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MILITARY HANDBOOK

WATER SUPPLY SYSTEMS

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ABSTRACT

This handbook provides design guidance for use by qualified engineers in designing water supply systems. The handbook includes criteria for determining quantity and quality requirements; selecting source of supply, pumps, and treatment processes and facilities; and for designing distribution and transmission systems, storage facilities, and buildings.

FOREWORD

This handbook has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. This handbook was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from this criteria, in the planning, engineering, design, and construction of naval shore facilities, cannot be made without prior approval of NAVFACENGCOMHQ Code 04.

Design cannot remain static any more than can the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commanding Officer, Southern Division, Code 04A3, Naval Facilities Engineering Command, P.O. Box 10068, Charleston, SC 29411-0068, telephone (803)743-0458.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

CIVIL ENGINEERING CRITERIA MANUALS

Criteria Manual	Title	PA
DM-5.01	Surveying	LANTDIV
DM-5.02	Hydrology	LANTDIV
DM-5.03	Drainage Systems	LANTDIV
DM-5.4	Pavements	PACDIV
DM-5.5	General Provisions and Geometric Designs for Roads, Streets, Walks, and Open Storage Areas	HDQTRS
DM-5.6	Trackage	NORTHDIV
MIL-HDBK-1005/7	Water Supply Systems	SOUTHDIV
MIL-HDBK 1005/8	Domestic Wastewater Control	HDQTRS
MIL-HDBK-1005/9	Industrial and Oily Wastewater Control	HDQTRS
DM-5.10	Solid Waste Disposal	PACDIV
DM-5.12	Fencing, Gates, and Guard Towers	WESTDIV
MIL-HDBK 1005/13	Hazardous Waste Storage Facilities	HDQTRS
DM-5.14	Groundwater Pollution Control	HDQTRS

NOTE: Design manuals, when revised, will be converted to military handbooks.

This handbook is issued to provide immediate guidance to the user. However, it may or may not conform to format requirements of MIL-HDBK-1006/3 and will be corrected on the next update.

WATER SUPPLY SYSTEMS

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Section 1: INTRODUCTION

1.1 Scope. This manual presents requirements for the design of water supply systems for Naval shore activities.

1.2 Cancellation. This handbook, MIL-HDBK-1005/7, Water Supply Systems, cancels and supersedes DM-5.7, Water Supply Systems, dated October 1979.

1.3. Source of Supply. The capacity of potable supplies shall be developed whenever possible, to obviate any need for a nonpotable supply (except for waterfront facilities, refer to NAVFAC DM-25 Series, Piers and Dockside Facilities, and DM-29 Series, Drydocks and Marine Railways).

1.3.1 Potable Water Sources. The potable water supply should be obtained from a nearby public system. If this is not feasible, sources shall be developed especially for the Naval activity. Brackish or salt water shall be used only when other sources are unavailable, and shall be converted to fresh water by a suitable process.

1.3.2 Nonpotable Water Sources. Separate nonpotable water supplies shall be considered for active waterfront facilities. At active and repair berths and drydocks, cooling, flushing and fire protection requirements may be met using nonpotable fresh or salt water supplies. Only one nonpotable system shall be provided, and it shall meet the requirements of DM-25 Series. At inactive berths, salt or nonpotable water shall be used, when available, for fire protection; if not available, potable water shall be used. Nonpotable water supplies shall be designed to preclude any possible contamination of potable water supply sources or systems.

1.4 Quantity Required. Water supply plans shall provide for quantities sufficient to fulfill the Naval activity's current demands, and all reasonable future or prospective demands.

1.5 Quality. The following criteria shall apply for the quality of water.

1.5.1 Potable Water Quality. Except when otherwise permitted by the Bureau of Medicine and Surgery (BUMED), the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act primary and secondary drinking water regulations, and all State and local water quality standards must be met in full by providing necessary treatment. Any additional specific standard set by BUMED must be observed where applicable. Refer to NAVMED P-5010-6, Manual of Naval Preventive Medicine, Chapter 6, Water Supply Afloat, for potable water requirements for ships.

1.5.2 Nonpotable Water. Segregate potable and nonpotable systems so that nonpotable water cannot be injurious to health or cause other hazards.

1.6 Cost Policy. Designs shall be the most economical obtainable, consistent with the Naval activity's requirements. For cost analysis, balance the annual operating cost against annual fixed charges for different sources of supply and different designs. The life of the system shall cover the expected need for the Naval activity. Fixed annual charges shall include insurance and either interest and depreciation or amortization. Annual operating cost shall include treatment chemicals, energy consumption, operating labor, maintenance, and replacements.

1.7 Design Policy. To give absolute assurance of a continuously safe water supply, design the system in accordance with approved engineering practice.

1.8 Hazard of War Damage. Observe all necessary precautions against sabotage and interruptions as a result of war damage. Refer to OPNAVINST 5510.45, U.S. Navy Physical Security Manual. Also refer to para. 3.3.2 on Water Contaminated by Warfare Agents.

1.9 Initial Design Investigation. Develop quantity and quality requirements as the first step in design. Surveys by a competent agency are required to obtain the following data on supply source:

a) hydrological data

b) geological data

c) quality of raw water

d) sources of pollution

e) conflicting uses

f) water rights

g) land ownership and rights-of-way, for offsite sources.

For additional required design data, refer to Table 1.

Table 1
Information Required for Design of Water Supply System

ITEM	REQUIREMENTS
Topographic map	For layout of system, use USGS maps for preliminary investigations. For final design, use specially prepared maps.
Soil conditions	Soil maps and subsurface data prepared from boring logs made by a competent agency, for structural design.
Transportation	Facilities available for system construction and operation.
Power supply	Available normal and emergency power from local utility or Navy's own power plant.
Local utility maps	Maps of water, sewer, drain, gas, electrical lines, etc., for designing the transmission and distribution systems. Obtain detailed information from local utility companies and surveys.
Skill of local labor	For construction, operation, and maintenance.
Suitability and availability of local material	Important when the site is remote or inaccessible.
Local code and trade union rules	Affects design and construction.

Section 2: QUANTITY REQUIREMENTS

2.1. Factors Affecting Use. Consider the following factors affecting use ashore:

a) water uses (domestic, industrial, fire protection)

b) peak demands (all uses)

c) other essential demands

d) missions of the activity

e) climatic effects

f) permanency of installation (permanent and temporary field bases).

2.2. Specific Requirements. Total requirements are related to domestic, industrial, and fire protection requirements. Specific requirements for use ashore are discussed below.

2.2.1 Domestic Uses. Domestic uses include drinking water, household uses, and household lawn irrigation.

2.2.1.1 Per Capita Requirements. Use data in Table 2 for permanent and temporary installation.

Table 2
Average Potable Domestic Water Requirements
Gallons Per Capita Per Day (gpcd)

USE CATEGORY	TROPIC	TEMPERATE
Unaccompanied Personnel Housing	175	150
Family Housing	200	150
Workers (per shift)	50	50

2.2.1.2 Controlling Demands. All demands will be multiples of the average demand, expressed as gallons per minute (gpm) or gallons per day (gpd). The average demand, in gpd, shall be calculated by Equation (1):

EQUATION: Avg demand in gpd = gpcd x design population x growth factor (1)

Use the following growth factors in equation (1):

a) Large systems (5,000 population or greater), 1.25.

b) Small systems (populations less than 5,000), 1.50.

This equation must be performed for each use category shown in Table 2, and the results must then be added together to determine total average demand.

Other controlling demands shall be evaluated by Equation (2):

EQUATION: Demand = avg demand in gpd x K (2)

using the following data for the coefficient, K:

DEMAND	UNITS OF DEMAND	COEFFICIENT K POPULATION <5000	POPULATION >5000
Maximum Day Flow	gpd	2.25	2
Maximum Hour Flow	gpm	$\frac{4.0}{1,440}$	$\frac{3.5}{1,440}$
Instantaneous Peak Flow	gpm	$\frac{5.0}{1,440}$	$\frac{4.5}{1,440}$

The designer may make allowances, as deemed necessary, for small activities where all or nearly all demand occurs during working hours.

If a planned buildup or population decrease can be foreseen, this change should be taken into account.

2.2.2 Industrial Uses. These uses include cooling, processing, flushing, issues to ships, irrigation, swimming pools, shops, laundries, dining facilities, air conditioning, and boiler makeup. As a guide to planning, refer to water demand data at other activities having uses similar to those anticipated. For specific requirements, refer to Table 3.

2.2.3 Fire Protection Demands. Refer to MIL-HDBK-1008A, Fire Protection for Facilities Engineering, Design, and Construction, for criteria.

2.3. Design Capacity of System Components. In planning, each system shall be analyzed to determine the governing water use. The coincident demand of various uses will determine the design capacities of components of the system.

2.3.1 Source of Supply. The source shall meet the Naval activity's quantity demands. Where there is inadequate storage between the source and the treatment plant or distribution system, the supply shall provide maximum day domestic demand expressed by Equation (2), plus industrial use demand. If wells are the source of supply, sufficient capacity should be available to satisfy the maximum day domestic demand plus industrial use demand, with the largest well (or mechanical system) out of service.

Table 3
Industrial Water Requirements
Potable Water - Permanent Installations

USE	UNIT	REQUIREMENTS MIN	AVG	MAX
Air conditioning:				
With conservation	gpm/ton	-	0.05	0.10
Without conservation	gpm/ton	-	2.50	4.00
Cooling - diesel engines:				
With conservation	gpm/bhp	-	0.01	0.02
Without conservation	gpm/bhp	0.25	0.33	0.40
Cooling - steam power plants:[1]				
With conservation	gal/kWh	1.30	0.80	1.70
Issue to ships (domestic uses):				
Single berth	gpm		1,000[2]	-
More than single berth	gpm	-	1,000[2]	2,000[3]
Laundries	gal/lb	3	-	6
Irrigation:				
Small lots	gpd/100 ft^2	16	-	32
Large areas	gpad	7,000	-	14,000
Motor vehicles	gpd/car	30	-	50
Restaurants	gal/meal	0.5	-	4.0

[1] Use as a guide only.
[2] Up to 2,000 linear ft of berthing length.
[3] 500 gpm for each additional 2,000 linear ft of berthing length, but not exceeding 2,000 gpm.

2.3.2 Treatment Plant. The design capacity of treatment plants shall be able to meet maximum day domestic demand expressed by Equation (2), plus industrial use demand, assuming adequate equalizing storage following treatment. Without equalizing storage, the plant must be able to meet maximum hour (h) flow expressed by Equation (2), plus industrial use demand.

2.3.3 Transmission Mains. Where the distribution is repumped from storage, transmission mains shall have capacities equal to the maximum-day demand as expressed by Equation (2), plus industrial use demand. Without such storage, they shall meet maximum hour demands.

2.3.4 Distribution System. The minimum capacity of a distribution system shall be sufficient to meet these conditions:

a) instantaneous peak domestic and industrial flows combined

b) maximum fire demands, plus 50 percent of average domestic demands, plus industrial demands which cannot be restricted during the fire

c) replenishment of normal storage volume within 24 h of average demand after a fire.

2.3.5 Reservoirs. Reservoir capacity shall be adequate to satisfy the total of the following requirements:

a) peak fire flow demand as given in MIL-HDBK-1008A

b) 50% of average daily consumption (domestic and industrial)

c) minimum working volume of one hour at average demand (domestic and industrial) for scheduling of treatment plant equipment and service pumps.

2.4 Specific Requirements for Waterfronts and Drydocks. For waterfront requirements, refer to NAVFAC DM-25 Series. For drydock requirements, refer to MIL-HDBK-1029/3, Drydocking Facilities Characteristics.

Section 3: QUALITY REQUIREMENTS

3.1 Water Examination

3.1.1 Qualities To Be Examined. Water for Naval activities shall be examined for the following characteristics (as appropriate):

a) bacteriological quality

b) physical characteristics

c) chemical characteristics

d) biological quality

e) radiological quality.

3.1.2 Sampling Points. For the locations of water sampling points and the reasons for sampling at each point, refer to Table 4. Facilities should be included for sampling at each location.

Table 4
Water Sampling Points

LOCATIONS	REASONS FOR SAMPLING
Source of supply	To evaluate and classify raw water quality To detect and assess the degree of pollution. To assess the treatment required for beneficial uses
Treatment plant	To ascertain the efficiency of the treatment processes To control quality as delivered to the distribution system
Transmission and distribution systems	To locate the cause of any sudden deterioration in quality within the system To control scale and corrosion or slime in the systems
Point of use	To ascertain the quality for potability, palatability, and other beneficial uses

3.1.3 Methods. Methods published in American Public Health Association (APHA) Standard Methods for Examination of Water and Wastewater (latest edition), or as specified by EPA or the state, shall be used in the examination of water.

3.1.4 Frequency of Examination. An initial investigation of a new source of supply is required. At least one complete bacteriological, physical, and chemical examination of raw water is required. When there are sufficient data from existing records, or from hydrological, geological, and sanitary surveys, to establish that the sample is representative, no additional tests are necessary.

3.1.4.1 Supplementary Investigations. Requirements for the frequency of sampling are contained in the 40 Code of Federal Regulation (CFR) Part 141, U.S. EPA National Primary Drinking Water Regulations. Designs should include permanent sampling points if subsequent sampling is required.

3.2 Limiting Criteria

3.2.1 Meaning of Limits. To judge whether a water is acceptable, evaluate its quality by means of the following characteristics.

3.2.1.1 Bacteriological Standards. After treatment, the water shall be free of disease-producing organisms. Easily detected coliform organisms are not in themselves causative agents of disease, but their presence in high concentrations in water indicates possible contamination by pathogenic organisms.

3.2.1.2 Physical Standards. Physical quality measurements give an indirect measure of pollution by undesirable substances, and gage the palatability and acceptability of the water to the consumers. The physical quality must be acceptable after treatment.

3.2.1.3 Chemical Standards. Chemical analyses give a direct measure of contamination by undesirable substances which are toxic, nonpalatable, or otherwise objectionable. Evaluate these to ensure that the water can be made acceptable by treatment.

3.2.1.4 Biological Standards. Biological determinations yield information on past or periodic pollution of the supply. Coordinate these analyses with sanitary surveys and treatment needs.

3.2.1.5 Radiological Standards. Radioactive substances in concentrations sufficient to cause cumulative physiological injuries must be avoided or removed.

3.2.2 Relation of Criteria to Use. The relation applies to water for domestic and industrial uses.

3.2.2.1 Water for Domestic Uses. Water for domestic uses shall meet the requirements of the 40 Code of Federal Regulation (CFR) Part 141, U.S. EPA National Primary Drinking Water Regulations shown in Table 5 and the National Secondary Drinking Water Regulations shown in Table 6, as may be modified by BUMED (refer to para 1.5.1), or by state standards.

3.3.2.2 Water for Industrial Uses. Limits are set on the constituents in water for particular industrial uses. Water for food processing must also meet domestic use standards. If an industrial use requires a higher quality water than the domestic supply, an economic evaluation should be conducted to determine the cost of treatment at the location of use versus the cost of treating the entire supply.

Table 5
U.S. Environmental Protection Agency National
Primary Drinking Water Regulations

MAXIMUM CONTAMINANT LEVELS (MCL) FOR INORGANIC CONTAMINANTS (EXCEPT FLUORIDE)

CONTAMINANT	MCL, mg/L
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05

MAXIMUM CONTAMINANT LEVELS FOR FLUORIDE

ANNUAL AVERAGE OF MAXIMUM DAILY AIR TEMPERATURE

°F	°C	MCL, mg/L
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.2 to 90.5	26.3 to 32.5	1.4

Determined by the annual average of the maximum daily air temperature for the location in which the community water system is situated.

MAXIMUM CONTAMINANT LEVELS FOR TURBIDITY

a) One turbidity unit (TU), as determined by a monthly average, except that five or fewer turbidity units may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not do any of the following:
   (1) Interfere with disinfection;
   (2) Prevent maintenance of an effective disinfectant agent throughout the distribution system; or
   (3) Interfere with microbiological determinations.

b) Five turbidity units based on an average for two consecutive days.

Table 5 (Continued)
U.S. Environmental Protection Agency National
Primary Drinking Water Regulations

MAXIMUM CONTAMINANT LEVELS (MCL) FOR COLIFORM ORGANISMS

a) When the membrane filter technique is used, the number of coliform bacteria shall not exceed any of the following:
   (1) One per 100 milliliters as the arithmetic mean of all samples examined per month;
   (2) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or
   (3) Four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

b) (1) When the fermentation tube method and 10 milliliter standard portions are used, coliform bacteria shall not be present in any of the following:
   (i) more than 10 percent of the portions in any month;
   (ii) three or more portions in more than one sample when less than 20 samples are examined per month; or
   (iii) three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

   (2) When the fermentation tube method and 100 milliliter standard portions are used, coliform bacteria shall not be present in any of the following:
   (i) more than 60 percent of the portions in any month;
   (ii) five portions in more than one sample when less than five samples are examined per month; or
   (iii) five portions in more than 20 percent of the samples when five or more samples are examined per month.

c) For community or noncommunity systems that are required to sample at a rate of less than 4 per month, compliance with paragraphs a), b)(1), or b)(2) of this section shall be based upon sampling during a 3-month period, except that, at the discretion of the state, compliance may be based upon sampling during a 1-month period.

Table 5 (Continued)
U.S. Environmental Protection Agency National
Primary Drinking Water Regulations

MAXIMUM CONTAMINANT LEVELS (MCL) FOR ORGANIC COMPOUNDS

CONTAMINANT	MCL, mg/L
Trihalomethanes	.1*
Endrin	0.0002
Lindane	0.004
Toxaphene	0.005
2,4-D	0.1
2,4,5,-TP (Silvex)	0.01
Methoxychlor	0.1

*MCL for trihalomethanes only applies to systems serving 10,000 or more persons.

MAXIMUM CONTAMINANT LEVELS (MCL) FOR ALPHA EMITTERS

Combined radium-226 and radium-228-5 picoCurie per liter (pCi/L).
Gross alpha particle activity (including radium-226 but excluding radon and uranium--15 pCi/L).

MAXIMUM CONTAMINANT LEVELS (MCL) FOR MAN-MADE RADIONUCLIDES, OR BETA AND PHOTON EMITTERS

The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 milliroentgen equivalent man per yr (mrem/yr). Except for the radionuclides listed below, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2-L/d drinking water intake using the 168-hour data listed in Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, as amended August 1963. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 mrem/yr.

RADIONUCLIDE	CRITICAL ORGAN	pCi/L
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

Source of Information: 40 Code of Federal Regulation (CFR) Part 141, U.S. EPA National Primary Drinking Water Regulations.

Table 6
U.S. Environmental Protection Agency National
Secondary Drinking Water Regulations

CONTAMINANT	LEVEL
Chloride	250 mg/L
Color	15 Color Units
Copper	1 mg/L
Corrosivity	Noncorrosive
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 Threshold Odor Number
pH	6.5-8.5
Sulfate	250 mg/L
Total Dissolved Solids (TDS)	500 mg/L
Zinc	5 mg/L

Source of Information: National Secondary Drinking Water Regulations, Part 40 CFR Part 1.43.

3.2.3 Specific Criteria. The criteria for uses and protection are as follows:

3.2.3.1 Domestic Uses. Ordinary requirements are stated in Tables 5 and 6.

3.2.3.2 Industrial Uses. Requirements for boiler feed water are listed in NAVFAC DM-3 Series, Mechanical Engineering. Other industrial requirements are outlined in American Water Works Association (AWWA) Water Quality and Treatment, a Handbook of Public Water Supplies, 1971.

3.2.3.3 Fire Protection and Flushing Uses. In nonpotable water, the following substances should generally be removed or reduced to harmless concentrations:

a) oil or grease, because of fire hazard

b) substances which accelerate corrosion and tuberculation

c) debris, silts, and other suspended solids

d) organic matters which generate odors and corrosive hydrogen sulfide gas in storage reservoirs

e) algae, fungi, worms, barnacles, and other slime-forming pollutants which can clog pipes or nozzles.

An economic study may be necessary relative to b) and d) above to determine if it is less expensive to remove these constituents or to make the system corrosion resistant.

3.2.3.4 Sanitary Protection. Avoid sources of supply that are subject to pollution by sewage, organic waste, and toxic substances. In designing, prevent entry of these substances into water supplies. If connections to a nonpotable system are absolutely unavoidable, an approved backflow-preventing device shall be installed at each point of connection, or it shall consist of a free-fall air gap twice the pipe diameter. Free-fall air gaps are preferable to backflow preventers. Where possible, it is best to avoid all connections to nonpotable systems.

3.3 Special Cases

3.3.1 Field Bases. Drinking, cooking, and washing water shall be free of pathogenic organisms, toxic chemicals, and radioactive substances. The water, except when both distilled and used within buildings, shall be disinfected. If sanitary surveys show hazards, disinfect distilled water. Comply with mandatory limits in Table 5 unless exceptions are approved by BUMED.

3.3.2 Water Contaminated by Warfare Agents. Water suspected of contamination by chemical, biological or radiological warfare agents shall not be used until tested and declared safe by a representative of BUMED.

Section 4: SOURCE OF SUPPLY

4.1 Selection of Water Source

4.1.1 Investigations. For permanent and temporary installations, investigate all reasonably promising sources. For field bases, carry out reconnaissance studies to locate sources with adequate supply and quality.

4.1.2 Types of Sources. Select supplies from the following sources which may meet requirements, and in the order of preference listed:

a) municipal supplies

b) groundwater (wells, infiltration galleries, and springs)

c) surface water (natural flows, natural storages, impounded storage, and rainwater catchments)

d) nonpotable sources (groundwater with high salinity, surface water with high salinity, and sea water)

e) hauled supplies.

4.1.3 Factors Affecting Selection. Determine availability of supply by whether sources exist and are not already fully used.

4.1.3.1 Adequacy of Yield. Compare the yield with the needs of the activity.

4.1.3.2 Suitability for Use. Water should be of a quality that does not require excessive and costly treatments to render it usable. Use Table 7 as a guide to classify raw water sources for domestic use.

4.1.3.3 Conflicting Uses. Interference with other uses of the same source of supply should be investigated and avoided. Possible conflicting uses include:

a) conservation requirements

b) pollution control requirements

c) prior water rights.

4.1.3.4 Water Rights. Legal advice should be obtained concerning the title of the water at the source of supply.

4.1.3.5 Economics of Water Development. Analysis of development economics should follow Navy policy.

4.2 Municipal Supplies

4.2.1 Quality Examination. Most public water supplies in the United States meet the standards in Tables 5 and 6. Examination of the water is not required if it is reported to be satisfactory by a competent agency. Unless

Table 7
Classification of Raw Water Sources for Domestic Uses

CONSTITUENT	UNITS	EXCELLENT SUPPLY REQUIRES DISINFECTION AND LITTLE ADDITIONAL TREATMENT	GOOD SUPPLY REQUIRES DISINFECTION AND COMPLETE TREATMENT	POOR SUPPLY REQUIRES SPECIAL TREATMENT AND DISINFECTION
BOD_5*	mg/L - Monthly avg.	<0.75	1.5 - 2.5	>2.5
BOD_5	mg/L - Max day or max sample	<1.0	3.0 - 3.5	>3.5
Coliform	mpn/100 ml - Monthly avg.	0 - 100	240 - 5,000	>10,000
Coliform	mpn/100 ml - Max day or max sample	<500	<20%>5,000 <5%>20,000	>20%>5,000 >5%>20,000
Dissolved Oxygen	mg/L - Monthly avg.	4.0 - 7.5	2.5 - 8.0	<2.5
Dissolved Oxygen	% saturation (no units) - Monthly avg.	50 - 75	25 - 90	<25
pH	No units - Monthly avg.	6.0 - 8.5	5 - 9	<5 or >9
Chlorides	mg/L - Max day or max sample	<50	<250	>500
Iron and Manganese together	mg/L - Max day or max sample	<0.3	<1.0	>2
Fluorides	mg/L - Annual avg.	1.0	1.0	>2
Phenolic compounds	mg/L - Max day or max sample	None	0.005	>0.025
Color	Color units - Monthly avg.	0 - 20	20 - 70	>150
Turbidity	Turbidity Units - Monthly avg.	0 - 10	40 - 200	>200
Hardness	mg/L - Monthly avg.	40 - 150	150 - 500	>500
Taste and Odor	Threshold Odor Number (65° C) - Monthly avg.	0 - 3	3 - 20	>20

*BOD—Biochemical Oxygen Demand

reported as satisfactory by a competent U.S. agency, all foreign public water should be considered as of doubtful quality. Examinations are mandatory. Treatment is required unless consistent high quality is absolutely certain.

4.2.2 Rights and Responsibilities. Liaison with municipal waterworks officials should be established by the Navy, and a determination made of the adequacy of the municipal source to meet the quantity, quality, and pressure of water required by the Navy. The location and method of connection to the municipal source must be acceptable to the supplier. Where the quality of the municipal water supply does not meet the standards of Tables 5 and 6, treatment by the Navy must be provided.

4.2.3 Information Required. Information on the municipal system will be obtained from the public water supply agency. Where no reliable records are available, conduct special surveys to obtain the information and data listed in Table 8.

Table 8
Information Required on Municipal Water Supplies

ITEM	DETAILED DATA REQUIRED
Quantity of supply	Type of water source(s). Safe yield (mgd). Population (present and projected future). Per capita consumption (gpcd). Fire demands. Industrial uses and demands. Other commitments and prior water rights.
Quality of supply	Type and capacity of municipal treatment plant(s). Summarized operating records of treatment plants(s). Water quality analysis.
Transmission lines and distribution system	System layout. Sizes and conditions of pipe lines. Pressures available in the system. System storage, size and location.
Local codes and regulations	Special regulations of local regulatory agencies.

4.2.4 Connecting Structures. Types and construction of connecting structures should be selected to meet local requirements insofar as they do not conflict with NAVFAC criteria.

4.2.4.1 Interconnections

a) Direct Connection to Pipeline. Use tapping sleeve valves when the flow cannot be interrupted during construction. Otherwise, cut in a tee. Include a valve and, where required, a reduced pressure backflow preventer between the municipal system and the Navy system.

b) Intake from Reservoir. Use existing intakes where feasible.

4.2.4.2 Appurtenances

a) Meters. Locate meters away from normal traffic but accessible, and protect them against unauthorized intrusion. Meter types are as follows:

(1) propeller type

(2) Venturi tube

(3) ultrasonic flowmeter

(4) Dall meter.

b) Backflow Preventers. Provide these safeguards at all points where a nonpotable water system must be connected to a potable system. Refer to NAVFACINST 11330.11D, Backflow Preventers, Reduced Pressure Principle Type, and para. 7.5.

c) Review manufacturer's literature to insure proper installation conditions.

4.3 Groundwater

4.3.1 Existence. Groundwater can be obtained from wells, springs and infiltration galleries. Such sources can be developed only under favorable geologic and hydrologic conditions. Therefore, adequate information on the underground geologic conditions as well as the hydrologic elements affecting the supply must be secured before a decision to develop these sources can be made.

4.3.2 Information Required. Use existing data, as far as practicable, before collecting field information. Refer to Table 9 for the information required in evaluating a supply.

4.3.2.1 Sources of Information

a) Government Publications and Agencies. Reports on groundwater conditions and resources may be available from the U.S. Geological Survey (USGS) and other Federal and state, geological and water resource agencies.

b) Private Sources. Obtain the following from well owners or drillers:

(1) well logs

(2) pumping records

(3) drawdown data

(4) water quality data.

c) Surface Investigation. Undertake surface exploration before any subsurface exploration.

(1) Aerial Surveys. Use air maps to obtain information for tentative appraisal of groundwater conditions in unconfined aquifers. Drainage and soils maps prepared from air photos may indicate springs, or shallow sources as described in Table 10.

Table 9
Information Required for Selection of Groundwater Supplies

CATEGORY	DETAILED DATA REQUIRED
Geologic data	Geologic history and stratigraphy. Physical dimensions of aquifers (extent and thickness). Physical properties of aquifer permeability, transmissibility, specific yield, coefficient of storage, permeability of adjoining aquicludes.
Hydrologic data	Piezometric surface (water table) maps; that is, locations, elevations, changes in elevations. Precipitation, if there is local recharge. Surface runoff, if there is local recharge. Consumptive uses (evaporation, transpiration). Subsurface recharge and discharge. Artificial recharge records.
Quality of water	Compare to standards and note any long-term changes.

Table 10
Aerial Groundwater Classification[1]

TERRAIN CHARACTERISTICS	POSSIBLE YIELD (gpm)
Granular deposits in stream terraces, alluvial plains, outwash plains, glacial sluiceways, and filled valleys all at low elevations.	Good (200)
Morainal (glacial) deposits, eskers, kames; generally at higher elevations.	Fair (50 to 200)
Upland till and organic topsoils.	Poor (50)

[1]Reference: Journal of American Water Works Association (JAWWA), 48, Application of Air Photo Interpretation in the Location of Groundwater, p. 1380, November, 1956.

(2) Sanitary Survey. A sanitary survey is necessary to determine existing water quality, and the potential for future degradation of water quality from wastewater discharges, agricultural runoff, and waste product disposal operations.

(3) Geological Exploration. Geological field reconnaissance, supplemented by available geologic data, is essential for evaluating the supply. This information must be interpreted by a person skilled in groundwater geology.

(4) Geophysical Exploration. When either of the two above methods indicates need for further surface investigation, geophysical exploration may be desirable. It must be conducted and interpreted by a qualified expert. The following methods have been used for groundwater exploration:

Electric resistivity method. Areal resistivity changes can be interpreted in terms of aquifer limits and changes in water quality; variable depth surveys may indicate aquifers, water tables, impermeable formations and bedrock depths.

Seismic refraction method. This method can provide information on subsurface geology and groundwater. It is not adaptable to small areas, because minimum distances of several hundred feet are needed for profiles in different directions.

d) Subsurface Exploration. All surface methods provide only indirect indications of groundwater. Subsurface data are required to confirm surface indications of groundwater. The following methods are useful.

(1) Test Drilling. Test holes should be drilled until at least one indicates favorable geologic conditions, or until the holes and surface data confirm that conditions are unfavorable. For each test hole, secure the following information:

Geologic log prepared by geologist at time the test hole is drilled;

Samples for each stratum and at intervals of 5 ft (1.52 m) or less;

Driller's log showing drilling time and mud loss rates, if a rotary hole.

(2) Electric Logging. Used in conjunction with a geologic log, electric logs can provide information on formation boundaries, groundwater yield and water quality.

4.3.3 Evaluation of Supply. Evaluate source of supply from the following standpoints:

4.3.3.1 Safe Yield. Determine the safe yield of a groundwater source on the basis of the hydrologic data, assessing the effects of conflicting needs. The evaluations should always include the following hydrological factors:

a) mean annual supply to the groundwater source

b) groundwater storage capacity

c) rate of movement of water through the aquifer between recharge and withdrawal areas

d) water conservation requirements.

4.3.3.2 Water Quality. With respect to quality, it is necessary to:

a) examine the proposed aquifer

b) investigate sources of contamination (geologic, sanitary, and similar sources)

c) investigate water quality control requirements (such as salt water intrusion control).

4.3.3.3 Water Rights. Title to the groundwater source in the United States is usually regulated at the state level. There are two major doctrines for establishing water rights in the United States. Secure legal advice regarding the applicability of:

a) Common Law Doctrine of Riparian Rights

b) Doctrine of Appropriation

c) Prior Water Rights.

The Common Law Doctrine governs the allocation of groundwater to some degree in 37 States, while the remaining 13 - all western states - adhere almost exclusively to the doctrine of prior appropriation.

4.4 Groundwater Collection Works

4.4.1. Wells. Selection of the type of well is to be guided by Table 11 and based upon the following factors:

a) purpose of water supply

b) quantity requirements

c) depth of groundwater

d) geologic conditions

e) available well construction facilities

f) economic factors.

Table 11
Type of Well Construction

TYPE	WELL DIAMETER (in.)	MAX. DEPTH (ft)	YIELD YIELD RATE (gpm)	METHOD	CONSTRUCTION LOCATION
Shallow wells:					
Dug wells	36 - 96	50	1 - 1,500	Excavation	Unconsolidated formations or soft rock
Bored wells	6 to 8	5	0 - 5	Hand auger	Same as above
Bored wells	Up to 36	>100	0 - 200	Power auger	Same as above
Driven wells	1-1/4 - 4	50	0 - 15	Impact driven	Unconsolidated formations with no gravel and rocks
Jetted wells	1-1/2 - 3	>50	2 - 40	Water jetting	Same as above
Drilled wells:[1]	Up to 24	Up to 3,000	20 - 1,000+	Standard	Consolidated rock formations
	Up to 30	Up to 3,000	200 - 1,000+	Hydraulic rotary	Unconsolidated formations
	up to 48	Up to 3,000	200 - 1,000+	Reverse rotary	Unconsolidated formations

[1]Rotary bit and shot drilling sometimes used in rock; and cable-tool methods on unconsolidated formations.

4.4.1.1 Test Well Pumping. After investigation has indicated the best location for groundwater development, a test well is generally used to determine well capacity and appropriate well spacing. A test well may be a small diameter temporary installation in a test hole or, if the preliminary data are very promising, it may be a permanent installation. Pumping tests require one pumped well and one or more observation wells. For a permanent installation, at least one observation well should be 10 to 15 ft (3 to 4.6 m) from the pumped well, with others 50 ft (15.2 m) or more away. The pumped well should be either in the best test hole or not more than 10 ft from it.

a) Duration of Test. The test should run a minimum of 24 h after development of well, or as long as required by any applicable regulations. Longer tests, up to several weeks duration, may be desirable to verify adequacy of the information.

b) Records Required. Secure the following data:

(1) Initial static water level in each well

(2) Pumping rates; at least every hour. Pumping should be maintained at a constant rate.

(3) Drawdown data. Measure water levels in pumping well and also in all observation wells.

(4) Rate of recovery

(5) Where the formation's capability is doubtful, register water levels at each observation well with an automatic recorder accurate to 0.02 feet.

(6) Water samples and analyses. For a major new development, or one of uncertain mineral quality, at least five samples should be taken at periods approximating 0.01, 0.05, 0.10, 0.5 times the test duration, and at the end of the test.

c) Analysis of Tests. Where the formation capacity is in question, use Theis' unsteady-state method as set forth in <u>Water and Wastewater Engineering</u>, Fair, Geyer, and Okun. The tests must be interpreted by a qualified individual.

4.4.1.2 <u>Characteristics</u>

a) Number. Provide at least two wells, if possible.

b) Yield. After making allowance for standby wells and reserve for future needs, the total yield shall be no less than the maximum daily consumption at the Naval activity.

c) Diameter. Determine the size of each well using the total yield required, the number of wells to be constructed, and the capacity of wells at different diameters. The dimensions may be governed by the construction facilities available. Use the following as a preliminary guide for sizing the diameter of deep-drilled wells according to the anticipated yield.

ANTICIPATED CAPACITY (gpm)	CASING DIAMETER (in.)
50	6
50-300	8
300-500	10
500-750	12
750-1,000	16
1,000-2,000	20
2,000-3,000	24
Over 3,000	30

d) Depth. Drill wells deep enough to:

(1) Penetrate an adequate depth into the water-bearing aquifer.

(2) Allow for installation of an adequate length of screen (refer to requirements in para. 4.4.1.3, Well Construction).

(3) Allow for installation of pumping equipment below depth of maximum drawdown.

e) Specific Capacity. This factor equals the yield divided by the drawdown, as determined by the pumping test. It is to be used as a measure of well capability for determining the pumping lifts required at different pumping rates (expressed as gallons per minute per foot (gpm/ft) of drawdown).

f) Spacing of Wells in the Field. Use test pumping data to determine minimum well spacing. Use the data collected from the pumping test to evaluate the effects of interference between wells. The drawdown at any point in the area of influence, caused by the discharge of several wells, equals the sum of the drawdowns (at that point), caused by the wells individually (unless the formation has severe limiting boundaries). Determine the final spacing of wells from investigation of the following factors:

(1) Operation estimated to be successful during the life of the facility.

(2) Extra pumping life required for closely spaced wells and increased pumping costs.

(3) Extra piping and power transmission lines required for widely spaced wells and resulting costs.

4.4.1.3 Well Construction. Wells are commonly constructed by one of five methods: digging, jetting, boring, driving or drilling. Drilled wells are the most common, and may be constructed by cable tool, standard or percussion methods; conventional rotary and reverse-rotary methods are also used. It is recommended that the method of drilling be left to the well contractor, unless it is known that a particular method will give superior results in the area of construction. Standards for AWWA A-100, Deep Wells, shall be met in full for all drilled and bored wells.

a) Casing. In all types of wells, double case, or single case and grout a minimum of the top 10 ft (3.0 m), except in Pacific atolls where this may not be possible. Commonly used materials are wrought iron, alloyed or unalloyed steel, ingot iron, and cast iron. In specialized applications, such as shallow wells on Pacific atolls, PVC casings may be acceptable.

(1) Shallow Dug Wells. Upper casings should be concrete of 6-in. (152.3 mm) minimum thickness to a depth of at least 10 ft below the ground. Lower casings should be perforated or should contain openings for the entry of the water, and must be firmly seated at the bottom. Wells must be grouted at the surface to prevent contamination from surface water.

(2) Shallow Bored Wells. Metal casings shall be the same as for deep wells. Concrete or tile casings should reach to at least 10 ft below the ground.

(3) Driven or Jetted Wells. Utilize the steel or wrought iron well pipes as the well's own casing. For wells jetted using PVC, the PVC may be used as the casing.

(4) Deep Wells. Carbon or stainless steel casings should be used. Stainless steel should only be used where corrosive conditions are encountered, or long life is essential.

b) Casing Joints. Joints shall be welded or threaded couplings where protection against contamination is required. Joints on temporary or construction casings may be riveted (refer to AWWA, A-100, Section A1-5.5, Casing Joints).

c) Screens. Use copper alloy, corrosion-resistant steels, or equally corrosion and erosion-resistant material. On Pacific atolls, PVC can be used for waters with high hydrogen sulfide concentrations.

(1) Openings. Use long, narrow, horizontal slots, larger on the inside than the outside. Provide slots only large enough to allow 50 percent or less of the surrounding grains of water-yielding formation to pass into the well. For total area of openings, keep the maximum slot velocity below 0.10 fps.

(2) Diameter and Length. Length, ordinarily, should not be less than the thickness of the water-bearing aquifer penetrated. If the aquifer has excess capability, partial penetration may be used. Do not use a screen of such length that it will adjoin aquiclude materials that may move into the well. Blanks in screen should be used to blank out clay bearing strata. The diameter and length should be such that the slots provide for the required low velocity.

d) Gravel Packing

(1) Shallow Dug Wells. Unless the well is sunk as a caisson, gravel should be backfilled around the casing and at the bottom, but no higher than within 10 ft (3.0 m) of the surface.

(2) Drilled and Large Bored Wells. Provide at least 2 in. (50.8 mm) of gravel packing around the screen and to a height above the screen sufficient to allow for losses during development of the well. The grain size distribution shall be such that the median size of the gravel is not more than five times the median size of the finest stratum of aquifer material penetrated; this to be determined by mechanical analyses from samples obtained from a pilot hole or from the fully cased well before the screen is installed.

e) Grouting and Sealing. Follow standards for AWWA, A-100.

f) Plumbness and Alignment. Follow standards for AWWA, A-100.

4.4.1.4 Well Development. After completion, each well should be developed to full capacity. The most commonly used methods are pumping and surging; with surging being the preferred method if sand is present or well capacity is low.

a) Methods Available

(1) Pump Surging. This method involves repeated cyclical pumping from a lower to a higher rate, until the capacity of the well is reached.

(2) Surge Block. In this method, surging is created by the rapid up-and-down motion of a plunger. Hexametaphosphates may be added to the well water to free clays or other fines. Surging should be continued until all sand and mud are removed from the well.

(3) Injection of Compressed Air. The injection of compressed air at 100 to 150 psi is repeated until the sand accretion becomes negligible.

(4) Backwashing. This method involves filling the well with water and forcing it out repeatedly by air pressure until the well is developed.

(5) Solid Carbon Dioxide. In this method, inhibited hydrochloric acid may be poured into the well first. Compressed air is then applied to force the acid into clay-clogged strata. Finally, solid carbon dioxide (dry ice) blocks are dropped into the well. The surge produced by the gas effects the release of the clays in the strata.

b) Results Required. At the conclusion of the development, suspended matter shall not exceed 2 mg/L in water delivered, as determined by various samplings. The point of collection is important as the samples must be representative.

4.4.1.5 Sanitary Protection. Protect all wells against surface and subsurface contamination in accordance with EPA-570/9-75-001, Manual of Individual Water Supply Systems. In particular, extend the well casing a minimum of 12 in. (305 mm) above grade and seal the well top against surface contamination.

a) Disinfection of Well. Follow standards for AWWA, A-100.

b) Sealing Abandoned Wells. Follow standards for AWWA, A-100.

4.4.1.6 Saltwater Intrusion Protection. In a coastal aquifer, avoid overpumping which induces salt water into a fresh groundwater basin. In certain situations, seawater intrusion barriers may be necessary. Such barriers are currently operated in Los Angeles County, California, by the Los Angeles County Flood Control District and in Orange County, California, by the Orange County Water District.

a) Control Methods. Control of saltwater intrusion may be accomplished by:

(1) modification of pumping

(2) artificial recharge

(3) pumping troughs

(4) pressure ridges

(5) subsurface barriers

b) Applications and Limitations of Control Methods.

(1) Modification of Pumping. Seek to reduce the pumping draft or to rearrange the pumping pattern by moving the wells inland toward the inflow portion of the groundwater basin. This is usually the most economical method, although it does not fully utilize the groundwater storage capacity.

(2) Artificial Recharge. An intruded aquifer may be artificially recharged from spreading areas or recharge wells with imported high quality supplemental water, with trapped surface runoff, or with treated wastewater.

(3) Pumping Trough. This method consists of forming a trough below the groundwater level, by pumping a mixture of fresh and salt water to waste from a line of wells adjacent to and paralleling the source of salt water. It reduces the usable storage capacity of the basin, wastes fresh water, and is costly to install and operate; but it is sometimes used as an expedient until other methods can be installed, or in conjunction with a pressure ridge.

(4) Pressure Ridge. Control is obtained by forming and maintaining a fresh water pressure ridge adjacent to and paralleling the coast. Although it does not reduce the usable groundwater storage capacity, it requires supplemental water of high quality and has high initial and operating costs.

(5) Subsurface Barrier. Such a barrier is feasible when located in a narrow, shallow alluvial canyon connecting inland to a large aquifer. This method maintains the storage capacity of the basin, but has a high initial cost.

4.4.2 Springs. Many springs fluctuate in their yield and are subject to possible pollution. Frequently, spring water is of less desirable sanitary quality than other underground sources.

4.4.2.1 Types. Springs may be characterized and classified as thermal, gravitational, depression, contact, artesian, and tubular or fracture. Thermal springs are not used since their waters are likely to be highly mineralized. Select from other types with due consideration of yield, quality, and other factors.

4.4.2.2 Collection Works. Select suitable types of collection works as follows:

a) collection chamber, for all gravitational springs

b) open trenches, for depression and contact springs

c) buried pipes, for depression and contact springs

d) wells, for artesian springs

4.4.2.3 Sanitary Protection. Provide protection against pollution of spring water in accordance with EPA-570/9-75-001.

4.4.3 Infiltration Galleries. For collateral readings, refer to Infiltration Galleries in Water and Wastewater Engineering, by Fair, Geyer, and Okun. These collectors, generally placed horizontally at right angles to the direction of flow, are served by gravity flow. Consider the applications and limitations of the following types.

4.4.3.1 Open Trench. Do not use open trenches; they are subject to problems of algae, erosion, clogging by vegetation, and surface contamination.

4.4.3.2 Buried Pipes. For diameters up to 2 ft (.61 m), perforated vitrified clay, concrete, cast iron, or tile drains laid with open joints, may be used. Bury the pipes in a trench and pack gravel around them. Trenches more than 20 ft (6.1 m) deep are usually uneconomical.

a) For the design of perforations, joint opening, and gravel packing, use the same criteria as for wells.

b) The design velocity in collecting pipes should not exceed 2 fps.

c) Collect the water in a covered sump and pump it.

d) Provide manholes spaced at 100 to 300 ft (30.5 to 91.4 m) to facilitate inspection and maintenance.

e) Valves should be placed at the end of the collecting pipes discharging into the sump, and thus providing a means for backflushing to improve the capacity and for isolation for repairs.

4.4.3.3 Tunnel or Gallery. For diameters from 2 to 5 ft (.61 to 1.5 m), use concrete or masonry conduits with perforated openings constructed by open excavation or tunneling. Design strength requirements for buried pipes are applicable.

4.4.3.4 Underground Dam. Subsurface sheet piling, masonry, or chemically solidified barrier dams may be used in conjunction with other collection systems where groundwater is confined in a narrow valley. Locate the dam downstream from the collecting system. It must reach to an impervious formation, in order to seal off the underflow and store it for withdrawal by the upstream collector system.

4.4.3.5 Radial Type Collector. Buried perforated pipes, driven radially from a collecting sump, may be installed near a place of recharge from surface waters, and occasionally elsewhere. This type is best adapted to permeable alluvial aquifers. Yields may range from 300 to 14,000 gpm (1135.5 to 52,990 Lpm).

4.4.4 Skimming Wells. Horizontal wells, termed Maui wells, are the same type as the infiltration galleries in horizontal tunnels.

4.4.4.1 Locations. These wells are used when the seawater is in contact with the fresh groundwater on one or more sides at the following locations:

a) Islands, atolls, peninsulas, spits, or bars surrounded by the sea.

b) Artesian aquifers which outcrop under the sea.

4.4.4.2 Construction. Skimming wells should, if possible, be constructed above sea level, and near the thickest section of the fresh water lens so as to utilize the greatest available hydrostatic pressure and storage. In Pacific atolls, construction below sea level may be permissible to allow withdrawal at low tide.

4.4.4.3 Design. Basis of design is as follows:

a) The yield of a particular lens is generally no higher than half of the recharge rate, and can be much less.

b) The recharge rate may reach half the annual rainfall where rainfall exceeds 20 in. (507.6 mm) in a yr, but may be as low as one percent of the rainfall where rains are less than 4 in. (101.5 mm) per yr. Exact relations will depend on vertical permeability, vegetative demands, and rate of rainfall and of losses through runoff.

c) Losses occur even without a draft on such lenses, through discharge to the sea and vegetative demands.

d) Because of the difference in density between fresh and seawater, a fresh water lens will extend 40 ft (12.2 m) below sea level for each ft it rises above sea level.

e) The quantity stored at the close of the recharge season equals the horizontal area of deposit, times the average thickness of the fresh water lens, times the effective porosity of the aquifer. The effective porosity in these circumstances may range from 10 percent in loose sand to 30 percent in coral. The presence of impermeable layers or of large open channels greatly reduces the effective storage. On a long-term basis, not more than half the quantity stored is recoverable between recharge seasons.

4.5. Surface Water

4.5.1 Existence. The development of surface sources depends on hydrologic conditions and geographic features of the area. A discussion of potential yield of surface supplies is given in NAVFAC DM-5.02, Hydrology and Hydraulics.

4.5.2 Information Required. Use existing data, as far as practicable, before collecting field information. For the detailed data required in evaluating surface supplies, refer to Table 12.

Table 12
Information Required for Selection of Surface Water Supplies

CATEGORY	DETAILED DATA REQUIRED
Hydrologic data	Refer to NAVFAC DM 5.02.
Geographic data	Topographic map of drainage area.
	Cross-section and profiles of streams and rivers. (Not always required.)
	Depths, surface areas, storage capacity of ponds, lakes or reservoir sites.
Geologic data	At dam site.
	At intake site.
	At reservoir site.
Water quality	Chemical characteristics.
	Bacteriological content.
	Sources of pollution.

In addition to all public sources, consult private water agencies and available surveys of other agencies.

4.5.3 Evaluation of Supply. Conflicting uses which modify the safe yield include:

a) conservation requirements, such as flood control, recreational uses (fishing, boating, bathing, and the like), and preservation of fish life

b) pollution control requirements

c) navigation requirements

d) hydroelectric power requirements

e) prior water rights

4.5.3.1 Safe Yield Determination

a) Natural Flow (Streams and Rivers). The minimum dry weather flow must equal:

(1) The peak demand when there is no distribution or storage reservoir.

(2) Maximum daily demand when there is adequate compensating storage.

b) Natural Storage (Lakes and Ponds). The yield from a natural supply should satisfy the average daily demand. In determining yield, regulatory restrictions on the decrease in water level may have to be considered.

c) Impounded Storage. The yield should satisfy the anticipated future average daily demand.

d) Rainwater Catchment. The minimum annual precipitation, less all losses, should satisfy the average daily demand. Adequate storage capacity must be provided.

4.5.3.2 Water Quality. The following factors are important:

a) water examination (chemical, physical and bacterial analyses)

b) sources of contamination:

(1) domestic wastes

(2) industrial wastes

(3) sediments from soil erosion

(4) hostile action

4.5.3.3 Limits of Economic Development. The following factors should be studied:

a) cost policy of the Navy

b) anticipated expansion at the Naval activity

c) time required for the anticipated future demand to exceed the safe yield from surface sources

d) Design life of the structures. Refer to NAVFAC DM-5.02 for the recommended design life of an impounded storage reservoir, and design frequency of spillways.

4.5.4 Water Rights. Water rights for surface water often differ from those for groundwater. They are generally regulated at the state level, except that interstate rights are regulated by the Federal Government. Secure legal advice for the applicable doctrine:

a) Riparian,

b) Appropriation, or

c) Allocation.

4.5.5 Sanitary Protection. Sanitary control of any water supply source is regulated by the state health agency. Designers must follow its regulations and BUMED requirements. Preventive and protective measures shall be taken to safeguard and improve the quality of raw water at the source during construction and operation.

4.5.6 Watersheds. Uses and activities in surface water supply watersheds may impact raw water quality and require higher levels of treatment. Recreational activities should only be allowed when adequate treatment is utilized.

4.6 Surface Water Collection Works

4.6.1 Intakes. Select the site where:

a) The water quality is best.

b) The current will not threaten the safety of the intake structure by debris, log jams, or ice jams.

c) Interference with navigation in the river channel is avoidable.

d) Shoals or bars will not form.

e) Wind waves will not stir up mud and silt from the bottom in such quantity as to impair the water quality.

4.6.1.1 Types and Applications

a) Submerged Intakes. These intakes are suited for both lakes and rivers. They shall consist of a conduit laid in the river or lake bed, terminating in one or more inlet ports provided with gratings or bar screens. Design for the following criteria:

ITEM	RECOMMENDED LIMITS
Velocity at inlet port through bar screen	0.25 fps, max
Bottom of inlet port above bed	2 fpm
Velocity through inlet conduit at rated capacity	3-4 fps
Top of inlet port below low water level	4 fpm

The inlet port submergence below low water is determined by the maximum drawdown required, possible ice formation, and whether suction is to be applied to the intake line. Shallow intakes may vortex; ice may reach a 20-ft (6.1 m) depth in areas like the Great Lakes.

b) Shore Intakes. This form is suitable for both lake and river intakes.

(1) Headwall Type. Intake conduits terminating at a concrete headwall shall have a bar rack in front of it. Also, provide stop-log grooves in front of the bar rack. Whenever possible, provide a gate at the entrance to the conduit. The design criteria shall be:

ITEM	RECOMMENDED LIMITS
Velocity through bar racks	0.5 fps, max
Velocity through intake conduit	2-3 fps
Elevation of crown of intake conduit below low water level	2 fpm
Elevation of intake invert above floor at headwall	2 fpm

(2) Chamber Type. Chambers shall have gated intake ports at several elevations. Bar racks shall be provided between them and the inlet conduit. This intake may be used as a base to support vertical pumps. Design criteria shall be:

ITEM	RECOMMENDED LIMITS
Velocity at intake port:	
With min temp >32.1° F	1.0 fps, max
With min temp <32.0° F	0.2 fps, max
Velocity through bar racks	2-3 fps
Velocity in intake conduit	2-3 fps
Elevation of invert of lowest port above floor	1 fpm

c) Pier Type. The pier shall run from shore out to the required depth of water. Set a vertical pump at the outer end, run the discharge pipe along the pier to the shore, and protect pump suctions with screens.

d) Intake Towers. Use these towers in rivers or reservoirs only for large water works. A tower shall have several gated intake ports. Access by bridge or boat shall be provided. The design criteria are the same as for shore intakes, except that the lowest intake port shall be at least 4 to 6 ft (1.2 to 1.8 m) above the waterway bed at the tower.

4.6.1.2 Appurtenances to Intakes

a) Gates. Use sluice gates or stop logs.

b) Bar Racks and Screens. At inaccessible locations, provide 2-in. (.51 mm) openings.

c) Air Bubbler System. Use an air bubbler system if necessary to keep the intake free of ice.

4.6.2 Reservoirs

4.6.2.1 Selection. The selection shall be based on the following factors:

a) Drainage areas must be adequate to provide the required flows.

b) Topography at the dam shall provide ample storage capacity at minimum cost, and a good site for a spillway to pass the flood flow.

c) The geology at the dam should provide suitable materials for dam construction, safe foundation for the dam and the spillway, and tightness against excessive seepage.

d) Selection should avoid the following sites: densely inhabited areas, heavily wooded areas, large swampy areas, areas requiring major highway relocation, areas fed by silt-laden streams, and areas with many prior water rights.

e) Intakes should be located so that tributary streams and treated or untreated wastes cannot be short-circuited through the reservoir to the intake.

f) Sites shall be as close as possible to the area served.

g) Plan for a gravity aqueduct from the intake to the point of delivery.

h) The site should have a minimum of shallow areas when flooded, since shallows encourage growth of weeds.

i) To reduce silting, seek the smallest practicable drainage area.

4.6.2.2 Reservoir Site Preparation. Before constructing dams and appurtenances, perform the following operations at the reservoir site:

a) Demolish and remove all structures below the high waterline. Consider removal of structures above the high waterline.

b) Clear and grub all trees, stumps, brush, weeds and grass below the high waterline. Clearing above this line may encourage an objectionable growth of underbrush.

c) Remove all sanitary waste and waste disposal structures, such as septic tanks and cesspools from the entire reservoir site.

d) Remove as much muck from swamps as possible, with emphasis below the high waterline.

e) Drain all pockets in marginal swamps.

4.6.3 Dams. For collateral reading, refer to Department of the Interior, Design of Small Dams.

4.6.3.1 Earthfill. Use earthfill dams wherever construction materials are available nearby and where a suitable spillway can be secured. A qualified expert in soil mechanics shall be consulted to analyze soil samples taken at the site, and to advise on design and construction. The design of earthfill dams shall fulfill the following requirements:

a) The materials shall be stable under all probable conditions of moisture content.

b) The foundation material shall have enough bearing capacity to support the loaded dam.

c) The dam shall be resistant to percolation of water.

d) The embankment slopes shall be protected against erosion due to wave action and surface runoff.

e) The freeboard shall suffice to prevent overtopping of the dam during extreme flood flow, damage due to frost penetration, and damage due to wave action.

f) The design of earthfill dams shall follow the criteria for Compacted Embankments in NAVFAC DM-7 Series on Soil and Foundations.

4.6.3.2 Rockfill. Use rockfill dams where rock is the only satisfactory material available. The dam shall have a seepage-retarding membrane, either in or on the upstream embankment. Design this membrane to remain watertight while subject to temperature changes and other forces. All other requirements for earthfill dams are applicable.

4.6.3.3 Concrete or Masonry. Use a concrete or masonry gravity dam only where earthfill and rockfill types are not applicable and where the spillway must be incorporated in a strong dam structure. The design of these dams shall fulfill the following requirements:

a) The dam must be stable against overturning, sliding, shear, uplift ice thrust pressure, and earthquake shocks.

b) The foundation must have enough bearing capacity to support the structure with the reservoir full.

c) The dam and the foundation must be leakproof.

4) The freeboard shall suffice to prevent overtopping during extreme high flood flow and wave action.

4.6.4 Spillways. Provide adequate main and emergency spillways to protect dams against overtopping by floods. They may be side channel, chute, or ogee type.

4.6.4.1 Main Spillway. This appurtenance shall:

a) Provide a capacity to pass a 100-year flood.

b) Be located, wherever possible, away from the intake and the dam.

c) Be built of concrete or stone, with sidewalls to protect the dam structures from damage by sprays and the high velocity in the spillway channel.

d) Be provided with an energy dissipator at its downstream end to reduce the velocity to a rate that is harmless to any downstream river channel on which the safety of the dam depends, or to any downstream structures.

e) Provide a smooth approach section such that the full design capacity of the spillway will be utilized.

f) Be provided with gated spillway openings only when:

(1) positive gate operation is assured,

(2) a full-time staff attends the dam, and

(3) good communications and flood routing information are available.

4.6.4.2 Stilling Basin. This basin shall be used as the energy dissipator for the main spillway. Its design shall fulfill the following requirements:

a) The floor shall be set so that the conjugate water depth in the basin matches the tailwater elevation.

b) The length shall embrace the hydraulic jump within the basin at maximum flow.

c) The basin shall be concrete, with sidewalls to prevent the erosion of soils behind them.

4.6.4.3 Emergency Spillway. This unit shall:

a) Provide a capacity, combined with the main spillway, to pass the maximum probable flood flow.

b) Be located away from the intakes and the dam.

c) Have its crest set at an elevation such that the design flood level of the main spillway will not be exceeded.

d) Have a low head discharge with a wide cross section to keep the maximum crest velocity low; except where no erosion from discharge will occur, when a fuseplug or washout type may be used.

e) Have its slope reduced, so as to cause velocities within the maximum allowable for the channel materials.

f) Have a smooth approach section.

g) Be constructed on firm material and, if an earth channel is used, always be well covered with grass and clear of trees, bushes, structures, and any other obstructions to flow.

h) Use flashboards to provide any additional storage or depth above the spillway crest. Special investigation of resultant hazards and associated problems will be required. Flashboards shall be of the washout type. Use criteria in American Civil Engineering Practice, Volume 2, by R. W. Abbett.

4.6.5 Rainwater Catchment Areas. The site should be selected for the following desirable factors:

a) Topography presenting a large surface area where rainwater can be easily collected. Slopes greater than 0.01 (1.0 percent) are desirable, as is space for a ponding basin to store peak flows.

b) Absence of heavily wooded areas.

c) Absence of large swampy areas.

d) A minimum distance of at least 100 ft (30.5 m) from the outer edge of the catchment or related structures to subsurface sources of contamination (such as septic tanks and cesspools) where the ground surface is used as a catchment area.

e) Locate as far from sources of air pollution as possible (for example, dust, soot, salt water spray).

4.6.5.1 Application. Such areas are to be used only:

a) Where there is no other adequate source of fresh water.

b) Where rainfall is sufficient to supply the required yield.

4.6.5.2 Types

a) Open Ground Surface Area. The catchment area should be graded to facilitate collection of rainwater and to eliminate depressions causing ponding, and shall be paved with impervious materials to prevent seepage losses. The collected waters shall be conveyed to a closed storage reservoir.

b) Roof Surface Area. Such areas shall be used for installations with small demand for water, or to supplement ground surface areas.

4.6.5.3 Structures

a) Ground Surface Paving. Selection of the type depends on soil conditions at the site. Use either concrete or soil cement.

b) Training Wall. Provide adequate training walls around the catchment area. Provide curbs and gutters outside the catchment for protection against erosion, scouring, and contamination during heavy rain.

c) Spillway. Provide an emergency spillway to prevent overtopping.

d) Ponding Basin. Where feasible, make the basin integral with the catchment area. Size it in conjunction with the peak flow rates and capacity for discharging to storage.

e) Discharge to Storage. Water may run to storage by gravity or pumping. Provide a blowoff to divert the initial slug of raw water; it may carry accumulated minerals or sediment. Provide an intake sump with bar racks of the grating type in front of the conduit.

f) Storage Reservoirs. Design to conform to requirements for underground reservoirs in Section 8.

g) Fencing. Fence the catchment area.

4.6.5.4 Sanitary Protection. Catchment areas must be lime washed immediately after construction. Water treatment, filtration and disinfection are required; (for methods, refer to Section 6 on Treatment).

4.6.5.5 Data Required. Rainfall data should include monthly rainfall quantities and where available, the number of days of rain per month. Catchment characteristics needed are: slope, roughness, pondage, and discharge capacity.

4.6.5.6 Basis of Design. For each rainstorm, there is a loss of moisture due to surface detention, pondage, and evaporation. Rather than analyze by individual storms, proceed on the basis of the number of days of rain. The loss will range from 0.06 in. (1.5 mm) per day of rain for steep, smooth catchments free of pondage to 0.25 in. (6.35 mm) per day of rain for paved areas having slopes of 0.01 and the roughness of screened surfaces, with some minor pondage. In this range, choose an appropriate unit loss allowance. Where data on the number of days of rainfall are unavailable, allow a gross yield of 0.5 gal/ft^2 (20.45 L/m^2) of catchment area per in. (25.4 mm) of rainfall.

a) Monthly Yield. For each month, multiply the loss allowance by the number of days of rain. Subtract this product from the month's rainfall to determine the gross yield.

b) Peak Rate. Check the peak rainfall rates and resultant flows against the outlet capacity. If a substantial part of the annual rainfall causes uncollectable spills, make allowance for this. An appropriate loss allowance for roof-gutter systems, or others where there are such losses, is 25 percent of the gross yield. Correct each month's value; rainy season corrections will probably be larger than those in drier months.

c) Storage. Plot a mass curve of the direct period on record and graphically determine the storage required on the basis of the desired net unit yield. From the unit yield and storage data, determine the area of catchment and the total storage required.

4.7 Hauled Supplies

4.7.1 Applications. Barges and mobile tanks for potable water, filled from ships or tank trucks, shall be used as methods of supply for Naval activities under the following conditions.

4.7.1.1 Transient Sites. Use these sites when the duration of the activity is only a few days and does not require the installation of other more costly measures.

4.7.1.2 In the Field. Use hauled supplies where no other source of water supply can be made available for that location.

4.7.2 Protection. Below are guidelines to protect from both outside and inside sources of damage.

4.7.2.1 Protection Against Outside Sources. Screens and other devices shall be provided for tank vents to prevent the entrance of insects, birds, animals, dust or spray. Access manholes should be raised at least 6 in. (152.4 mm) above the top of the tanks, and the manhole covers must be watertight and locked. All cross connections to nonpotable waters shall be provided with suitable backflow preventers.

4.7.2.2 Protection Against Damage from Inside. Hauled supplies shall be protected against freezing and corrosion.

4.8 Nonpotable or Salt Water Systems

4.8.1 Utilization

4.8.1.1 Waterfront Fire Protection Cooling and Flushing Water. Separate nonpotable water supplies shall be provided for active waterfront facilities. At active and repair berths and drydocks, cooling, flushing and fire protection requirements shall be met using nonpotable fresh or saltwater supplies. Only one nonpotable system shall be provided, and it shall meet the requirements of the DM-25 Series. At inactive berths, salt or nonpotable water shall be used, when available, for fire protection; if not available, potable water shall be used. Nonpotable water supplies shall be designed to preclude any possible contamination of potable water supply sources or systems. Saltwater systems, including distribution mains, shall not be placed within a fresh water aquifer, as any leaks would contaminate the aquifer.

4.8.1.2 Condenser or Cooling Water. Use nonpotable systems for cooling and similar industrial uses when the quality of water is not a critical factor.

4.8.1.3 Demineralization or Distillation. Use nonpotable water for intake and waste sections of demineralization or distillation systems. The potable portion of such systems shall be completely separated from nonpotable sections.

4.8.2 Precautions. Special precautions for nonpotable or saltwater systems are discussed below.

4.8.2.1 Cross Connections. The criteria given in para 7.5 are applicable for all systems utilizing nonpotable water.

4.8.2.2 Elevated Storage Tanks. For nonpotable supply storage tanks, use air breaks to prevent polluting the potable water system. Every inlet from the potable water system into the tanks shall be placed at least 6 in. (152.4) above overflow level. In other respects, use the criteria for tanks on potable water systems in para 8.4.3.

4.8.2.3 Outlets. All outlets of a nonpotable water system must be marked appropriately.

4.8.3 Requirements. Criteria for requirements of nonpotable or saltwater systems are as follows.

4.8.3.1 Fire Protection. For fire protection of shore facilities, refer to MIL-HDBK-1008A.

4.8.3.2 Waterfront Operational Facilities. Requirements for fire protection and flushing/cooling water are given in NAVFAC DM-25 Series.

4.8.3.3 Graving Docks. The demands for graving docks must be considered in the design or evaluation of overall station capacity. Refer to NAVFAC DM-29.1, Graving Drydocks, for graving dock requirements.

4.8.3.4 All Other Uses. Uses other than those discussed previously shall be as required by the process being served.

4.8.4 Intakes. The general criteria for fresh water intakes given in para. 4.6.1 are applicable with the following additional requirements.

4.8.4.1 Location. Keep suction lines short, but avoid proximity to sewer outfalls, storm drains, and areas subject to waterborne trash or refuse. Combine with condenser or cooling water intakes when feasible. The intake structure can be separate from the pump house.

4.8.4.2 Secondary Inlet. Provide emergency inlet or screen bypass at the bulkhead. Make the inlet accessible for manual operation.

4.8.4.3 Screening. All intakes shall be screened as follows.

a) Traveling Water Screens. Traveling water screens should be considered for all saltwater intakes.

b) Fixed Screens. At small intakes, operating less than 2 hours per day, a series of fixed screens can be used. Follow the sequence and sizes of bar, coarse, and fine screens as given in para. 6.2. Framing and screening shall be heavy, hot-dipped galvanized steel, corrosion-resistant alloy, or fiberglass when screens are not exposed to sunlight. Provide easy access for cleaning and maintenance.

4.8.5 Pumping. System pressure and capacity are determined by fire, flushing and cooling water requirements. The basic criteria for pumping stations are identical with those for fresh water stations given in Section 5 and Section 9 of this manual, except as discussed below.

4.8.5.1 Power. Steam turbine drives can be used if the pump station is in, or adjacent to, a central heating plant or powerplant that uses steam-driven auxiliaries. Power must be available at all times. Where the seawater system is a main source of firefighting water, provisions shall be made for either standby power or auxiliary drive by either gasoline or diesel power. Standby power or auxiliary drive units shall be automatically supervised and thrown into operation, unless the pumping station is to be manned continuously.

4.8.5.2 Pumps. The use of cast iron for pumps, other than standby pumps, is prohibited for saltwater systems. Pump suppliers can be consulted for recommended materials based on service and pressure. However, designers should evaluate the corrosivity of the water and specify appropriate materials. Easy dismantling is essential for this type of service. Capacity of the standby power system or auxiliary drive system shall provide at least 50 percent of the total pumping capacity, unless electric power is provided from two separate sources.

4.8.5.3 Alarms. Where the system will be in continuous service, provide low pressure alarms. If the pumps operate intermittently, the alarm system shall be operative only when driving units operate, after a suitable time delay.

4.8.6 Distribution System. Use applicable criteria for potable water systems, Section 7. Include additional loops and branches required for graving docks and waterfront operational facilities.

4.8.6.1 Pressure. Provide pipe and fittings of a class suitable for the operating pressure, plus an allowance, based on detailed analysis, for water hammer. Assume a fouling factor in pipeline friction based on local experience. Where local data are unavailable, use a friction factor of n = 0.017 or Hazen-Williams coefficient of c = 100.

4.8.6.2 Materials. Materials for water mains should be selected from the following:

a) Ductile iron pipe with cement mortar lining (and polyethylene encasement for buried lines), AWWA C100, Iron Pipe, C110/A21.10, Ductile-Iron and Gray-Iron fittings, 3 in. Through 48 in., for Water and Other Liquids, latest edition, and C105/A21.5, Polyethelyene Encasement for Ductile-Iron Piping for Water and Other Liquids, latest edition.

b) AWWA C950, Glass-Fiber-Reinforced Thermosetting Resin-Pressure Pipe (latest edition).

c) AWWA C900, Polyvinyl Chloride (PVC) Pressure Pipe 4 in. Through 12 in., for Water, latest edition, and 40 CFR Part 141.50.

Materials for exposed pipes under piers shall be either flanged ductile iron or cement mortar lined, steel pipe, AWWA C205-80, Cement-Mortar Protective Lining and Coating for Steel Water Pipe--4 in. and Larger--Shop Applied, latest edition. Steel pipe is preferable where insulation is required. Pipe shall have a 250 psi rating and be properly coated for corrosion protection.

4.8.6.3 Valves. Use butterfly valves having a 250 psi (1723.7 kPa) rating constructed of materials resistant to corrosion by the source of water.

4.8.6.4 Construction. Check loads at joints, bends, fittings, valves and other necessary locations, and provide necessary tie-downs and blocking. Operating pressures can be higher than those of potable water systems, and some of the pipe cannot be buried.

a) Location. Where pipes run under or inside of structures, provide access manholes in the structures.

b) Access. Provide blind flanges, hand holes, removable sections, and other types of openings into the piping for cleaning and inspection.

c) Protection Against Freezing. Perform a detailed analysis to determine if insulation or other type of protection is necessary. Allow for the lower freezing temperature of seawater.

d) Protection Against Wind Damage. Pipes suspended aboveground or on structural supports shall be anchored to withstand wind velocities specified for the design of structures (refer to NAVFAC DM-2 Series, Structural Engineering).

e) Protection Against Current/Tidal Action. Seawater intake structures and piping exposed to current/tidal action shall be adequately protected.

f) Expansion/Contraction. Expansion/contraction requires detailed analysis to determine if provisions for expansion or contraction are necessary.

4.8.7 Corrosion and Fouling. Special criteria related to corrosion and fouling are outlined below.

4.8.7.1 Cast Iron. Cast iron, which is normally used for pumps and piping in potable water systems, is slowly attacked by seawater which removes the iron, leaving a graphite residue (graphitization). In quiescent water, this graphitized layer remains intact and protects against the penetration of water and further corrosion. This protective layer is soft, and high velocity flow in pumps or piping will remove it and expose fresh base metal to high-rate corrosion. Furthermore, the graphite particles are cathodic and can accelerate the corrosion of new cast iron brought into contact with them.

4.8.7.2 Cement Lined Steel and Cast Iron Pipe. Usually, cement lining is good protection against corrosion. However, the lining can be eroded by high velocity flow of sediment-bearing water, fouling organisms can break the lining away from the pipe wall, and impact and vibration at waterfront structures can weaken the lining.

4.8.7.3 Plastic Piping. There is no significant corrosion problem in the use of plastic piping and the pipe is not as susceptible to fouling as other nontoxic materials. Plastic pipe should be protected from ultraviolet radiation and properly supported when installed in exposed locations. When installed underground backfilling with selected material must be specified in order to prevent surface gouging. PVC piping for drinking has become suspect by the EPA (refer to 40 CFR Part 141.50).

4.8.7.4 Copper Based Materials. Copper based materials are commonly used on ships and other floating structures to overcome both corrosion and fouling. Costs and the rough use that this type of pipe will receive at shore installations may preclude its use in extensive distribution systems and particularly in large diameter pipes. Copper based materials are susceptible to corrosion by hydrogen sulfide.

4.8.7.5 Cathodic Protection. Details for cathodic protection design are given in MIL-HDBK-1004/10, Cathodic Protection. This type of protection will probably control corrosion economically at the intake piping and structures, and in some cases may be feasible to use for protecting transmission lines. Consideration must be given to the effect on adjacent buried utilities.

4.8.7.6 Fouling. A fouling problem will exist in all saltwater handling systems. Fouling organisms may reduce corrosion by protecting the base material or accelerate it by breaking up protective coatings or corrosion films. Some barnacles are capable of penetrating bituminous coatings up to 1/4-in. (6.35 mm) thick. An important additional point is that fouling organisms obtain a more secure hold on hard smooth surfaces than soft material. For example:

a) Barnacles adhere strongly to stainless steel.

b) Fouling organisms can be fairly easily removed from soft rubber.

c) Common protective paints, (nonantifouling) with hard, glossy finishes afford good foundations for fouling organisms while soft paint finishes do not.

4.8.7.7 Control of Fouling

a) Fine Screening. This method reduces the number of organisms entering the system; however, most fouling growths attach themselves at an early growth stage when they are small enough to pass through fine screens.

b) Chemical Treatment. Chlorination is the most common treatment used in saltwater handling systems, and is recommended. Chlorine cannot protect the sections of piping upstream of the point of application unless back-flushing is feasible. The method is fairly successful in piping or circulation systems. It may be relatively expensive to add a large dosage of chlorine to large volumes of water. This is often overcome by slug-feeding at high rates about 10 percent of the time of operation. Copper sulfate may also be useful in controlling fouling.

c) Antifouling Paints. These paints are in very common use for protection of exposed material. Almost all antifouling paints utilize copper because of its toxicity to waterborne organisms. Antifouling paints must be separated from a ferrous base metal by a primer coat to prevent interaction between copper and iron.

d) Velocity Control. Above certain velocities fouling organisms cannot anchor themselves on piping and/or pumps. Below the following approximate velocities, fouling will occur:

PIPE MATERIAL	LIMITING VELOCITY (approx. fps)
Glass	7
Plastic	8
Steel	11
Cement lining	15

It is not feasible to maintain these velocities in most sections of a distribution system.

4.8.7.8 Combined Control of Corrosion and Fouling

a) Desired Protection. On most systems, it is recommended that multiple protection be provided. A typical system would have an intake protected by a traveling screen, chlorination, and corrosion resistant or lined piping.

b) Copper Base Material. Not commonly used due to cost and the inability to stand rough handling.

Section 5: PUMPS

5.1. Pumping Installation Planning

5.1.1 Information Required. Refer to Table 13 for the detailed data needed for design of pumping installations.

Table 13
Information Required for Pumping Installation Planning

CATEGORY	DETAILED DATA AND INFORMATION
Purpose of service	Transmission of water from water source. Pumping in the distribution system. Pumping to elevated storage tank. Pumping for fire protection. Booster pumping. Pumping service at treatment plant. Other miscellaneous pumping services.
Piping layout	Lengths, sizes, fittings.
Demand requirements	Maximum demand: Mgd or gpm. Average demand: Mgd or gpm. Minimum demand: Mgd or gpm. Variation in demand. Effect of storage on demand rates.
Static lift requirements	Static suction head or lift
Liquid characteristics	Static discharge heads Specific gravity Temperature Vapor pressure Viscosity pH Chemical characteristics Solids content
Power available	Type Characteristics

5.1.2 System Head Curve. Refer to NAVFAC DM-5.02 for the method of determining system head curves.

5.1.3 Pumping Arrangements. Select the pumping arrangement based on the types, applications, and limitations listed in Table 14.

5.1.4 Determining Pump Capacity. Determine single or multiple pump type as follows.

5.1.4.1 Single-Pump Installation. This type of installation may be used only for extremely small demands, when standby service is positively assured.

a) To meet the peak instantaneous demand where there is no elevated storage reservoir.

Table 14
Applications and Limitations of Pumping Arrangements

TYPE OF ARRANGEMENT	WHERE TO USE	LIMITATIONS
Throttling pump discharge	Not to be used for normal operation in a large installation, except during emergency when other arrangements are noperative	Waste of power
Bypassing the discharge (all or part)	Same as above--use bypass only for installations where throttling might overload motor or overheat pump	Waste of power
Multiple pumps in parallel operation	Use this arrangement as a normal installation	Requires multiple pumps, and possibly jockey pump to pressurize system at low demands
Intermittent pumping with storage reservoirs riding on hydraulic gradient	Use this arrangement wherever possible	
Manual or automatic speed variation to control pump discharge	Use only if detailed cost study indicates economic feasibility	Usually expensive

b) To meet the maximum daily demand where there is an elevated storage reservoir.

5.1.4.2 Multiple-Pump Installation. Use this arrangement normally; determine the capacity of each pump from a detailed study of various combinations to meet variations in demand. Provide at least three pumps. The necessary station capacity shall be available with the largest pump out of service. Refer to NAVFAC DM-5.02 for pump criteria.

5.2 Selection and Installation of Pumps

5.2.1 Types and Applications. Refer to Table 15 for characteristics of pumps normally used in a water supply system and their applications.

5.2.2 Pump Selection. Seek catalog information and guidance of several pump manufacturers in selecting a particular pump. Refer to Table 16 for the factors involved.

Table 15
Pump Characteristics

CLASS	TYPE	MAX CAPACITY (gpm)	MAX HEAD (ft)	SUCTION LIFT (ft)	SPECIFIC SPEED (rpm)	EFFICIENCY (%)	PRIMING	LIQUID HANDLED	APPLICATION***	LIMITS ON APPLICABILITY
Centrifugal	Volute	40,000	500	15	<4,200 (single suction)	75 to 90	Not self-priming	Clean and clear	General-purpose pumps. Fire pumps.	Not suited to operate under high suction lifts.
Centrifugal	Diffuser or turbine	-	-	*	-			Clean and clear	Boilerfeed pumps.	-
Centrifugal	Regenerative-turbine	100	575	-	<6,000 (double suction)	70 to 85	Not self-priming	Clean and clear	Chemical pumps, small general-purpose pumps.	Not suited to operate under high suction lifts.
Centrifugal	Vertical-turbine	30,000	>1,500	*	-	70 to 86	Not self-priming	Clean and clear	General purpose supply deep-well pumps, and line booster pumps.	Cannot handle liquids containing solids.
Centrifugal	Mixed flow	100,000	100	*	4,200-9,000	75 to 90	Not self-priming	Liquid with solids	Low-lift pumps at raw-water intakes. Irrigation pumps. Flood-control pumps.	Generally installed below suction water level, as submergence is needed for proper operation. Not suited for high-lift service at low capacity. Power need near shut-off head is greater than power as rated head.
Centrifugal	Axial flow	200,000+	50	*	>9,000	75 to 90	Not self-priming	Liquid with solids.	-	Same limitations as mixed-flow type but limitations are more severe.

Table 15 (Continued)
Pump Characteristics

CLASS	TYPE	MAX CAPACITY (gpm)	MAX HEAD (ft)	SUCTION LIFT (ft)	SPECIFIC SPEED (rpm)	EFFICIENCY (%)	PRIMING	LIQUID HANDLED	APPLICATION***	LIMITS ON APPLICABILITY
Rotary	Helical, gear, lobular, etc.	55	1,000	22	-	Up to 70	Self-priming	Viscous non-abrasive.	Small well pumps, and chemical service.	Not suited for large capacity pumping. Cannot handle liquids containing solids.
Reciprocating	Piston or diaphragm	300	800	22	-	50 to 90	Self-priming	Clean and clear to liquid with solids.	Small pumps for moderate pumping, chemical service. Sludge pumps.	Suitable only for moderate capacity services. Not suitable for operation requiring steady and smooth discharge.
Jet		50	100	**	-	20 to 25	Self-priming	Liquid with solids.	Small shallow-well pumps.	Suitable for small capacity for low-lift services. Has low efficiency because most of water pumped is recirculated.
Air lift		2,000	1,000	**	-	30 to 50	Self-priming	Liquid with solids.	Deep-well pumps, aeration, sludge handling.	Requires extra depth to provide adequate submergence. Not suitable for direct pumping to a distribution system. Not suitable for horizontal transmission of water. Oxygen in water increases corrosive action. Low efficiency. Excellent erosion-resisting capabilities.

* Obtain manufacturer's recommendations.
** Must be submerged.
***Does not cover all applications.

Table 16
Factors in Pump Selection

ITEM	DETAILS AND FACTORS
Pump characteristics	Capacity range (gpm) Discharge head range (feet) Characteristic curve (steepness, kinks) Efficiency Power input Speed (rpm) Specific speed Suction requirements
Pump construction	Conform to standards of Hydraulic Institute (HI) Pump materials must be suitable for liquids to be handled Bearing and seal construction
Space requirements	Compare vertical with horizontal type and select pump requiring least space, other factors being equal
Operating flexibility	Pump starting characteristics Pump priming requirements Behavior under parallel operation
Economy	Power Maintenance

5.2.3 Installation Requirements. Use applicable sections in the Hydraulic Institute's (HI) Hydraulic Institute Standards. Some typical pump stations are shown in American Civil Engineering Practice, Volume 2.

5.2.3.1 Pump Location. Except for submersible sump pumps, pump drives should not be placed in a pit or other location subject to flooding. Wherever possible, locate pumps so there is a positive suction head.

5.2.3.2 Piping Arrangement. Wherever possible provide loop headers or otherwise arrange piping for minimum interruption of service due to any one piping break. Where fire demand water is furnished, arrange to supply at least 50 percent of the system demand despite a possible break in any piping.

5.2.3.3 Suction Piping. Static lift should not exceed 15 ft (4.57 m), including all losses through suction piping due to the pump location. In all conditions of suction lift, a positive priming facility shall be provided.

5.2.3.4 Valves. Valves at pumps should be arranged to provide for removing any pump unit from service without interruption to others.

5.2.3.5 Pressure Relief Valves. Provide a pressure relief valve or a small bleeder line on pump discharge, if the characteristics of the pump permit development of excessive pressure, or if damage to the pump could result from overheating because of operation with zero flow. This must be done when the pump discharges into a distribution system which does not include an elevated storage tank, or if the system includes an elevated tank that is protected against overflow. Review manufacturer's data for selection criteria required to prevent cavitation damage.

a) Recirculation Line. Where potable water is pumped from an underground reservoir, a recirculation line should be provided, discharging from the pressure relief valve into a properly checked reservoir fill line.

b) Fire Pumps. Pressure relief valves should be provided on fire pumps in accordance with National Fire Protection Association (NFPA) Standard No. 20, Installation of Centrifugal Fire Pumps.

5.2.3.6 Flexible Coupling. To relieve any strain transmitted to the pumps and to take up misalignment, piping near pumps should be provided with flexible couplings.

5.2.3.7 Vertical Pumps. Design criteria for vertical pumps are delineated below.

a) Wet Pit or Well Submergence. Use the value recommended by the pump manufacturer for operation at sea level with water at 70° F (21° C), and adjust the value for elevation above sea level and water above 70° F.

(1) Add 14 in. (356 mm) submergence for every additional 1,000 ft (305 m) of elevation above sea level.

(2) Provide additional submergence for water temperatures above 70° F, as follows:

TEMPERATURE		ADDITIONAL SUBMERGENCE	
°F	°C	in.	mm
80	27	4	102
90	32	10	254
100	38	17	432
110	43	26	660
120	49	38	965
130	54	54	1372
140	60	74	1880
150	66	100	2540
160	71	125	3175
170	77	160	4064
180	82	205	5207
190	88	250	6350
200	93	300	7620

b) Vertical Booster Pumps. Vertical booster pumps aid in reducing space and piping requirements. Direct-connected and can-type units are suitable.

c) Intake Sump Design. Provide bar racks and screens to protect pumps, piping, valves, and fittings from debris and aquatic life. Dimensions of the sump should be such as to prevent vortex and turbulence, which are detrimental to pump performance. Use Figure 1 and the HI Hydraulic Institute Standards as guides in design.

5.2.3.8 Priming Facilities. Use the requirements of the HI Hydraulic Institute Standards for planning priming facilities.

5.3. Power

5.3.1 Choice of Power. Factors affecting choice of power include dependability, availability, and economic considerations.

5.3.1.1 Types of Power. Select power from the following:

a) Electricity

b) Petroleum products (diesel oil, gasoline)

c) Natural gas

d) Compressed air

e) Steam

5.3.1.2 Applications. For preferential choice and applications, refer to Table 17.

5.3.2 Standby. Standby power for pumps shall be provided for all installations as described below.

5.3.2.1 Electric Power. Provide two separate sources (two separate feeders). Feeders should follow separate routes, and originate from separate substations or other sources.

5.3.2.2 Internal Combustion Engines. Provide internal combustion engines where there is no second separate electric power source. Such engines shall provide a standby capacity which is equal to the required supply. Gasoline engine-driven pumps should be installed above grade in accordance with NFPA Standard No. 20.

5.3.3 Drives. To select the proper drives to connect power to pumps, design for the following data:

5.3.3.1 Electric Drives

a) Torque Requirements. Use a constant torque motor for reciprocating and rotary pumps, and a variable torque motor for centrifugal pumps.

b) Alternating Current Motors. Use a squirrel-cage induction motor for 200 horsepower (hp) (149.2 kW) or less, at constant speed. Use a wound rotor induction or multispeed motor for 200 hp or less, when several different speeds are required. Where the power factor is important, use a synchronous motor for power above 200 hp.

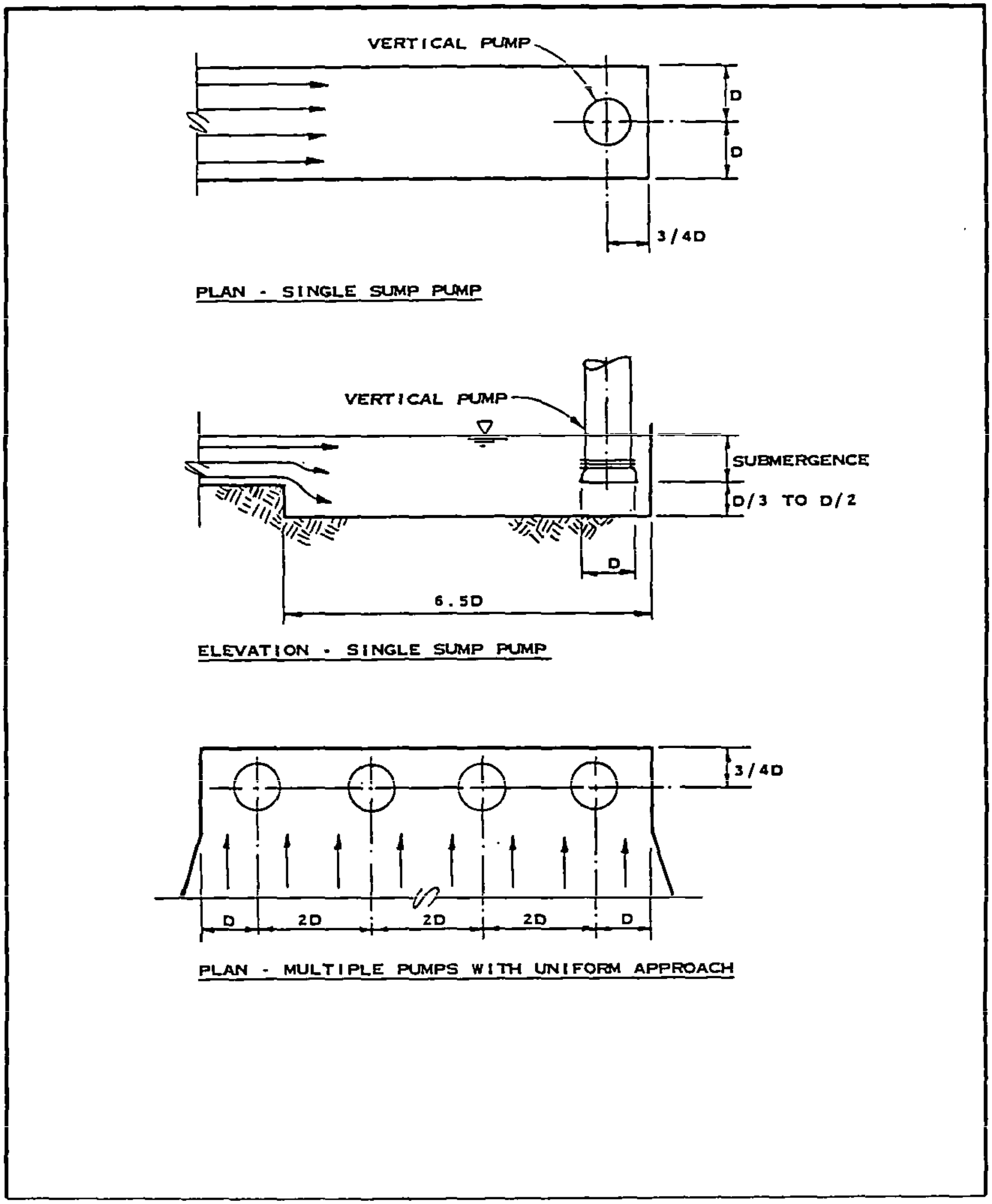


FIGURE 1
Pump Intake Sump Design

Table 17
Preferential Choice and Application of Pump Drive

POWER	CHOICE	DRIVE	APPLICATION
Electricity	First	AC motors DC motors	Primary power for stationary pumping installation
Diesel oil, gasoline	First	Internal combustion engines	In isolated area for stationary pumping As emergency standby power source Portable pumping power source
Natural gas	Second	Gas turbine or internal combustion engine	In isolated area for stationary pumping As emergency standby power source Portable pumping power source.
Air compressor driven by electric motors or internal combustion engine	Second	Compressed air	At small installations for airlift pumps, and for other pneumatic pumps

c) Direct Current Motors. Use direct current (dc) motors only when speed adjustment is an important factor and when economic factors permit.

d) Enclosure. Use appropriate standards of the National Electrical Manufacturers Association (NEMA). General types and applications are as follows.

(1) Dripproof. Use in nonhazardous, clean surroundings.

(2) Totally enclosed, fan-cooled. Use in nonhazardous corrosive atmospheres containing dusts or high concentrations of chemicals, or where hosing down or splashing is encountered.

(3) Totally enclosed, explosionproof. Use in atmospheres containing potentially explosive gases, chemicals, or dust.

5.3.3.2 Selection of Other Drives. Apply the selection factors in NAVFAC DM-3 Series, for internal combustion engines, gas turbines, steam turbines, and air compressors.

5.4 Pump Characteristics

5.4.1 Curves. Obtain characteristic curves from several manufacturers prior to the selection of a pump, including the following curves for centrifugal pumps: head capacity (H-Q), efficiency capacity (E-Q), brake horsepower capacity (BHP-Q), suction lift capacity, and net positive suction head (NPSH) required.

5.4.2 Head and Capacity. Choose the head and capacity to obtain the maximum efficiency for the range of operating conditions.

5.4.2.1 Axial Flow, Mixed Flow, Vertical Turbines, and Other Centrifugal Pumps. Check the points delineated below and select a pump accordingly.

a) Suitability of Curve Steepness. Determine the suitability of the curve steepness in the design range for the duty required.

(1) Does the pump provide (or prevent) the required variance in flow?

(2) Will the pump perform satisfactorily in parallel with others?

b) Curve Shape. Evaluate the curve shape on the basis of the following:

(1) Does the curve need to rise continually to the shutoff head?

(2) Is there any likelihood that the pump may be caught in a dip in the curve, resulting in unstable operation?

c) Motor Overload. Do not allow motor overload at any possible operating point of the curve. Check the operating range, shutoff condition (if applicable), and low head condition.

5.4.2.2 Rotary, Reciprocating, and Jet Pumps. Study the manufacturers' rating curves, and select accordingly. Provide relief valves for all positive displacement pumps, between the pump and the first shutoff valve on the discharge line.

5.4.2.3 Airlift Pumps. Use airlift pumps for low lift service or when aeration is needed.

5.4.3 Speed. Selection of speed is governed by the criteria given below:

5.4.3.1 Centrifugal Pumps. The governing factors for centrifugal pumps include:

	DESIGN PUMP LIFE (years)	
FACTORS	MORE THAN 10	LESS THAN 10
Maintenance costs	Low	High
Maximum speed (rpm)		
Operates less than 3 hpd	1,800	3,600
Operates more than 3 hpd	1,200	1,800

5.4.3.2 Rotary Pumps. Operating speeds shall not exceed those approved by the manufacturer.

5.4.3.3 Reciprocating Pumps. Operating speeds shall not exceed basic speeds prescribed in HI Hydraulic Institute Standards.

5.4.4 Specific Speed. Centrifugal pump selection is strongly influenced by efficiency and cavitation considerations. The specific speed of a particular pump at the discharge head and suction lift conditions shall not exceed that prescribed for pumps of this type in HI standards, unless the application is of sufficient importance for Navy representatives to witness satisfactory operation-in-shop tests at higher specific speeds.

5.4.5 Net Positive Suction Head (NPSH). For centrifugal pumps, design of the intake system should ensure that the available NPSH exceeds the required NPSH, to prevent boiling under reduced pressure conditions and cavitation of the impeller. A reasonable margin of safety should be provided, at least 2 or 3 ft (.6 or .9 m). Required NPSH can be obtained from the pump manufacturers, and available NPSH can be calculated using formulas in Hydraulic Institute Standards.

5.4.6 Lubrication. The choice (oil, grease, or water) and treatment shall be consistent with the bearings used, as follows:

a) Oil for sleeve bearings.

b) Grease for antifriction bearings.

c) Water where the heat generated is excessive.

d) Lubrication to be applied in accordance with the manufacturer's instructions.

e) The system must prevent entry of oil or grease into a potable water supply.

f) For vertical pump line shafts, use rubber bearings and water lubrication.

5.4.7 Seals. Mechanical seals shall be used where corrosive or volatile liquids are handled. Stuffing boxes shall be properly packed and sealed by a sealing liquid in accordance with the manufacturer's instructions.

5.4.7.1 Water Seal. An independent water seal supply, not connected to the potable water system or a potable water supply protected by an air gap or backflow preventer, shall be used where the water quality or pump characteristics prevent a self-sealing system as follows:

a) When the suction lift exceeds 15 ft (4.6 m).

b) When the discharge pressure is less than 23 ft (7 m).

c) When the pump handles hot water.

d) When the water is muddy, sandy, or gritty.

5.4.7.2 Stuffing Box Water Cooling. Cooling water shall be applied to the stuffing box jackets where pumps operate at a high stuffing box pressure.

5.4.8 Surge Prevention. Surge or water hammer, produced by a sudden change of flow in the pumping system, shall be carefully studied. For large, high pressure systems, the help of a qualified expert is recommended; and his recommendation shall be incorporated into the design. For additional information, refer to Hydraulic Transients, by George R. Rich.

5.4.8.1 Methods of Control. Surges are handled by one or more of the following methods:

a) Moderating the valve closure time by either a manual or automatic valve controller;

b) A surge tank with a free water surface;

c) An air chamber on the discharge line;

d) A surge suppressor;

e) A surge relief valve;

f) A vacuum relief valve.

Section 6: TREATMENT

6.1 Policies and Methods

6.1.1 Policies. At permanent and temporary installations, disinfection by chlorination or other means shall be applied to all water for potable uses, except from municipal or private water supply sources which conform to the bacteriological criteria set forth in Section 3. Additional treatment beyond disinfection shall be considered for water with an average monthly coliform concentration between 20 and 100 bacteria per 100 mL, and is necessary for water with an average monthly coliform concentration which exceeds 100 microorganisms per 100 mL.

6.1.1.1 Field Bases. Disinfection shall be applied to all water before use. Additional treatment shall be provided to naturally contaminated water. Special decontamination treatment shall be applied to chemically contaminated water in addition to regular treatment.

6.1.2 Related Criteria. For design criteria of boiler feed water and power plant water supplies in central heating and power plants, refer to Water Conditioning in the NAVFAC DM-3 Series on Mechanical Engineering.

6.1.3 Methods. Factors affecting the selection of treatment methods include: dependability, ease of operation, and cost consideration. Use Table 18 as a guide in selecting treatment.

6.1.3.1 Application of Chemicals. Refer to Table 19 for typical dosing points, and paras. 6.7-6.9, and 6.12 for chemicals to be used.

6.1.3.2 Pilot Study. For all permanent installations where water is to be handled by processes not adequately tested in nearby plants, operating on a similar water supply, a pilot study shall be conducted to determine both the efficiency and arrangement of proposed treatment used.

6.1.4 Materials of Construction. To the maximum practical extent, use materials that are standard in ordinary engineering practice. Special materials may be used, where economy allows, or conditions dictate, to provide needed corrosion resistance or other characteristics especially required in parts of the treatment works.

6.1.5 Commercial Devices. These devices may be adopted where adequate experience substantiates that their use will be advantageous to the Navy. Examples are:

a) solids contact reactors,

b) pressure or gravity filters,

c) forced draft aerators,

d) microstrainers, package-complete water treatment plants, and

f) package activated carbon units.

Table 18
Application of Treatment Methods

Water quality		Pretreatment				Treatment				Special treatments				
Constituents	Concentration	Screening	Prechlorination[1]	Plain settling	Aeration	Lime softening	Coagulation and sedimentation	Rapid sand filtration	Slow sand filtration	Postchlorination	Superchlorination or chloramine formation[2]	Active carbon	Special chemical treatment	Brackish or salt water conversion[3]
Coliform, monthly avg concentration/100 ml	0-20	-	-	-	-	-	-	-	-	E	-	-	-	-
	20-100	-	-	O	-	-	O	O	O	E	-	-	-	-
	100-5,000	-	E	-	-	-	E	E	O	E	-	-	-	-
	>5,000	-	E	O[4]	-	-	E	E	-	E	O	-	-	-
Turbidity, Turbidity units	1-10	O	-	-	-	-	-	E[6]	O	-	-	-	-	-
	10-200	O	-	-	-	-	E	E	-	-	-	-	-	-
	>200	O	-	O[5]	-	-	E	E	-	-	-	-	-	-
Color, color units	15-70	-	-	-	-	-	O	O	-	-	O	O	-	-
	>70	-	-	-	-	-	E	E	-	-	O	O	-	-
Tastes and odors	Noticeable	-	O	-	O	-	-	-	O	-	O	O	-	-
$CaCO_3$, mg/L	>200	-	-	-	-	E[7]	E[7]	E[7]	-	-	-	-	E	-
pH	<5.0->9.0	-	-	-	-	-	-	-	-	-	-	-	E	-
Iron and manganese, mg/L	≤0.3	-	O	O	-	-	-	S	-	-	-	-	-	-
	0.3-1.0	-	-	-	O	-	E	E	O	-	-	-	-	-
	>1.0	-	-	-	E	-	E	E	O	-	-	-	O	-
Chloride, mg/L	250-500	-	-	-	-	-	-	-	-	-	-	-	-	O
	500+	-	-	-	-	-	-	-	-	-	-	-	-	E
Phenolic compounds, mg/L	0-0.005	-	-	-	-	-	O	O	-	-	O	O	-	-
	>0.005	-	-	-	-	-	E	E	-	-	O	E	O	-

Note: E=essential, O=optional

[1]When trihalomethane precursor content of raw water is high, consider changing the point of prechlorine addition to after settling, or use of an alternate disinfectant such as chlorine dioxide, chloramines, or ozone.

[2]Superchlorination shall be followed by dechlorination.

[3]As alternate, blend with low chloride water.

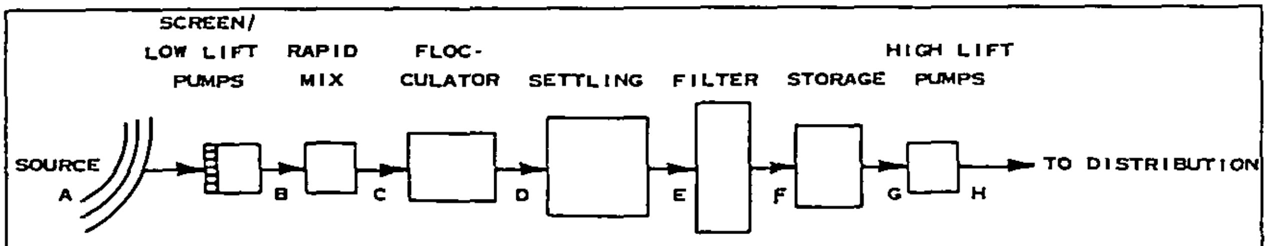
[4]Double settling shall be provided for coliform concentrations exceeding 20,000/100 ml.

[5]For extreme muddy water, presedimentation by plain settling may be provided.

[6]Optional for groundwater sources.

[7]Essential for laundry and dining facilities only.

Table 19
Possible Application Points for Chemicals



TYPICAL FLOW DIAGRAM OF WATER TREATMENT PLANT

Category of chemicals	Possible application points							
	A	B	C	D	E	F	G	H
Algicide	X	-	-	-	X	-	-	-
Disinfectant	-	X	X	-	X	X	X	X
Activated carbon, powdered	-	X	X	X	X	-	-	-
Activated carbon, granular	-	-	-	-	X	X	-	-
Coagulants	-	X	X	-	-	-	-	-
Coagulation aids	-	X	X	-	X	-	-	-
Alkali:								
For flocculation	-	-	X	-	-	-	-	-
For corrosion control	-	-	-	-	-	X	-	-
For softening	-	-	X	-	-	-	-	-
Acid	-	-	X	-	-	X	-	-
Fluoride	-	-	-	-	-	X	-	-
Dechlorinating agent	-	-	-	-	-	X	-	X

Note: With solids contact reactors, points C and D are the same

6.1.5.1 New Devices. New treatment devices may be used only:

a) where there are special needs that cannot be met by generally accepted methods, and

b) after testing by an impartial research or development organization has established their usefulness and dependability.

6.2 Screening

6.2.1 Types and Application. Bar racks with 1 1/2- to 2-in. (38 to 51 mm) openings shall be used to keep the large floating debris out of intake conduits, and for all intakes to low lift pumping stations.

6.2.1.1 Coarse Screens. For water to be filtered, use screens with 1-in. (25.4 mm) mesh to remove the small floating debris, vegetation, and fish that cannot be handled by bar racks.

6.2.1.2 Fine Screens. Where fresh water is not to be filtered, use screens with 1/4-in. (6.4 mm) mesh or finer to remove solid matter from the water.

6.2.1.3 Traveling Water Screen. Use this type at freshwater intakes following the bar racks; or at treatment plants to remove high concentrations of coarse suspended or floating matter.

6.2.2 Materials of Construction. In fresh water, use steel frames for construction of screening.

6.3 Aeration

6.3.1 Application. Aeration may be used where:

a) concentrations above 10 mg/L of carbon dioxide exist in water to be lime softened,

b) tastes and odors from volatile sources, such as hydrogen sulfide are objectionable,

c) iron and manganese are present in amounts above 0.3 and 0.5 mg/L respectively, and

d) high concentrations of volatile organic chemicals are present.

6.3.2 Equipment. For approved types and characteristics of aerators, refer to Table 20. When forced draft blowers are used, they should be located to prevent dust, leaves, and water spray or splash from entering the blower intake.

6.3.2.1 Efficiency Factors. Wherever possible, provide for maximum efficiency by designing for:

a) increased water surface exposed to air;

b) rapid change of air in contact with water (high air:water ratio); and

c) increase in the aeration period.

Greater removal efficiency will result where high concentrations of volatile matter exist in the water, but this is not a factor which the designer can control.

6.4 Plain Settling

6.4.1 Limitations. Since plain settling removes only settleable suspended solids, a detention time exceeding 12 h is often required to remove fine particles. Plain settling reduces the loading of settleable solids on subsequent processes and reduces the turbidity.

Table 20
Characteristics of Aerators

TYPE	OPERATING HEAD (ft)	LOADING CAPACITY	POWER*	REQUIREMENTS	REMARKS
Spray	8-28	4-180 gpm/nozzle	G,P	Nozzles to produce thin sheet of spray.	Requires protection from loss of water by wind; ice hazard in cold climates.
Cascade	3-10	-	G,P	Thinnest practicable water film.	Requires large space.
Perforated tray	-	20-50 gpm/ft^2	G,P	3/16-1/4 in. perforations, 1 in. oc; use at least 4 trays; 20 if possible.	Requires larger space and higher head than coke tray.
Coke tray	6-10	<35 gpm/ft^2	G,P	Use trays; fill each with 8-12 in. to 1/2 x 2 in. of coke. Space trays apart.	Used also for iron and manganese removal.
Forced draft	10-25	16-18 gpm/ft^2	G, P AB	Requires blower.	Compact but more complex than above types.
Diffused air	5-10 psi**	0.02-0.2 cf/gal***	AC	10-15 ft depth; width not more than twice depth; provide 15-45 min detention; consult diffuser manufacturer.	Requires compressed air; mostcomplex.

* G = Gravity,
P = Pumping,
AB = Air Blower,
AC = Air Compressor
** Air pressure depends upon water depth and pipe friction losses.
***Air requirement.

6.4.2 Design Features. Determine the overflow rate using laboratory tests of settling velocity. In the absence of data from other plants treating a similar water, use 1- or 2-liter beakers, and measure the turbidity on specimens siphoned out from a specific depth. Using consistent units, divide the flow by the overflow rate to determine the surface area required.

a) Settling Velocity. To determine settling velocity, use the method outlined in Water and Wastewater Engineering by Fair, Geyer, and Okun.

b) Surface Loading. To determine the surface loading, multiply the settling velocity in centimeters per second (sec) by 21,200 to give gpd/ft^2.

6.4.2.1 Detention Time. Determine the detention time from the surface loading, flow, and depth. Compute the flow velocity:

a) The depth shall be 6 to 15 ft (1.8 to 4.6 m), but shall not exceed that through which particles will fall during the settling time allowed. Add depth needed for sludge storage.

b) The flow velocity through the basin shall not exceed 1 fpm (.3 m/min).

c) Where data on settling velocity are unavailable, use a 24-h detention for plain sedimentation.

6.4.2.2 Layout. Basin outlets shall be weirs loaded at not more than 50,000 gpd (189,250 Lpd) per ft of weir length.

a) Rectangular Basins. Provide length-to-width ratios greater than 3 to 1, preferably in excess of 4 to 1. Slope the bottom toward the drain at no less than 1 percent. Use multiple port inlets along the entire inlet wall, if possible. If fewer than four inlet ports are used, provide an inlet baffle.

b) Square or Circular Basins. Provide a 1-on-12 bottom slope to drain. Use a baffled center inlet.

6.4.2.3 Sludge Removal. Sludge removal is generally with mechanized sludge collectors, although it may be manual in some installations. If manual, provide at least two basins so that one basin may be taken out of service for cleaning without interruption of operation. Provide for hydraulic removal of settled solids by draining and flushing if possible, otherwise by manual load-and-haul.

6.5 Coagulation and Sedimentation

6.5.1 Chemical Treatment Required. On the basis of local operating experience and jar tests, determine these factors:

a) Type of coagulant and optimum dosage

b) Optimum pH value

c) Need for coagulant aid

d) Settling velocities of flocculated particles.

6.5.2 Mixing. Use rapid mixing to disperse coagulation chemicals.

6.5.2.1 Characteristics. Refer to Table 21 for characteristics of different methods of rapid mix.

Table 21
Characteristics of Rapid Mix

TYPE	CHARACTERISTIC
Mechanical mixer	Very effective; not affected by flow variation. Provide 0.5-1 hp per Mgd. Little headloss.
Baffled	Not suitable where flow varies widely. Loses head.
Hydraulic jump	Short detention time. Loses head.
Air agitation	Useful if preaeration is desired.
Pump	Injection of chemicals head of low lift pumps; time brief; cost often low; no headloss.
In-line blenders	Good instantaneous mixing with minor headloss.

6.5.2.2 Design. Base the design upon the required detention time necessary for a given velocity gradient as shown below:

Contact Time, sec.	20	30	40	50
Velocity Gradient (G), sec^{-1}	1000	900	790	700

Where the velocity gradient is calculated using Equation (3).

EQUATION: $$G = (P/uv)(1/2) \quad (3)$$

Where:

G = velocity gradient, sec^{-1}
P = power input, ft-lb/sec
u = viscosity, lb-sec/ft^2
v = volume, ft^3

6.5.3 Flocculation. Provide proper mechanical agitation for the period necessary to entrap colloids in floc. Use a multicelled flocculating basin to reduce short-circuiting. Design the basin to prevent "dead" spots.

6.5.3.1 Design Basis. Base the design on jar tests at various mixer speeds and times, or on experience in nearby plants treating similar water.

6.5.3.2 Design Requirements. Provide for mixer velocity and detention time according to the type of floc produced, for example:

TYPE OF FLOC	PERIPHERAL VELOCITY OF MIXER (fps)	DETENTION TIME (min)	USUAL OCCURRENCE
Fragile water needing coagulant aids	0.5	60	Cold
Tough water needing no coagulant aids	2.0	20	Warm

Energy input (G) and flocculation detention time (T) are related: GT = 30,000 to 150,000. Typical power input is 0.5 hp/Mgd treated.

6.5.4 Settling. For conventional plants, settling basins are circular, rectangular, or square; the decision between these types being one of designer preference or a result of site constraints. Solids contact units are generally used only in lime softening applications.

6.5.4.1 Characteristics. Refer to Table 22 for characteristics of settling basins.

Table 22
Characteristics of Settling Basins

SHAPE	DESIGN CRITERIA
Rectangular	L:W ratio 3:1 to 5:1. Maximum length 250 ft, 100 ft length is common. Depth 10 to 15 ft, generally deeper for longer basins. Bottom slope 1:100 toward end with sludge hopper. Surface loading 600 gpd/ft^2, 1000 gpd/ft^2 is maximum.
Circular or Square	Maximum diameter of circular basins is 200 ft, 100 ft is common. Square tanks are usually less than 70 ft on a side. Depth - 10 to 15 ft; generally deeper for larger basins. Bottom slope - 8% to central sludge hopper. Surface loading 600 gpd/ft^2, 1000 gpd/ft^2 is maximum.
Solids Contact Units	Maximum diameter is 150 ft. Units are factory prefabricated, and circular in shape. Designs vary between manufacturers, and each manufacturer uses design criteria specific to its unit. Most common application is for lime softening sludges.

Note: Surface loading rates may be increased by as much as 50 percent under conditions favoring the use of settling tubes or parallel plates.

6.5.4.2 Inlets. Inlets shall consist of a perforated baffle arrangement. Velocity through the perforations shall be from 0.5 to 2.0 fps (.15 to .61 m/s), as required by the character of floc.

6.5.4.3 Velocity Through Basin. Design rectangular basins based upon 1 to 3 fpm (.3 to .9 m/min). There is no corresponding parameter for radial flow velocity in circular basins.

6.5.4.4 Outlets. Use v-notch type weirs with means for vertical adjustment. Weir overflow rate should be 8 to 10 gpm/ft (99 Lpm to 124 Lpm/meter) for light alum floc, 10 to 15 gpm/ft (124 Lpm to 186 Lpm/meter) for heavy alum floc, and 15 to 18 gpm/ft (186 Lpm to 223.5 Lpm/meter) for lime softening floc.

6.5.4.5 Materials of Construction

a) Concrete. Use concrete for all permanent installations constructed on-site.

b) Steel. Use steel only for temporary units, factory prefabricated units, or small circular basins. It may be used for internal parts of a solids contact reactor, but for permanent installations, provide adequate corrosion protection.

6.5.4.6 Sludge Removal. Where sludge is removed manually, follow the criteria given in para. 6.4 of this Section.

a) Mechanical Sludge Removal. For rectangular basins, chain and flight scrapers are typically used, and for circular and square basins, center sweep collectors are used.

(1) Sludge Scrapers. This method would be used for the majority of basins, unless the material removed is minimal and is inorganic. Linear velocity of sludge scrapers shall not exceed 15 fpm (4.6 m/min).

(2) Sludge Pumps. For detailed criteria, refer to Pumping Facilities in MIL-HDBK-1005/8, Domestic Wastewater Control.

b) Solids Contact Basins. Where solids contact basins are used, provide:

(1) A sludge drawoff pipe and valve. Control the valve with an automatic timer or equivalent open-and-shut device.

(2) An adjustable slurry recirculation rate of three to five times the rated inflow.

6.6 Filtration

6.6.1 Policies. Adhere to the following policies for both permanent as well as temporary installations:

a) Slow sand filters are permissible for any use, where space, material, and labor are economical; rapid sand or mixed-media filters are generally more favorable.

b) Pressure sand filters may be used for water supplies where their use is economically justified.

c) Diatomaceous earth filters (either pressure or vacuum type) may be considered for use in exceptional cases.

6.6.2 Number of Filters. Provide at least three filter units of any type at each facility.

6.6.3 Types and Characteristics. For applicable data, characteristics, and criteria of filters, refer to Table 23.

6.6.4 Underdrains. Types of underdrains which are acceptable for use in rapid and slow sand filters are given in the following tabulation:

TYPE	RAPID SAND FILTERS	SLOW SAND FILTERS
Ferrous header and perforated laterals	A	S
Same with concrete spacer blocks	A	S
Vitrified tile block	A	S
Inverted concrete pyramids and porcelain spheres	A	N
Vitrified tile pipes	N	A
Porous plates	S	N

Symbols used are: A = acceptable.
N = nonacceptable.
S = special justification required.

Base the selection on these factors:

a) Durability and corrosion resistance.

b) Uniformity of distribution of flow during backwash. This usually requires a head loss of 2 ft (.61 m) or more at 15 gpm/ft^2 (732 Lpm/m^2).

c) Freedom from clogging by sand or encrustants.

6.6.5 Filter Media. Use sand and gravel for rapid sand filters; anthracite coal, sand, and gravel for dual media filters; and anthracite coal, sand, garnet, and gravel for mixed media filters. Conform to standards for AWWA B-100, Filtering Material.

6.6.5.1 Gravel Size. Grade the gravel in not less than three layers, from the coarse size recommended by underdrain manufacturers to fine gravel having a minimum size of 0.1 in. (2.54 mm). No layer shall contain a maximum size greater than twice the minimum.

6.6.5.2 Sand for Slow Sand Filters. The effective size shall be 0.3 to 0.5 millimeters (mm), and the uniformity coefficient shall be 2.5 maximum.

6.6.5.3 Fine Media for Rapid Filters. Selection of sand will take into account the character of applied water, sand size and depth, and loss of head through filter in accordance with the breakthrough index (K) which is given in Equation (4).

Table 23
Characteristics of Filters

	PERMISSIBLE FILTRATION RATES (gpm/ft^2)		DESIGN PRETREATMENT TO REDUCE TURBIDITY IN APPLIED WATER TO: TURBIDITY UNITS		HEAD REQUIRED (ft)		LENGTH OF FILTER RUN (h)		MINIMUM THICKNESS (in.)	
FILTER TYPE	MAX. DAY	MAX. RATE*	AVG.	MAX.	CLEAN FILTER	MAX.	AVG.	MIN.	GRAVEL	SAND
Rapid Sand	2**	3**	2	5	1	8*	36	5	12	20*
Rapid Filters, Dual or mixed media	5	6.5	2	5	1	8	48	5	12	24-30***
Pressure	2	3	2	5	1	25	48	5	12	24
Slow Sand	0.05	0.10	1	3	0.02	4	1,000	250	12	42
Diatomite	2	3	1	3	7	70	6	0.5	-	-

* May be modified as specified in text.
** Except as provided in text, maximum day rates are to be used for potable supplies, and maximum rates apply only to swimming pools.
***Dual media consists of 18 in. of coal overlying 8 in. of sand. Mixed media consists of 18 in. of coal, which overlies 9 in. of sand, which overlies 3 in. of garnet sand.

EQUATION: $K = Vd^3H/L$ (4)

Where:

V = filtration rate (gpm/ft^2).
d = effective size of the media (mm).
H = head loss through the media (ft).
L = sandbed thickness (ft).

a) The smallest value of K that occurs in operation is the most critical one. It should be determined by examination of nearby plant records or by pilot plant tests through the period of weakest flocculation (usually the months of coldest water).

b) The most critical value is determined by computation from the values of V, d, H and L existing at the time turbidity begins appearing in the filtrate in objectionable concentrations.

c) Filter design and control shall be such that K must exceed the most critical value during any filter run. Typical values of K for several conditions are as follows:

CONDITION	LOWEST K ENCOUNTERED
Raw water difficult to coagulate; average pretreatment	0.4
Raw water not difficult to coagulate; average pretreatment	1.0
Average raw water; high grade pretreatment	2.0

6.6.5.4 Diatomaceous Earth Filters. Diatomite filters may be used for clarification of potable supplies without coagulation and filtration, where the raw water meets the Public Health Service bacteriological requirements for treatment by chlorination alone. Pilot testing or experience nearby will be required to establish the practicability of diatomite treatment.

6.6.6 Washing Rapid Sand Filters. For backwashing, provide a filter washing rate sufficient to expand the sand by 50 percent during washing; at least 15 gpm/ft^2 (732 Lpm/m^2). Refer to Water and Wastewater Engineering by Fair, Geyer, and Okun to find the criteria for the relationship between the sand size, bed depth, and washing rate.

6.6.6.1 Wash Water Troughs. Use reinforced concrete, reinforced plastic, or steel with corrosion-preventing coating.

a) Elevation. Wash water troughs should be set with their bottoms 1 to 3 in. (25.4 to 76.2 mm) above the expanded sand level.

b) Spacing. Space troughs 6 to 7 ft (1.8 to 2.1 m) on centers.

c) Capacity. Troughs must be able to carry off the wash water without flowing full, but with sufficient velocity to prevent sediment accumulation.

6.6.6.2 Wash Water Pump. Wash water pumps shall be used wherever possible.

a) Capacity. Determine the pump capacity from the filter washing rate for at least one filter unit.

b) Standby. Provide at least two pumps unless an adequate standby connection to the high pressure supply is provided.

c) Head. This shall be determined by head losses at the desired wash rate.

6.6.6.3 Wash Water Tank. An elevated wash water tank should be used only when it is economically feasible.

a) Capacity. Provide a minimum of 20 min supply at the backwash rate.

b) Height of Tank. This shall be determined by the head losses that occur at the desired wash rate. Usual heights are in the range of 15 to 40 ft (4.6 to 12.2 m) above the filter sand bed.

6.6.6.4 Surface Wash. Washers of the high velocity jet type with fixed nozzles or nozzles on rotary arms should be provided unless there is experience to establish that they are not required. Refer to the manufacturer's catalog for discharge and operating pressure requirements.

6.6.7 Washing Diatomite Filters. Washing methods for diatomite filters vary with their design. They include pumped backflow, air bump, and sluicing. The method to be used must have demonstrated ability to keep not less than 95 percent of the filter area available for filtration after 100 filter runs and washing operations, as determined by observation of filter elements after washing and after precoating.

6.6.8 Filtered Water Storage. Provide filtered water storage (clearwell) to serve the following purposes:

a) To meet wash water demand.

b) To provide water during peak demands, in order to make up the difference between the treatment rate and pumping rate.

c) To permit water treatment and production at maximum day demand rate.

d) To supply water when filters are temporarily out of service for cleaning, washing, and repairing.

e) To provide contact time for posttreatment.

f) In some cases, to make up for deficiencies in transmission or distribution storage.

g) To supply water for other emergency demands.

6.6.8.1 Location. Locate the filtered water reservoir at the treatment plant as close to the plant and distribution system pumping station as possible.

6.6.8.2 Capacity. The minimum capacity should equal the larger of the following:

a) Twelve hours of maximum daily consumption.

b) Maximum hour flow with one of the filters out of service for backwashing, cleaning, or repairing.

6.6.8.3 Construction. Use concrete tanks for all permanent installations. Tanks may be prestressed concrete or nonprestressed.

a) Steel tanks may be used for temporary installations.

b) All type soft tanks shall be covered.

c) In Seismic Zones 2, 3, and 4, NAVFAC P-355, Seismic Design for Buildings, steel tanks shall be mounted on steel or concrete pedestals. Tops of tanks shall be fastened to walls.

6.7 Disinfection

6.7.1 Disinfection. Disinfection by applying chlorine, chlorine dioxide, chloramines, or ozone to produce a desired oxidant residual (except when using ozone) in water shall be used for all installations. Chlorine disinfection is the most commonly used approach.

6.7.2 Chlorination. The dosage for adequate disinfection shall be determined by tests on the water to be treated.

6.7.2.1 Contact Period. The contact period for free available chlorine is not less than 20 min. For combined available chlorine residual, not less than 2 h. Contact can be achieved in a chlorine contact basin, the plant clearwell, or the distribution system.

6.7.2.2 Water pH. Reliable chlorination requires that the pH of water be below 9.0. The required residual varies with pH value. Design the chlorination facilities to produce chlorine residuals as follows, after the required contact period. The minimum free chlorine residual indicated below shall be available at the most remote point in the distribution system.

AVAILABLE CHLORINE RESIDUAL

pH	FREE (mg/L)	COMBINED (mg/L)
Up to 7.0	0.2	1.0
7.0-8.0	0.3	1.5
8.0-9.0	0.4	2.0

6.7.2.3 Special Conditions. When required in special cases, for example in areas where hepatitis or amebiasis are prevalent, both the minimum chlorine residuals and minimum contact period shall be increased as directed by a representative of BUMED.

6.7.2.4 Points of Applications. Refer to Table 18 for acceptable application points.

6.7.2.5 Feeding. For criteria on chlorine feeding, refer to para 6.12. For chlorination room criteria, refer to para. 9.1.1.5. Installation requirements are:

a) The equipment capacity shall be at least 50 percent greater than the highest expected dosage excluding standby capacity.

b) At least one standby unit of the same capacity as the largest chlorination unit shall be provided.

c) Automatic proportioning of the chlorine feed to water flow rate shall be provided at all major activities, and at any activity where the flow of water varies more than 50 percent from the daily average.

d) Manual control of chlorination equipment shall be permitted only when qualified operators are always on hand to promptly effect any necessary adjustment, and when the rate of flow is relatively constant.

e) At low feed rates, reliquefaction of chlorine may occur between the cylinders and the chlorinator. To prevent reliquefaction, the chlorine cylinders should be kept cooler than the chlorinator. The minimum allowable temperature in the chlorine storage area should be 50° F (10° C).

6.7.2.6 Well Disinfection. New wells, repaired wells, or wells which have been inundated by surface flooding should be disinfected prior to use. The recommended chlorine concentration in the well water is 100 mg/L, at a minimum contact time of 8 h.

6.7.3 Chlorine Dioxide. Chlorine dioxide is produced onsite by the reaction of chlorine and sodium chlorite. Its principal advantage is that use of chlorine dioxide (without excess chlorine) does not result in formation of trihalomethanes. Chlorine dioxide demand, expressed in mg/L, is approximately equal to the chlorine demand. Dosages should be established by running a chlorine dioxide demand test. Chlorine dioxide can be used as either a predisinfectant or a postdisinfectant (refer to para. 6.12).

6.7.4 Chloramines. Reaction of chlorine and ammonia produces chloramines. Chloramines are a slower acting disinfectant than chlorine, but are advantageous because their use does not result in the formation of trihalomethanes, and because they maintain a long lasting residual. Disinfection can be enhanced by adding chlorine 15 to 30 min before ammonia addition, although trihalomethanes will be formed during this 15 to 30 min period. Chloramines can be used as a predisinfectant or a postdisinfectant. Appropriate dosages of chloramine must be detemined by running a demand test.

6.7.5 Ozone. Ozone can be generated onsite, and similarly to UV light disinfection, is particularly suitable to small installations where treatment is not continuous, but is intermittent in response to demand. Ozone in a complete treatment plant (Table 19) is best applied after filtration. Ozone is advantageous because it is a rapidly acting disinfectant which does not produce trihalomethanes. Conversely, a key disadvantage is the lack of a residual (refer to para. 6.12).

6.7.6 Ultraviolet Light Disinfection. Ultraviolet (UV) light may be an appropriate disinfectant in certain situations. Small installations in remote locations can use units which operate intermittently on the basis of demand. The principal disadvantage of UV disinfection is the lack of a residual.

6.7.7 Control of Trihalomethane Formation. Free available chlorine reacts with certain naturally occurring organic precursor material to produce trihalomethanes (THM's). The maximum contaminant level for THM's is 0.1 mg/L (refer to Table 5) for populations greater than 10,000. A variety of control techniques are possible, including use of alternate disinfectants. Guidance is provided in EPA - 600/1-81-156, Treatment Techniques for Controlling Trihalomethanes in Drinking Water, September, 1981.

6.8 Softening

6.8.1 Softening Processes. Refer to Table 24 for the characteristics of softening processes as a basis of process selection.

6.8.2 Design Features. The most desirable total hardness for potable water supplies is about 100 mg/L, with a carbonate hardness not less than 40 mg/L. Water softer than 100 mg/L total hardness is often corrosive. For water used only for domestic purposes, excessive hardness causes increased usage of soap and decreased lifetime of water heaters. There is no recognized, unacceptable upper limit for hardness, and the decision to soften can be based on economic analysis, consumer preference, or the judgment of the designer. The health effects of added sodium should be considered in evaluating any water softening program.

For a boiler water conditioning, hardness requirements and softening techniques are discussed in NAVFAC DM-3 Series.

6.8.2.1 Lime Softening Process Equipment. Use conventional flocculation and settling basins or solids contact reactors with 2,500 gpd/ft^2 (101,857 Lpd/m^2) maximum loading; also use filtration following settling.

6.8.2.2 Recarbonation. Include this process only if it is proven to be required. Provide at least 20 min detention time in the recarbonation basin after settling. Use a diffuser type aerator.

6.8.2.3 Sodium Base Ion Exchange Softeners. These softeners may be used for small supplies which do not require filtration but do require softening.

a) Capacity. The exchange capacity varies from 2.5 to 27.0 kilograins of hardness removed per cubic foot of ion exchange material. Consult manufacturers for the capacity of the ion exchange material considered.

Table 24
Characteristics of Softening Processes

PROCESS	TYPES OF HARDNESS REMOVED CAR-BONATE	NONCAR-BONATE	MIN. HARDNESS OBTAINABLE (mg/L as $CaCO_3$)	REMARKS
Lime	Yes	No	(Calcium) 15-35 (Magnesium) 17-33	Sulfates and chlorides remain in solution as sodium salts.
Lime soda	Yes	Yes	(Total) 20-68	No reduction of sodium alkalinity.
Excess lime soda	Yes	Yes	(Total) 16	Recarbonation required after settling.
Split lime soda	Yes	Yes	(Total) 16-68	Bicarbonates, sulfates, and chlorides remain in solution as sodium salts.
Sodium base ion exchange	Yes	Yes	(Total) 0-3[1] 20[2] 41[3]	Not applicable to turbid, iron bearing, or acid wastes. Regeneration required to restore softener efficiency.
Hydrogen base ion exchange	Yes	Yes	(Total) 0-2	Sulfates and chlorides remain as corresponding acids. Regeneration and carbon dioxide removal required.
Demineralization by ion exchange or reverse osmosis	Yes	Yes	(Total) 0-2	Sulfates and chlorides are also removed or reduced. Regeneration of ion exchange resin required. Reverse osmosis membranes must be periodically cleaned. Carbon dioxide removal required.

[1]Where calcium, magnesium, and sodium salts in raw water do not exceed 500 mg/L.

[2]Where calcium, magnesium, and sodium salts in raw water do not exceed 1,000 mg/L.

[3]Where calcium, magnesium, and sodium salts in raw water do not exceed 2,000 mg/L.

b) Regeneration. For this step, provide for salt consumption varying from 0.3 to 0.67 lb (.136 to .30 kg) per kilograin of hardness removed. Ascertain the value from equipment manufacturers.

c) Allowable Loading Rate. Use 2 gpm/ft^2 (81 Lpd/m^2) of ion exchange bed as the loading rate unless the operating data show that higher rates may be used.

d) Depth of Ion Exchange Bed. Provide at least 2 ft (.61 m), but do not exceed 9 ft (2.74 m).

e) Gravel. Provide at least a 12-in. (304.8 mm) layer of gravel to support the ion exchange bed. Consult manufacturers for the gravel size to be used.

f) Underdrains. Provide the same underdrains as for rapid sand filters.

g) Controls. Refer to para. 6.13 for instrumentation and controls criteria.

h) Backwashing Facilities. Provide for the same backwashing facilities as rapid sand filters. Consult manufacturers for the backwash rates to be used.

i) Blending. Blending of softened and unsoftened water should be considered to meet desired hardness objectives and reduce costs.

6.8.2.4 Hydrogen Base Ion Exchange Softener. Secure current information from manufacturers as for sodium exchange softeners. For boiler feed, do not use silica base gravel.

6.8.2.5 Demineralization. Provide cation and anion exchangers or reverse osmosis. Carbon dioxide removal equipment should be provided in accordance with the manufacturer's recommendations.

6.8.2.6 Installation. For guidance on installation, refer to Seismic Zones 2, 3, and 4 in NAVFAC P-355. Steel tanks shall be mounted on steel or concrete pedestals. Tops of tanks shall be fastened to walls.

6.9 Special Treatment

6.9.1 Iron and Manganese Removal. Table 25 gives characteristics guiding the selection of iron and manganese removal processes. Further process details and other methods are given in: AWWA, Water Quality and Treatment, 1971; AWWA, Water Treatment Plant Design, 1969; and National Lime Association, Water Supply & Treatment, 1970. Conduct laboratory or field test before final choice of a process.

6.9.2. Taste and Odor Control. Use the following processes, as appropriate.

6.9.2.1 Copper Sulfate Treatment. Use this treatment in impounding reservoirs, lakes, storage reservoirs, and occasionally in settling basins or treated water, to prevent biological growths. Check the effects on fish

Table 25
Characteristics of Iron and Manganese Removal Processes

PROCESSES	IRON AND/OR MANGANESE REMOVED	pH REQUIRED	REMARKS
Oxidation,[1] settling, and filtration	Ferrous bicarbonate Ferrous sulfate Manganous bicarbonate Manganous sulfate	7.5 8.0 10.3 10.0	Provide aeration unless incoming water contains adequate dissolved oxygen.
Oxidation,[1] free residual chlorination, settling, and filtration	Ferrous bicarbonate Manganous bicarbonate	5.0 9.0	Provide aeration unless incoming water contains adequate dissolved oxygen.
Oxidation,[1] lime softening, settling, and filtration	Ferrous bicarbonate Manganous bicarbonate	8.5-9.6	Requires lime, and alum or iron coagulant.
Oxidation,[1] coagulation, lime softening, settling, and filtration	Colloidal or organic iron. Colloidal or organic manganese.	8.5-9.6 10	
Ion exchange	Ferrous bicarbonate Manganous bicarbonate	6.5±	Water must be devoid of oxygen. Iron and manganese in raw water not to exceed 2.0 mg/L. Consult manufacturers for type of ion exchange resin to be used.

[1]Oxidation by aeration, chlorination, ozonation, potassium permanganese, chlorine dioxide, or other means.

life. Dosages may vary from 0.5 to 2.0 milligrams per liter (mg/L); the lower dosage ordinarily suffices for soft water. For very hard water, a dosage above 2.0 mg/L may be used after laboratory tests are used to determine the necessary algicidal dose.

6.9.2.2 Aeration. Use this process to improve taste and reduce odors in water where the cause is volatile organics, hydrogen sulfide or the absence of dissolved oxygen. This method has little effect on taste and odors caused by other substances. For removal of hydrogen sulfide, a pH less than 7.0 is recommended, since a greater percentage of total sulfide is in the ionized form at higher pH; the dissociated form cannot be removed by aeration. Aeration processes should provide air:water ratios between 5:1 and 15:1 (volume basis).

6.9.2.3 Activated Carbon. Either powdered or granular activated carbon may be used to remove taste and odors. Dosages may vary from 0.5 to 200 mg/L; ordinarily ranging from 2 to 10 mg/L. For powdered activated carbon, provide space for storing the activated carbon, equipment for feeding it, and laboratory facilities for determining the proper dosage. Beds of granular activated carbon may also be used. Design criteria is 5 to 15 min of contact time (based upon empty volume of the carbon contactor). This design basis is referred to as empty bed contact time.

6.9.2.4 Superchlorination and Dechlorination. Use this treatment to destroy tastes and odors caused by organic matter and industrial wastes, especially phenolic wastes. Normally, the dosage required will be several times greater than required for ordinary disinfection, but less than required for the breakpoint. Provide chlorinating equipment capable of dosing at these high values; allow a minimum of 20 min contact time; furnish equipment for dechlorinating with sulfur dioxide or other reducing agent. Also, provide storage space for chemicals to be used. The chlorination dosage requirements for taste and odor control may often be supplied by the chlorination equipment used for disinfection.

6.9.2.5 Chlorine-Ammonia Treatment. Where chloro-substitution products cause tastes and odors, chlorine-ammonia treatment (chloramines) may be used to prevent them. It may also be used for maintaining the combined residual chlorine for an extended period as, for example, in reservoirs or distribution systems, and to limit the formation of trihalomethanes during the disinfection process.

a) Chloramines are less active disinfectants than free chlorine and, therefore, may not be substituted where adequate disinfection requires free residual chlorine.

b) The ratio of chlorine to ammonia required for disinfection varies from 3:1 to 7:1.

c) Periodic laboratory tests shall be conducted to determine the proper dosage. Apply chlorine after ammonia has been properly dispersed in the water.

6.9.2.6 Free Residual Chlorination. Use this method before filtration to reduce tastes and odors caused by organic matter at locations where experience shows it to be effective and acceptable. Increase the chlorine dosage until the residual consists solely of free available chlorine. Provide for frequent laboratory tests to determine the proper dosage.

6.9.2.7 Chlorine Dioxide. In some cases this chemical may be used advantageously to destroy phenolic and other organic tastes and odors in raw water. Determine its applicability by laboratory tests before the design stage. The dosage varies from 0.2 to 0.3 mg/L, as determined by the test. Chlorine dioxide also prevents the formation of trihalomethanes (THM's), and should be considered if both THM and iron and manganese are problems.

6.9.2.8 Microstraining. This method may be used as a means of reducing the number of algae and other organisms in the water, and thus reduces the subsequent production of tastes and odors. The microstrainer removes no dissolved or colloidal organic matter. It utilizes monel metal cloth with 35 micron (0.0014 in.) openings. Finer mesh may be obtained.

6.9.3 Corrosion and Scale Control. The Langelier calcium carbonate saturation index shall be used for control of corrosion and scale formation. Provide treatment which will maintain a Langelier index from +0.6 to +1.0 in the treated water. For explanation of the Langelier Index, refer to AWWA Water Quality and Treatment, 1971.

6.9.3.1 Degasification. For details of carbon dioxide removal design, refer to para. 6.3.1. For hydrogen sulfide removal, use a perforated tray aerator or forced air circulation.

6.9.3.2 Cold Water Vacuum De-aeration. Where required for corrosion control, use this treatment for removing dissolved oxygen. Consult equipment manufacturers for capacity and installation details.

6.9.3.3 Other Treatments. Polyphosphates and silicates may be used individually, or in combination, for corrosion control. Silicates are most effective on water with low hardness and alkalinity, and pH less than 8.4. Selection of the proper dosages of these chemicals is complex, and should be performed by a specialist in this area of treatment, after appropriate laboratory tests have been conducted, or based on past experience with the water in a given area.

6.9.4 Fluoridation. The optimum fluoride content of a water supply is a function of the ambient air temperature to which the consumer is exposed, due to the close relationship between air temperature and human water consumption. The required adjustment may be upwards or downwards.

6.9.4.1 Warrants. A significant portion of the consumers must be children aged 16 yr or younger. Above this age level, little benefit is obtained by adjustment in the fluoride content.

6.9.4.2 Limits. The concentration of fluoride shall not exceed:

ANNUAL-AVERAGE OF MAXIMUM DAILY AIR TEMPERATURES[1] °F	°C	FLUORIDE CONCENTRATIONS (mg/L)
50.0-53.7	10.0-12.0	2.4
53.8-58.3	12.1-14.6	2.2
58.4-63.8	14.7-17.7	2.0
63.9-70.6	17.7-21.4	1.8
70.7-79.2	21.5-26.2	1.6
79.3-90.5	26.3-32.5	1.4

[1]As determined over a period of 5 years or longer by a National Weather Service station (or other reliable source of meteorological data).

6.9.4.3 Addition of Fluorides. For chemicals which can be used, their handling, strength, and other characteristics, refer to para. 6.12.

6.9.4.4 Defluoridation. Removal of fluorides shall be practiced only when specified by BUMED. Two methods of defluoridation are currently in use: removal incident to water softening, and pressure activated alumina contact filters used primarily for defluoridation.

a) Softening. Where lime softening is used, fluoride reduction occurs concurrently with magnesium removal. Removal of 45 to 65 mg/L of magnesium reduces fluoride by 1 mg/L. Because of the large quantity of chemicals required, this process generally applies only to waters containing less than 4 mg/L of fluoride.

b) Pressure Activated Alumina Contact. Where lime softening is not practiced or where additional hardness reduction is required, use contact beds of activated alumina. The beds resemble ion exchange units, and appropriate criteria for them apply. The size of the activated alumina is between the 24- and 48-in. (610- and 1219-mm) mesh, and the beds are 2 to 5 ft (.61 to 1.5 m) deep.

Regeneration is with sodium hydroxide, followed by sulfuric acid neutralization. The activated alumina exchange capacity for fluoride varies with feed water quality, and most importantly with pH. Typical values are 1000-2000 grains of fluoride per ft^3 of activated alumina.

6.9.4.5 Standby. It is not necessary to provide standby equipment for fluoride addition or removal since a short-term interruption in treatment for repairs and maintenance is not considered detrimental to the long-range effects of this type of treatment.

6.9.5 Reverse Osmosis Treatment. Reverse osmosis can be used for the removal of all of the inorganic compounds listed in Tables 5 and 6, as well as radioactivity and color. Treatment units are typically sized after conducting pilot studies, particularly when units are being used for the removal of specific inorganics. Brine solutions produced during treatment can be discharged to a sanitary sewer, to a brine evaporation pond, or in some cases, to a watercourse such as a river or body of salt water.

6.9.6 Heavy Metals Removal. Heavy metals listed in Table 5 can be removed by a number of treatment techniques, including reverse osmosis, alum or ferric coagulation, lime softening, anion exchange, and cation exchange. Guidance on removal capabilities of these processes for various heavy metals is presented in EPA-600/8-77-005, Manual of Treatment Techniques for Meeting The Interim Primary Drinking Water Regulations, and EPA-600/2-79-162a, Estimating Water Treatment Costs, Volume 1, Summary.

6.10 Saltwater Conversion

6.10.1 Application. Where freshwater supplies are not available, some means of saltwater conversion must be provided.

6.10.2 Treatment Processes. Select one of the treatment techniques listed in Tables 26 and 27. Review recommendations of manufacturers to develop criteria on design. Refer to reports of the Office of Saline Water, U.S. Department of Interior, for descriptions of processes.

6.11 Disposal of Wastes from Water Treatment Plants

6.11.1 Approach. Apply criteria below to disposal of liquid and solid wastes from water treatment processes. Refer to Table 28 for typical characteristics, disposal possibilities, and related treatment requirements for different types of wastes. Sludges and filter washwaters generally are not permitted by regulatory agencies to be returned to watercourses.

Table 26
Characteristics of Salt Water Conversion Equipment - Technical

	PROCESS					
	ELECTRODIALYSIS	REVERSE OSMOSIS	FLASH DISTILLATION[1]	SUBMERGED COMBUSTION DISTILLATION	SUBMERGED TUBE DISTILLATION[1]	VAPOR COMPRESSION DISTILLATION
Equipment required	Prefilter, electrodialysis stack, pumps, controls.	Prefilter, feed pumps, reverse osmosis membranes and modules, product water degasifier, and controls.	Evaporator, boiler, air ejector vacuum system, chemical treatment equipment, pumps, controls.	Evaporator, cyclone separator, air-cooled condenser, air compressor, engine, distillate neutralizer, pumps, controls.	Evaporator, boiler air ejector vacuum system chemical treatment equipment, pumps, controls.	Diesel engine or electric motor, heat exchanger evaporator, starting heater, pumps, controls.
Characteristics:						
Max raw water TDS,[2] mg/L	15,000	None	None	None	None	None
Finished water TDS, mg/L	Variable	Variable	2-10	10-100	2-10	0.5-10
Waste to product water ratio	0.1-1.0	0.1-3.0	10-20	0.5-1.0	15-30	0.5-1.0
Lb steam per gal product water	None	None	3-5	None	3-5	None
Shaft hp per 1,000 gpd capacity	1/2-2	1.1-2.1[4]	1	6-8	1	6-20
Operating temperature						
Water	(see Footnote 5)	(See Footnote 6)	145°-175° F	180°-195° F	145°-175° F	215° F
Heat source	*None*	*None*	*215°-227° F*	Flame	*215°-227° F*	230° F
Total input energy, Btu per gal product water	500[3]	68-130[4]	5,000-6,000	2,000-3,000	5,000-6000	700-1,500

[1]Chemical treatment required for corrosion and scale control.
[2]Total dissolved solids.
[3]Brackish water, 5,000 mg/L, TDS removed.
[4]For brackish water, hp/1,000 gpd is 0.04-0.07, and total input energy is 24-42 Btu/gallon of product water.
[5]Maximum water temperature 110° F.
[6]Maximum water temperature 86°-122° F, depending on type of membrane.

Table 27
Characteristics of Salt Water Conversion Equipment - Descriptive

Process	Energy source	Method of energy transfer	General description
Electrodialysis	Electrical	Potential difference and ion and current flow.	Migration of the ions to be removed is induced by the potential difference across the brine solution. Selective membranes allow either positive or negative ions to pass through, thus providing alternate channels of demineralized and highly mineralized water.
Reverse osmosis	Electrical	Pressure across a semi-permeable membrane.	Membranes are used which allow water to pass, but reject the passage of positive and negatively charged ions, high pressure is used to counteract the natural osmotic pressure across the membrane, and to speed the movement of water across the membrane, demineralized water and a highly mineralized waste stream are produced.
Flash distillation	Waste or exhaust steam	Heat exchanger outside of evaporation vessel.	Similar to submerged tube, below, except that the main heat input is in an external exchanger where no evaporation takes place. Water flashes into steam in the evaporator vessel away from hot coils, thus reducing scaling.
Submerged combustion distillation	Gas or liquid fuel	Combustion takes place in the evaporation vessel.	Fuel plus compressed air burn in evaporator. Combustion products are directed through the brine, heating and causing evaporation. Exhaust gases, mixed with steam, flow through a separator. Heat is recovered from condensate.
Submerged tube distillation	Waste or exhaust steam	Steam coils in the evaporator.	Original marine equipment: Heat exchanger is the evaporator vessel. Steam flows through coils in the evaporator. Low pressure (2 psia) maintained in the evaporator. Heat recovered from condensate heats incoming brine. Noncondensing waste gases evacuated by air ejector.
Vapor compression distillation	Compressor (also auxiliary heat)	Vacuum applied on evaporation side, compression on the condensate side.	Initial heat added through auxiliary heater. Subsequent maintenance of low pressure in the evaporator causes brine to flash into steam. Heat is recovered from compressed vapor and transfers energy to brine.

Table 28
Water Treatment Plant Waste Disposal Guide

TYPE OF WASTES	QUANTITIES	CHARACTERISTICS	DISPOSAL TREATMENT REQUIRED	POSSIBILITIES
Screenings	Vary widely; particular source must be evaluated; check other plants using same source or other similar plants.	See remarks on Quantities.	None required, although treatment may be desirable depending upon method of disposal.	Return to watercourse if quantities are small, and regulatory agencies permit. Truck to landfill. Investigate disposal with sewage treatment plant screenings.
Plain settling sludges	Vary widely; particular source must be evaluated; check other plants using same source or other similar plants.	See remarks on Quantities.	None.	Dredging or draglining and hauling to landfill; multiple, drainable basins make cleaning easier.
Coagulation sludges	For basins where sludge is continuously withdrawn, assume solids are withdrawn at 0.5%. For drain and clean basins, check plants with similar raw water; quantity is basin volume plus minor amount of flushing water.	Solids content—0.1% to 2%; 75-90% of total is suspended; 20-35% of total is volatile. BOD_5 30-150 mg/L. BOD_{ult} often 3 times BOD_5. COD 500-15,000 mg/L (high values with powdered activated carbon treatment of water). Dry unit weight 75-95 lbs/ft^3. Composed of raw water impurities and coagulation chemicals.	Concentration through sedimentation often desirable, recycling supernatant to plant influent especially when plant's sedimentation basins are drained. Sludge concentrations of 0.5-1.0% can be obtained. and/or Drying beds. Freezing and heat treatment processes are effective for alum sludge dewatering but expensive except in climates where sludges can be lagooned and frozen naturally. Pressure filtration dewaters sludge to 15-20% solids often requiring lime as conditioner. Centrifuges dewater sludges up to 15% solids.	Send concentrated sludge or continuously withdrawn sludge to sewage treatment plant*. Haul dried sludge to landfill or to spreading and harrowing.
Filter wash water**	Normal wash lasts a maximum of ten min at a rate of 15 gpm/ft^2 filter area.	Chemically-raw water impurities and coagulation chemicals; BOD_5 0-4 mg/L; COD up to 160 mg/L pH 6.9-7.8. For alum plants, total solids varies with time up to 1,000 mg/L, average 400 mg/L. Plants removing iron and manganese may be 4 times higher in total solids.	Flow equalization and concentration through sedimentation and decanting.	Same as for coagulation sludges. Combine with coagulation sludge where applicable. Where no coagulation used, dispose as shown for softening sludge combined with the settling sludge, where applicable.

Lime softening sludges	Assume solids are discharged at 0.5%.		Dewatering lime softening sludges is not particularly difficult: the following methods can be used: (1) Lagooning (up to 50% solids concentration obtained). (2) Vacuum filtration (up to 45-50% solids concentration obtained). (3) Centrifuging (up to 60-65% solids concentration obtained). Return decant, filtrate, or centrate to plant influent if economically practical.	Discharge to sewage treatment plants.* Dewatered sludge hauled to landfill (agricultural applications possible). Recalcining limited to large plants (>20 Mgd) by economical considerations.
Diatomite sludges	See filter manufacturer's literature.	Solids normally 60-70% filter aid; remainder raw water impurities; dry density about 10 lbs/ft^3; specific gravity 2.	Lagooning-supernatant to plant influent.	Haul solids from lagoon to landfill.
Brines (ion exchange, reverse osmosis, and desalination)	See manufacturer's literature.	Ion exchange: Total solids up to 20,000 mg/L. Chlorides up to 12,000 mg/L. Almost no suspended solids. Reverse osmosis: Total solids up to 20,000 mg/L.	Evaporation lagoons where concentration is desired and climate permits. No treatment is required if brine is discharged to a sewer.	Best solution is ocean disposal. Return to watercourse only if allowed by regulatory agencies. Discharge to sewage treatment plant only if sufficiently diluted by sewage. Disposal wells possible but are easily plugged and potentially damaging to groundwater quality.

* For discharge to sanitary sewers, avoid cross connections and slug flow. Always check:
(1) Potential waste damage to sewer system.
(2) Amenability of waste to sewage treatment process.
(3) Hydraulic capacity of sewers and treatment facilities.
(4) Effluent quality (might improve settling of wastewater solids and for phosphate removal).

**Sedimentation basins or solids contact reactors ahead of filters will generally remove 70-90% of total plant solids. The remainder of solids will appear in the filter wash water.

6.11.2 Solids Quantity Determination. Determine both average and peak solids quantities. Use average quantities to predict holding requirements, disposal requirements, and other long period parameters. Design treatment units to handle peak loads unless storage is provided as part of the treatment train.

6.11.2.1 Existing Water Treatment Plants. Where wastes from an existing plant must be handled, conduct a sampling program to determine the quantities and characteristics of the wastes actually produced at the plant. Consider variations in chemical feed.

6.11.2.2 Water Treatment Plants Under Design. Determine solids quantities from investigation of processes selected and chemical dosages required to treat the particular raw water. Use each of the following procedures where applicable:

a) Analyze the wastes produced in jar tests and scale quantities up to the full size plant.

b) Study the quantities of wastes produced in similar plants treating similar waters.

c) Where solids contact reactors, ion exchange units, diatomaceous earth filters, or other manufactured treatment units are used, consult with manufacturers.

d) For information on coagulation and lime softening plants, refer to Table 29.

6.11.3 Criteria for Treatment and Disposal Facilities. Special criteria are given below for wash water equalization and sludge concentration tanks and for drying beds and lagoons. Related general criteria from MIL-HDBK-1005/8 apply where consistent with criteria herein. Also refer to MIL-HDBK-1005/8 for criteria on sludge filters, centrifuges, and sludge conditioning.

6.11.3.1 Wash Water Equalization and Sludge Concentration Tank. Refer to NAVFAC P-272, Definitive Designs for Naval Shore Facilities, Parts I and II, Drawing 1402905. Unit is intended to operate as a batch settling basin with clear supernatant decanted through the floating launder and recycled to plant influent. Concentrated sludge is directed to its ultimate disposal. Neither supernatant nor underflow is to be withdrawn during filter washing.

a) Tank Volume

(1) For plants with continuous sludge removal or no sedimentation basins, provide volume above sludge scraper for two 10-min washes at 15 gpm/ft^2 (611 Lpm/m^2) and backwash rate.

(2) For plants with drain and clean sedimentation basins, provide volume for two filter washes as above plus volume of largest basin to be cleaned. (Include volume below top of sludge scraper.)

b) Tank Depth. The depth is 10 to 20 ft (3.05 to 6.1 m).

c) Supernatant Flow Rate. The flow is 5 percent of plant flow rate.

Table 29
Suspended Solids Quantities Computation for Coagulation and Lime Softening Sludges

Directions for use	M = alkalinity; H = total hardness; MgH = magnesium hardness (hardness expressed as calcium carbonate)
For coagulation plants	Calculate Total (A).
For lime softening plants	When H>M or when calcium chloride is used to react with sodium carbonate, calculate Total (A+B). When H>M and when calcium chloride is not used to react with sodium carbonate, calculate Total (A+C).
For softening plants using lime and soda ash	When H>M or when calcium chloride is used to react with sodium carbonate, calculate Total (A+B+D). When M>H and calcium chloride is not used to react with sodium carbonate, calculate Total (A+C+D).

A. Turbidity removed (turbidity units)	________	x 1.0 =	________
Aluminum sulfate (mg/L)	________	x 0.26 =	________
Ferrous sulfate (mg/L)	________	x 0.39 =	________
Ferric chloride (mg/L)	________	x 0.64 =	________
Ferric sulfate (mg/L)	________	x 0.47 =	________
Activated silica (mg/L)	________	x 1.0 =	________
	TOTAL A		________ mg/L of treated water
B. M (mg/L)	________	x 2.0 =	________
MgH (mg/L)	________	x 0.58 =	________
	TOTAL B		________ mg/L of treated water
C. M (mg/L)	________	x 1.0 =	________
H (mg/L)	________	x 1.0 =	________
MgH (mg/L)	________	x 0.58 =	________
	TOTAL C		________ mg/L of treated water
D. H (mg/L)	________	x 1.0 =	________
M (mg/L)	________	x 1.0 =	________
	TOTAL D		________ mg/L of treated water

6.11.3.2 Sand Drying Beds

a) Characteristics. Square or rectangular, generally not more than 100 ft (30.5 m) on a side. Total number should be at least four, to allow beds to be dewatering or to be cleaned while another bed(s) is being filled. Water removal is by evaporation and percolation to underdrains.

b) Design. Six or more in. (≥152.4 mm) of sand overlies 8 to 18 in. (203 to 457 mm) of graded gravel. The gravel surrounds the underdrains, which are usually spaced 50 ft (15.2 m) apart. Underdrain piping can be plastic or vitrified clay, with 4-in. (101.6 mm) minimum diameter. In high precipitation areas, covered drying beds should be considered. Bed area must be determined by field testing, or results from nearby plants drying similar sludges.

c) Polymer Conditioning. Proper conditioning reduces drainage time on the beds, thereby reducing the required bed area. Pilot scale testing must be performed to determine appropriate dosage.

d) Normal application depth is 8 to 12 in. (203 to 305 mm). Optimum depth must be determined during operation.

6.11.3.3 Evaporation Lagoons

a) Characteristics. Generally constructed using earthen dikes. Basic method of water removal is by evaporation, although drainage may occur in some situations. Natural drainage should be encouraged where possible. Most appropriate location is in a hot climate with low percolation. However, alternate freezing and thawing in cold climates is very effective for thickening/dewatering alum sludge. Lagoons are most appropriate for lime sludges where up to 50 percent solids can be produced; often, alum sludges will only thicken to 10 percent in a lagoon.

b) Design. Generally earthen dikes in a rectangular shape are used to contain the lagoon. A minimum of two lagoons should be used to allow one lagoon to be decanting and/or drying, while the other(s) is being filled. Provisions should be made for mowing side slopes, equipment access to remove dried sludge, and vehicle movement atop the dikes.

c) Operation. Sludge depth is between 3 and 5 ft (.9 and 1.5 m), plus an additional 3 to 5 ft of freeboard. Decant should be used to remove water from the lagoon surface, with subsequent treatment or disposal of this decant. Without removal of decant, it is difficult, and in some cases impossible to dewater sludge if the liquid level remains above the level of the sludge solids.

6.12 Chemical Feeding and Handling

6.12.1 Policies. Equipment shall be as simple as possible. In any installation or facility, equipment procurement shall be limited to the smallest practicable number of manufacturers.

6.12.1.1 Standardization. Equipment shall be standardized wherever possible. Use identical or similar components to the maximum extent. Feeding equipment should be homogeneous (that is, all self-powered, all pneumatic, etc.).

6.12.1.2 Equipment Accuracy. Equipment accuracy tolerances shall be as low as possible consistent with the functions desired.

6.12.1.3 Equipment Ranges. Before selecting equipment, the required maximum and minimum capacities shall be computed, and ranges shall be kept as narrow as possible for any piece of equipment.

6.12.1.4 New Products. New products and applications are constantly being developed. Approval or advice on their uses shall be requested from Naval Facilities Engineering Command Headquarters (NAVFACHQ).

6.12.2 Chemicals. Functions of various chemicals which can be used in water treatment are shown in Table 30; usual chemical strengths and other data on these chemicals are shown in Table 31. All chemicals used in water treatment operations should meet purity requirements of American Water Works Association (AWWA) standard specifications. Design shall be based on the assumption that chemicals will be purchased in normal shipping containers (such as bags, drums, cylinders, or carboys) rather than bulk car or truckloads.

6.12.2.1 Handling. Refer to Table 31 for handling precautions. Provide the following:

a) Roofed unloading platforms.

b) Mechanical handling aids for unloading and transporting chemicals to the storage area, feed hoppers, and solution tanks.

c) Dust control equipment for dry, dusty chemicals.

d) Washdown and cleanup facilities for dry and liquid chemical spills.

6.12.2.2 Storage. Refer to Table 32 for space criteria and Table 33 for type criteria. Refer to Concrete Sanitary Engineering Structures, American Concrete Institute (ACI), for criteria on protection of concrete against chemicals.

a) Store materials in original containers in dry rooms on boards or pallets.

b) Locate storage for dry chemicals at the level of feed hopper inlets if possible.

c) Do not exceed safe floorload limits.

d) For liquified gas cylinders, provide cool, dry, well-ventilated, aboveground storage rooms of noncombustible construction, remote from heat sources, walkways, elevators, stairways, and ventilating system intakes.

e) Determine compatibility of all chemicals stored. Store incompatible chemicals separately.

f) Refer to para. 6.12.2.5 for personnel safety precautions.

Table 30
Function of Chemicals Used in Water Treatment

Chemical	Application							
	Adsorption	Disinfection	Fluoridation	Coagulation	pH Adjustment	Softening	Corrosion or Scale Control	Taste and Odor Control
1. Activated Carbon	X	-	-	-	-	-	-	X
2. Aluminum Sulfate (alum)	-	-	-	X	-	-	-	-
3. Ammonia (aqua or gas)	-	X	-	-	-	-	-	-
4. Ammonium Sulfate	-	X	-	-	-	-	-	-
5. Calcium Carbonate (limestone)	-	-	-	-	X	-	X	-
6. Calcium Hydroxide (hydrated lime)	-	-	-	X	X	X	X	-
7. Calcium Oxide (quicklime)	-	-	-	X	X	X	X	-
8. Calcium Hydrochlorite (HTH, perchloran)	-	X	-	-	-	-	-	X
9. Carbon Dioxide	-	-	-	-	X	-	X	-
10. Chlorine	-	X	-	-	-	-	-	X
11. Chlorine Dioxide	-	X	-	-	-	-	-	X
12. Clay or Bentonite	-	-	-	X	-	-	-	-
13. Ferric Chloride	-	-	-	X	-	-	-	-
14. Ferric Sulfate (ferrifloc)	-	-	-	X	-	-	-	-
15. Ferrous Sulfate	-	-	-	X	-	-	-	-
16. Fluosilicic Acid	-	-	X	-	-	-	-	-
17. Hydrochloric Acid	-	-	-	-	X	-	X	-
18. Ozone	-	X	-	-	-	-	-	X
19. Polymers (polyelectrolytes)	-	-	-	X	-	-	-	-
20. Potassium Permanganate	-	-	-	-	-	-	-	X
21. Sodium Aluminate	-	-	-	X	-	-	-	-
22. Sodium Carbonate	-	-	-	X	X	X	X	-
23. Sodium Chloride	-	-	-	-	-	X	-	-
24. Sodium Chlorite	-	X	-	-	-	-	-	-
25. Sodium Hypochlorite	-	X	-	-	-	-	-	X
26. Sodium Fluoride	-	-	X	-	-	-	-	-
27. Sodium Hexametaphosphate	-	-	-	-	-	-	X	-
28. Sodium Hydroxide	-	-	-	-	X	X	X	-
29. Sodium Tripolyphosphate	-	-	-	-	-	-	X	-

Table 30 (Continued)
Function of Chemicals Used in Water Treatment

Chemical	Application							
	Adsorption	Disinfection	Fluoridation	Coagulation	pH Adjustment	Softening	Corrosion or Scale Control	Taste and Odor Control
30. Sodium Silicofluoride	-	-	X	-	-	-	-	-
31. Sodium Silicate	-	-	-	X	-	-	X	-
32. Sulfur Dioxide	-	X	-	-	-	-	-	-
33. Sulfuric Acid	-	-	-	-	X	-	-	-
34. Tetra Sodium Pyrophosphate	-	-	-	-	-	-	X	-

Note: There are some overlapping functions among the various unit processes described. A few examples are as follows:

1. Activated carbon can control taste and odor by adsorbing the compound or precursor material yet it can be used to remove other organics and for dechlorination.
2. Coagulation is always an integral part of lime or lime-soda softening.
3. Sulfur dioxide is used to remove excess chlorine in some instances and is therefore classified under disinfection. Ammonia is also in this classification, since it is sometimes used to convert a free chlorine residual to a combined chlorine residual.

Table 31
Data on Chemicals Used in Water Treatment

	Chemical			
	Activated Carbon	Aluminum Sulfate (alum) Al $(SO_4)_3 \cdot 14H_2O$	Ammonia NH_3	Ammonium Sulfate $(NH_4)_2SO_4$
Available form	a. Powder b. Granular	a. Slab, lump, powder b. Liquid	a. Liquified gas b. Water solution	a. Crystals
Shipping container	a. Bags, bulk b. Bags, bulk	a. Bags (100-200 lb), drums b. Bulk	a. Cylinders (100, 150 lb), bulk b. Carboys, drums, bulk	a. Bags (100 lbs)
Bulk weight, lb/ft^3	a. Varies b. 20 to 35	a. 60 to 75 b. 10.71 lb/gal		a. 54
Commercial strength		a. 17% Al_2O_3 b. 5.8 to 8.5% Al_2O_3	a. 99 to 100% b. .15 to 30%	
Water solubility, lb/gal	a. Insoluble	a. 5.2 @ 32°F, 5.5 @ 50°F, 5.9 @ 68°F b. Complete	a. 3.9 @ 32°F b. 3.1 @ 60°F	a. 5.9 @ 32°F, 6.1 @ 50°F, 6.3 @ 68°F, 6.5 @ 86°F
Feeding form	a. Dry or slurry b. Static or fluidized bed	a. Dry or solution b. Solution	a. Gas b. Solution	a. Solution
Feeder type	a. Volumetric metering pump	a. Volumetric metering pump b. Metering pump	a. Metering pump	a. Metering pump
Accessory equipment	a. Slurry tank, dust control devices	a. Dissolver or solution tank b. Solution tank	a. Solution tank	a. Solution tank
Suitable handling materials	a. Dry-iron, steel b. Wet-rubber, plastic, stainless steel	a. Dry-iron, steel, concrete b. Wet-lead, rubber, plastic	a. Dry-steel, iron b. Wet-stainless steel	a. Plastic
Comments	a. Combustible dust			

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical			
	Calcium Carbonate $CaCO_3$	Calcium Hydroxide $Ca(OH)_2$	Calcium Oxide CaO	Calcium Hypochlorite $Ca(OCl)_2 \cdot 4H_2O$
Available form	a. Powder, crushed various sizes	a. Powder, granules	a. Lump, pebble, ground	a. Granules, tablets
Shipping container	a. Bags, barrel, bulk	a. Bags (50 lb) bulk	a. Bags (80 lb) barrels, bulk	a. Cans (5 lb), drums (100, 300, 800 lb)
Bulk weight, lb/ft^3	a. Powder, 48 to 71; crushed, 70 to 110	a. 25 to 50	a. 40 to 70	a. 50 to 55
Commercial strength		a. Normally 13% $Ca(OH)_2$	a. 75 to 99% normally 90% CaO	a. 70% available chlorine
Water solubility, lb/gal	a. Nearly insoluble	a. Nearly insoluble	a. Nearly insoluble	a. 1.8% @ 32°F
Feeding form	a. Dry slurry used in fixed beds	a. Dry or slurry	a. Dry or slurry (must be slaked to $Ca(OH)_2$)	a. Solution or dry
Feeder type	a. Volumetric metering pump	a. Volumetric metering pump	a. Dry-volumetric, wet-slurry (centrifugal pump	a. Solution-metering pump. Dry-tablet contact feeder
Accessory equipment	a. Slurry tank	a. Slurry tank	a. Slurry tank, slaker	a. Solution tank
Suitable handling materials	a. Iron, steel	a. Iron, steel, plastic, rubber hose	a. Iron, steel, plastic, rubber hose	a. Glass, plastic, rubber
Comments			a. Provide means for cleaning slurry transfer pipes	a. Soft water required for solution

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical			
	Carbon Dioxide CO_2	Chlorine Cl_2	Chlorine Dioxide ClO_2	Clay or bentonite
Available form	a. Liquified gas	a. Liquid gas	a. Gas	a. Powder
Shipping container	a. Cylinders, bulk	a. Cylinders (100, 150, 200 lb), bulk	a. Prepared on-site using chlorine and sodium chlorite, solution pump, and contactor column	a. Bags, barrels, bulk
Bulk weight, lb/ft^3	a. -	a. Liquid-91.7 Gas-0.19 @ 60°F and atm press.	a. -	a. 30 to 70
Commerical strength	a. 99+%	a. 99.8%	a. -	a. -
Water solubility, lb/gal	a. Varies with pressure, temperature, and alkalinity of water	a. 0.12 @ 32°F 0.047 @ 87°F	a. 0.07 @ 60°F 0.04 @ 100°F	a. Insoluble
Feeding form	a. Gas	a. Water solution of gas	a. Water solution of gas	a. Dry or slurry slurry
Feeder type	a. Gas diffuser	a. Vacuum chlorinator with water ejector	a. Chlorinator plus sodium chlorite solution pump	a. Dry-volumetric, slurry-pump
Accessory equipment	a. Flowmeters	a. Scales, switch over devices, leak detector	a. Scales, switch over devices, leak detectors, reactor tower	a. -
Suitable handling materials	a. Steel, iron for dry. Plastic for diffuser and wetted parts	a. Sched. 80 steel for gas under pressure. Plastic or rubber-lined for gas under vacuum or water solution.	a. Sched. 80 steel for gas under pressure. Plastic or rubber-lined for gas under vacuum or water solution.	a. Iron, steel
Comments	a. -	a. Provide gas masks for emergency use. Irritant to eyes and lungs. Toxic and corrosive.	a. -	a. -

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical			
	Ferric Chloride $FeCl_3$	Ferric Sulfate $Fe_2(SO_4)_3 \cdot XH_2O$	Ferrous Sulfate $FeSO_4 \cdot 7H_2O$	Fluosilicic Acid H_2SiF_6
Available form	a. Powder b. Liquid	a. Powder b. Granule	a. Crystals, powder, lumps b. Liquid	a. Liquid
Shipping container	a. Drums (135, 350 lb) b. Bulk	a. Bags (50, 100, 175 lb) b. Drums (200, 400, 425 lb), bulk	a. Bags (50, 100 lb), drums (55 gal), bulk b. Bulk	a. Carboys (13 gal), drums (55 gal), bulk
Bulk weight, lb/ft^3	a. 175 b. 87 to 94	a. 70 to 72	a. 62 to 66 b. Varies. Consult producer.	a. 10.5 lb/gal (30%)
Commercial strength	a. 98% b. 39 to 45%	a. 21.0% soluble iron	a. 55 to 58% b. Varies. Consult producer.	a. 20 to 35%
Water solubility, lb/gal	a. 4.6 @ 32°F b. 5.8 @ 55°F	a. Very soluble		a. Complete
Feeding form	a. Liquid b. Liquid	a. Liquid	a. Liquid b. Liquid	a. Liquid
Feeder type	a. Metering pump b. Metering pump	a. Metering pump	a. Metering pump b. Metering pump	a. Metering pump
Accessory equipment	a. Solution tank	a. Solution tank	a. Solution tank	a. Dilution tank
Suitable handling materials	a. Glass, rubber, plastic	a. Glass, rubber, plastic	a. Glass, rubber, plastic	a. PVC, rubber-lined steel
Comments	a. Dilution limited due to iron hydrolosis	a. Dilution limited due to iron hydrolosis	a. Dilution limited due to iron hydrolosis	

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical			
	Hydrochloric Acid HCl	Ozone O_3	Polymers	Potassium Permanganate $KMnO_4$
Available form	a. Liquid	a. Gas	a. Liquid, powder	a. Crystals
Shipping container	a. Barrels, drums, bulk	a. Generated on-site from air or oxygen	a. Drums, bulk	a. Drums (110, 220, 550 lb), bulk
Bulk weight, lb/ft^3	a. 27.9%-0.53 lb/gal 31.45%-9.65 lb/gal 35.2%-9.83 lb/gal		a. The various cationic, anionic and nonionic polymers vary in composition, density and other characteristics. Consult supplier for data.	a. 100
Commercial strength	a. 27.9% 31.45% 35.2%			a. 95 to 99%
Water solubility lb/gal	a. Complete			a. 0.525 @ 68°F
Feeding form	a. Liquid	a. Gas solution	a. Solution	a. Liquid
Feeder type	a. Metering pump			a. Metering pump
Accessory equipment	a. Dilution tank	a. Consult equipment supplier	a. Storage and dilution tanks	a. Dissolving tank
Suitable handling materials	a. Hastelloy A, selected plastic and rubber types	a. Unplasticized PVC, stainless steel	a. Consult supplier	a. Iron, steel, PVC
Comments		a. Toxic, irritant		

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical			
	Sodium Aluminate $NaAlO_2$	Sodium Carbonate Na_2CO_3	Sodium Chloride NaCl	Sodium Chlorite $NaClO_2$
Available form	a. Powder b. Liquid	a. Powder	a. Rock, evaporated	a. Flake b. Liquid
Shipping container	a. Bags (100, 150, 250, 440 lb) b. Drums	a. Bags (100 lb), bulk	a. Bags, barrels, bulk	a. Drums (110 lb) b. Drums, bulk
Bulk weight, lb/ft^3	a. 50 to 60 b. Varies	a. 34 to 62	a. 50 to 70	b. Varies
Commercial strength	a. 72 to 90% b. Varies	a. 99.2%	a. Varies	b. Varies
Water solubility, lb/gal	a. 2.45 @ 32°F 2.8 @ 50°F 3.1 @ 68°F 3.3 @ 86°F	a. 0.58 @ 32°F 1.04 @ 50°F 1.79 @ 68°F 3.33 @ 86°F	a. 2.97 @ 32°F 2.97 @ 50°F 3.00 @ 68°F 3.02 @ 86°F	
Feeding form	a. Dry b. Liquid	a. Dry b. Liquid	a. Solution	a. Solution
Feeder type	a. Volumetric feeder b. Metering pump	a. Volumetric feeder b. Metering pump	a. Pump	a. Metering pump
Accessory equipment	a. Dissolving tank	a. Dissolving tank	a. Dissolving tank	a. Dissolving tank
Suitable handling materials	a. Wet or dry-iron, steel, rubber, plastics	a. Iron, steel	a. Plastic, iron, steel	a. Plastic (avoid cellulose materials)
Comments		a. Can cake		a. Use to produce chorine dioxide

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical		
	Sodium Tripolyphosphate $Na_5P_3O_{10} \cdot 6H_2O$	Sodium Silicofluoride $NaSiF_6$	Sodium Silicate $Na_2O \cdot XSiO_2$
Available form	a. Crystals	a. Powder, crystal	a. Liquid
Shipping container	a. Bags (100 lb), drums (100 and 300 lb)		a. Drums, bulk
Bulk weight, lb/ft^3	a. 64	a. 65 to 85	a. 11.6-11.7 lb/gal
Commercial strength	a. 45.6% P_2O_5	a. 90 to 98%	a. 8.9 to 9.1% NaO 28.7 to 29.5% SiO_2. Other compositions available.
Water solubility, lb/gal	a. 1.8 @ 75°F	a. 0.03 @ 32°F 0.06 @ 75°F	a. Complete
Feeding form	a. Solution	a. Dry solution	a. Liquid
Feeder type	a. Metering pump	a. Volumetric feeder, metering pump	a. Metering pump
Accessory equipment	a. Solution tank	a. Solution tank	a. Dilution tank
Suitable handling materials	a. Iron, steel		a. Iron, steel, plastics
Comments			

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical		
	Sulfur Dioxide SO_2	Sulfuric Acid H_2SO_4	Tetra Sodium Pyrophosphate $Na_4P_2O_7$
Available form	a. Liquified gas	a. Liquid	a. Granular, powder
Shipping container	a. Cylinder (150, 2,000 lb)	a. Carboys, drums (825 lb) b. Bulk	a. Bags (100 lb), drums (125 and 350 lb)
Bulk weight, lb/ft^3	a. Liquid-89.6 Gas @ 32°F and 1 atm-0.183	a. 106 b. 114	a. 58
Commercial strength	a. 99%	a. 60°Be-77.7% 66°Be-93.2%	a. 53% P_2O_5 46.3% Na_2O
Water solubility, lb/gal	a. 1.0 @ 60°F	a. Complete	a. 0.5 @ 75°F 2.5 @ 150°F
Feeding form	a. Water solution of gas	a. Liquid	a. Liquid
Feeder type	a. Vaccum-sulfur-meter with water ejector	a. Metering pump	a. Metering solution
Accessory equipment	a. Scales, switch over devices		a. Solution pump
Suitable handling materials	a. Dry-316 stainless steel, wet and low pressure-plastic, rubber		a. Iron, steel tank
Comments	a. Provide gas masks for emergency use	a. Provide for spill cleanup and neutralization	

Table 31 (Continued)
Data on Chemicals Used in Water Treatment

	Chemical			
	Sodium Hypochlorite NaOCl	Sodium Fluoride NaF	Sodium Hexametaphosphate $(NaPo_3)_6$	Sodium Hydroxide NaOH
Available form	a. Liquid	a. Powder, crystal	a. Ground, powder, plate	a. Solid flake, ground flake, liquid
Shipping container	a. Carboys (5, 13, 59 gal), bulk (1,300, 2,000 gal), truckload	a. Bags (100 lb), drums (125, 400 lb)	a. Bags (100 lb), drums (100, 300 to to 330 lb)	a. Drums (735 lb) Drums (100 lb) Drums (450 lb)
Bulk weight, lb/ft^3		a. 50 to 90		a. Varies
Commercial strength	a. 12 to 15% available chlorine	a. 23 to 95%		a. 98%
Water solubility, lb/gal	a. Complete	a. 0.34 @ 77°F	a. 12.4 @ 75°F	a. 3.5 @ 32°F 4.3 @ 50°F 9.1 @ 68°F 9.2 @ 86°F
Feeding form	a. Solution	a. Dry, soludion	a. Solution	a. Solution
Feeder type	a. Metering pump	a. Volumetric feeder, metering pump	a. Metering pump	a. Metering pump
Accessory equipment	a. Solution tank	a. Solution tank	a. Solution tank (dissolving basket for plates)	a. Dissolving tank
Suitable handling materials	a. Plastic, glass, rubber	a. Plastic, glass, rubber	a. Plastic, stainless steel	a. Iron, steel
Comments				a. Dissolving solid form generates much heat

Table 32
Chemical Storage Space Criteria

CLASS OF CHEMICALS	NONINTERRUPTIBLE	INTERRUPTIBLE
Examples of class.	All chemicals used for disinfection. Chemicals used for coagulation in treatment plants where raw water is polluted. Softening chemicals.	Chemicals used for corrosion control. Taste and odor, fluoridation.
Minimum stock to be maintained, in days.[1]	30	10
Additional allowance based on shipping time, in days.[1,2]	2 times shipping time.	1-1/2 times shipping time.

[1]Based on maximum use expected for total consecutive days plus additional allowance.
[2]Additional allowance must be large enough to accommodate maximum expected size shipping equipment (truckload, carload, fractional shipload).

Table 33
Chemical Storage Type Criteria

TYPE OF STORAGE	DRY	WET
Handling requirements.	Allow for access corridors between stacks of packaged chemicals.	Provide agitation for slurries such as carbon or lime-not less than 1 hp mixing for 100 ft^3.
	Palletize and use forklift truck only in large installations.	Check manufacturers of feed and mixing equipment for pumps, pipe sizing, and materials selection.
Safety and corrosion requirements.	Provide separated storage spaces for combustibles and for toxic chemicals, such as carbon or chlorine gas.	Double-check corrosion resistance of bulk storage linings, pipe, mixing, and pumping materials.
	Provide ample space between stores of materials that may interact, such as ferrous sulfate and lime.	Isolate hazardous or toxic solutions such as fluosilicic acid.
		Prefer below-ground or outdoor storages.

6.12.2.3 On-Site Generation and Feeding Equipment

a) Ozone. Ozone can be generated from air or from high-purity oxygen.

(1) Generation from air requires the air to be filtered, and dried to a dew point less than -58° F (-50° C) by desiccation and refrigeration.

(2) When using oxygen for the production of ozone, refrigeration and desiccation are not required except when recycling is used. Use oxygen for the generation of ozone where savings are indicated. Power consumption is halved when oxygen is used to generate ozone, but oxygen must be recycled.

(3) For ozone feeding equipment, use porous diffusers, injectors, or emulsion turbines to ensure optimum contact.

b) Hypochlorite. Compare the cost of hypochlorite generated from brine with cost of purchased hypochlorite solution delivered to site. Generation is generally cheaper and may compare favorably with the cost of gaseous chlorine.

c) Chlorine Dioxide. Chlorine dioxide can be generated using a solution of sodium chlorite ($NaClO_2$) and a solution feed-type gas chlorinator.

(1) Solutions are fed through packed media reactor for generation of chlorine dioxide in solution.

(2) Optimum operating conditions are: pH ≤ 4; chlorine solution ≥ 500 mg/L; 1:1 weight ratio of pure chlorite to chlorine; and reaction time ≥ 1.0 min.

(3) Reactor effluent will contain approximately 70 percent hypochlorite and 30 percent chlorine dioxide. Approximate yield is 0.4 lb ClO_2/lb Cl_2. Near 100 percent conversion to chlorine dioxide can be achieved by available recycle equipment. (Yield = 1.0 lb ClO_2/lb Cl_2). More exacting control to minimize hypochlorite formation may be necessary if trihalomethanes are a problem.

(4) A practical dosage range is 0.1 to 0.5 mg/L. Systems operating as flow-proportional should provide acid injection directly upstream from the chlorinator injector to maintain optimum pH.

(5) Chlorine dioxide solutions are unstable in open vessels. All solution lines and diffusers must be designed so there is minimum possibility of chlorine dioxide coming out of solution.

6.12.2.4 Chemical Feeders. Refer to Table 34 for applications of various types of feeders.

Table 34
Types of Chemical Feeders Used in Water Treatment

TYPE OF FEEDER	USE	LIMITATIONS GENERAL	CAPACITY ft³/h	RANGE
Dry Feeders:				
Volumetric:				
Oscillating plate	Any material, granules or powder	-	0.01 to 35	40 to 1
Oscillating throat (universal)	Any material, any particle size	-	0.02 to 100	40 to 1
Rotating disc	Moist materials including NaF, granules or powder	Use disc unloader for arching	0.01 5o 1.0	20 to 1
Rotating cylinder (star)	Any material, granules or powder	-	8 to 2,000 or 7.2 to 300	10 to 1 or 100 to 1
Screw	Dry, free flowing material, powder granules	-	0.05 to 18	20 to 1
Ribbon	Dry, free flowing material, powder, granules, or lumps	-	0.002 to 0.16	10 to 1
Belt	Dry, free flowing material up to 1-1/2-in. size, powder or granules	-	0.1 to 3,000	10 to 1 or 100 to 1
Gravimetric:				
Continuous-belt and scale	Dry, free flowing, granular material or floodable material	Use hopper agitator to maintain constant density	0.02 to 2	100 to 1
Loss in weight	Most materials, powder, granules or lumps	-	0.02 to 80	100 to 1
Solution Feeder:				
Nonpositive Displacement:				
Decanter (lowering pipe)	Most solutions or light slurries	-	0.01 to 10	100 to 1
Orifice	Most solutions	No slurries	0.16 to 5	10 to 1
Rotometer (calibrated valve)	Clear solutions	No slurries	0.005 to 0.16 or 0.01 to 20	10 to 1 10 to 1
Loss in weight (tank with control valves)	Most solutions	No slurries	0.002 to 0.20	10 to 1
Eductor	Most solutions	No slurries	For batch or continuous rate of feed only	
Positive Displacement:				
Rotating dipper	Most solutions or slurries	-	0.1 to 30	100 to 1
Proportioning Pump:				
Diaphragm	Most solutions. Special unit for 5% slurries	-	0.004 to 0.15	100 to 1
Proportioning Pump:				
Piston	Most solutions, light slurries	-	0.01 to	20 to 1
Gas Feeders:				
Solution feed	Chlorine	-	8,000 lb/d maximum	20 to 1
	Ammonia	-	2,000 lb/d maximum	20 to 1
	Sulfur dioxide	-	7,600 lb/d maximum	20 to 1
Direct feed	Chlorine	-	300 lb/d maximum	10 to 1
	Ammonia	-	120 lb/d	7 to 1

[1]Use special heads and valves for slurries.

a) Dry Feeder Accessories. Dry feeders may require specific auxiliary equipment or accessories when the chemical to be fed has unusual characteristics. Accessories and the conditions under which they are used are as follows:

ACCESSORY	CHARACTERISTIC OF MATERIAL REQUIRING USE OF ACCESSORY
Agitator	Arches in hoppers.
Rotolock mechanism	Tends to flood.
Dissolving chamber	To be fed in solution.
Dust collector	Dusty.
Vapor collector	Noxious or irritating fumes.

b) Feeder Construction. Mechanisms of feeders shall be constructed out of materials resistant to substances to be handled. Refer to Table 31 for data on resistant materials.

c) Feeder Accuracy. The accuracy of feeders should be in these ranges:

(1) Volumetric feeders, accuracy of ±3 percent.

(2) Gravimetric feeders, accuracy of ±1 percent. Gravimetric feeders are more expensive than volumetric feeders.

6.12.2.5 Safety Precautions. Provide the following safety factors, as a minimum:

a) First aid kits.

b) Continuous toxic gas monitors with alarms and pressure demand self-contained breathing apparatus (SCBA) for emergency gas situations.

c) A readily accessible potable water supply to wash away chemical spills including emergency deluge shower and eyewash facilities located within easy access to those in need.

d) Special handling clothing and accessories, such as gloves, goggles, aprons, and dust masks.

e) Adequate ventilation as determined by the medical activity industrial hygienist.

f) No electrical convenience outlets in activated carbon storage or feeding rooms. Store activated carbon in a separate room with adequate fire protection.

g) Entry into confined spaces will require adherence to a gas free engineering program.

6.12.2.6 Chemical Feeder Capacity and Standby Requirements. Base feeder capacity on maximum expected instantaneous flow and dosage. Essential (noninterruptible) chemical feeders such as disinfection units must have a standby unit having capacity equal to the largest unit. The need for standby units or other treatment processes depends on raw water quality. Where two chemical feed systems could use the same spare chemical feeder, one standby unit to serve both is adequate. Refer to EPA-430-99-74-001, Design Criteria for Mechanical, Electrical and Fluid System and Component Reliability.

6.12.3 Sampling. Except where raw water quality is highly variable during short time periods, composite sampling is usually not necessary for raw water. Composite sampling or continuous monitoring may be desirable for certain parameters in treated water, such as turbidity. Turbidity, chlorine residual, suspended solids, alkalinity, hardness, fluoride, and pH are the normal process control variables in potable water treatment. These are measured at least once per operating day. Other parameters that are measured quarterly, or annually are total trihalomethanes (TTHM), heavy metals, specific herbicides, pesticides and synthetic organics, and total organic carbon (TOC). Frequency of sampling these parameters depends on local conditions and regulatory requirements.

6.12.4 Analytical Methods. Refer to APHA Standard Methods for the Examination of Water and Wastewater for detailed laboratory procedures. In addition to standard laboratory methods, continuous monitoring is often required or desirable for certain water quality parameters. Where continuous monitoring is employed, laboratory methods are required for monitoring instrument calibration and quality assurance. For routine testing during plant operation, refer to Table 35. Sampling and testing must satisfy minimum requirements of regulatory agency.

Table 35
Minimum Testing Program for Water Treatment Plant Operation[1]

	FREQUENCY FOR PLANT CAPACITY		
TEST	0 to 1.4 mgd	1.5 to 5.0 mgd	5.1 to 10.0 mgd
Chlorine residual of treated water	Twice daily	Twice daily	Continuous monitoring
Turbidity of treated water	Twice per shift[2]	Continuous monitoring	Continuous monitoring
Alkalinity, calcium, and total hardness	Twice per shift[3]	Twice per shift[3]	Twice per shift[3]
Alkalinity, calcium, and total hardness	Once weekly[4]	Twice weekly[4]	Daily[4]
Fluoride[5]	Once per shift	Once per shift	Once per shift
pH[6]	Daily	Daily	Once per shift or continuous monitoring

[1]As a minimum, satisfy regulatory agency requirements.
[2]Composite samples.
[3]Softening processes only, or where corrosion or scaling can be a problem.
[4]Nonsoftening processes only.
[5]Where fluoride is added, or is being added.
[6]Chemical coagulation or softening only.

6.13 Metering, Instrumentation and Control

6.13.1 Policies. Devices and systems shall be as simple as possible. In any installation or facility, equipment procurement shall be limited to the smallest practicable number of manufacturers.

6.13.1.1 Standardization. Equipment shall be standardized wherever possible. Use identical or similar components to the maximum extent. Instrumentation and control equipment should be homogeneous (that is, all self-powered, all pneumatic, and so forth).

6.13.1.2 Equipment Accuracy. Equipment accuracy tolerances shall be as low as possible consistent with the functions desired.

6.13.1.3 Equipment Ranges. Before selecting equipment, the required maximum and minimum capacities shall be computed, and ranges shall be kept as narrow as possible for any piece of equipment.

6.13.1.4 New Products. New products and applications are constantly being developed. Approval or advice on their uses shall be requested from Naval Facilities Engineering Command Headquarters (NAVFACHQ).

6.13.2 Information Required. Obtain the following information to assist in equipment selection:

a) Type of treatment.

b) Chemical, physical, and bacteriological qualities of raw water, and actual variations; treated water, permissible limits.

c) Variations of flow rate or demand for raw water or waste, treated water or waste.

d) Ranges of other related variables.

e) Size of plant.

6.13.3 Primary Measuring Devices. Primary measuring devices are required at significant locations in water supply systems to sense and measure flow, pressure level, temperature, weight, pH, and other process variables essential to proper operating control and evaluation of plant performance. Refer to Table 36 for examples of locations of measuring devices and types of measurements.

6.13.3.1 Use Limitations. Different types of measuring devices are available for each application. Refer to Table 37 for a listing of primary devices and examples of their application. The listed "capacity" of a device includes most sizes and types of the device that are available. The "range" is the useful turndown-ratio of a particular device.

6.13.3.2 Discrete vs. Analog Devices. Alarm functions and many control functions require only the presence or absence of a process variable input for their operation. For example, a sump pump may start if the liquid level is above a certain point or a tank heater may start if the temperature is below a

Table 36
Metering, Instrumentation and Control Requirements for Water Supply and Treatment

Location and use	Type of measurement	Type of instrument readout[1]	Range of measurement and/or readout	Controls: Item regulated	Controls: Type
Source of Supply:					
Surface (river or reservoir):					
Intake	Level	Indicator (O) Recorder (O)	Depends on site. Cover extreme levels.	None	
Diversion structure	Flow	Recorder (O)	1 to 4	None	
Groundwater:					
Pump discharge	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure.	None	
Well	Level	Indicator (E)	Static level to pump bowls.	None	
Pumping and Conveyance:					
Low service pump discharge	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure.	None	
Raw or treated water pipeline	Flow	Indicator (E) Totalizer (E) Recorder (O)	1 to 4	Chemical feeds, disinfection, flow splitting	Proportional-automatic (O)
Coagulation-Clarification:					
Settling basin	Level	Indicator (O)	Depth of basin	None	
	pH	Indicator (O) Recorder (O)	0 to 14 units	Chemical feeds	Automatic (E)
Filtration:					
Filter effluent	Flow	Indicator (E) Recorder (O)	1 to 4	Filtration rate[2]	Automatic (E)
	Turbidity	Indicator (O) Recorder (O)	1 to 100	Time for backwash	Automatic (E)
	pH	Indicator (O) Recorder (O)	0 to 14 units	Chemical feed	Automatic (E)
Filter headloss	Pressure differential	Indicator (E) Recorder (O)	1 to 3	Time for backwash	Manual (E)
Filter backwash	Flow	Indicator (E) Recorder (S)	1 to 4	Backwash rate	Manual (E) Automatic (O)
	Turbidity	Indicator (O)	1 to 100	Backwash rate and length	Automatic (O)

Table 36 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and use	Type of measurement	Type of instrument readout[1]	Range of measurement and/or readout	Controls: Item regulated	Controls: Type
Sand expansion	Level	Indicator (S)	1 to 1.5	Backwash rate	Manual
Surface wash	Flow	Indicator (S)	1 to 4	Surface wash rate	Manual (E)
Washwater storage tank	Level	Indicator (E)	Depth of tank	Washwater makeup	Automatic (E)
		Recorder (S)			
Chemical Softening:					
Softening unit	Flow	Indicator (E) Totalizer (E) Recorder (O)	1 to 4	Chemical feed	Manual (E) Automatic (O)
	pH	Indicator (O) Recorder (O)	0 to 14 units	Chemical feed	Manual (O) Automatic (O)
Recarbonation unit	pH	Indicator (E) Recorder (O)	0 to 14 units	Chemical feed	Manual (O) Automatic (O)
Ion Exchange Softening:					
Influent or effluent line to each exchange unit	Flow	Indicator (O) Totalizer (E)	1 to 4 At least 2 times volume between regenerations	Rate of flow through unit Start of regeneration cycle	Manual (E) Manual (E) Automatic (O)
	Conductivity	Indicator (O)	1 to 2	Start of regeneration cycle	Manual (O)
Loss of head	Pressure differential	Indicator (E)	1 to 3	Cleaning or replacement of bed material	Manual (E)
Regeneration system	Level	Indicator (E)	Depth of tank	Supply of regenerant	Manual (E)
	Flow	Indicator (E)	1 to 4	Rate of regeneration	Manual (E)
Aeration:					
Aerator sump	Level	Indicator (E)	Depth of sump	Influent flow	Manual (E) Automatic (O)
Disinfection and Fluoridation:					
Chlorine, hypochlorite, or fluoride solution	Flow	Indicator (E)	1 to 10	Rate of application[2]	Manual (E), Proportional-automatic (O)
	Residual	Indicator (E) Recorder (S)	1 to 10	Rate of application[2]	Proportional-automatic (O)

Table 36 (Continued)
Metering, Instrumentation and Control Requirements for Water Supply and Treatment

Location and use	Type of measurement	Type of instrument readout[1]	Range of measurement and/or readout	Controls: Item regulated	Controls: Type
Treatment unit effluent	Flow	Indicator (E) Totalizer (E) Recorder (O)	1 to 4		
Ozonation:					
Ozonized air	Flow	Indicator (E)	1 to 10		Manual (E) Automatic (O)
Air- and water-operated supply	Pressure	Indicator (E)	1 to 1.5 times shutoff pressure	Air and water feed	Manual (E)
Air inlet and outlet of desiccators	Temperature	Indicator (E)	0° to 120°F		Manual (E)
Air leaving desiccators	Humidity	Indicator (E)	0 to 100%	Humidity of air feed	Automatic (E)
Treated effluent	Residual	Indicator (O) Recorder (S)	1 to 10	Rate of ozone application	Proportional-automatic (O)
Ozone production	Voltage	Indicator (E)	0 to 100%		Manual (E) Automatic (O)
Clearwell:					
Influent line	Flow	Indicator (O)	1 to 4	Postdisinfection and fluoridation	Manual (E) Automatic (O)
Clearwell basin	Level	Indicator (E) Recorder (O)	Depth of basin	Raw water supply	Manual (E) Automatic (O)
	pH	Indicator (E) Recorder (O)	0 to 14 units	Chemical feed	Manual (E) Automatic (O)
Distribution:					
Booster pumps	Flow	Indicator (E) Recorder (O)	1 to 4	None	
	Pressure	Indicator (E)	0 to 1.5 times shut-off pressure	Booster pumps	Automatic (E)
Elevated tank	Level or pressure	Indicator (E) Recorder (S)	Depth of tank	Distribution pumps	Manual (E) Automatic (O)[3]
	Temperature	None	0° to 120°F	Tank heater	Automatic (E)[4]
Service connections	Flow	Totalizer (E)	Six months' flow volume	None	Automatic (E)
Miscellaneous:					
Wet well for pumps	Level	Indicator (O)	Depth of well	Pump on/off	Manual (E)
Raw water, filters, chemical dissolving tanks, atmosphere	Temperature	Indicator (O)	-40° to 120°F	None	

Table 36 (Continued)
Metering, Instrumentation and Control Requirements
for Water Supply and Treatment

Location and use	Type of measurement	Type of instrument readout[1]	Range of measurement and/or readout	Controls: Item regulated	Controls: Type
Pump discharge lines	Pressure	Indicator (E)	0 to 1.5 times shutoff pressure	None	
Chlorine storage and feed rooms	Weight	Indicator (E)	3 times full container weight	None	
	Gas concentration	None		Concentration alarm	Automatic (E)

[1]Symbols:
E = Essential. Items described are required wherever particular applications occur.
O = Optional. These items may be required (choice of designer).
S = Special cases. This refers to items sometimes used in large installations. These are applied only when circumstances justify their use.
[2]Measurement device may be integral with feeder or controller.
[3]Use automatic if readout is unattended.
[4]For freezing climates only.

Table 37
Types of Measuring Devices Applicable to Water Treatment Plants

Primary measurement and type of device	Use examples	General	Capacity	Range
Open Channel Flow:		Accuracy is dependent on piping configuration. Consult vendor data on specific device.		
Flume (Parshall or Palmer-Bowlus	Plant influent, bypass lines	Suspended matter does not hinder operation. More costly than weir.	10 gal/min and up	75:1
Weir	Plant influent, plant effluent	Requires free fall for discharge and greater headloss than flume. Influent weirs may plug.	0.5 gal/min and up	100:1 and up
Pressure Pipeline Flow:				
Differential producers	Filled lines. Fluids under positive head at all times.	Impulse lines may clog if used with suspended matter. Consider automatic purging if device must be used in suspended matter.		
Venturi tube or flow tube	Most fluid lines where solids build up and scale will not be a problem.	Long laying length required. Costly in large pipe sizes.	5 gal/min and up for liquid; 20 ft^3/min and up for gas.	10:1
Orifice plate	Air and gaslines, water except filter effluent	Clean fluids only. Headloss greater than flow tubes.	0.5 gal/min and up for liquid; 5 ft^3/min and up for gas.	4:1
Flow nozzle	Water except filter effluent	Clean fluids only	5 gal/min and up for liquid, 20 ft^3/min for gas.	5:1
Average pitot tube	Water, air, gas	Clean fluids only	Determined by pipe sizes.	3:1
Displacement meters	Plant water and distribution system service connections. Plant gaslines, sludge gaslines. Chemical addition lines.	Different types available. Maximum flow volume somewhat limited. May be in conjunction with chemical feed pump. Clean fluids only.	0.1 to 9,000 gal/min for liquid; 0 to 100,000 ft^3/min for gas.	10:1

Table 37 (Continued)
Types of Measuring Devices Applicable to Water Treatment Plants

Primary measurement and type of device	Use examples	General	Capacity	Range
Target meters	Plant effluent, sludge dirty fluids	Suspended matter does not hinder operation	0.07 gal/min and up	10:1
Velocity meters, propeller meter	Water, clean liquids	Insertion turbine or full bore types available	0.001 to 40,000 gal/min for liquids, to 10,000,000 ft^3/min for gas	10:1 to 50:1
Magnetic meter, sonic or ultrasonic meter	Plant influent, sludge, clean to dirty liquids, plant effluent	No obstruction in flow stream. Well suited for suspended matter and solids. Sonic meters are subject to interference by air bubbles. Suitable for confined piping systems.	0.01 to 500,000 gal/min	10:1
Vortex shedding meter	Heat exchanger water lines		3 to 5,000 gal/min	15:1
Variable area rotameter	Gas and gas solution feeders, chemical dilution systems, influent lines to ion exchange units, water and clean liquids	Available in very small to very large flow rates at lowest cost for flow indicator	0.01 ml/min to 4,000 gal/min for liquids, to 1,300 ft^3/min for gas	5:1 to 12:1
Openflow nozzle	Plant influent or effluent, sludge	Requires free fall from end of pipeline	5 to 11,000 gal/min	5:1 to 10:1
Level:				
Staff gauge	Water supply intake	Indication only	Unlimited	100:1
Float	Wet wells, sumps	Indication near tank, has moving parts	Unlimited	100:1
Capacitance probes, RF probes	Elevated tanks, chemical storage tanks, batch tanks, most level applications	Many types immune to conductive build-up and coating on probe. Continuous or on/off available.	Unlimited	100:1
Sonic or ultrasonic meters	Supply intake, batch tanks	Continuous type does not contact the liquid, may not be suitable for foaming liquids. Gap type for on/off applications.	Unlimited	50:1

Table 37 (Continued)
Types of Measuring Devices Applicable to Water Treatment Plants

Primary measurement and type of device	Use examples	General	Capacity	Range
Differential pressure	Batch tanks, chemical tanks	Specific gravity should be fairly constant. Build-up may be a problem.	Unlimited	20:1
Bubble tube	Water supply wells	Requires air supply for automatic. Manual (hand pump type) available for indication only.	Depth limited by air pressure if automatic	10:1
Pressure:				
Pressure gauge	Pump discharge, transmission mains, elevated tanks	Seals or diaphragms may be required to prevent corrosion or plugging of pressure impulse connections	Vacuum to 1,500 lb/in^2g	10:1
Loss of head gauge	Gravity filters		Unlimited	3:1
Temperatures:				
Thermometer or resistance thermal device	Plant influent, clearwell, atmosphere		-80° to 1,000°F	10:1
Analytical Instruments:				
pH	Plant influent or effluent precipitator, neutralization, oxidation or reduction processes		0 to 14 units	
Oxidation Reduction Potential (ORP)	Precipitator, oxidation, or reduction processes	May also be used for free residual chlorine	-400mV to +400mV[1]	
Turbidity	Filter influent/effluent Settling basin effluent		0 to 1,000 NTU	
Residual chlorine, residual ozone	Treatment unit effluent		0 to 2 mg/L[1]	
Specific ion electrodes	Treatment unit effluent		0 to 2 mg/L[1]	

[1] Depends on actual effluent requirements.

Table 37 (Continued)
Types of Measuring Devices Applicable to Water Treatment Plants

Primary measurement and type of device	Use examples	General	Capacity	Range
Sand Expansion:				
Float	Gravity filter		Unlimited	20:1
Weight:				
Scales	Chemical feed and storage equipment, sludge cake conveyor	Weighing devices may be integral to gravimetric feeders	1 to unlimited	12:1
Gas Concentration:				
Concentration indicator or alarm	Chlorine rooms		0 to 100%	12:1
Time:				
Elapsed time meter (ETM)	Motors requiring periodic service, motors driving principal pumps		0 to 10,000 hp	100,000:1
Revolutions:				
Counter	Positive displacement sludge pumps	May be used for primary metering of sludge flow	0 to 100 million	100 M:1
Electric Power Use:				
Watt-hour meter	Plant power	Public Utility may have governing requirements	Unlimited	10,000:1

selected point. Control these functions by discrete devices such as flow switches, temperature switches, level switches, and pressure switches. If the actual status of the process variable is required, rather than on/off, for indication or control, an analog primary device should be used. Some alarm switches are not included in the tables; for example, clarifier torque switches, speed switches, and other equipment protection switches that are normally supplied with the equipment.

6.13.4 Instrumentation. Instrumentation covers all secondary instruments (such as gages, indicators, recorders, or totalizers) needed for efficient operation of water supply systems. Information sensed by a primary device is translated by instruments into an operator usable form. Most analog primary devices require secondary instruments, although a few (such as displacement meters) contain built-in counters. Instrumentation should be used only where operating convenience and cost savings outweigh added maintenance needs. Data logging devices should be considered where cost can be offset by reduced operating manpower needs. Refer to Table 36 for recommended instrumentation usage.

6.13.4.1 Use Limitations. Instruments may be obtained in any combination to total, indicate, or record the information developed by primary devices. Other more sophisticated forms of instruments (such as summation and multiplication of variables) are possible, but are not normally needed.

6.13.4.2 Transmission. Select means of transmitting information from primary measuring devices to secondary instruments from the following:

a) Mechanical. Transmission distance is limited to a few feet. Consider the effects of corrosion, wear, or icing on mechanical linkages.

b) Pneumatic. Transmisson distance can be up to 1,000 ft (304.8 m). Reaction time of pneumatic loops is relatively long if transmission distance is long.

c) Electrical. There is no limitation on distance. Analog signals may require amplification for transmission distances greater than 1,000 ft.

6.13.4.3 Remote Indication. Remote indicators should provide the operator with the status of any function necessary for remote operation of the plant. Panel lights should indicate the on/off status of pumps or other discrete devices, alarm functions and operator-actuated functions (for example, initiate backwash, fill day tank).

6.13.5 Controls. Controller devices are needed to regulate the functions of equipment throughout the process. Consider automatic controls where significant improvement in performance will result, or where cost can be offset by reduced operating manpower needs. Otherwise, keep controls as simple as possible. Wherever feasible, use fixed or manual controls (for example, weirs, launders, siphons, or throttling valves) in preference to mechanical devices, and direct acting controls (for example, float valves) in preference to electrically or pneumatically actuated devices. Always consider effects of possible control malfunctions. Controls may be classified by the degree of automation (refer to Table 36).

6.13.5.1 Manual. Use manual control where the operator will start, stop, or adjust rates of operations based on instrument observations, laboratory tests, or indicated conditions.

6.13.5.2 Automatic. Use automatic control to start, stop, or regulate rates of operations automatically in response to changes in a measured variable or other input. All equipment must also have manual control to override automatic control regardless of the degree of automation provided.

6.13.5.3 Design Considerations. Many controls combine manual and automatic operations. The operator may initiate an automatic-timed cycle backwash system, or adjust set points of a proportional controller based on instrument observation.

Controls that seldom require adjustment (rate of flow to filters, for example) should be manual. Controls requiring frequent adjustment (starting sump pumps, proportional chemical feeding) should be automatic. Decisions on whether the automation is on/off-timed cycle, or proportional, must be based on analysis of plant requirements.

Section 7: DISTRIBUTION AND TRANSMISSION

7.1 Distribution

7.1.1 System Planning. Basic data on design requirements for the distribution system are as follows:

7.1.1.1 Information Required. For planning distribution systems, secure the following information:

a) Topographic Map of Area Served. Secure all data on present and planned streets, elevations of ground level, and all control features of area.

b) Utilities. Secure data on sewers and drains, gas and petroleum oils and lubricants (POL) lines, steam lines, underground electric cables, and buried tactical and communication facilities.

c) Quantity Requirements. Secure gpm data at various points.

d) Pressure Requirements. Secure psi data at various points.

7.1.1.2 Design. Areas on high ground or with high pressure requirements should have a separate high service system. Provide for maintaining pressures with pumping, backed by elevated storage where possible. Mains should be designed for the maximum daily demand plus reserve capacity. Demand projections should be based on not less than 20 years in the future, with 50 years being preferable. Arterial mains should form a loop when possible.

a) Storage Reservoirs. Refer to Section 8 for reservoir criteria.

b) Valve System. Provide shutoff valves to sectionalize the system. Refer to Water Supply Distribution Systems in MIL-HDBK-1008A for additional criteria on the use of valves in water distribution systems.

(1) Lay out sections so that most of the design flow can be maintained if any one section is cut out of the system. Refer to MIL-HDBK-1008A for fire flow requirements.

(2) Place valves in each branch at the point of connection to an arterial main.

(3) Sectionalizing valves should be spaced at 1,200 ft (366 m) or less.

(4) At intersections, only one branch may be without a valve.

a) Fire Hydrant Location. Refer to Water Supply Distribution Systems in MIL-HDBK-1008A for criteria.

7.1.2 Size of Mains. Compute quantity requirements in accordance with Section 2.

7.1.2.1 Minimum. No main in a distribution system shall be less than 6 in. (152 mm).

7.1.2.2 Pressure Requirements

a) Ashore. Select the smallest pipe satisfying all of the following conditions:

(1) Flowing water pressure shall be not less than 20 psi; higher pressures are required for ship berthing and drydock facilities in accordance with NAVFAC DM-25 Series and NAVFAC DM-29 Series.

(2) Residual pressure meeting the requirements of automatic fire extinguishing systems while providing 50 percent of the average domestic and industrial flows, and the fire flow.

b) Waterfronts and Graving Docks.

(1) Graving docks. Refer to NAVFAC DM-29.1 for criteria on graving docks.

(2) Active berthing piers and wharves. Refer to NAVFAC DM-25 Series for pressure requirements.

(3) Inactive berthing piers and wharves. Refer to NAVFAC DM-25 Series for pressure requirements.

7.1.2.3 Computations. Analyze extensive systems using the Hardy-Cross method of successive approximations. Use the procedure in American Civil Engineering Practices, Volume 2. Study shall be given to future expansion of the system.

7.1.3 Materials of Construction. Refer to Table 38 and NFGS-02660, Exterior Water Distribution Systems, for pipeline materials allowed and for detailed information on these materials.

7.1.3.1 Selection Factors. Consider the following factors:

a) Resistance to corrosion.

b) Strength against both internal and external loads.

c) Hydraulic characteristics.

d) Installation and field conditions.

e) Economic considerations.

f) Ease of maintenance.

g) Ease of making taps and connections.

7.1.3.2 Corrosion Protection. Refer to para. 7.3 for methods to be used in corrosion protection.

7.1.3.3 Maintenance of Low Friction. Refer to para. 7.2 for guidance on maintenance of low friction.

7.1.3.4 Structural Requirements. Refer to NFGS-02660 for methods of determining and specifying pipe wall thickness for each pipe material and for other information pertaining to strength of pipe. The publications referenced in NFGS-02660 and mentioned in the Notes thereto also give pertinent information on this subject.

7.1.4 Installation. In locating mains, consider the following factors:

a) Mains should be clear of all structures, adjacent to and parallel to streets, and where possible out of roadways.

b) By policy, mains should be in an allocated higher part of street rights-of-way, to simplify separation from sewers and groundwater.

c) Mains should be laid in trenches separate from sewer lines, and above and at least 10 ft (2.02 m) away from nearby sewers; preferably on the opposite side of the street.

d) Where a sanitary sewer crosses over a main, it shall be in pressure pipe or encased in at least 8 in. (203 mm) of concrete for 10 ft on either side.

e) Avoid laying mains in water or in trenches subject to flooding during construction.

f) Provide metallic tracer tape or wire over nonmetallic lines.

g) Pipes suspended above ground or on structural supports shall be anchored to withstand thrust and wind velocities specified for the design of structures (refer to NAVFAC DM-2.02, Structural Engineering Loads).

7.1.5 Joints

7.1.5.1 Ductile Iron Pipe Joints. As specified in NFGS-02660 with the following recommendations:

a) The push-on joint is recommended for general use.

b) The mechanical joint should be used in soft soils where settlement is anticipated, or where flexibility is required, as in Seismic Zones 2, 3, and 4 of NAVFAC P-355.

c) The ball joint may be used for river crossings and other installations requiring large joint deflections.

d) Flanged joints should be used where valves, fittings, and accessories are to be attached to pipes, in vaults, pits, and aboveground locations where rigidity is required.

e) Sleeve-type mechanical couplings are useful where greater deflection is needed, where alignment problems may arise, and for connecting cast iron pipe to other pipe materials.

Table 38
Distribution Main and Transmission Pipe Materials

MATERIAL	APPLICATION	DIA. (in.)	MAX. WORKING PRESSURE (psi)	CORROSION RESISTANCE	ADVANTAGES	DISADVANTAGES
Reinforced concrete[1]	Large diameter underground lines	16-120	50	Good	Durable with low maintenance. Good flow conditions. Resists uneven backfill and external loads well.	Deteriorates in strong alkali or acid soil. Difficult to repair. Subject to impact damage.
Prestressed concrete[1]	Large diameter underground lines	16-120	250	Good	Durable with low maintenance. Good flow conditions. Resists uneven backfill and external loads well.	Deteriorates in strong alkali or acid soil. Difficult to repair. Subject to impact damage.
Iron, ductile, (cement-lined)	Underground lines; under-water lines (use flexible joint pipe)	4-48	350	Good[2]	Durable and strong. Easily tapped. Good flow characteristics.	Subject to electrolysis and external attack from acid and alkali soils. High cost in large sizes. Heavy to handle. Lining subject to impact damage.
Glass-fiber-reinforced thermo-setting-resin	Underground lines only	4-144	250	Excellent	Lightweight and easy to install. Strong. Low coefficient of expansion. Low cost.	Somewhat fragile. Not time-tested. Heavier than PVC pipe. If thermoplastic liner is used, strength decreases above 70° F (21° C). Subject to deterioration by exposure to sunlight.
Polyvinyl chloride (PVC)	Underground lines only	4-12	200	Excellent	Lightweight. Easy to transport and install. High strength to weight ratio. Low cost.	Subject to high expansion. Somewhat fragile. Strength decreases above 70° F. Subject to deterioration by exposure to sunlight. Not available in large diameters.

High-density polyethylene (HDP)	Swamp, marsh and underwater applications	4-48	200	Excellent	Lightweight. Easy to transport. Greater flexibility than other materials. Low cost. Butt fused joints provide monolithic line.	Strength decreases above 70° F. Somewhat fragile. Subject to expansion. Must be anchored when installed under water.
Steel[1]	Aboveground lines	4-120	High	Good[3]	Lightweight and easily installed. High tensile strength. Low cost. Good hydraulically when lined. Adapted to locations where some movement may occur.	Subject to electrolysis. External corrosion from acid or alkali soil. Low resistance to external pressure in larger sizes. Air-vacuum valves imperative for large sizes. Subject to turberculation when unlined.

[1]Generally cost-effective only in larger sizes and for long conduits.
[2]Ductile iron pipe as specified in NFGS-02660 has cement-mortar lining.
[3]Steel water pipe as specified in NFGS-02660 is coated and lined.

f) Clamp-type mechanical couplings are allowed as an optional jointing method to flanged joints except on pump suction lines; the pipe must be grooved or shouldered to accept this coupling.

g) Where the line must be maintained as an electrical conductor for cathodic protection, or where the pipe may need electrical thawing, use lead-tipped rubber gaskets on mechanical joints and conductor wedges at the side of the bell on push-on joints.

7.1.5.2 Concrete Pipe Joints. Concrete pipe joints shall be designed as specified in NFGS-02660.

7.1.5.3 Steel Pipe Joints. Steel pipe joints shall be selected as specified in NFGS-02660 with the following recommendations:

a) Rubber-gasketed joints and sleeve-type mechanical couplings are recommended for general use. The couplings are useful for the same purposes as listed for cast iron pipe.

b) Welded joints may be used on pipes which have no inside coating and for pipes with inside diameter greater than 24 in. (610 mm) with inside coating, where the inside is accessible and the joints are lined after welding.

c) Flanged joints and clamp-type mechanical couplings. Same as for cast iron pipe.

d) Expansion joints of the stuffing box type shall be used at appropriate intervals on pipe with welded joints to relieve strains, especially for exposed pipe.

e) Where a line must be maintained as an electrical conductor for cathodic protection, use bonding cables and lugs.

7.1.5.4 Polyvinylchloride (PVC) Joints. PVC joints shall be selected as specified in NFGS-02660.

7.1.5.5 FRP-TR Joints. ANSI-AWWA C900-81 Standards shall be followed in selecting FRP-TR joints.

7.1.6 Trenches, Backfill, Anchors, and Supports. Follow NFGS-02225, Excavation, Backfilling, and Compacting for Utilities, NFGS-02660, and WPCF Manual of Practice (MOP) No. 9 when considering trenches, backfill anchors, and supports.

7.1.6.1 Trench Conditions. Trench bottoms in stiff material shall be cut 6 in. (152 mm) below pipe inverts in order to provide proper bedding (refer to NFGS-02225). For guidance on trench loads, refer to NAVFAC DM-5.03, Drainage Systems.

7.1.6.2 Bedding. No pipe shall rest directly on rocks or boulders. Except as provided in the following statement, all pipes shall be uniformly supported throughout their lengths on compacted based using firm trench soil or granular materials. Full-length crushed stone or gravel bedding may support the pipe where soils are soft and set. Where the ground has inadequate bearing value, provide pipe supports and stringers.

7.1.6.3 Supports. Exposed pipe shall be supported either on saddles or by hangers. Supports shall be spaced to limit deflection of steel pipe to a maximum of 1/360 of the span, and to prevent overstressing any joints.

7.1.6.4 Anchorage. Anchorages shall also be provided as required to accommodate expansion due to temperature rise. Anchorages shall be provided for buried or exposed pipe at all bends, as required to resist vertical or horizontal thrust. Refer to NFGS-02660 for standard blocking.

7.1.7 Railroad Crossings. Mains to be laid near railroads shall be designed to withstand the dynamic loads and vibrations caused by trains. Place the mains in a larger sized conduit, to reduce the vibration effects of moving trains. Refer to American Railway Engineering Association (AREA), Manual for Railway Engineering, Volumes I and II.

7.1.8 Stream Crossings. Wherever possible, underwater mains shall be buried in the stream beds for protection against freezing and disturbance by currents, ice, floating debris, ship anchors, and dredging. Consider multiple crossings when a high degree of reliability is required. The following conditions are recommended:

a) All joints shall be watertight. Use flexible ball joints with rigid pipe materials or flexible plastic pipe.

b) Provide shutoff valves at each end, so that the mains may be isolated during testing and repairing.

c) Provide flushing facilities.

d) Because of inaccessibility, make special provision for corrosion control.

7.1.9 Valves. Refer to paras. 7.2 and 7.4 which recommend air, vacuum, and blowoff valves to be used. Make any necessary provision to release trapped air, break vacuums, and permit main flushing.

7.1.10 Testing. Testing shall be performed as specified in NFGS-02660.

7.1.11 Disinfection. NFGS-02660 shall be followed for guidance on disinfection.

7.2 Transmission

7.2.1 Location of Transmission Line. Transmission lines convey water from the source to the treatment plant or to the distribution system. This water may be treated or untreated, depending on the location of the treatment plant. Routes shall be selected, consistent with economic considerations, to meet the following desirable characteristics:

a) It should use a gravity line, if head is available.

b) It should be the shortest route from the point of intake to point of delivery.

c) It should bypass rough or extremely difficult terrain and be accessible for construction and repairs.

d) It should be below the hydraulic grade line but as close to it as practicable.

e) It should avoid dangers of landslides and flood waters.

7.2.2 Types. In designing transmission lines, note the following:

a) Avoid pumping if feasible, and thus reduce pressures on the line, as well as costs.

b) Pumping facilities may sometimes be planned for a transmission storage location rather than at the source.

7.2.2.1 Pipelines. Gravity or pressure pipelines should be used for transmission except when special circumstances justify the use of aqueducts or tunnels.

7.2.2.2 Aqueducts. Aqueducts or canals under no pressure, may be used to convey large flows when the construction is economically justified. They are used only for very large works or under special circumstances.

7.2.2.3 Tunnels. A tunnel of the gravity or pressure type shall be used to convey water underground, under either of the following conditions:

a) Where there is no other alternative route.

b) Where its construction is economically justified.

7.2.3 Capacity. Provide sufficient transmission line capacity to meet the following requirements.

a) Permanent Installation.

(1) Domestic and General Uses. Plan for the maximum daily demand plus reserve capacity for the estimated load not less than 20 years in the future, unless this growth factor has already been used in computing the maximum daily demand. Evaluate effect of long detention time on decay of chlorine residual.

(2) Essential to Defense. The basis of design shall be the maximum daily demand plus reserve capacity for the estimated load 20 to 40 years in the future.

b) Temporary Installations. Use the maximum daily demand plus a reasonable reserve capacity for the expected life of the installation.

7.2.3.1 Design Methods. Refer to NAVFAC DM-5.02 for hydraulic criteria.

7.2.3.2 Design Velocity. Velocities above 5 ft (1.52 m) per second should not be used because of high friction losses. Where excess head is available, limit the velocities as follows:

TYPE OF STRUCTURE	MAXIMUM VELOCITY (fps)
Unlined tunnels	12
Pipe:	
Cement-lined concrete	15
Steel and ductile iron	15

7.2.3.3 Size. Determine the hydraulic details from cost studies. Allowance should be provided for the loss of carrying capacity during the expected service life.

7.2.3.4 Arrangements. Where there is only one major source of supply, and little or no transmission storage, multiple conduits shall be provided, whenever possible, so that delivery of water need not be interrupted during repairs. If feasible, the conduits should be arranged to enter the Naval activity from opposite directions.

7.2.4 Materials of Construction. Refer to Table 38 and NFGS-02660 (with special attention to General Note 10 thereto) for types of materials to be used.

7.2.4.1 Selection Factors. Consider the following factors.

a) Resistance to corrosion

b) Strength against both internal and external loads

c) Hydraulic characteristics

d) Installation and field conditions

e) Economic considerations

7.2.4.2 Tunnels. A thorough geologic investigation must be undertaken in the design stage of a rock tunnel. It shall be lined if needed to attain carrying capacity. Grout the rock seams as needed to reduce or prevent leakage. Expert guidance should be sought in the design and construction.

7.2.4.3 Corrosion Protection. Provide adequate internal and external protection to ensure the necessary life of the line (refer to para. 7.3).

7.2.4.4 Preserving Low Hydraulic Friction. The following factors tend to lower the hydraulic efficiency:

a) Tuberculation. Pipes subjected to tuberculation shall be provided with protective lining.

b) Slime Formation. Provide control of slime by chemical treatment at the intake of the line. If attributable to manganese or iron, provide for removing these substances before the water is transmitted.

c) Encrustations. Provide for adjusting the chemical stability of the water as required to prevent excessive deposition in the line.

7.2.4.5 Structural Requirements. Refer to para. 7.1 for structural criteria. All steel pipe 30 in. (762 mm) and over shall be designed for a unit stress of 15,000 psi (103,421.4 kPa) and for a joint efficiency of 100 percent.

7.2.5 Pipe Installation. Except in special cases, all pipes shall be buried with a minimum cover of 2.5 ft (.762 m). Where frost penetration exceeds 2.5 ft, as indicated on National Weather Service charts, the depth of cover shall be increased to 6 in. (152.4 mm) below the maximum recorded depth of frost penetration based on local records in the area of installation. See Figure 2 for generalized frost information.

7.2.5.1 Exposed Pipe. Exposed pipe may be placed on bridges or piers for crossing streams or ravines. Exposed nonmetallic pipe may be used only in climates not subject to freezing. Exposed cast iron or steel pipe subjected to freezing shall be insulated or protected.

7.2.5.2 Inspection. All large conduits shall be accessible for internal inspection.

a) Joints. Refer to para. 7.1 for recommended joints.

b) Trenches, Backfill, Anchors, and Supports. Refer to para. 7.1 for criteria related to trenches, backfill, anchors, and supports.

c) Railroad Crossings. Refer to para. 7.1 for criteria for railroad crossings.

d) River Crossings. Refer to para. 7.1 for criteria for river crossings.

e) Valves. Refer to para. 7.4 for detailed information on valve types, applications and characteristics. The following paragraphs pertain to transmission line valves.

(1) Provide air release valves as required based on an analysis of the system. For flexible pipe which might collapse under a vacuum, place vacuum valves as necessary, based on an analysis of the system; also adjacent to each shutoff valve on the downstream side. An active building service connection at a summit may serve as an air release valve.

(2) Provide a blowoff at each depression for draining the pipe. The minimum size of blowoff valves should be 2 in. for every ft of diameter of the pipeline.

(3) Shutoff valves shall be installed at reasonable locations to allow isolation of any particular section during repair and testing. The spacing shall not exceed 5,000 ft (1524 m) on long lines and 1,500 ft (457.2 m) on loops.

(4) Check any danger of water hammer on long lines, and provide special valving to reduce it. Refer to para. 5.4.8 for further information regarding surge prevention.

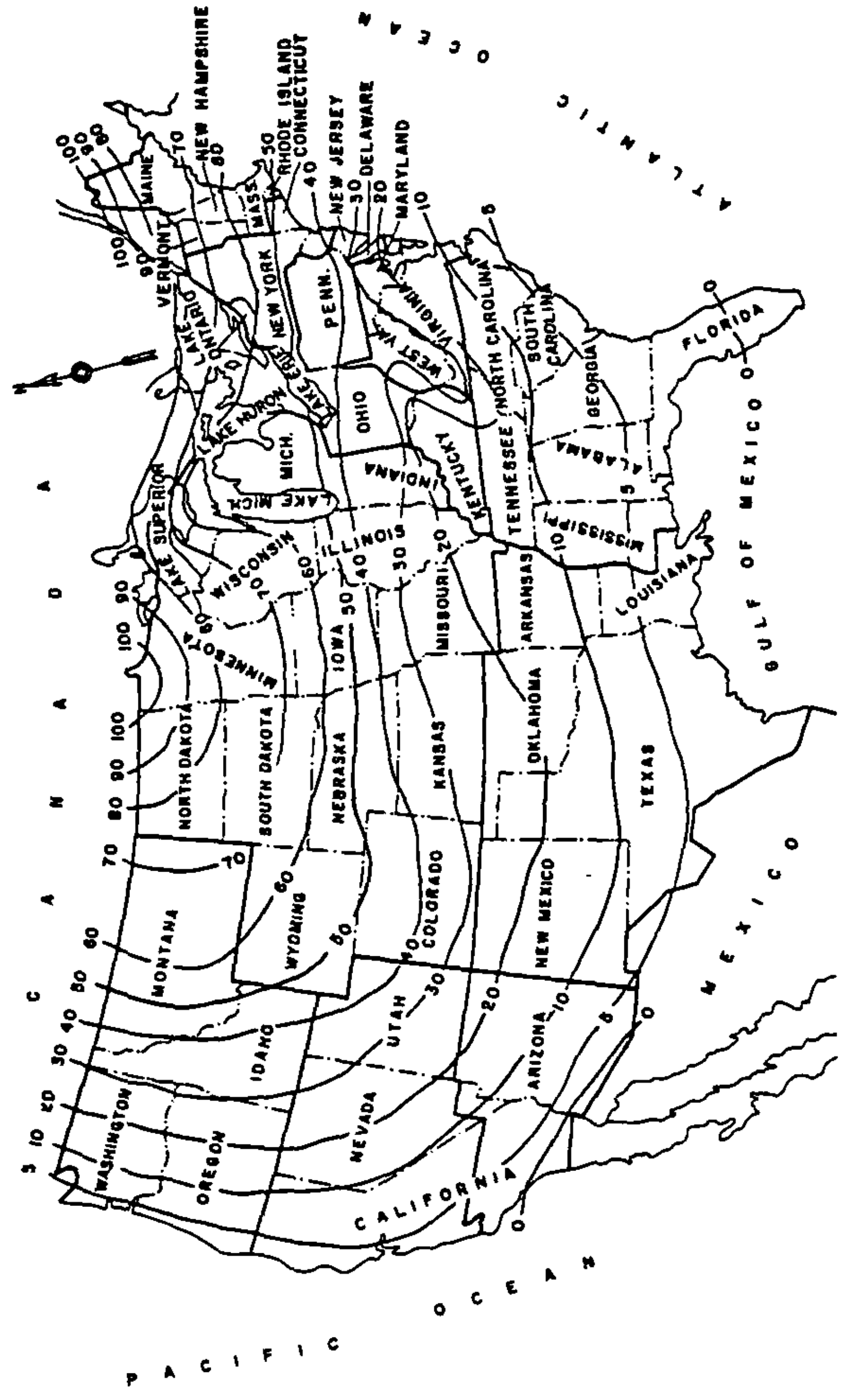


Figure 2
Extreme Frost Penetration

7.2.6 Testing. All new or repair pipes shall undergo a hydrostatic pressure test before being put into service. Each pressure section shall be isolated and pressure tested according to AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances, latest edition. Each gravity and pressure section shall be tested for leakage. Leakage should not exceed rates specified in AWWA standard for pipe material being tested.

7.2.7 Disinfection. Refer to para. 7.1 for criteria concerning disinfection.

7.3 Corrosion Protection

7.3.1 Advance Planning. To design against corrosion, the following information must be secured:

a) Soil characteristics along right-of-way. Chemical constituents, electrical resistivity, and water table elevation.

b) Water characteristics. Chemical analysis, temperature records, and dissolved oxygen content.

c) Atmospheric conditions. Humidity and temperature.

7.3.1.1 Sources of Information

a) Soil maps from Governmental agencies, for example: National Bureau of Standards (NBS), Department of Agriculture, and U.S. Geological Survey.

b) Special Naval surveys.

c) Local corrosion experience.

7.3.2 Corrosion Problems. Pipes are subject to corrosion both inside and outside. Protection must be provided against various types:

a) Galvanic corrosion.

b) Electrolytic.

c) Chemical reaction.

d) Direct oxidation.

e) Biological action.

7.3.2.1 Undesirable Substances in Water and Soils. Certain chemicals present in either water or soils are related to corrosion and necessitate correction. For summaries of these chemicals and the concentrations producing corrosion, refer to Table 39.

Table 39
Corrosiveness of Salts

CONSTITUENT	CONCENTRATION mg/L	DEGREE OF CORROSION
Chlorides, Cl	10-25	Slightly corrosive
Chlorides, Cl	100-500	Very corrosive
Chlorides, Cl	500 and over	Extremely corrosive
Sulfates, SO_4*	20-30	Slightly corrosive
Sulfates, SO_4*	300 and over	Severely corrosive
Sodium carbonate, $NaCO_3$	100 and over	Severely corrosive
Nitrates, NO_3	0.5 and over	Active and undesirable

*Sulfate is harmful to concrete in situations where it can be converted to sulfuric acid by biological or other action.

7.3.2.2 Electric Resistivity of Soil. Corrosion also is affected by the electrical resistivity of the soil, which has the following effects:

RESISTANCE (ohm/cc)	DEGREE OF CORROSION
10,000-6,000	little or none
6,000-4,500	mild
4,500-2,000	heavy
2,000- 0	severe

7.3.2.3 Soil Classification. Refer to Table 40 for soils grouped according to their corrosive action on steel and iron.

7.3.3 Methods of Protection. Using corrosion resistant material, bolts and connectors subject to corrosion should be more resistant in composition than the main piping metal. Install dielectric fittings between ferrous mains and cuprous building services.

7.3.3.1 Applications of Coating and Linings. Refer to Table 41 for guidance on selection of pipe coatings and linings.

7.3.3.2 Treatment of Water. Refer to Section 6 for acceptable methods of treatment.

7.3.3.3 Cathodic Protection. Use this method only for major mains and transmission lines when necessary, in which case construct the pipeline as a continuous electric conductor. Obtain criteria from MIL-HDBK-1004/10, Cathodic Protection.

7.4 Valves and Hydrants

7.4.1 Valves. Refer to Table 42 for the availability of types of valves and their applications.

7.4.1.1 General Purpose Valves

a) Gate Valves. Refer to the criteria for control valves for distribution systems in MIL-HDBK-1008A. Use valves conforming to AWWA Standard C500, Gate Valves, 3 Through 48 in., NPS, For Water and Sewage Systems, Underwriters Laboratories' Standard UL262, Gate Valves for Fire Protection Service, or Federal Specification WW-V-58, Valves, Gate, Cast-Iron; Threaded and Flanged (for Land use) as set forth and as recommended by NFGS-02660.

b) Butterfly Valves. Use the same criteria as was recommended for gate valves; also use AWWA Standard C504, Rubber-Seated Butterfly Valves.

c) Sluice Gates. Use AWWA Standard C501, Sluice Gates, for guidance on sluice gates.

7.4.1.2 Special Purpose Valves. Consult manufacturers for capacities and construction of the various types, to be used as follows:

a) Air Valves. Use air valves to release any air collecting at high points in filling lines.

b) Altitude Valves. Use altitude valves for supply lines to elevated tanks or reservoirs. These valves are actuated by the water level in the tanks or reservoirs, to close when the tank is full and open when the level on the system pressure lowers. Also refer to MIL-HDBK-1008A.

c) Float Valves. Use float valves on supply lines to fill tanks or reservoirs and maintain their water levels.

d) Plug Valves. Use for control of pumping rates at low volume.

e) Pressure Regulating Valves. Use pressure regulating valves to deliver water from a high to a low pressure system wherever the pressure downstream drops below a present value. In addition, these valves can be fitted to open when upstream pressure drops below downstream pressure. Pressure regulating valves on water distribution system shall be located in accordance with MIL-HDBK-1008A.

f) Pressure Relief Valves. Use pressure relief valves to relieve any pressure in tanks or pipelines above a preset value.

g) Vacuum Valves. Use vacuum valves to admit air into tanks or pipelines for relieving vacuums induced by a break or a rapid opening of valves.

7.4.2 Hydrants. Refer to criteria for hydrants for distribution systems in MIL-HDBK-1008A. Use hydrants conforming to AWWA standards C502, Dry Barrel Fire Hydrants; C503, Wet Barrel Fire Hydrants, or to Underwriters Laboratories' Standard UL246, Hydrants for Fire Protection Service, as set forth and as recommended by NFGS-02660.

7.4.2.1 Installation. Follow installation requirements in MIL-HDBK-1008A and NFGS-02660.

Table 40
Corrosion of Ferrous Metals by Soils

CLASS	DEGREE OF CORROSION	SOIL TYPES	SOIL CHARACTERISTICS
1	Light	Loams: coarse sand or sandy; light textured silt; porous; clay oxidized to great depths	Aeration good; no mottling anywhere in soil profile, and very low water table.
2	Mild	Sandy loams Silt loams	Aeration fair; slight mottling in lower part of soil profile, and low water table.
3	Heavy	Clay loams Clay	Aeration poor; heavy texture and mottling close to surface with water table at about pipe depth.
4	Extreme	Muck Peat Tidal marsh Adobe clay Arid region soils with high salt content	Aeration very poor; water table at surface; extreme impermeability because of colloidal material present. Condensation of atmosphere water around pipe causes corrosion.

7.4.2.2 Valve. A shutoff valve with a valve box shall be installed on the branch between the hydrant and the main. Wherever possible, provide a concrete collar around the branch between the valve and the hydrant, to protect the valve in case the hydrant receives impact damage. The branch line to the hydrant and the valve shall be of 6-in. (152 mm) diameter.

7.4.3 Appurtenances. Criteria regarding selection of appurtenances are given below:

7.4.3.1 Operator Shutoff Valves and Gates. Use manual, direct, and geared type on all shutoff valves and gates for normal operations. Use automatic type, either motorized, hydraulic, or pneumatic, above grade or housed, in the following applications:

a) Where the gates or shutoff valves are too large for manual operation.

b) Where a specific rate is set for opening or closing, to reduce surges in pipelines.

c) Where frequent operation is required (medium sized valves).

d) Where required at large multipump installations.

e) Where their installation is justified both economically and functionally.

7.4.3.2 Valve Boxes. Use valve boxes for small and medium sized underground shutoff valves.

Table 41
Pipe Coating and Lining For Ferrous Pipe

PIPE MATERIAL	PIPE IN CONTACT WITH SOIL OR AIR: SOIL OR AIR CONDITION	PIPE IN CONTACT WITH SOIL OR AIR: EXTERIOR PROTECTION	PIPE IN CONTACT WITH WATER: WATER CONDITIONS	PIPE IN CONTACT WITH WATER: INTERIOR PROTECTION
Cast iron	Lightly or noncorrosive soil.	Manufacturer's standard coating.	Lightly or noncorrosive.	Cement mortar lining, AWWA C104 - latest edition, standard thickness.
	Mildly corrosive soil.	Same as above.	Mildly corrosive.	Same as above.
	Heavily corrosive soil.	Coal tar base coating. Refer to NFGS-02660. See also Note 1.	Actively corrosive and salt water system.	Cement mortar lining, AWWA C104 - latest edition, consider double thickness or 1 mil asphaltic lining, AWWA C151 - latest edition.
	Extremely corrosive soil.	Same as above.		
	Above ground, but not exposed to weather.	Manufacturer's standard coating.		
	Above ground but exposed weather.	Coal tar primer and to enamel.		
Steel	Lightly or noncorrosive soil.	Coal tar system, AWWA Std. C203; 1 coat of coal-tar primer, 1 coat of coal-tar enamel, and 1 coat of water resistant whitewash.	Lightly or noncorrosive.	Cement mortar lining, AWWA C203 - latest edition; or Coal-Tar System (See Note 2) AWWA C203 - latest edition.
	Mildly corrosive soil.	Same as above, but with 2 coats of coal-tar enamel and final wrapping of kraft paper.	Mildly corrosive.	Same as above.

Heavily corrosive soil.	Same as above, with an additional asbestos felt wrapping before wrapping of kraft paper, or plastic tape coating system, AWWA C214 - latest edition.	Actively corrosive.	Same as above.
Extremely corrosive soil.	Shotcrete shield after the application of same coatings of coal-tar enamel, or plastic tape coating system, AWWA C214 - latest edition.		
Above ground but not exposed to weather.	1 coat of synthetic red lead primer, and 1 coat of synthetic white enamel.		
Above ground but exposed to weather.	Same as above, plus a coat of aluminum paint.		

[1]For protective system using polyethylene encasement of pipeline, see NFGS-02660.
[2]Pipe lining materials prohibited by BUMED or EPA at time of project must not be used.

Table 42
Application of Valves

TYPE	APPLICATION	REMARKS
Check valves:		
Swing checks	All horizontal applications	Refer to NFGS-02660.
Ball checks	On reciprocating pumps	Small diameter.
Vertical checks	All vertical applications	Refer to NFGS-02660.
Cone checks	Surge relief	Requires automatic operator.
Cushioned checks	Surge relief	Slow closing.
Foot valves	Prevents loss of prime in suction lines	-
Flap valves	At pipe outlets	-
Shutoff valves:		
Gate valves[1]	All applications	-
Butterfly valves	All applications	Largest size over 120 in.
Plug valves, eccentric	All applications	Suitable for water containing solids and for 3-way valves.
Globe valves	All applications	Small diameter.
Needle valves	All applications	Small diameter.
Hydraulic needle valves	Reservoir outlets	Very large size requiring hydraulic operators.
Mud valves	Bottom drain opening of basins	-
Gates:		
Radial gates	Channel and reservoir outlets	-
Slide gates	Channel and reservoir outlets	Low heads.
Sluice gates	Wall openings	-
Shear gates	Wall openings (low head)	Size up to 24 in.

[1]Except for low pressure, service gate valves 16-20 in. (406-508 mm), and larger shall be equipped with bypass.

7.4.3.3 Valve Vaults or Manholes. Use vaults or manholes for large shutoff valves on transmission lines, on arterial mains of distribution systems, and where accessibility for servicing is required.

7.5 Cross Connections with Nonpotable Supplies

7.5.1 Backflow. Backflow of waste or contaminated water into the distribution system due to back-siphonage or backpressure must be prevented.

7.5.1.1 Sources. Conditions under which backflow can occur are given below. Such conditions should not be permitted.

a) Improper plumbing designs.

b) Direct connections with nonpotable supplies.

(1) Improper pipeline interconections.

(2) Potable supply lines submerged in nonpotable water.

(3) Direct connections of drains from such as a fire hydrant or valve box to a storm or sanitary sewer.

(4) Improper connections by users.

c) Improperly designed or constructed distribution systems. These are systems within an area subject to flooding or systems that may be too close to subsurface sources of contamination, such as septic tanks, drain fields, sewers, and cesspools. Any leakage combined with lower pressure in the distribution system can cause backsiphonage.

d) A backflow preventer installed in a location subject to submergence.

7.5.1.2 Protection Against Contamination

a) Design for the absolute minimum number of interconnections.

b) Provide siphon breakers in all plumbing systems.

c) Provide positive separations (air gaps) between potable water lines and any units containing contaminated water, such as hospital sterilizers, washing machines, and tanks of dangerous liquids.

d) Provide backflow-preventing devices at all interconnections with nonpotable water lines that cannot be eliminated or protected by an air gap.

e) Provide backflow-preventing devices on irrigation systems, refer to para. 7.7.

7.5.2 Backflow Preventers. Where it would be extremely difficult to provide an air gap between two systems, and where back pressures are possible, a reduced pressure principle backflow preventer can be used. In lieu of air gaps, only reduced pressure principal backflow preventers are acceptable.

Follow recommendations of the Manual of Cross-Connection Control (latest edition) of the Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California, and the criteria of NAVFACINST 11330.11D, Backflow Preventers, Reduced Pressure Principle Type.

7.5.3 Air Gaps. Use an air gap (between a supply pipe and receiving vessel) whenever possible on any potable water line discharging to any place where contamination could occur. An air gap removes the physical link to a potential contamination source, and is preferred over backflow prevention devices, which are subject to failure. When installed, the air gap shall be at least twice the diameter of the supply pipe, but in no case less than 6 in. (152.4 mm)

7.6 Service Connections

7.6.1 Piping. Refer to Table 43 and NFGS-02660 for piping materials allowed and the advantages and disadvantages of these materials.

7.6.1.1 Selection Factors. Consider the following factors in selecting service piping:

a) Durability.

b) Type of water.

c) Availability.

d) Ease of installation and maintenance.

e) Economic considerations.

7.6.1.2 Structural Requirements. Refer to NFGS-02660, especially General Note 15 thereto, on structural requirements.

7.6.2 Appurtenances. Refer to NFGS-02660 for requirements concerning appurtenances.

7.6.2.1 Corporation Stops or Cocks. Install these stops at all connections less than 2-in. (51 mm) diameter to water mains. Use tapping saddles and valves for larger connections.

7.6.2.2 Curb Stops or Cocks. Install curb stops, with valve boxes, at the street line to shut off service lines. Where lines may need draining, use the stop-and-waste type.

7.6.2.3 Goosenecks. Use a flexible gooseneck to connect nonflexible service pipe to main.

7.6.2.4 Service Meters. For warm climate, install in a covered meter box away from traffic. For cold climate, install indoors or in a frostproof enclosure. Types as follows:

a) Displacement. Use this type when the minimum flow is below 12 gpm (45.4 Lpm). Use a meter yoke for 1-in. (25.4 mm) and smaller meters.

Table 43
Service Pipe Materials[3]

MATERIAL	SIZES AVAILABLE	ADVANTAGES	DISADVANTAGES
Brass	All standard sizes	Corrosion resistant. Good hydraulic characteristics.	Nonflexible.[1] Not suitable for soft water with high CO_2 content Not suitable in presence of seawater.
Copper (pipe)	All standard sizes	Corrosion resistant. Good hydraulic characteristics.	Nonflexible.[1] Not suitable for soft water with high CO_2 content.
Copper (tubing)	All standard sizes	Corrosion resistant. Flexible in small sizes. Ease of installation. Good hydraulic characteristics.	Not suitable for soft water with high CO_2 content.
Ductile iron	3 in. and larger	Corrosion resistant.[2] Good hydraulic characteristics.[2] Strong and suitable for large service lines.	Nonflexible.[1]
Galvanized steel	All standard sizes	Less expensive.	Nonflexible.[1] Low corrosion resistance.
Polyvinyl chloride (PVC)[4] ABS plastic pipe and fiber-glass reinforced plastic pipe	All standard sizes	Corrosion resistant. Less expensive. Ease of installation. Good hydraulic characteristics. Lightweight.	Cannot be thawed electrically. Life expectancy may be reduced by constant exposure to sunlight. Exposed pipe requires support. Nonflexible.[1] Selected bedding may be required.

[1]Non flexible pipe requires a flixible gooseneck at the connection to main.
[2]When cement-mortar lined as required by NFGS-02660.
[3]Safe Drinking Water Act, Pub. L.93-533 as amended 1986.
[4]When PVC is in compliance with 40 CFR Part 141.50.

b) Compound. These meters are used where flow ranges exceeding 10 to 1 are to be measured.

c) Propeller Type (Velocity). Use this type to measure large flows where only a small loss of head is allowed.

d) Fire Flow Meter. Fire flow meters should be used in lines carrying water for fire protection.

7.6.2.5 Stop-and-Waste Valve. Install this unit at the end of service lines just inside the building wall.

7.6.2.6 Seismic Zones 2, 3, and 4. Provide an earthquake valve in a pit on water service lines to all buildings. (NAVFAC P-355, Triservice Engineering Manual for Seismic Design of Buildings.)

7.6.3 Installations. Refer to NFGS-02660 for installation requirements. All connections shall be at least 10 ft (3.05 m) away from any subsurface source contamination.

7.7 Irrigation Systems

7.7.1 Information Required. The designer must assemble certain data before planning irrigation systems. Information required includes the following:

7.7.1.1 Topographic Map. Topographic map of area to be irrigated is required.

7.7.1.2 Quantity and Duration of Irrigation. Refer to Sprinkler Irrigation Systems, V. E. Young, for irrigation and lawn sprinkling criteria.

7.7.2 System Design. For criteria on sprinkler system design, refer to Sprinkler Irrigation Systems, by V. E. Young.

7.7.2.1 Small Areas. Portable sprinklers shall be used for small areas.

7.7.2.2 Large Areas

a) Mains. Follow the same design criteria as for arterial mains in a distribution system.

b) Laterals. Follow the same design criteria for distributors in a distribution system, except that smaller diameters may be allowed.

7.7.3 Sanitary Protection. To protect a potable system from contamination by an irrigation system, comply with the following criteria.

7.7.3.1 Backflow Prevention. Provide a pressure type vacuum breaker or a reduced pressure type backflow preventer at each point where an underground sprinkler system is connected to a potable water supply. A pressure type vacuum breaker is adequate when it is located aboveground, higher than the highest sprinkler head and its elevation is above that which may be flooded. Otherwise a reduced pressure backflow preventer is required. Delete this requirement when the system is connected to a nonpotable water supply system.

7.7.3.2 Buried Sprinklers. Sprinkler heads buried in the ground and flush type heads are prohibited, except where a separate nonpotable water system is being used.

7.7.3.3 Sprinklers With Risers. Fixed or automatic "pop up" risers are permitted.

7.7.4 Materials. Materials shall be as specified in NFGS-02441, Underground Sprinkler Systems.

7.8 Meter Vaults and Boxes

7.8.1 Meter Vaults. Vaults shall be easily accessible but away from normal traffic.

7.8.1.1 Construction. Where necessary, watertight structures shall be used.

a) Small Vaults. Use concrete blocks, brick, or reinforced concrete structures.

b) Large Vaults. Use reinforced concrete structures.

7.8.1.2 Access. Vaults shall be locked where necessary to protect against unauthorized intrusion.

7.8.2 Boxes. Wherever possible, place meter boxes away from normal traffic.

7.8.2.1 Construction Boxes. Construction boxes may be made of sections of clay or concrete pipe, or precast concrete or cast iron.

7.8.2.2 Covers. Box covers shall be cast iron or aluminum with a locking device.

7.8.2.3 Combinations. In nonfreezing climates, it is permissible to use aboveground cast iron combination meter boxes and meter yokes.

Section 8: STORAGE

8.1 Function

8.1.1 General. Wherever feasible, design storage to provide flowthrough circulation, with compartments.

8.1.2 Purpose. Storage reservoirs serve the following purposes:

a) To allow a balanced flow through pipelines between the source and the treatment plant or distribution system.

b) To supply water during peak demand periods.

c) To maintain pressure in the distribution system.

d) To supply water during power outage or repair of pumps.

e) To provide an emergency supply for fire protection.

8.1.3 Location. Guidelines for location are:

a) Hydraulic analysis should be used to determine the best storage reservoir locations for each system.

b) Terminal storage reservoirs may be used at the end of a pipeline from the source, and prior to treatment.

c) In small distribution systems, the best location will usually be at the end of the distribution system furthest from the source of supply.

d) In medium and large distribution systems, storage reservoirs are generally located near centers of heavy demand.

8.1.4 Filtered Water Storage. Refer to Section 6 for design criteria. Filtered water storage capacity is not to be included in computing available distribution storage.

8.2 Types of Storage

8.2.1 Ground Storage Tanks. Use these tanks where the station topography permits in lieu of the more expensive elevated tanks, or where required by the following conditions:

8.2.1.1 Size Limitation. Where requirements are very large and costs of elevated storage run unusually high, part of the distribution storage may be provided as ground-level storage.

8.2.1.2 Height Limitation. Where the height of elevated tanks required by the operating pressure becomes an aviation hazard, use ground storage tanks.

8.2.1.3 Transmission Line Storage. Use ground storage in conjunction with long transmission lines, to aid in meeting peak demands.

8.2.2 Elevated Tanks. Use elevated tanks to store water at the elevation required to maintain proper operating pressure and to allow gravity discharge from the tank into the distribution system. Standard capacities for welded steel tanks are given in AWWA Standard D100, Welded Steel Tanks for Water Storage. In most cases the cost of elevated tanks limits their maximum practical size to between 1 and 2 million gallons.

8.2.3 Underground Storage Tanks. Use this type of storage as required by the following conditions:

a) Where economy of construction results.

b) Where protection against freezing is required.

c) Where the area above the ground is to be utilized otherwise.

d) Where the hydraulic grade at a tank site requires the tank to be below grade.

e) Where protection against sabotage and destruction warrant concealment.

8.2.4 Hydropneumatic Tanks. Use hydropneumatic tanks at small activities where the demand is not enough to justify any other type of storage. Locate the tank below ground level if necessary for protection from freezing. Design the tank to meet pressure vessel requirements. Provide air compressors, safety valve, and sight glass, to show the air:water ratio.

8.3 Materials and Construction

8.3.1 Materials. For available material and their characteristics, refer to Table 44.

8.3.1.1 Selection. Consider the following factors affecting material selection:

a) Life expectancy

b) Capacity and head requirements

c) Availability

d) Economic considerations

e) Water characteristics

f) Environmental conditions

8.3.2 Construction. Construction of the principal types of storage tanks is as follows:

8.3.2.1 Aboveground Storage Tanks

Table 44
Storage Tank Materials

MATERIALS	TYPE OF TANK	MAXIMUM CAPACITY (gal)	ADVANTAGES	DISADVANTAGES
Concrete	Ground storage tank Standpipes	Unlimited 1,000,000	Large volume. Lower maintenance cost than steel	Low head; do not exceed 50 ft Greater weight. Higher first cost than steel.
	Underground storage tanks	Unlimited	Adaptability to architectural treatment. Ease in burying underground.	Less watertight than steel unless prestressed or lined.
Steel	Elevated storage tanks	5,000,000	Adaptability to high heads.	Higher maintenance and protection cost than concrete.
	Ground storage tanks	10,000,000 15,000	Ease or erection Lower first cost than concrete Stores water under pressure.	Require protection against freezing. High cost per unit stored.
	Standpipes	1,000,000	Lighter in weight than concrete. Leaks easily repaired.	
	Ground storage tanks	100,000	Ease of erection.	Short life.
Fabric	Ground storage	20,000	Low cost. Ease of erection. Portable.	Not watertight. Small volume. Short life.

a) Piping Arrangement. For large tanks, place inlet and outlet pipes at opposite ends or sides, to provide circulation with the outlet pipe near the bottom. Otherwise, provide baffles in the tank.

(1) Provide overflow and drain pipes discharging to storm drains, but provide air gap to prevent contamination.

(2) Place valves on all pipes except overflow pipes.

(3) Install all valves so that they will stand out of groundwater or runoff, to prevent possible contamination, and to be easily accessible to operating personnel.

b) Depth. The total water depth shall be a minimum of 12 ft (3.66 m) to avoid the growth of organisms due to temperature and the reduction of capacity due to ice.

c) Appurtenances. Include the following appurtenances:

(1) Outside tank ladder.

(2) Roof hatch with lock.

(3) Screened vent.

(4) Flanged access hole near the ground.

(5) Water level indicator and alarm.

(6) Sampling access points.

d) Structural Design. For criteria on structural design of reinforced concrete and prestressed concrete, refer to NAVFAC DM-2.04, Concrete Structures. Steel tanks shall meet AWWA Standard D100.

e) Dual Tanks. When storage for a station or area is provided by ground storage only, consideration should be given to the provision of two tanks to maintain partial capacity during repairs or cleaning of one tank.

8.3.2.2 Underground Storage Tanks. Requirements for the design of underground storage tanks are given below:

a) Piping Arrangements. Follow the criteria given for ground storage tanks.

b) Depth. Design for a minimum depth of 8 ft (2.4 m).

c) Insulation. Cover the waterproofed roof with a minimum of 2 to 3 ft (.61 to .91 m) of earth, planted with grass, graded, and drained to prevent ponding of surface water.

d) Compartments. Divide large tanks into several compartments, to minimize the loss of storage capacity during repair of any one section.

e) Appurtenances. Provide the following appurtenances:

(1) Access and valve chambers with their tops 6 in. (152.4 mm) above grade.

(2) Inside ladders or manhole steps.

(3) A screened vent above ground.

(4) Water level indicators and alarms.

(5) Sampling access points.

f) Structural Design. For design criteria of concrete underground structures, refer to NAVFAC DM-7.02, Foundations and Earth Structures, and NAVFAC DM-2.04.

8.3.2.3 Standpipes. The design of standpipes shall be based on the criteria given below.

a) Useful Storage Capacity. Locate the standpipes on high ground, to obtain maximum usable storage volume above the required static head.

b) Height. Determine the necessary height from the following considerations.

(1) Capacity required.

(2) Head needed to develop the required distribution pressure.

(3) Limitation for aviation clearance set by military or civilian authorities.

(4) Structural stability.

(5) Watertightness for concrete standpipes. A special membrane is required for those subjected to heads in excess of 50 ft (15.2 m).

(6) Economic considerations.

c) Piping Arrangements. Use a single riser pipe as both inlet and outlet.

(1) Provide an overflow and drains. Drains shall not be connected directly to sewers.

(2) Place valves on all pipes except the overflow.

d) Appurtenances. Provide the following appurtenances:

(1) Ladders on the outside of the tank and on the roof.

(2) A roof hatch with lock.

(3) Screened vent, altitude valve, and overflow.

(4) Water level indicators and alarms.

(5) Bottom access manholes.

(6) Sampling access points.

e) Structural Design. Criteria for the design of reinforced concrete and prestressed concrete standpipes are given in NAVFAC DM-2.04. For steel standpipes, use AWWA Standard D100.

8.3.2.4 Elevated Storage Tanks. Design elevated storage tanks in accordance with the criteria given below.

a) Height. Use the same criteria given for standpipes.

b) Piping Arrangements. Use the same criteria given for standpipes.

c) Appurtenances. Provide the following appurtenances:

(1) Tower, outside tank, and roof ladders.

(2) A roof hatch with lock.

(3) A screened vent, an altitude valve, and an overflow.

(4) A water level indicator and alarm.

(5) A valve vault.

(6) Heating equipment for freezing climates.

(7) Sampling access points.

d) Structural Design. For criteria on structural design, use AWWA Standard D100 for steel elevated tanks. For wooden elevated tanks, refer to MIL-HDBK-1002/5, Timber Structures.

e) Location. Adequate clearance should be provided between the exposed steel of elevated tank legs and buildings, structures, or open storage of any flammable materials. Otherwise, fireproofing of legs is required. Refer to NFPA Standard No. 22, Water Tanks for Private Fire Protection, for details.

8.3.2.5 Hydropneumatic Tanks. For design criteria, refer to Booster System in NAVFAC DM-3.

8.4 Protection

8.4.1 Freezing. In areas where frost penetration exceeds 30 in. (762 mm) (see Figure 2) protect storage tanks against freezing.

8.4.1.1 External Insulation. Cover all exposed piping (including risers to elevated storage tanks) with adequate insulation.

8.4.1.2 Heating Equipment. Special considerations for heating equipment in locations where freezing can occur are given below.

a) Aboveground and Elevated Tanks and Standpipes. In locations where freezing can occur, heat shall be provided in accordance with the provisions of NFPA Standard No. 22. The method of heating should be selected on the basis of economy of installation and operation for the particular location involved.

b) Exposed Piping and Valves. Provide electric heating elements inside a small enclosure covering these parts.

8.4.1.3 Altitude Valves. Provide an altitude valve that can, in winter, be set to keep the high water level at minimum of 3 ft (.9 m) below the overflow, thus preventing floating ice from damaging the tank roof when lifted by rising water.

8.4.2 Corrosion Protection. Interior coatings shall be approved by BUMED. Refer to NAVFAC MO-110, Paints and Protective Coatings, and NFGS-13209, Water Storage Tanks, for interior coatings of steel, potable water storage tanks. Use only vinyl or epoxy coatings. Contact manufacturer with respect to purchased components. Check the following for possible sources of contamination: paints, coatings, filter media, ion exchange media and purchased components. Exterior coatings for steel tanks may be used as listed in NFGS-13209. For cathodic protection, refer to MIL-HDBK-1004/10.

8.4.3 Pollution. Protection against pollution shall be accomplished as discussed below.

8.4.3.1 Roof. Cover all tanks and reservoirs with roofs to prevent contamination from the atmosphere. Lumber treated for preservation may contain arsenic or other toxic chemicals.

8.4.3.2 Ground. To divert the surface runoff, grade and drain around ground storage and underground storage tanks.

8.4.3.3 Vents. To keep out insects and rodents, provide 20-mesh bronze insect screens over all vent openings. The vents shall be rainproofed by using goosenecks or vent caps.

8.4.3.4 Underground Storage Tanks. These tanks shall have watertight joints to avoid contamination from subsurface sources.

8.4.3.5 Vaults and Valve Chambers. These chambers must be watertight or self-draining.

8.4.4 Safety. Provide structural and operational safety.

8.4.4.1 Structural Safety

a) Vent. Adopt a size to relieve the air pressure caused by the change of water level. Maximum air velocity through the opening area shall not exceed 1,000 fpm (304.8 m/min). Design the screen so that, if clogged by insects or frost, it will either swing on hinges or collapse before allowing damage to the tank.

b) Overflow. Provide a minimum capacity equal to the maximum inlet flow.

8.4.4.2 Operational Safety

a) Ladders. Provide ladders for standpipes and elevated tanks with a safety cage and safety line wherever possible.

b) Railings. Provide railings for all elevated tank balconies.

8.4.5 Protection Against Vandalism. Install a wire fence and locked gate around outdoor storage tanks, to prevent unauthorized intrusion. Refer to Fencing in NAVFAC DM-5.12, Fences, Gates, and Guard Towers, for criteria. Ladder cages shall have locked gates.

Section 9: BUILDINGS

9.1 Uses

9.1.1 Pumping Stations. Choose a location safe from fire, explosion, and flood hazards, taking into account the system hydraulics.

9.1.1.1 Layout. The layout of piping, valves, and machinery shall be simple and systematic. Wherever possible, arrange multiunit machines symmetrically.

a) Space. Provide sufficient clearance for accessibility to all equipment, thus facilitating operation and maintenance. Special consideration shall be given to the space and access for removing equipment for repair, without interrupting other equipment.

b) Instruments. Switchgear, instrument panels, and other controls shall be placed at convenient locations with good visibility and where damage from flooding is at a minimum. Refer to para. 6.13 for instrumentation requirements.

c) Lighting. Utilize natural lighting as much as possible. Arrange ample artificial lighting to serve all vital machinery and the instruments used for control.

d) Heating. Provide for enough heat to prevent damage to machinery by frost, and to ensure comfort to the operator. For details on heating, refer to NAVFAC DM-3.03, Heating, Ventilating, Dehumidifying, and Air Conditioning Systems.

e) Ventilation. Supply ventilation adequate for all heat generating equipment and to ensure comfort to the operator. For details, refer to NAVFAC DM-3.03.

f) Drainage. The pumping room floor, pipe trenches, and sumps shall be provided with drains to remove condensation water, leakage, and similar elements.

9.1.1.2 Office. Where required, locate and construct an office, and insulate it from operating noises. Refer to NAVFAC DM-1 Series on Architecture, for noise and vibration control.

9.1.1.3 Lavatory. Depending upon the number of hours per day operators or maintenance personnel will be in the pumping station, as well as the proximity of adjacent buildings with lavatory facilities, consider including toilet facilities. Design these to protect the water supply against contamination.

9.1.1.4 Workshop and Store Room. These rooms should be within easy access of the operating rooms.

9.1.1.5 Chlorination Room. Where chlorination is necessary for disinfection, a chlorination room should be provided as prescribed in filter buildings (refer to para. 9.1.2 below).

9.1.2 Filter Buildings. Locate these buildings as far as possible from any exterior fire, explosion, and flood hazards. Avoid locations having underground materials that may allow entrance of subsurface pollution.

9.1.2.1 Layout. Follow the principle of simplicity in arrangement as with pumping stations.

a) Space. This should meet the same requirements as for pumping stations, with special attention to pipe galleries.

b) Instrumentation. Duplicate the requirements for pumping stations. Filter operating tables shall be located next to the filters, to aid the operator.

c) Filters. These shall be protected from freezing in winter and from algae growth in summer, as follows:

(1) Sand filters shall be covered, if either of the above is a potential problem.

(2) Pressure filters and diatomaceous earth filters shall be placed indoors.

d) Sanitary Protection. Eliminate all possibilities of contamination of filtered water by untreated water and wastes.

(1) No direct connection shall be made between piping for filtered water and that for raw, or partially treated water.

(2) Protect filter tanks, filtered water storage tanks, and conduits against external contamination by waterproofing and by using positive waterstops at all construction and expansion joints.

(3) Where common walls between filtered water and water of lesser purity are unavoidable, coat both sides of walls with a well-bonded flexible waterproofing, such as sulfur-base synthetic rubber.

e) Safety. Provide necessary railings, safety treads on stairs and ample clearance for heads and feet of operating personnel.

f) Lighting, Heating, and Ventilation. The same requirements apply here as in pumping stations.

g) Drainage. Pipe galleries shall be provided with depressed gutters along walls to drain condensates.

9.1.2.2 Office. Provide desk space, record storage, and (for large installations) instrumentation for reporting plant output and system pressures.

9.1.2.3 Laboratory. Provide facilities and equipment for routine water examination and for filter plant operation. Provide facilities for special investigations as follows:

a) Under war conditions, when the water system may be contaminated by chemical, biological, and radiological warfare agents.

b) Under peacetime conditions, when there are no adequate laboratories nearby.

9.1.2.4 Chlorination Housing. Safety to personnel and security of operation are the major considerations in design.

a) Doors. Provide, as a rule, only exterior doors. If an additional interior door must be provided, it should be of gas-tight construction. Doors shall open outward and have panic hardware.

b) Equipment Arrangement. Arrange chlorinators and scales along one side of the wall. Fit a gas-tight glass window in the wall so that chlorinator operation and scales may be observed from outside the room.

c) Lighting. Use natural lighting to the extent possible. Artificial lighting should also be used when natural lighting is insufficient and for nighttime operation.

d) Ventilation. Provide ventilation to achieve the following requirements:

(1) For small installations, natural ventilation is usually adequate. To provide this ventilation use windows in opposite walls, doors with louvers near floor level, or a rotating vent in the ceiling.

(2) For larger installations where natural ventilation is not feasible, use ventilating fans mounted near the floor, designed for six air changes per hour during normal operation, and 10 air changes per hour during emergency conditions.

(3) Prevent short-circuiting by proper location of inlet and outlet openings. Outlets and inlets shall be near floors. Discharged air shall be directed into areas not used by personnel, and on the opposite side of the building from the access doors.

(4) Control the ventilation equipment from outside the chlorination room door.

e) Heating. Heating equipment shall maintain a minimum temperature of 55° F (12.8° C) in the chlorine storage and chlorine metering equipment areas. The chlorine metering equipment area should not be more than 5° to 10° F (2.8° to 5.5° C) cooler than the chlorine storage area, if reliquefaction of chlorine is to be prevented.

f) Safety Precaution. Provide gas masks and a bottle of ammonia at a convenient location outside the chlorination room door.

g) Storage Space. Adequate space shall be provided to store and maintain chlorine cylinders and to assure sufficient reserve supply.

9.1.2.5 Shower. An emergency shower and an emergency eyewash with a quick opening valve and a 1-in. (25.4 mm) water line connection are required. These should be located near the door of the chlorine storage area.

9.1.2.6 Workshop and Storage Space. Provide adequate facilities for routine maintenance of chlorinators.

9.1.2.7 Chemical Storage. Provide separate rooms for chemicals that present toxic, explosive or other storage and handling hazards. Provide suitable ventilation, fire protection, and access for storage rooms.

9.2 Materials and Construction

9.2.1 Aesthetics. Ornate decoration is not required. Simple, clean, and functional design shall be stressed. Refer to NAVFAC DM-1 for architectural criteria.

9.2.2 Materials. Use noncombustible construction materials for pumping stations, filter building, chemical storage rooms, and buildings required to house water supply equipment. Refer to Construction in MIL-HDBK-1008A, for material selection criteria.

9.2.2.1 Health and Sanitation. In material selection, consider health and sanitation, not only for personnel served by the systems but for operating personnel.

9.2.2.2 Insulation. For guidance on insulation, refer to NAVFAC DM-1 Series. It shall be provided for these reasons:

a) To avoid overheating of heat-generating equipment, combustible chemicals, and hazardous compressed gases.

b) To protect against freezing of vital piping, controls and equipment.

c) For the comfort of operating personnel.

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B100	Filtering Material
C100	Iron Pipe
C104	Cement-Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water
C105/A21.5	Polyethylene Encasement for Ductile-Iron Piping for Water and Other Liquids
C110/A21.10	Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids
C151	American National Standard for Ductile-Iron Pipe Centrifugally Cast in Metal- or Sand-Lined Mold for Water or Other Liquids
C203	Coal-Tar Protective Coatings and Linings for Steel Water Pipelines - Enamel and Tape - Hot-Applied
C205-80	Cement-Mortar Protective Lining and Coating for Steel Water Pipe - 4-in. and Larger - Shop Applied
C214	Tape Coating Systems for the Exterior of Steel Water Pipelines
C500	Gate Valves, 3 through 48 in., NPS, for Water and Sewage Systems
C501	Sluice Gates
C502	Dry-Barrel Fire Hydrants
C503	Wet-Barrel Fire Hydrants
C504	Rubber-Seated Butterfly Valves

C600	Installation of Ductile-Iron Water Mains and Their Appurtenances
C900	Polyvinyl Chloride (PVC) Pressure Pipe 4 in. Through 12 in. for Water
C950	Glass-Fiber-Reinforced Thermosetting-Resin Pressure Pipe
D100	Welded Steel Tanks for Water Storage
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NAVFAC DM-1 Series	Architecture
NAVFAC DM-2 Series	Structural Engineering
NAVFAC DM-2.02	Structural Engineering Loads
NAVFAC DM-2.04	Concrete Structures
MIL-HDBK-1002/5	Timber Structures
NAVFAC DM-3 Series	Mechanical Engineering

NAVFAC DM-3.03	Heating, Ventilating, Air Conditioning and Dehumidifying Systems
MIL-HDBK-1004/10	Cathodic Protection (Proposed)
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NAVFAC DM-29.1	Graving Drydocks
MIL-HDBK-1029/3	Drydocking Facilities Characteristics
NFGS-02225	Excavation, Backfilling, and Compacting for Utilities
NFGS 02441	Underground Sprinkler Systems
NFGS-02660	Exterior Water Distribution System
NFGS-13209	Water Storage Tanks
NAVFAC MO-110	Paints and Protective Coatings
NAVFAC P-272	Definitive Designs for Naval Shore Facilities, Parts I and II
NAVFAC P-355	Seismic Design for Buildings (Tri-Service Manual)
NAVMED P-5010-6	Manual of Naval Preventive Medicine
WW-V-58B	Valves, Gate, Cast-Iron; Threaded and Flanged (for Land use)

Naval Facilities Instructions (NAVFACINST) and Operational Naval Instructions (OPNAVINST) are available from the Naval Publications and Forms Center (NPFC), Code 3015, 5801 Tabor Avenue, Philadelphia, PA 19120.

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NFPA publications are available from National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

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