Water Treatment Project

Typhoon Mawar – May 24, 2023

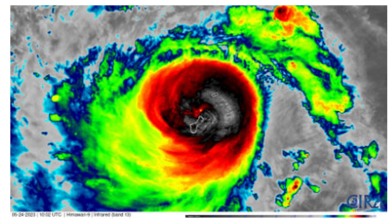
Typhoon Mawar passed north of Guam as a Category 4-equivalent typhoon on May 24, bringing hurricane-force winds and heavy rain.

1

Water Treatment Project

Typhoon Mawar – May 24, 2023

The center of Mawar passed the northern tip of Guam as a Category 4-equivalent typhoon with maximum sustained winds up to 140 mph with gusts up to 165 mph.

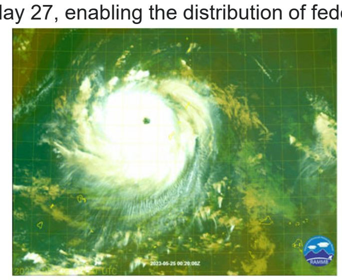


2

Water Treatment Project

Typhoon Mawar – May 24, 2023

U.S. President Joe Biden declared Guam a major disaster area on May 27, enabling the distribution of federal funds.



3

Water Treatment Project

Typhoon Mawar – May 24, 2023

Multiple locations in Guam received at least 20 inches of rain during Typhoon Mawar, with most falling in just three hours.

With power outages and flooding, the Guam Waterworks Authority (GWA) restored 50% of operable water wells, with connections yet to be restored to Navy-supplied sources.

A boil water advisory remained in place for residents with access to tap water.

4

Water Treatment Project

Typhoon Mawar – May 24, 2023

Due to the nature of the disaster, it is anticipated that the water treatment systems have been disrupted and will need to be repaired.

Representatives of the U.S. Army Corps. of Engineers, Vicksburg District, are soliciting bids for a new water treatment system (WTS) to be constructed in Guam.

Each system is expected to provide a maximum of 20 million gallons per day (MGD).

5

Water Treatment Project

Typhoon Mawar – May 24, 2023

Due to the nature of the disaster, it is anticipated that the water treatment systems have been disrupted and will need to be repaired.

Representatives of the U.S. Army Corps. of Engineers, Vicksburg District, are soliciting bids for a new water treatment system (WTS) to be constructed in Guam.

Each system is expected to provide a maximum of 20 million gallons per day (MGD).

6

Water Treatment Project

The bid package must include:

Proposal bids must be submitted no later than **Sunday, February 18, 2024,** with company representatives on hand to present a brief **5-minute** overview of the proposed design.

7

Water Treatment Project

Proposal packages should be addressed to:

Lieutenant General Scott A. Spellmon
Commanding General of the
U.S. Army Corps of Engineers
441 G St NW
Washington DC, 20314

8

Water Treatment Project

Schedule:

Month	Date	Event
January	23-25	Project introduction; jar test; Water System #1
	30-31	Water System #2
February	1	Water System #2
	6-8	Water System #3
	13-15	Design, construct, and test Water System
	18	Project Report and Presentation Sunday evening at 6:00 p.m.

9

Water Treatment Project

The objective of this project is to utilize, within given constraints, a prototype WTS to design a full-scale system.

The effectiveness of the WTS will be evaluated by the yearly operational and maintenance costs.

10

Water Treatment Project

Each prototype WTS will be scaled-up to handle a flowrate of 20 million gallons per day (MGD).

The effluent water must have an average turbidity less of less than 2 NTU

To handle backwashing and cleaning of the WTS, the overall size of the treatment system should be increased by 20% or a safety factor SF of 1.2

11

Water Treatment Project

The full-scale WTS may be constructed with any combination of the following three processes:

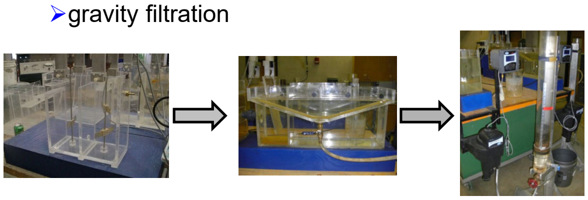
- coagulation and flocculation basins (5 MGD)
- sedimentation tanks (each tank is 75,000 gallons)
- ~32-foot square filters (1,000 ft.^{2} per filter)

12

Water Treatment Project

The prototype WTS will consist of three sequential processes:

- coagulation and flocculation
- sedimentation
- gravity filtration



13

Water Treatment Project

Each prototype WTS must meet the following criteria:

1. The filter material height may not be greater than 8 in.
2. Anthracite and/or filter sand may be used in the filter
3. The maximum filter run is 60 minutes
4. The effluent must have an average turbidity of less than 2 NTU
5. The water height above the filter material must be maintained at 6 in.

14

Water Treatment Project

Coagulation and Flocculation Cost

From jar tests data you should be able to select a cost-effective dosage of ferric chloride that destabilizes the suspend solids.

The coagulation and flocculation cost of the treatment system are:

- Operation and maintenance (OM) cost including construction
- Material costs - ferric chloride

15

Water Treatment Project

Coagulation and Flocculation Cost

- Operation and maintenance cost for the coagulation and flocculation system (OMCF) is dependent on the system flowrate and the cost per unit.
- A single full-scale coagulation and flocculation unit capable of treating 5 MGD has a cost of $25,000 per year
- Ferric chloride and associated chemicals cost $1 per kg

16

Water Treatment Project

Coagulation and Flocculation Cost

The weight of coagulant wt_c required per gallon of treated water is estimated as:

$$wt_c\left[{}^{kg}\!/\!_{gal}\right] = \left(\frac{\text{dosage mg}}{\text{L}}\right)\left(\frac{3.785\text{ L}}{\text{gallon}}\right)\left(\frac{\text{kg}}{10^6\text{ mg}}\right)$$

17

Water Treatment Project

Coagulation and Flocculation Cost

The number of coagulation and flocculation units *NCF* required is:

20% Factor of Safety

$$NCF = \left[\frac{\text{required flowrate (gpd)}}{5\times10^6\text{ (gpd)}}\right]\times SF$$

18

Water Treatment Project

Coagulation and Flocculation Cost

The number of coagulation and flocculation units required is:

$$Cost_{CF} = NCF\left(\frac{\$25{,}000}{\text{year}}\right)$$

$$+\left(wt_c\,\frac{\text{kg}}{\text{gal}}\right)[\text{required flowrate (gpd)}]\left(\frac{365\text{ days}}{\text{year}}\right)\left(\frac{\$1}{\text{kg}}\right)$$

19

Water Treatment Project

Sedimentation System Cost

The size of the prototype sedimentation tank can be varied - each sedimentation basin contains four individual tanks

Each prototype tank is 6 in. wide, 10 in. deep, and 6 in. long (volume = 360 in.^{3})

You may operate these tanks in any manner you wish; however, once a tank is in use it become a permanent part of your treatment system

20

Water Treatment Project

Sedimentation System Cost

The full-scale sedimentation tanks will have the following characteristics:

1. The volume of each tank is 75,000 gallons
2. To provide continuous sedimentation during the year, approximately 20% of your tanks must be inoperative at any given time (this will accommodate the cleaning time)

21

Water Treatment Project

Sedimentation System Cost

Step 1 - Compute the prototype sediment tank ***retention time*** t_p

$$t_P = \frac{n_t\left(\text{Volume}_{\text{tank}}\right)}{Q_S}$$

where: n_t is the number of prototype tanks
Volume$_{\text{tanks}}$ is the volume of one tank
Q_S is the flowrate in the sedimentation tanks (mL/min)

22

Water Treatment Project

Sedimentation System Cost

Step 1 - Compute the prototype sediment tank ***retention time*** t_p

$$\text{Volume}_{\text{tank}} = 360\text{ in.}^3\left(\frac{\text{gallon}}{231\text{ in.}^3}\right) = 1.56\text{ gallons}$$

$$t_P = \frac{n_t(1.56\text{ gallons})}{\left(\text{flowrate}\,\frac{\text{mL}}{\text{minute}}\right)\left(\frac{\text{gallon}}{3{,}785\text{ mL}}\right)}$$

23

Water Treatment Project

Sedimentation System Cost

Step 2 - The full-scale ***treatment flowrate*** Q_{ST} (gpm) per sedimentation tanks is:

$$Q_{ST} = \frac{\text{tank volume (gallons)}}{t_P}$$

The full-scale sedimentation tanks are 75,000 gallons

$$Q_{ST} = \frac{75{,}000\text{ gallons}}{t_P}$$

24

Water Treatment Project

Sedimentation System Cost

Step 3 - The ***effective flowrate*** Q_{SE} (gpm) in a sedimentation tank is:

$$Q_{SE} = Q_{ST}\left(\frac{\text{filter run time}}{60\text{ minutes}}\right)$$

25

Water Treatment Project

Sedimentation System Cost

Step 4 - The number of full scaled sedimentation tanks, ***NS*** required to handle the daily volume is estimated as:

$$NS = \left[\frac{\text{required daily volume (gpd)}}{Q_{SE}\text{(gpm)}}\right]\left[\frac{\text{day}}{1{,}440\text{ min}}\right] \times SF$$

20% increase for cleaning

26

Water Treatment Project

Sedimentation System Cost

The operation and maintenance costs per full-scale sedimentation tank is $35,000/tank

The yearly costs per sediment tank is:

$$Cost_S = NS\left(\frac{\$35{,}000}{\text{tank}}\right)$$

27

Water Treatment Project

Filtration System Cost

Each WTS must meet the following criteria:

1. The filter material height may not be greater than 8 in.
2. Anthracite and/or filter sand may be used in the filter
3. The maximum filter run is 60 minutes
4. The effluent must have an average turbidity of less than 2 NTU
5. The water height above the filter material must be maintained at 6 in.

28

Water Treatment Project

Filtration System Cost

The full-scale filters will have the following characteristics:

1. Each filter is 31 ft. by 31 ft. in area (~1,000 $ft.^2$)
2. A 20% factor of safety (this will accommodate the backwashing time)
3. The filter media will be replaced every five years

29

Water Treatment Project

Filtration System Cost

If either of the following criteria are violated:

1. the pressure head exceeds above 6 in.
2. The average turbidity > 2 NTU

The time when the filter exceeded these criteria is the filter run time (less than 60 minutes).

30

Water Treatment Project

Filtration System Cost

Step 1 - Convert the average flowrate through the prototype filter (the 3.5 in. diameter prototype filter has an area of 0.0668 ft.²) into a prototype ***filter loading rate*** $\boldsymbol{Q_F}$ (gpm/ft.²).

$$Q_F = \left(\text{flowrate}\frac{\text{mL}}{\text{minute}}\right)\left(\frac{\text{gallon}}{3{,}785\text{ mL}}\right)\left(\frac{1}{0.0668\text{ ft.}^2}\right)$$

31

Water Treatment Project

Filtration System Cost

Step 2 - The full-scale ***treatment flowrate*** $\boldsymbol{Q_{FT}}$ is:

$$Q_{FT} = Q_F\left(\text{gpm}/\text{ft.}^2\right)\times\text{filter area}\left(\text{ft.}^2\right)$$

Remember that the full-scale filters are 1,000 ft.²

$$Q_{FT} = Q_F\left(\text{gpm}/\text{ft}^2\right)\times 1{,}000\text{ ft.}^2$$

32

Water Treatment Project

Filtration System Cost

Step 3 - Considering that each filter is inoperable during backwashing, the ***effective flowrate*** $\boldsymbol{Q_{FE}}$ is:

$$Q_{FE} = Q_{FT}\left(\frac{\text{filter run time}}{60\text{ minutes}}\right)$$

33

Water Treatment Project

Filtration System Cost

Step 4 - The number of full-scaled filters ***NF*** required to handle the daily volume is estimated as:

$$NF = \left[\frac{\text{required daily volume (gpd)}}{Q_{FE}\text{(gpm)}}\right]\left[\frac{\text{day}}{1{,}440\text{min}}\right]\times SF$$

20% increase for backwashing

34

Water Treatment Project

Filtration System Cost

The total yearly costs to operate and maintain a full-scale filter system is separated into two components:

The operation and maintenance (OM_F) costs per filter - $45,000/filter

The costs of filter media:
anthracite - $9.50/ft.³
filter sand - $5.90/ft.³

35

Water Treatment Project

Filtration System Cost

The yearly cost per filter is:

$$Cost_F = NF\left(\frac{\$45{,}000}{\text{filter}}\right)$$

36

Water Treatment Project

Filtration System Cost

The yearly cost for anthracite is:

$$Cost_{FM_A} = \text{thickness}(\text{in.})\left(\frac{\$9.50}{\text{ft.}^3}\right)\left(\frac{\text{ft}}{12\text{ in.}}\right)\left(1{,}000\text{ ft.}^2\right)\left(\frac{NF}{5}\right)$$

Material replaced every five years

The yearly cost for filter sand is:

$$Cost_{FM_S} = \text{thickness}(\text{in.})\left(\frac{\$5.90}{\text{ft}^3}\right)\left(\frac{\text{ft.}}{12\text{ in.}}\right)\left(1{,}000\text{ ft.}^2\right)\left(\frac{NF}{5}\right)$$

$$Cost_{FM} = Cost_{FM_A} + Cost_{FM_S}$$

37

Water Treatment Project

Total Treatment System Cost

$$\text{Total Cost} = Cost_{CF} \quad \text{Coagulation}$$
$$+\, Cost_{S} \quad \text{Sedimentation}$$
$$+\, Cost_{F} \quad \text{Filtration}$$
$$+\, Cost_{FM} \quad \text{Filtration Media}$$

38

Water Treatment Project

Any questions?

39