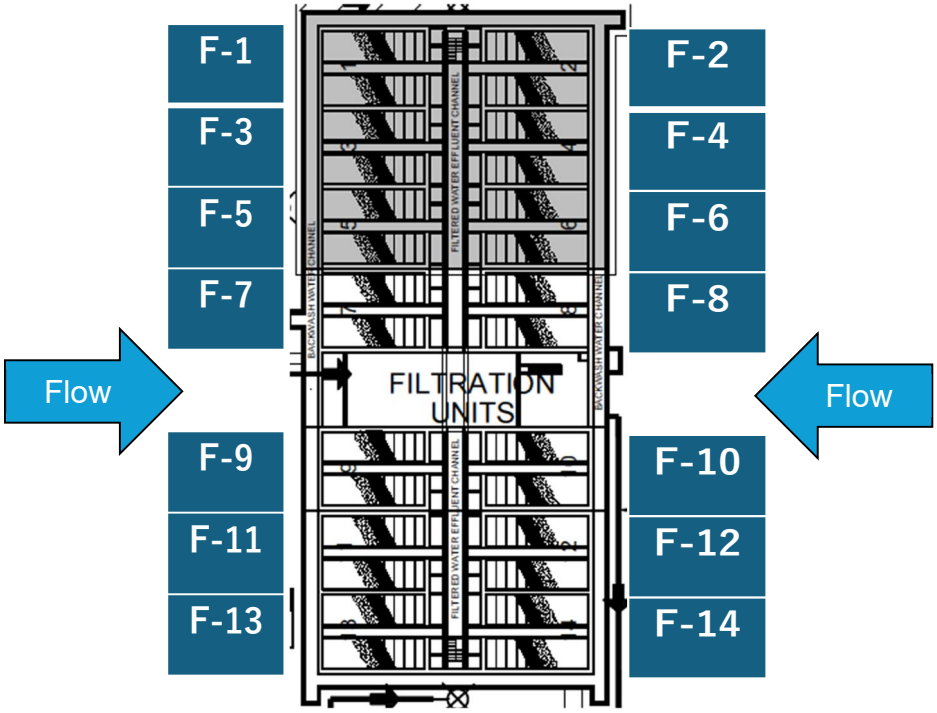

Figure 3.11 Section division of the sand filtration tank in the backwashing operations

Table 3.12 Backwashing Schedule (Backwashing / Month: As of 2082/4)

F-1	F-3	F-5	F-7	F-9	F-11	F-13
6	6	10	8	7	0	6
F-2	**F-4**	**F-6**	**F-8**	**F-10**	**F-12**	**F-14**
6	6	9	5	7	4	2

Note: The frequency of backwashing should be determined as appropriate, considering head increase of the filtration tank and changes in the quality of the filtered water (turbidity).

(3) Water quality target value

Efforts should be made to maintain the following water quality at the outlet of WTP (Clear water tank).

Table 3.13 Target water quality in the clear water tank

Item	Target value
Clearness	Turbidity < 5 NTU
Biological safety	Free residual chlorine 1.2 mg/L

Note: New Sundarijal WTP has set a higher free residual chlorine concentration than other WTPs because it supplies water over a wider area.

Chapter 4 Water quality monitoring plan

This chapter describes the implementation plan for water quality monitoring in the water quality management plan (i.e., monitoring locations, implementing laboratories, monitoring items, and schedule), and also describes the applicable water quality analysis SOPs.

Water quality monitoring in water supply management plans can be divided into the following two categories.

1) Monitoring for water treatment process management at water treatment plants (Section 4.1 WTP monitoring plan)
2) Monitoring for quality assurance of distribution systems and service taps (Section 4.1.2 BDS and service tap monitoring plan)

4.1 WTP monitoring plan

WTP monitoring is water quality monitoring for controlling the water treatment process at the WTP. Monitoring is conducted by each WTP's laboratory

Sampling points, schedule, and monitoring items are shown below.

Table 4.1 New Sundarijal WTP

Sampling point	Schedule	Monitoring item
Raw water	8 times a day	Turbidity, pH, Total alkalinity
Settled water	8 times a day	Turbidity, pH, Total alkalinity
Treated water	8 times a day	Turbidity, pH, EC, Total alkalinity, FRC

Table 4.2 Mahankalchaur WTP

Sampling point	Schedule	Monitoring item
Raw water	4 times a day	Turbidity, pH, Total alkalinity
Settled water	4 times a day	Turbidity, pH, Total alkalinity
Treated water	4 times a day	Turbidity, pH, EC, Total alkalinity, FRC

Table 4.3 Bansbari WTP

Sampling point	Schedule	Monitoring item
Raw water	3 times / day	Turbidity, pH, Total alkalinity
Settled water	3 times / day	Turbidity, pH, Total alkalinity
Treated water	3 times / day	Turbidity, pH, EC, Total alkalinity, FRC

Table 4.4 Bode WTP

Sampling point	Schedule	Monitoring item
Raw water	3 times / day	Turbidity, pH, Total alkalinity
Settled water	3 times / day	Turbidity, pH, Total alkalinity
Treated water	3 times / day	Turbidity, FRC, Combined residual chlorine, Total Iron, Total Ammonia, pH, Total Alkalinity

SOPs corresponding to the analytical equipment deployed in each laboratory are listed below (***Ref***: Chapter 2). When conducting water quality analysis tasks, refer to the SOPs to ensure correct operation.

Table 4.5 List of Water quality equipment and SOPs

Laboratory	Monitoring item	SOP No.	Title of SOPs
New Sundarijal Laboratory	Turbidity	TURB001	Turbidity
	FRC	TURB002	TB300IR
	pH	pH001	pH
	EC	EC001	Electrical Conductivity
	Total alkalinity	TALK001	Total Alkalinity
Mahankalchaur Laboratory (Central Laboratory)	Turbidity	TURB001	Turbidity
	FRC	FRC001, CM001	Free Residual Chlorine, Chlorometer
	pH	pH001	pH
	EC	EC001	Electrical Conductivity
	Total alkalinity	TALK001	Total Alkalinity
Bansbari Laboratory	Turbidity	TURB002	TB300IR
	FRC	FRC001	Free Residual Chlorine
	pH	pH001	pH
	EC	EC001	Electrical Conductivity
	Total alkalinity	TALK001	Total Alkalinity
Bode Laboratory	Turbidity	TURB003	TB 211
	FRC	CM001	Chlorometer
	Combined residual chlorine	CM001	Chlorometer
	pH	pH001	pH
	EC	EC001	Electrical Conductivity
	Total Iron	TFe001	Total Iron
	Total ammonia	TAm001	Total Ammonia
Common items	Sampling and Sample handling	-	Sampling and preservation

4.2 Bulk Distribution System and Service tap monitoring plan

Melamchi BDS water quality monitoring will be conducted at the New Sundarijal WTP and Service reservoir.

The connection diagram of New Sundarijal WTP and each service reservoir on BDS is shown below.

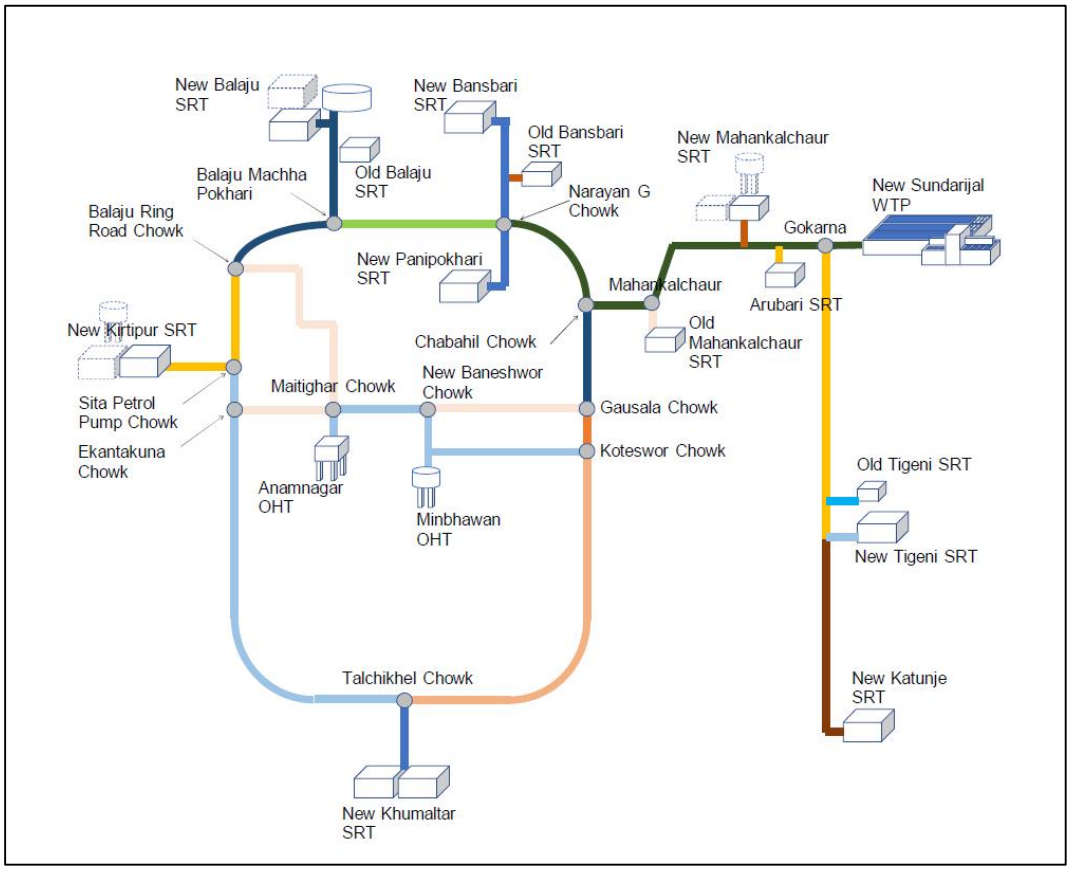

Figure 4.1 Connection diagram of BDS reservoirs

Connection of BDS reservoirs could be divided into two routes: one connecting the service reservoirs located in the area surrounding the Ring Road, and the other connecting Tigeni SRT / New Tigeni SRT and New Katunje SRT.

Table 4.6 New Sundarijal WTP – Surrounding ring route

Location	Schedule	Monitoring by	Sampling point	Monitoring item
New Sundarijal Laboratory	8 times a day	New Sundarijal Laboratory	Clear water tank outlet	Turbidity, FRC, pH, EC
Arubari SRT	Once a week	Central laboratory	Reservoir outlet	
New Mahankalchaur SRT	Once a week			
Bansbari SRT	2 times a day			
Panipokhari SRT	Alternative day			
Balaju SRT	Alternative day			
Kirtipur SRT	Alternative day			
Anamnagar SRT	Daily			
Minbhawan SRT	Daily			
Khumaltar SRT	Alternative day			

Table 4.7 New Sundarijal WTP - Tigeni SRT / New Tigeni SRT - New Katunje SRT

Location	Schedule	Monitoring by	Sampling point	Monitoring item
New Sundarijal WTP	8 times a day	New Sundarijal Laboratory	Clear water tank outlet	Turbidity, FRC, pH, EC
New Tigeni SRT	Once a day	Bode WTP Laboratory	Reservoir outlet	
New Katunje SRT	Once a day	Central Laboratory	Reservoir outlet	

4.3 Service tap monitoring plan

Water quality monitoring of service taps is conducted in cooperation with the Central Laboratory and KUKL branch offices.

The water distribution areas of the WTP covered by this plan are the following three areas.

- Mahankalchaur WTP service area
- Bansbari WTP service area
- Bode WTP service area

The monitoring locations of service taps are shown below.

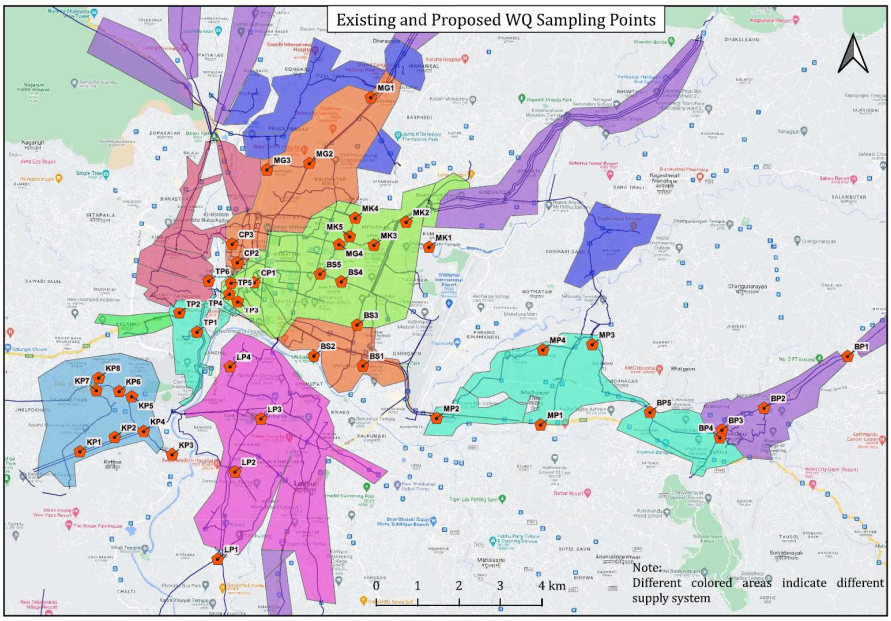

Figure 4.2 Monitoring locations of service tap

Monitoring plan for each WTP distribution area is described below.

Table 4.8 Mahankalchaur WTP service area

Location	Sampling point	Monitoring by	Schedule	Monitoring item
Mahankalchaur WTP	Clear water tank outlet	Central laboratory	4 times a day	Turbidity, FRC, pH, EC
Mahankalchaur branch	Guheshwori (MK1)	Mahankalchaur branch	Weekly*	Turbidity, FRC
	Maijubahal (MK2)			
	Siphal (MK3)			
	Handigaun (MK4)			
	Maligaun (Mk5)			
Baneshwor branch	Maitidevi (BS3)	Baneshwor branch	Weekly*	
	Gyaneshwor (BS4)			
Chhetrapati branch	New road Kumri bank (CP1)	Chhetrapati branch	Weekly*	
Maharajguni branch	Sano Gaucharan (MG4)	Maharajguni branch	Weekly*	
Tripureshwor branch	Lagan (TP3)	Tripureshwor branch	Weekly*	
	Jaisideval (TP4)			
	Jaisideval (TP5)			

* The sampling date is determined in accordance with the water distribution plan.

Table 4.9 Bansbari WTP service area

Location	Sampling point	Monitoring by	Schedule	Monitoring item
Bansbari WTP	Bansbari reservoir	Bansbari WTP Laboratory	3 times / day**	Turbidity, FRC, pH, EC, Alkalinity
Chhetrapati branch	Naradevi (CP2)	Chhetrapati branch	Weekly***	Turbidity, FRC
	Dhalko (CP3)			
Maharajguni branch	Mahapur marga (MG1)	Maharajguni branch	Weekly***	
	Maharajguni office (MG2)			
	Samakhushi Rehdon college (MG3)			

**Monitoring is conducted only on the day of water supply.

*** The sampling date is determined in accordance with the water distribution plan.

Table 4.10 Bode WTP service area

Location	Sampling point	Monitoring by	Schedule	Monitoring item
Bode WTP	Clear water tank outlet	Bode WTP laboratory	3 times / day	Turbidity, FRC, Combined residual chlorine, Total Iron, Total Ammonia, pH
Tigeni Reservoir	Reservoir outlet	Bode WTP laboratory	Once a day	Turbidity, pH, FRC, Combined residual chlorine, EC
Madhyapur-Thimi branch	Sinchitar (MP3)	Madhyapur-Thimi branch	Weekly****	Turbidity, FRC, Combined residual chlorine
	Dhunchepakha (MP4)	Madhyapur-Thimi branch		
	Sankhadhar chowk (MP7)	Madhyapur-Thimi branch		
Bhaktapur branch	Sallaghari (BP3)	Bhaktapur branch	Weekly****	

**** The sampling date is determined in accordance with the water distribution plan.

Water quality monitoring conducted by the branch office shall be carried out in accordance with the following SOPs (***Ref:*** Chapter 2). When conducting water quality analysis tasks, refer to the SOPs to ensure correct operation.

Table 4.11 List of applicable SOPs: Branch office

Laboratory	Monitoring item	SOP No.	Title of SOP
Branch office	Turbidity	EQPTURB001	Turbidimeter
	FRC	CM001	Chlorometer

Note1 : Branch water quality analysis uses common equipment and SOPs.

Note2 : Analysis for *E. coli* is to be done when the FRC is less than 0.2 mg/L.

4.4 Evaluation of Water quality measurement data

4.4.1 WTP monitoring

The evaluation of water quality measurement results in WTP shall be conducted in accordance with the following principles.

Table 4.12 Principles for evaluating water quality monitoring data at WTP

WTP	Sampling point	Principle of data evaluation
All WTP	Raw water	✓ Determination of coagulant injection rate and lime injection rate. ✓ Detection of water quality incidents (high turbidity) and decision-making for intake suspension measures.
	Settled water	✓ Assessment of the appropriateness of operation management in the coagulation – sedimentation process.
	Treated water	✓ Assessment of the clarity and safety of treated water. ✓ The assessment shall be conducted in accordance with the Nepal Drinking Water Quality Standard. ✓ To maintain residual chlorine levels within the water distribution network, the residual chlorine concentration in treated water shall comply with the target levels shown in the table below.

Table 4.13 Residual chlorine target level in treated water

WTP	Management target level in treated water tank
New Sundarijal	1.2 mg/L as Free residual chlorine
Mahankalchaur	1.0 mg/L as Free residual chlorine
Bansbari	1.0 mg/L as Free residual chlorine
Bode	1.0 mg/L as Combined residual chlorine

Note: The issue of ammonia in the raw water at Bode WTP has not been definitively resolved. Therefore, safety of drinking water shall be managed by combined residual chlorine for the time being.

4.4.2 BDS and Service tap

The water quality of BDS and Service Tap shall be determined in accordance with the Nepal drinking water quality standard.

The key parameters are turbidity and residual chlorine. The suitability of water quality shall be determined based on the following standard values.

- ✓ Turbidity: < 5NTU
- ✓ Free residual chlorine: 0.1 mg/L – 0.5 mg/L

Chapter 5 Risk assessment and countermeasures for WTP

This chapter identifies potential hazards and associated risks arising in WTP operations.

For each identified Hazards and Risks, a qualitative risk assessment is conducted to clarify the severity of risks.

In addition, the countermeasures for each hazard and risk are explained, and the related SOPs and manuals to follow are also provided.

5.1 Definition of risk assessment and Risk control

Ref: https://oshatrainingcentre.com/risk-assessment-osha-standards/

What is Risk assessment?

Risk assessment is a fundamental process to identify, evaluate, and control workplace hazards. It plays a crucial role in ensuring worker safety and health by systematically addressing potential risks and implementing measures to mitigate them.

Process of Risk assessment and Risk control

1. ***Identifying Hazards:*** Employers must systematically identify and document workplace hazards through inspections, observations, incident investigations, and input from workers.
2. ***Assessing Risks:*** Once hazards are identified, employers assess the severity of potential harm and the likelihood of exposure to these hazards.
3. ***Controlling Risks:*** Implement controls to eliminate or minimize identified hazards.
4. ***Reviewing and Updating:*** Regularly review and update risk assessments to reflect changes in process, equipment, and workplace conditions.

5.2 Calculation method for Qualitative Risk assessment

Risk assessment for each WTP (New Sundarijal, Mahankalchaur, Bansbari and Bode WTP) was conducted in accordance with the Water Safety Plan Handbook Nepal 2013.

Calculate risk rating for each extracted hazard/risk and evaluate its significance and priority.

The risk rating is calculated as follows.

Risk rating = “Likelihood coefficient” x “Severity / Consequence coefficient”

The likelihood coefficient and severity/consequence coefficient are defined as follows .

Table 5.1 Likelihood coefficient and Definition

Description	Definition	Likelihood coefficient
Unlikely	It could occur at some time but has not been observed; it may occur only in exceptional circumstances.	1
Possible	Might occur at some time; has occurred occasionally (e.g., monthly to quarterly or seasonally)	2
Likely	Will occur in most circumstances; has been observed regularly (e.g., daily to weekly)	3

Table 5.2 Severity / Consequence coefficient and Definition

Description	Definition	Severity / Consequences coefficient
No / Minor impact	**Minor or negligible Water Quality impact**; e.g., not enough related, aesthetic impact for a small percentage of customers; some manageable disruptions to operation; rise in complaints not significant	1
Moderate impact	**Minor Water Quality impact**; e.g., not health related, aesthetic impact for a significant percentage of customers; clear rise in complaints; community annoyances; minor breach of regulatory requirement	2
Major impact	**Major Water Quality impact**; e.g., illness in community associated with water supply, considerable number of complaints; significant level of customer concerns; significant breach of regulatory requirement	3

The calculated risk rating is assessed according to its numerical value across three risk levels.

Risk rating calculation			***Severity / Consequence***		
			No / Minor impact	Moderate impact	Major impact
			1	2	3
Likelihood	Unlikely	1	1	2	3
	Possible	2	2	4	6
	Likely	3	3	6	9

Figure 5.1 Risk rating calculation matrix

Table 5.3 Definition of Risk rating

Risk rating	***Risk Level***	***Definition***
6 - 9	High	Clearly a priority; requires urgent attention
3 – 5	Medium	Medium-term or Long-term priority; requires some attention
1 – 2	Low	Clearly not a priority

5.3 Risk assessment results for each WTP

The results of the risk assessment for each water treatment plant are shown on the following pages. The table has been amended to include the rationale for selecting the Likelihood coefficient and Severity / Consequence coefficient for each event.

Table 5.4 Risk analysis: New Sundarijal WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Likelihood (A)	Reasons for determining the "Likelihood coefficient" (A)	Severity (B)	Reasons for determining the "Severity coefficient" (B)	Risk Score (A×B)	Risk Rating
Natural disaster	Heavy rain	Inundation of WTP	Biological pollution of treated water	2	This phenomenon occurs due to rainfall within seasonal variations.	3	As this relates to treated water quality and drinking water safety..	6	High
			Turbidity increase of treated water	2	This phenomenon occurs due to rainfall within seasonal variations.	3	As this relates to treated water quality and drinking water safety.	6	High
			Damage of equipment	2	This phenomenon occurs due to rainfall within seasonal variations.	3	As this relates to treated water quality and drinking water safety	6	High
Power source	Electricity	Power outage	Loss of WTP function	1	Power outages are not a regularly occurring phenomenon, and it was determined that they are an event that occurs only occasionally.	3	Should the water treatment plant cease functioning due to a power outage, safe water supply would become impossible, with the impact spreading over a wide area.	3	Medium
	Generator	Lack of fuel	Loss of auxiliary power and loss of WTP function	1	The failure of generators due to fuel shortages is an event that must be prevented through routine management of fuel stocks. That is to say, it is an event that ought to occur only rarely. For this reason, coefficient 1 was assigned.	2	The failure of generators (emergency power source) due to fuel shortages is an event that should be prevented from occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.	2	Low
		Malfunction	Loss of auxiliary power and	1	The failure of a generator rendering it unusable is an event	2	The failure of generators (emergency power sources) due to	2	Low

			loss of WTP function		that must be prevented through routine generator maintenance (this is the meaning of preventive maintenance). That is to say, it is an event that should rarely occur. For this reason, coefficient 1 was assigned.		mechanical trouble is an event that should be prevented from occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.		
Melamuchi water quality	Rainfall	Increase turbidity	–	2	As this phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	2	The impact of fluctuations in turbidity and alkalinity on water treatment processes can be mitigated by carefully operating coagulation - sedimentation processes based on raw water quality monitoring. For this reason, coefficient of 2 was assigned.	4	Medium
		Decrease alkalinity	–	2	As this phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	2	The impact of fluctuations in turbidity and alkalinity on water treatment processes can be mitigated by carefully operating of alkalinity adjustment and coagulant injection control based on raw water quality monitoring. For this reason, coefficient of 2 was assigned.	4	Medium
Water quality of Dam & Reservoir	Algal proliferation	Decrease pH	–	2	The proliferation of algae in dam lakes is attributable to natural phenomena such as temperature fluctuations and	2	The impact of pH fluctuations on water treatment processes can be mitigated by carefully operating pH control based on raw	4	Medium

					precipitation. For this reason, coefficient 2 was assigned.		water quality monitoring. For this reason, coefficient of 2 was assigned.		
Procurement of water purification chemicals	Difficulty in chemical procurement	Insufficient coagulant injection	Poor floc formation and increasing turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
		Insufficient lime injection	Poor floc formation and increasing turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
		Insufficient chlorine injection	Increase biological hazard due to incomplete chlorination	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	3	Incomplete chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium

Chemical dissolution facilities	Failure of chemical dissolution facilities	Difficult to control coagulant injection	Poor floc formation	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
		Difficult to control lime injection	Poor floc formation	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
Chlorine gas disinfection facility	Chlorine gas injection failure	Chlorine gas leakage	Woker injury	1	The functions within WTP must be maintained in consistently good operating conditions through regular maintenance activities. Particular attention must be paid to the safety management of equipment handling chlorine gas at all times, and it must be managed with care. For this reason, coefficient 1 was assigned.	3	Chlorine gas is a toxic substance, and its leakage into the work area or outside would have significant consequences. For this reason, a coefficient of 3 was assigned.	3	Medium
		Leakage outside WTP	Hazards to surrounding	1	The functions within WTP must be	3	Chlorine gas is a toxic substance, and its	3	Medium

			areas due to chlorine gas		maintained in consistently good operating conditions through regular maintenance activities. Particular attention must be paid to the safety management of equipment handling chlorine gas at all times, and it must be managed with care. For this reason, coefficient 1 was assigned.		leakage into the work area or outside would have significant consequences. For this reason, a coefficient of 3 was assigned.		
		Difficult to control chlorine injection	Insufficient chlorination	2	The functions within WTP must be maintained in consistently good operational conditions through regular maintenance activities. However, the chlorine gas injection equipment has previously experienced malfunctions, making it an event that is more likely to occur compared to leakage accidents For this reason, coefficient 1 was assigned.	3	Insufficient chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	6	High
WTP operation	Failure of coagulant injection	Difficult to control coagulant injection	Poor floc formation and turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low

					avoided. For this reason, coefficient 1 was assigned.				
	Failure of lime injection	Difficult to control lime injection	Poor floc formation and turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
Maintenance of WTP	Insufficient cleaning of sedimentation pond	Increased turbidity load to sand filtration	Decline in sand filter performance	1	The functions within WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in functionality caused by inadequate maintenance activities must be avoided under any circumstances. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Insufficient backwashing of sand filter	Decline in sand filter performance	Increased turbidity in treated water	1	The functions within WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in functionality caused by inadequate maintenance activities must be avoided under any circumstances. For this reason,	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low

					coefficient 1 was assigned.				

Table 5.5 Risk analysis: Mahankalchur WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Likelihood (A)	Reasons for determining the "Likelihood coefficient" (A)	Severity (B)	Reasons for determining the "Severity coefficient" (B)	Risk Score (A×B)	Risk Rating
Natural disaster	Heavy rain	Inundation of WTP due to rainfall	Biological pollution of treated water	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety. For this reason, coefficient 3 was assigned.	6	High
			Turbidity increase of treated water	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety. For this reason, coefficient 3 was assigned.	6	High
			Damage of equipment	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety For this reason, coefficient 3 was assigned.	6	High
Power source	Power supply	Power outage	Loss of WTP function	1	Power outages are not a regularly occurring phenomenon, and it was determined that they are an event that occurs only occasionally. For this reason, coefficient 1 was assigned.	3	Should the water treatment plant cease functioning due to a power outage, safe water supply would become impossible, with the impact spreading over a wide area. For this reason, coefficient 3 was assigned..	3	Medium
	Generator	Lack of fuel	Loss of auxiliary power and loss of WTP function	1	The failure of generators due to fuel shortages is an event that must be prevented through routine management of fuel	2	The failure of generators (emergency power source) due to fuel shortages is an event that should be prevented from	2	Low

					stocks. That is to say, it is an event that ought to occur only rarely. For this reason, coefficient 1 was assigned.		occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.		
		Malfunction	Loss of auxiliary power and loss of WTP function	1	The failure of a generator rendering it unusable is an event that must be prevented through routine generator maintenance (this is the meaning of preventive maintenance). That is to say, it is an event that should rarely occur. For this reason, coefficient 1 was assigned.	2	The failure of generators (emergency power sources) due to mechanical trouble is an event that should be prevented from occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.	2	Low
Water intake facility (Manohara river)	Insufficient river flow of Manohara river	Lack of raw water	Insufficient water supply	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	The insufficient flow of the Manohara River may have long-term effects during certain periods each year. For this reason, coefficient of 3 was assigned.	6	High
	Blockage of collection pipe	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	A shortage of raw water significantly impacts the water treatment plant. However, the malfunctions in the facilities causing this issue are events that should be avoided through routine maintenance and management, and such malfunctions should be promptly rectified through repairs or similar measures.	2	Low

							For this reason, coefficient of 2 was assigned.		
	Malfunction of pump	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	A shortage of raw water significantly impacts the water treatment plant. However, the malfunctions in the facilities causing this issue are events that should be avoided through routine maintenance and management, and such malfunctions should be promptly rectified through repairs or similar measures. For this reason, coefficient of 2 was assigned.	2	Low
Water intake facility (Deep well)	Clogging / breakage of strainers	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	A shortage of raw water significantly impacts the water treatment plant. However, the malfunctions in the facilities causing this issue are events that should be avoided through routine maintenance and management, and such malfunctions should be promptly rectified through repairs or similar measures. For this reason, coefficient of 2 was assigned.	2	Low
	Malfunction of pump	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the	2	A shortage of raw water significantly impacts the water treatment plant. However, the	2	Low

					implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.		malfunctions in the facilities causing this issue are events that should be avoided through routine maintenance and management, and such malfunctions should be promptly rectified through repairs or similar measures. For this reason, coefficient of 2 was assigned.		
Procurement of water purification chemicals	Difficulty in chemical procurement	Insufficient coagulant injection	Poor floc formation and increasing turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
		Insufficient lime injection	Poor floc formation and increasing turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
		Insufficient chlorine injection	Increase biological hazard due	1	The procurement of necessary materials such as water	3	Incomplete chlorination increases the biological hazards of tap water	3	Medium

			to incomplete chlorination		purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.		and reduces its safety. For this reason, coefficient of 3 was assigned.		
Water purification chemical dissolving facility	Failure of coagulant dissolving tank	Inaccurate coagulant injection rate	Insufficient flocculation	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Failure of lime dissolving tank	Inaccurate lime injection rate	Insufficient flocculation	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Failure of bleaching powder dissolving tank	Inaccurate chlorine injection rate	Incomplete chlorination (disinfection) and increase of biological hazard	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of	3	Insufficient chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium

					inactivity must be avoided. For this reason, coefficient 1 was assigned.				
Water purification chemical injection facility	Chemical injection failure (pump, pipeline)	Difficult to control coagulant injection	Poor coagulation, increased turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Chemical injection failure (pipeline)	Difficult to control lime injection	Poor coagulation, increased turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Chemical injection failure (pump, pipeline, rotameter)	Difficult to control chlorine injection	Incomplete chlorination, biological hazard	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	3	Insufficient chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium
Maintenance	Insufficient	Increased	Decline in	1	The functions within	2	Increased turbidity in	2	Low

of WTP	cleaning/desludging of sedimentation pond	turbidity load to sand filtration	sand filter performance		WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in functionality caused by inadequate maintenance activities must be avoided under any circumstances. For this reason, coefficient 1 was assigned.		treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.		
	Insufficient backwashing of sand filter	Decline in sand filter performance	Increased turbidity in treated water	1	The functions within WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in functionality caused by inadequate maintenance activities must be avoided under any circumstances. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low

Table 5.6 Risk analysis: Bansbari WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Likelihood (A)	Reasons for determining the "Likelihood coefficient" (A)	Severity (B)	Reasons for determining the "Severity coefficient" (B)	Risk Score (A×B)	Risk Rating
Natural disaster	Heavy rain	Inundation of WTP due to rainfall	Biological pollution of treated water	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety. For this reason, coefficient 3 was assigned.	6	High
			Turbidity increase of treated water	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety. For this reason, coefficient 3 was assigned.	6	High
			Damage of equipment	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety For this reason, coefficient 3 was assigned.	6	High
Power source	Power supply	Power outage	Loss of WTP function	1	Power outages are not a regularly occurring phenomenon, and it was determined that they are an event that occurs only occasionally. For this reason, coefficient 1 was assigned.	3	Should the water treatment plant cease functioning due to a power outage, safe water supply would become impossible, with the impact spreading over a wide area. For this reason, coefficient 3 was assigned..	3	Medium
	Generator	Lack of fuel	Loss of auxiliary power and loss of WTP function	1	The failure of generators due to fuel shortages is an event that must be prevented through routine	2	The failure of generators (emergency power source) due to fuel shortages is an event that should be	2	Low

					management of fuel stocks. That is to say, it is an event that ought to occur only rarely. For this reason, coefficient 1 was assigned.		prevented from occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.		
		Malfunction	Loss of auxiliary power and loss of WTP function	1	The failure of a generator rendering it unusable is an event that must be prevented through routine generator maintenance (this is the meaning of preventive maintenance). That is to say, it is an event that should rarely occur. For this reason, coefficient 1 was assigned.	2	The failure of generators (emergency power sources) due to mechanical trouble is an event that should be prevented from occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.	2	Low
Raw water quality (Meramuchi water)	Rainfall	Increase turbidity	–	2	As this phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	2	The impact of fluctuations in turbidity and alkalinity on water treatment processes can be mitigated by carefully operating coagulation - sedimentation processes based on raw water quality monitoring. For this reason, coefficient of 2 was assigned.	4	Medium
		Decrease alkalinity	–	2	As this phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	2	The impact of fluctuations in turbidity and alkalinity on water treatment processes can be mitigated by carefully operating of	4	Medium

							alkalinity adjustment and coagulant injection control based on raw water quality monitoring. For this reason, coefficient of 2 was assigned.		
Raw water quality (Local water source)	Rainfall	Increase turbidity	–	2	As this phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	2	The impact of fluctuations in turbidity and alkalinity on water treatment processes can be mitigated by carefully operating coagulation - sedimentation processes based on raw water quality monitoring. For this reason, coefficient of 2 was assigned.	4	Medium
		Decrease alkalinity	–	2	As this phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	2	The impact of fluctuations in turbidity and alkalinity on water treatment processes can be mitigated by carefully operating of alkalinity adjustment and coagulant injection control based on raw water quality monitoring. For this reason, coefficient of 2 was assigned.	4	Medium
Procurement of water purification chemicals	Difficulty in chemical procurement	Insufficient coagulant injection	Poor floc formation and increasing turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient	2	Low

					is an event that should not occur. For this reason, coefficient 1 was assigned.		of 2 was assigned.		
		Insufficient lime injection	Poor floc formation and increasing turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
		Insufficient chlorine injection	Increase biological hazard due to incomplete chlorination	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	3	Incomplete chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium
Water purification chemical dissolving facilities	Failure of coagulant dissolving tank	Inaccurate coagulant injection rate	Insufficient flocculation	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low

	Failure of lime dissolving tank	Inaccurate lime injection rate	Insufficient flocculation	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Failure of bleaching powder dissolving tank	Inaccurate chlorine injection rate	Incomplete chlorination (disinfection) and increase of biological hazard	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	3	Insufficient chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium
Water purification chemical injection facility	Chemical injection failure (pump, pipeline)	Difficult to control coagulant injection	Poor floc formation, turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Chemical injection failure (pipeline)	Difficult to control lime injection	Poor floc formation, turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water	2	Low

					preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.		quality parameter related to safety. For this reason, coefficient of 2 was assigned.		
	Chemical injection failure (pump, pipeline, rotameter)	Difficult to control chlorine injection	Incomplete chlorination, biological hazard	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	3	Insufficient chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium
Maintenance of WTP	Insufficient cleaning/desludging of sedimentation pond	Increased turbidity load to sand filtration	Decline in sand filter performance	1	The functions within WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in functionality caused by inadequate maintenance activities must be avoided under any circumstances. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Insufficient backwashing of sand filter	Decline in sand filter performance	Increased turbidity in treated water	1	The functions within WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For	2	Low

					functionality caused by inadequate maintenance activities must be avoided under any circumstances. For this reason, coefficient 1 was assigned.		this reason, coefficient of 2 was assigned.		

Table 5.7 Risk analysis: Bode WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Likelihood (A)	Reasons for determining the "Likelihood coefficient" (A)	Severity (B)	Reasons for determining the "Severity coefficient" (B)	Risk Score (A×B)	Risk Rating
Natural disaster	Heavy rain	Inundation of WTP due to rainfall	Biological pollution of treated water	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety. For this reason, coefficient 3 was assigned.	6	High
			Turbidity increase of treated water	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety. For this reason, coefficient 3 was assigned.	6	High
			Damage of equipment	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	As this relates to treated water quality and drinking water safety For this reason, coefficient 3 was assigned.	6	High
Power source	Power supply	Power outage	Loss of WTP function	1	Power outages are not a regularly occurring phenomenon, and it was determined that they are an event that occurs only occasionally. For this reason, coefficient 1 was assigned.	3	Should the water treatment plant cease functioning due to a power outage, safe water supply would become impossible, with the impact spreading over a wide area. For this reason, coefficient 3 was assigned..	3	Medium
	Generator	Lack of fuel	Loss of auxiliary power and loss of WTP function	1	The failure of generators due to fuel shortages is an event that must be prevented through routine management of fuel	2	The failure of generators (emergency power source) due to fuel shortages is an event that should be	2	Low

					stocks. That is to say, it is an event that ought to occur only rarely. For this reason, coefficient 1 was assigned.		prevented from occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.		
		Malfunction	Loss of auxiliary power and loss of WTP function	1	The failure of a generator rendering it unusable is an event that must be prevented through routine generator maintenance (this is the meaning of preventive maintenance). That is to say, it is an event that should rarely occur. For this reason, coefficient 1 was assigned.	2	The failure of generators (emergency power sources) due to mechanical trouble is an event that should be prevented from occurring in the first place. However, should it occur, the impact is severe. For this reason, coefficient of 2 was assigned.	3	Medium
Water intake facility (Manohara river)	Insufficient river flow of Manohara	Lack of raw water	Insufficient water supply	2	This phenomenon occurs due to rainfall within seasonal variations. For this reason, coefficient 2 was assigned.	3	The insufficient flow of the Manohara River may have long-term effects during certain periods each year. For this reason, coefficient of 3 was assigned.	6	High
	Blockage of collection pipe	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this	2	A shortage of raw water significantly impacts the water treatment plant. However, the malfunctions in the facilities causing this issue are events that should be avoided through routine	2	Low

					reason, coefficient 1 was assigned.		maintenance and management, and such malfunctions should be promptly rectified through repairs or similar measures. For this reason, coefficient of 2 was assigned.		
	Malfunction of pump	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	A shortage of raw water significantly impacts the water treatment plant. However, the malfunctions in the facilities causing this issue are events that should be avoided through routine maintenance and management, and such malfunctions should be promptly rectified through repairs or similar measures. For this reason, coefficient of 2 was assigned.	2	Low
Water intake facility (Deep well)	Clogging/breakage of strainers	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1	2	A shortage of raw water significantly impacts the water treatment plant. However, the malfunctions in the facilities causing this issue are events that should be avoided through routine maintenance and	2	Low

					was assigned.		management, and such malfunctions should be promptly rectified through repairs or similar measures. For this reason, coefficient of 2 was assigned.		
	Malfunction of pump	Lack of raw water	Insufficient water supply	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	A shortage of raw water significantly impacts the water treatment plant. However, the malfunctions in the facilities causing this issue are events that should be avoided through routine maintenance and management, and such malfunctions should be promptly rectified through repairs or similar measures. For this reason, coefficient of 2 was assigned.	2	Low
Procurement of water purification chemicals	Difficulty in chemical procurement	Insufficient coagulant injection	Poor floc formation and increasing d turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low

					was assigned.				
		Insufficient lime injection	Poor floc formation and increasing turbidity	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
		Insufficient chlorine injection	Increase biological hazard due to incomplete chlorination	1	The procurement of necessary materials such as water purification chemicals must be conducted smoothly and in a planned manner. Procurement stagnation is an event that should not occur. For this reason, coefficient 1 was assigned.	3	Incomplete chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium
Water purification chemical dissolving facilities	Failure of coagulant dissolving tank	Inaccurate coagulant injection rate	Insufficient flocculation	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Failure of lime dissolving tank	Inaccurate lime injection rate	Insufficient flocculation	1	The equipment within WTP should be managed to prevent	2	Increased turbidity in treated water makes it difficult to supply clear	2	Low

					failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.		water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.		
	Failure of bleaching powder dissolving tank	Inaccurate chlorine injection rate	Incomplete chlorination (disinfection) and increase of biological hazard	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	3	Insufficient chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium
Water purification chemical injection facility	Chemical injection failure (pump, pipeline)	Difficult to control coagulant injection	Poor floc formation and increasing turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Chemical injection failure (pipeline)	Difficult to control lime injection	Poor floc formation and increasing turbidity	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient	2	Low

					inactivity must be avoided. For this reason, coefficient 1 was assigned.		of 2 was assigned.		
	Chemical injection failure (pump, pipeline, rotameter)	Difficult to control chlorine injection	Incomplete chlorination and increasing biological hazard	1	The equipment within WTP should be managed to prevent failures through the implementation of preventive maintenance, and prolonged periods of inactivity must be avoided. For this reason, coefficient 1 was assigned.	3	Insufficient chlorination increases the biological hazards of tap water and reduces its safety. For this reason, coefficient of 3 was assigned.	3	Medium
Maintenance of WTP	Insufficient cleaning/desludging of sedimentation pond	Increased turbidity load to sand filtration	Decline in sand filter performance	1	The functions within WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in functionality caused by inadequate maintenance activities must be avoided under any circumstances. For this reason, coefficient 1 was assigned.	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low
	Insufficient backwashing of sand filter	Decline in sand filter performance	Increased turbidity in treated water	1	The functions within WTP must be maintained in good working order at all times through routine maintenance activities. Deterioration in functionality caused by inadequate maintenance activities	2	Increased turbidity in treated water makes it difficult to supply clear water. However, turbidity is not a water quality parameter related to safety. For this reason, coefficient of 2 was assigned.	2	Low

					must be avoided under any circumstances. For this reason, coefficient 1 was assigned.				

5.4 Countermeasures for each Hazards and Risks

The risk ratings derived from risk assessments for each WTP's anticipated Hazards / Risks, and proposed countermeasures for each Hazards / Risks are shown on the following pages.

Table 5.8 Possible Countermeasures for each Hazards and Risks: New Sundarijal WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Risk Rating	Countermeasures	SOPs / Manuals being referenced
Natural disaster	Heavy rain	Inundation of WTP due to rainfall	Biological pollution of treated water	High	• Temporarily suspended water supply • Clean water tank • Conduct water quality tests to confirm compliance with water quality standards before resuming operations	Water Quality Analysis SOPs Nepal Drinking Water Quality Standards New Sundarijal WTP SOP
			Turbidity increase of treated water	High	Water supply temporarily suspended Cleaning of the clear water tank Water quality tests were conducted to confirm compliance with water quality standards before operations resumed.	Water Quality Analysis SOPs (Table 4.5) Nepal Drinking Water Quality Standards New Sundarijal WTP SOP
			Damage of equipment	High	Temporary suspension of WTP operation Prompt implementation of repairs to the relevant equipment	Service manuals for each equipment
Power source	Electricity	Power outage	Loss of WTP function	Medium	Start the generator to maintain WTP function.	Generator operation manual
	Generator	Lack of fuel	Loss of auxiliary power and loss of WTP function	Low	Check fuel inventory Ensure sufficient fuel is always available	Fuel inventory
		Malfunction	Loss of auxiliary power and loss of WTP function	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Generator service manual
Melamuchi water quality	Rainfall	Increase turbidity	–	Medium	Set the appropriate chemical injection rate based on water quality measurement data.	Water Quality Analysis SOPs (Table 4.5) Nepal Drinking Water Quality Standards

					Should water quality values significantly deviating from normal be detected, water intake shall be temporarily suspended.	New Sundarijal WTP SOP
		Decrease alkalinity	–	Medium	Set the appropriate chemical injection rate based on water quality measurement data. Should water quality values significantly deviating from normal be detected, water intake shall be temporarily suspended.	Water Quality Analysis SOPs (Table 4.5) Nepal Drinking Water Quality Standards New Sundarijal WTP SOP
Water quality of Dam & Reservoir	Algal proliferation	Decrease pH	–	Medium	Set the appropriate chemical injection rate based on water quality measurement data. Should water quality values significantly deviating from normal be detected, water intake shall be temporarily suspended.	Water Quality Analysis SOPs (Table 4.5) Nepal Drinking Water Quality Standards New Sundarijal WTP SOP
Procurement of water purification chemicals	Difficulty in chemical procurement	Lack of coagulants, Insufficient coagulant injection	Poor floc formation and increasing turbidity	Low	Check coagulant inventory Ensure sufficient coagulant is always available **Response in the event of prolonged procurement difficulties** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	Coagulant inventory
		Lack of lime, Insufficient lime injection	Poor floc formation and increasing turbidity	Low	Check lime inventory Ensure sufficient lime is always available **Response in the event of prolonged procurement difficulties** Refer to inventory levels at other water treatment plants and facilitate mutual	Lime inventory

					supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	
		Lack of chlorine gas, insufficient chlorine injection	Increase biological hazard due to incomplete chlorination	Medium	Check chlorine gas inventory Ensure sufficient chlorine gas is always available **<u>Response in the event of prolonged procurement difficulties</u>** Assuming the cessation of operations of New Sundarijal Water Treatment Plant, review the operational plans and water distribution plans for other water treatment plants.	Chlorine gas inventory
Chemical dissolution facilities	Failure of chemical dissolution facilities	Difficult to control coagulant injection	Poor floc formation	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus New Sundarijal WTP SOP
		Difficult to control lime injection	Poor floc formation	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus New Sundarijal WTP SOP
Chlorine gas disinfection facility	Chlorine gas injection failure	Chlorine gas leakage	Woker injury	Medium	Close all valves Start exhaust system Evacuate from chlorine gas handling room and go to the **upwind side** **Note:** In the event of an incident related toxic gas, evacuate to the upwind side. Before re-entering the room, ensure that	Chlorine gas facility safety measures manual ***Ref***: OSHA Web page https://www.osha.gov/chemicaldata/650

					the chlorine gas concentration has decreased to a safe level.	
		Leakage outside WTP	Hazards to surrounding areas due to chlorine gas	Medium	Immediately notify nearby residents and direct them to evacuate to the upwind side of the water treatment plant. Vent the chlorine gas from the room Once the chlorine gas has reached a safe concentration, proceed with repairing the leak Once the chlorine gas leak has been stopped and it has been confirmed that the chlorine gas concentration downwind has reached the safe concentration level, the evacuation of residents shall be lifted.	Neighborhood evacuation guidance plan ***Ref***: OSHA Web page https://www.osha.gov/chemicaldata/650
		Difficult to control chlorine injection	Insufficient chlorination	High	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus New Sundarijal WTP SOP
Chemical injection facility	Failure of coagulant injection	Difficult to control coagulant injection	Poor floc formation and turbidity	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of lime injection	Difficult to control lime injection	Poor floc formation and turbidity	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
Maintenance of WTP	Insufficient cleaning of sedimentation pond	Increased turbidity load to sand filtration	Decline in sand filter performance	Low	Conduct regular cleaning of the sedimentation pond according to the schedule Monitor turbidity measurement data from	New Sundarijal WTP SOP

					the water purification process (after sedimentation), and perform cleaning of the sedimentation pond when it exceeds a specified value	
	Insufficient backwashing of sand filter	Decline in sand filter performance	Increased turbidity in treated water	Low	Monitor turbidity measurement data during the water purification process (after sedimentation) to assess the condition of the sand filter bed Monitor the accumulation of contamination on the surface of the filter sand and clean the sand filter layer as required Replace the filter sand if necessary	New Sundarijal WTP SOP

Table 5.9 Possible Countermeasures for each Hazards and Risks : Mahankalchaur WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Risk Rating	Countermeasures	SOPs / Manuals being referenced
Natural disaster	Heavy rain	Inundation of WTP due to rainfall	Heavy rain	High	Water supply temporarily suspended Cleaning of the clear water tank Water quality tests were conducted to confirm compliance with water quality standards before operations resumed.	Water Quality Analysis SOPs Nepal Drinking Water Quality Standards Mahankalchaur WTP SOP
			Turbidity increase of treated water	High	Water supply temporarily suspended Cleaning of the clear water tank Water quality tests were conducted to confirm compliance with water quality standards before operations resumed.	Water Quality Analysis SOPs Nepal Drinking Water Quality Standards Mahankalchaur WTP SOP
			Damage of equipment	High	Temporary suspension of WTP operation Prompt implementation of repairs to the relevant equipment	Service manuals for each equipment Mahankalchaur WTP SOP
Power source	Power supply	Power outage	Power supply	Medium	Start the generator to maintain WTP function.	Generator operation manual
	Generator	Lack of fuel	Generator	Low	Check fuel inventory Ensure sufficient fuel is always available	Fuel inventory
		Malfunction	Loss of auxiliary power and loss of WTP function	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Generator service manual
Water intake facility (Manohara river)	Insufficient river flow of	Lack of raw water	Insufficient river flow of Manohara	High	Use alternative water sources (Bagmati River and Riverma River)	

	Manohara river		river			
	Blockage of collection pipe	Lack of raw water	Blockage of collection pipe	Low	Implement regular inspection and cleaning of the water collection pipe	
	Malfunction of pump	Lack of raw water	Malfunction of pump	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Pump service manual
Water intake facility (Deep well)	Clogging/breakage of strainers	Lack of raw water	Clogging/breakage of strainers	Low	Monitor production and clean the strainer when a downward trend in production is observed.	
	Malfunction of pump	Lack of raw water	Malfunction of pump	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Pump service manual
Procurement of water purification chemicals	Difficulty in chemical procurement	Insufficient coagulant injection	Difficulty in chemical procurement	Low	Check coagulant inventory Ensure sufficient coagulant is always available **<u>Response in the event of prolonged procurement difficulties</u>** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	Coagulant inventory
		Insufficient lime injection	Poor floc formation and	Low	Check lime inventory Ensure sufficient lime is always	Lime inventory

			increased turbidity		available **<u>Response in the event of prolonged procurement difficulties</u>** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	
		Insufficient chlorine injection	Increase biological hazard due to incomplete chlorination	Medium	Check breaching powder inventory Ensure sufficient breaching powder is always available **<u>Response in the event of prolonged procurement difficulties</u>** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	Breaching powder inventory
Water purification chemical dissolving facility	Failure of coagulant dissolving tank	Inaccurate coagulant injection rate	Failure of coagulant dissolving tank	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of lime dissolving tank	Inaccurate lime injection rate	Failure of lime dissolving tank	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of bleaching	Inaccurate chlorine	Failure of bleaching	Medium	Securing necessary spare parts	Spare parts inventory

	powder dissolving tank	injection rate	powder dissolving tank		Preventing malfunctions through regular inspections Conduct a prompt repair	Service manual of each apparatus
Water purification chemical injection facility	Failure of coagulant injector (pump, pipeline)	Difficult to control coagulant injection	Chemical injection failure (pump, pipeline)	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of lime injector (pipeline)	Difficult to control lime injection	Chemical injection failure (pipeline)	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of chlorine injector(pump, pipeline, rotameter)	Difficult to control chlorine injection	Chemical injection failure (pump, pipeline, rotameter)	Medium	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
Maintenance of WTP	Insufficient cleaning/desludging of sedimentation pond	Increased turbidity load to sand filtration	Insufficient cleaning/desludging of sedimentation pond	Low	Conduct regular cleaning of the sedimentation pond according to the schedule Monitor turbidity measurement data from the water purification process (after sedimentation), and perform cleaning of the sedimentation pond when it exceeds a specified value	Conduct regular cleaning of the sedimentation pond according to the schedule Monitor turbidity measurement data from the water purification process (after sedimentation), and perform cleaning of the sedimentation pond when it exceeds a specified value
	Insufficient backwashing of sand filter	Decline in sand filter performance	Insufficient backwashing of sand filter	Low	Monitor turbidity measurement data during the water purification process (after sedimentation) to assess the condition of the sand filter bed Monitor the accumulation of contamination on the surface of the filter sand and clean the sand filter layer	Monitor turbidity measurement data during the water purification process (after sedimentation) to assess the condition of the sand filter bed Monitor the accumulation of contamination on the surface of the filter sand and clean the sand filter layer as required

					as required Replace the filter sand if necessary	Replace the filter sand if necessary

Table 5.10 Possible Countermeasures for each Hazards and Risks: Bansbari WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Risk Rating	Countermeasures	SOPs / Manuals being referenced
Natural disaster	Heavy rain	Inundation of WTP due to rainfall	Heavy rain	High	Water supply temporarily suspended Cleaning of the clear water tank Water quality tests were conducted to confirm compliance with water quality standards before operations resumed.	Water Quality Analysis SOPs Nepal Drinking Water Quality Standards Bansbari WTP SOP
			Turbidity increase of treated water	High	Water supply temporarily suspended Cleaning of the clear water tank Water quality tests were conducted to confirm compliance with water quality standards before operations resumed.	Water Quality Analysis SOPs Nepal Drinking Water Quality Standards Bansbari WTP SOP
			Damage of equipment	High	Temporary suspension of WTP operation Prompt implementation of repairs to the relevant equipment	Service manuals for each equipment
Power source	Power supply	Power outage	Power supply	Medium	Start the generator to maintain WTP function.	Generator operation manual
	Generator	Lack of fuel	Generator	Low	Check fuel inventory Ensure sufficient fuel is always available	Fuel inventory
		Malfunction	Loss of auxiliary power and loss of WTP function	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Generator service manual
Raw water quality	Rainfall Rainfall	Increase turbidity	Rainfall	Medium	Monitor turbidity and water intake stopping until turbidity falls to an acceptable level.	Water Quality Analysis SOPs

		Decrease alkalinity	–	Medium	Monitor turbidity and water intake stopping until turbidity falls to an acceptable level.	Water Quality Analysis SOPs
		Increase turbidity	Rainfall	Medium	Monitor turbidity and water intake stopping until turbidity falls to an acceptable level.	Water Quality Analysis SOPs
		Decrease alkalinity	–	Medium	Monitor turbidity and water intake stopping until turbidity falls to an acceptable level.	Water Quality Analysis SOPs
Procurement of water purification chemicals	Difficulty in chemical procurement	Insufficient coagulant injection	Difficulty in chemical procurement	Low	Check coagulant inventory Ensure sufficient coagulant is always available **<u>Response in the event of prolonged procurement difficulties</u>** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	Coagulant inventory
		Insufficient lime injection	Poor floc formation and increased turbidity	Low	Check lime inventory Ensure sufficient lime is always available **<u>Response in the event of prolonged procurement difficulties</u>** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	Lime inventory
		Insufficient chlorine	Increase biological	Medium	Check breaching powder inventory	Breaching powder inventory

		injection	hazard due to incomplete chlorination		Ensure sufficient breaching powder is always available **<u>Response in the event of prolonged procurement difficulties</u>** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	
Water purification chemical dissolving facilities	Failure of coagulant dissolving tank	Inaccurate coagulant injection rate	Failure of coagulant dissolving tank	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of lime dissolving tank	Inaccurate lime injection rate	Failure of lime dissolving tank	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of bleaching powder dissolving tank	Inaccurate chlorine injection rate	Failure of bleaching powder dissolving tank	Medium	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
Water purification chemical injection facility	Failure of coagulant injector (pump, pipeline)	Difficult to control coagulant injection	Poor floc formation, turbidity	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
	Failure of lime injector	Difficult to control lime	Poor floc formation,	Low	Securing necessary spare parts Preventing malfunctions through regular	Spare parts inventory

	(pipeline)	injection	turbidity		inspections Conduct a prompt repair	Service manual of each apparatus
	Failure of chlorine injector(pump, pipeline, rotameter)	Difficult to control chlorine injection	Incomplete chlorination, biological hazard	Medium	Securing necessary spare parts Preventing malfunctions through regular inspections Conduct a prompt repair	Spare parts inventory Service manual of each apparatus
Maintenance of WTP	Insufficient cleaning/desludging of sedimentation pond	Increased turbidity load to sand filtration	Insufficient cleaning/desludging of sedimentation pond	Low	Conduct regular cleaning of the sedimentation pond according to the schedule Monitor turbidity measurement data from the water purification process (after sedimentation), and perform cleaning of the sedimentation pond when it exceeds a specified value	Conduct regular cleaning of the sedimentation pond according to the schedule Monitor turbidity measurement data from the water purification process (after sedimentation), and perform cleaning of the sedimentation pond when it exceeds a specified value
	Insufficient backwashing of sand filter	Decline in sand filter performance	Insufficient backwashing of sand filter	Low	Monitor turbidity measurement data during the water purification process (after sedimentation) to assess the condition of the sand filter bed Monitor the accumulation of contamination on the surface of the filter sand and clean the sand filter layer as required Replace the filter sand if necessary	Monitor turbidity measurement data during the water purification process (after sedimentation) to assess the condition of the sand filter bed Monitor the accumulation of contamination on the surface of the filter sand and clean the sand filter layer as required Replace the filter sand if necessary

Table 5.11 Possible Countermeasures for each Hazards and Risks: Bode WTP

Category	Source of Hazard	Hazardous Event (1)	Hazardous Event (2)	Risk Rating	Countermeasures	SOPs / Manuals being referenced
Natural disaster	Heavy rain	Inundation of WTP due to rainfall	Biological pollution of treated water	High	Water supply temporarily suspended Cleaning of the clear water tank Water quality tests were conducted to confirm compliance with water quality standards before operations resumed.	Water Quality Analysis SOPs Nepal Drinking Water Quality Standards Bode WTP SOP
			Turbidity increase of treated water	High	Water supply temporarily suspended Cleaning of the clear water tank Water quality tests were conducted to confirm compliance with water quality standards before operations resumed.	Water Quality Analysis SOPs Nepal Drinking Water Quality Standards Bode WTP SOP
			Damage of equipment	High	Temporary suspension of WTP operation Prompt implementation of repairs to the relevant equipment	Service manuals for each equipment
Power source	Power supply	Power outage	Loss of WTP function	Medium	Start the generator to maintain WTP function.	Generator operation manual
	Generator	Lack of fuel	Loss of auxiliary power and loss of WTP function	Low	Check fuel inventory Ensure sufficient fuel is always available	Fuel inventory
		Malfunction	Loss of auxiliary power and loss of WTP function	Medium	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repair	Spare parts inventory Generator service manual
Water intake facility (Manohara river)	Insufficient river flow of	Lack of raw water	Insufficient water supply	High		

	Manohara					
	Blockage of collection pipe	Lack of raw water	Insufficient water supply	Low	Implement regular inspection and cleaning of the water collection pipe	
	Malfunction of pump	Lack of raw water	Insufficient water supply	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repair	Spare parts inventory Pump service manual
Water intake facility (Deep well)	Clogging/breakage of strainers	Lack of raw water	Insufficient water supply	Low	Monitor production and clean the strainer when a downward trend in production is observed.	
	Malfunction of pump	Lack of raw water	Insufficient water supply	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repair	Spare parts inventory Pump service manual
Procurement of water purification chemicals	Difficulty in chemical procurement	Insufficient coagulant injection	Poor floc formation and incomplete coagulation – increased turbidity	Low	Check coagulant inventory Ensure sufficient coagulant is always available **Response in the event of prolonged procurement difficulties** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	Coagulant inventory
		Insufficient lime injection	Poor floc formation and increased turbidity	Low	Check lime inventory Ensure sufficient lime is always available **Response in the event of prolonged**	Lime inventory

					<u>procurement difficulties</u> Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	
		Insufficient chlorine injection	Increase biological hazard due to incomplete chlorination	Medium	Check breaching powder inventory Ensure sufficient breaching powder is always available **<u>Response in the event of prolonged procurement difficulties</u>** Refer to inventory levels at other water treatment plants and facilitate mutual supply arrangements Review WTP operation plan based on the total quantity of chemicals available across the entire KUKL	Breaching powder inventory
Water purification chemical dissolving facilities	Failure of coagulant dissolving tank	Inaccurate coagulant injection rate	Insufficient flocculation	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repairs to the relevant generator	Spare parts inventory Service manual of each apparatus
	Failure of lime dissolving tank	Inaccurate lime injection rate	Insufficient flocculation	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repairs to the relevant generator	Spare parts inventory Service manual of each apparatus
	Failure of bleaching powder	Inaccurate chlorine	Incomplete chlorination and increase	Medium	Securing necessary spare parts Preventing malfunctions through regular	Spare parts inventory

	dissolving tank	injection rate	of biological hazard		inspections Prompt implementation of repairs to the relevant generator	Service manual of each apparatus
Water purification chemical injection facility	Failure of coagulant injector (pump, pipeline)	Difficult to control coagulant injection	Poor floc formation, turbidity	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repairs to the relevant generator	Spare parts inventory Service manual of each apparatus
	Failure of lime injector (pipeline)	Difficult to control lime injection	Poor floc formation, turbidity	Low	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repairs to the relevant generator	Spare parts inventory Service manual of each apparatus
	Failure of chlorine injector(pump, pipeline, rotameter)	Difficult to control chlorine injection	Incomplete chlorination, biological hazard	Medium	Securing necessary spare parts Preventing malfunctions through regular inspections Prompt implementation of repairs to the relevant generator	Spare parts inventory Service manual of each apparatus
Maintenance of WTP	Insufficient cleaning/desludging of sedimentation pond	Increased turbidity load to sand filtration	Decline in sand filter performance	Low	Conduct regular cleaning of the sedimentation pond according to the schedule Monitor turbidity measurement data from the water purification process (after sedimentation), and perform cleaning of the sedimentation pond when it exceeds a specified value	Conduct regular cleaning of the sedimentation pond according to the schedule Monitor turbidity measurement data from the water purification process (after sedimentation), and perform cleaning of the sedimentation pond when it exceeds a specified value
	Insufficient backwashing of sand filter	Decline in sand filter performance	Increased turbidity in treated water	Low	Monitor turbidity measurement data during the water purification process (after sedimentation) to assess the condition of the sand filter bed Monitor the accumulation of	Monitor turbidity measurement data during the water purification process (after sedimentation) to assess the condition of the sand filter bed Monitor the accumulation of contamination

					contamination on the surface of the filter sand and clean the sand filter layer as required Replace the filter sand if necessary	on the surface of the filter sand and clean the sand filter layer as required Replace the filter sand if necessary

Chapter 6 Implementing organization for water quality management

The implementation of water quality management should ideally follow the PDCA cycle. This chapter assumes the implementation of the PDCA cycle at KUKL, outlining the relationships between relevant departments and identifying the actors and their respective roles at each process: (i) Plan, (ii) Do, (iii) Check, and (iv) Act.

(1) Implementation of the PDCA Cycle in KUKL's Water Quality Management: Definition of Each Process

The PDCA cycle flow (circulation) in water quality management is shown in Figure 6.1.

The PDCA cycle is an organizational management concept aimed at achieving higher-level problem-solving through a cyclical process.

To facilitate the explanation and understanding of the PDCA cycle, the explanation is given from Check process, in which Water Quality Management Section play as a main actor, and proceed in the order of Act, Plan, and Do processes.

Check process: Verifies the degree of compliance with water quality standards and the suitability of water treatment process management at the water treatment plant through water quality monitoring.

Act process: Considering water quality data, WTP operational management data, and other relevant information, identifies the issues and challenges for water quality improvement and considers improvement measures.

Plan process: Transforms the improvement measures proposed in the Act process into a feasible improvement plan.

Do process: Implements the improvement plan.

By implementing a check process for the improvement plans carried out, continuously identifying further areas for improvement (Act), formulating improvement plans (Plan), and implementing these plans (Do), we achieve a higher quality water supply service.

(2) The roles of each department/section within KUKL in implementing the PDCA cycle

Actor of each process in the PDCA cycle is as follows. Table 6.1 describes the detailed role of each actor.

Check process: WTP manager, Branch Manager, Division chief (Operation, Production, Support), W/WWQAD Division (Central laboratory: under Planning Support Department)

Act process: Division chief (Operation, Production, W/WWQAD), Branch manager, E/M section (Adviser)

Plan process: CEO, Division chief (Operation division, Production division, W/WWQAD Division), Branch manager

Do process: Branch manager, WTP Manager (WTP responsible officer), E/M section (Under Support division), WTP laboratory

Table6.1 Actors and their roles in the PDCA cycle for water quality improvement

<table>
<tr>
<td><u>Act</u>
Based on the results of the verification of the effectiveness of the implemented measures to improve water quality, consider more effective measures with the aim of further improving water quality.

Actors:
• Division chief (Operation, Production, W/WWQAD)
• Branch manager
• E/M section (Adviser)

Role of each actor
<u>Division chief (Operation division, Product division, W/WWQAD)</u>
• Based on the results of verification of the implemented measures, consider more effective measures in cooperation with related sections / division (e.g., E/M section).

<u>Branch manager</u>
• Based on the results of verification of the implemented measures, consider more effective measures in cooperation with related sections / division (e.g., E/M section).</td>
<td><u>Plan</u>
Based on the verification of implemented measures, develop plans for water quality improvement and provide instructions to the corresponding department / section.

Actors:
• CEO
• Division chief (Operation division, Production division, W/WWQAD Division)
• Branch manager
Role of each actor
<u>CEO</u>
• Make final decision and approval.

<u>Division Chief (Operation division, Production division, W/WWQAD)</u>
• Consider measures to improve water quality and plans for implementation.

<u>Branch manager (under Operation division)</u>
• Consider measures to improve water quality and plans for implementation.</td>
</tr>
<tr>
<td><u>Check</u>
Verify the effectiveness of implemented measures to improve water quality.

Actors:
• WTP manager
• Branch Manager
• Division chief (Operation, Production, Support)
• W/WWQAD Division (Central laboratory: under Planning Support Department)

Role of each actor
<u>Division chief</u>
• Production division to monitor and assess New Sundarijal WTP O&M

• Operation division to monitor and assess Mahankalchaur, Bansbari, and Bode WTP O&M, and water distribution system O&M

<u>WTP manager</u>
• Monitoring WTP operation conditions and performance of WTP workers every day.

<u>Branch Manager</u>
• Supervise WTP (Mahankalchaur, Bansbari, Bode) operation condition and performance of WTP worker at least once a week or as per requirement.
• Supervise water distribution system O&M.

<u>W/WWQAD Division</u>
• Collect and analyze daily water quality data from the water treatment plant laboratory
• Collect and analyze water quality data of service reservoirs
• Collect and analyze tap water quality data from each branch.
• Identification of issues and problems in water quality</td>
<td><u>Do</u>
Implement measures to improve water quality.

Actors:
• Branch manager
• WTP Manager (WTP responsible officer)
• E/M section (Under Support division)
• WTP laboratory

Role of each actor
<u>Branch manager</u>
• Distribution network operation and maintenance
• Water Quality monitoring of tap water and service reservoir

<u>WTP manager (WTP responsible officer)</u>
• Maintenance of WTP facility
• Keep the records of WTP operation

<u>E/M section (under Support division)</u>
• WTP Maintenance

<u>WTP laboratory (Under branch)</u>
• Daily monitoring of water treatment process
• Report daily monitoring data to W/WWQAD
• Suggest appropriate chemical dosing rate based on the monitoring data</td>
</tr>
</table>

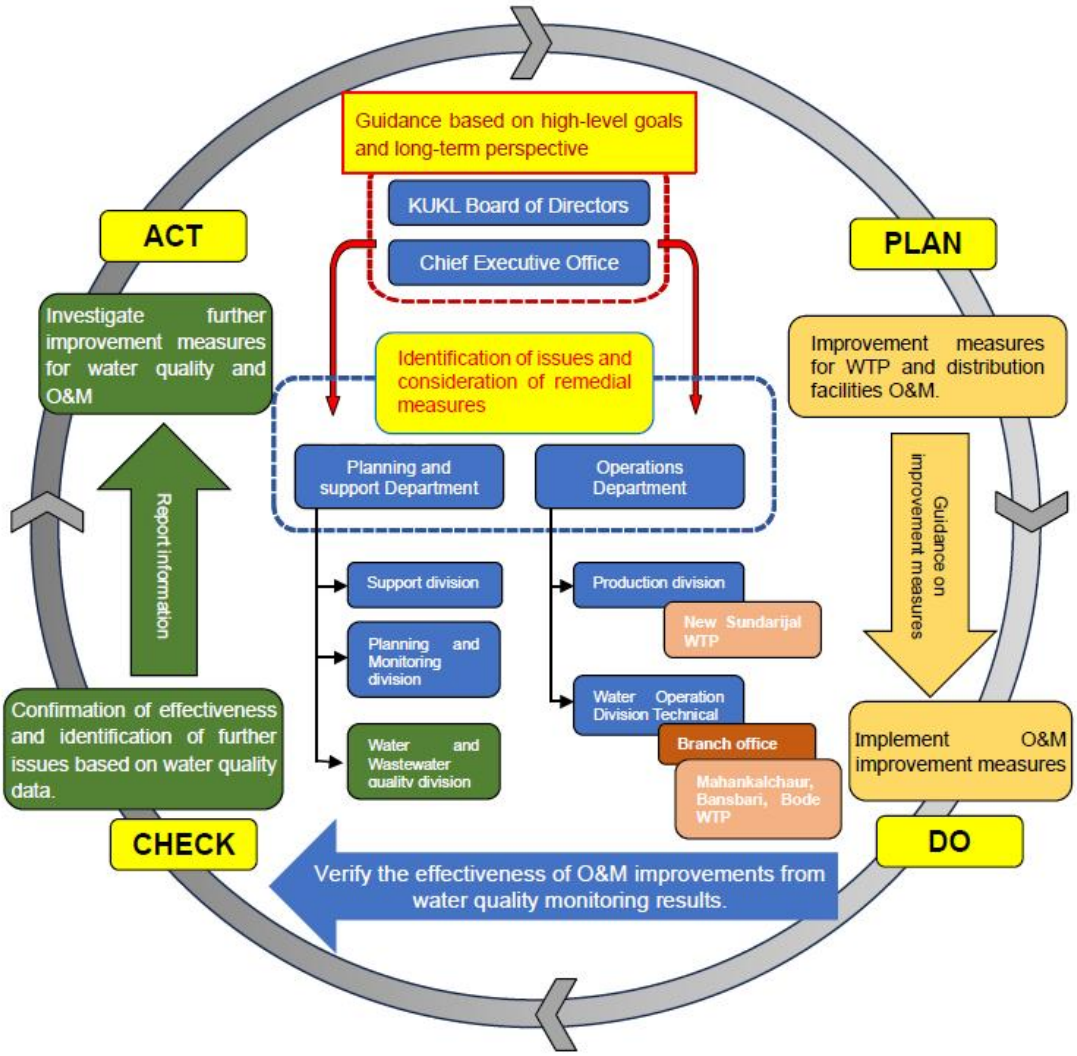

Figure 6.1 PDCA cycle in KUKL water quality management activity