WATER FACILITY DESIGN GUIDELINES
(REVISED JANUARY 2021)

CITY OF SAN DIEGO
PUBLIC UTILITIES DEPARTMENT

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PREFACE

This Guidelines and Standards Book contains information to assist planners and engineers with the design and construction of water facilities. The City's intent is to ensure uniformity of design concepts, formats, methodologies, procedures, construction materials, types of equipment and quality of work products. These standards have been produced and adopted to encourage exceptional quality while using current technology for all Public Utilities facilities.

These Guidelines and Standards are not a substitute for good Engineering. Sound judgement must be exercised in all applications to create quality and cost-efficient facilities.

Public Utilities Department management encourages the creation of relationships between project stakeholders that promotes engineering excellence and timely completion of projects. City staff and consultants are encouraged to take the time at the beginning of all projects to identify common goals, common interests, lines of communication, and a commitment to cooperative problem solving.

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Chapter
1

INTRODUCTION

This book provides guidelines for estimating water demands, establishing service criteria, and designing pipelines, pressure control facilities, storage facilities, and pumping stations to be built as part of the Water infrastructure.

These Guidelines are presented in seven chapters:

- Chapter 2 - Water Demands and Service Criteria
- Chapter 3 - Transmission and Distribution Pipelines
- Chapter 4 - Pressure Control Stations
- Chapter 5 - Storage Facilities
- Chapter 6 - Pumping Stations
- Chapter 7 - Corrosion Control Design Criteria
- Chapter 8 - Seismic Criteria
- Chapter 9 – Security Design Criteria

Chapters 3, 4, 5, and 6 include related guidelines for the following disciplines when appropriate:

- Civil
- Structural
- Architectural
- Electrical
- Instrumentation - PLC (programmable logic controllers)
- Heating, Ventilating, and Air Conditioning
- Mechanical - Equipment
- Mechanical - Piping
- Hydraulics

1.1 Purpose and Use of Facility Design Guidelines

The purpose of these Guidelines is to identify general planning, predesign and design details and approaches to be used for the Water infrastructure. These Guidelines are intended to provide uniformity in key concepts, equipment types, and construction materials on facilities built as part of the Water Infrastructure. These design Guidelines do not limit the responsibility of the DESIGN CONSULTANT, but assist in providing professionally sound, efficient, uniform, and workable facilities; whether pipelines, pressure control facilities, pumping stations, or storage facilities. Not all aspects of design are addressed in these Guidelines. In areas which are not addressed, the DESIGN CONSULTANT must use good engineering judgment and practices.

The DESIGN CONSULTANT incorporates the planning and design criteria presented in these Guidelines into the overall facilities design. Sometimes the criteria are given in ranges, in which case the final criteria are selected within the indicated range. In other cases, specific criteria have been given and are to be followed by the DESIGN CONSULTANT.

If the DESIGN CONSULTANT desires to deviate from the criteria presented in these Guidelines, the DESIGN CONSULTANT proposes such modifications, with justification, to the City Project Manager.

This document incorporates by reference, wherever appropriate, the applicable building codes and industry standard procedures typically used for the design of similar facilities. This includes codes and specifications published by the International Code Conference (ICC), the American Concrete Institute (ACI) and the American Water Works Association (AWWA). Nothing in this document should be construed to allow design of new facilities to a level less than required by the applicable building codes and industry standards.

If documents referenced in these Guidelines have been updated since the writing of the Guidelines, the DESIGN CONSULTANT should use the documents current at the time the design is initiated. Such document use should be referenced in writing to the City Project Manager.

All figures in the design Guidelines use Water CIP standard symbols and abbreviations as defined in the City-wide Drafting Standards.

1.2 Units of Measurement

Units of measurement to be used in design calculations should conform to the United States system of measurement. Commonly used units and their abbreviations are listed in **Table 1-1**.

Table 1-1
Units of Measurement

Parameter	Abbreviation
Flow/Discharges	
(United States) million gallons per day	mgd
(United States) gallons per minute	gpm
(United States) gallons per hour	gph (for chemicals only)
(United States) gallons per day	gpd
cubic feet per second	cfs
cubic feet per minute	cfm

Parameter	Abbreviation
pounds per day	lb/day
pounds per hour	lb/hr
standard cubic feet per minute	scfm (for gases only)
liters per second	lps
Volume	
(United States) gallons	gal
cubic inches	cu in
cubic feet	cu ft
cubic yards	cu yd
acre-feet	ac-ft
liter	l
milliliter	ml
cubic meters	m^3
Weight or Force	
ounce(s)	oz
pounds	lb
ton	ton
kilogram	kg
gram	g
milligram	mg
thousand pounds	kip
Length	
inches	in
feet/foot	ft
yards	yd
millimeter	mm
meter	m
micron	μ
Area	
acres	ac
square yard	sq yd

Parameter	Abbreviation
square feet	sq ft
square inches	sq in
Velocity	
feet per second	fps
feet per minute	fpm
miles per hour	mph
revolutions per minute	rpm
Pressure	
feet of water	ft water
pounds per square inches	psi
pounds per square inches absolute	psia
pounds per square inches gage	psig
Power	
Kilowatts	kW
Horsepower	hp
Volts ac	Vac
Volts dc	Vdc
amperes	A
milliampere	mA
power factor	pf
frequency	Hz
Temperature/Heat	
degrees Centigrade (Celsius)	°C
degrees Fahrenheit	°F
British Thermal Unit	Btu
Density	
pounds per cubic feet	pcf
pounds per gallon	lb/gal
kilograms per cubic meter	
Concentration	
milligrams per liter	mg/l

Parameter	Abbreviation
parts per billion	ppb
parts per million	ppm
pounds per million gallons	lb/10^6 gal
pounds per gallon	lb/gal
pounds per cubic feet	pcf
Loadings	
pounds per square inch	psi
pounds per square feet	psf
gallons per day per square foot	gpd/sf
gallons per day per linear foot	gpd/ft
gallons per minutes per square foot	gpm/sf

Chapter
2

Water Demands and Service Criteria

2.1 General

This chapter outlines planning procedures to estimate water demands and fire flows. Water system service requirements are also defined in terms of water pressure and reservoir storage.

2.2 Service Area

The DESIGN CONSULTANT defines the project's service area and identifies the pressure zones in which it is located. The Senior Civil Engineer in charge of either Water Planning or new development approves the service area boundaries.

2.3 Land Use and Residential Population

The DESIGN CONSULTANT develops present and future land use maps for the service area to define the following land use categories: residential (by zone in accordance with **Table 2-1**), central business district, commercial and institutional, parks, hospitals, hotels, industrial, office, and schools.

The DESIGN CONSULTANT estimates the residential population in the service area based on present and future allowable land use. Unless more accurate population density estimates are available, the residential population in the service area is estimated based on the figures presented in **Table 2-1**.

Table 2-1
Residential Population Density

Zone	Dwelling Unit Density (dwelling unit/ net acre)	Unit Density (persons/ dwelling unit)	Population Density (persons/ net acre)
AR-1-1	0.1	3.5	0.4
AR-1-1	0.2	3.5	0.7
AR-1-2	1	3.5	3.5
RS-1-1/RS-1-8	1	3.5	3.5
RS-1-2/RS-1-9	2	3.5	7.0
RS-1-4/RS-1-11	4	3.5	14

Zone	Dwelling Unit Density (dwelling unit/ net acre)	Unit Density (persons/ dwelling unit)	Population Density (persons/ net acre)
RS-1-7/RS-1-14	9	3.5	32
RM-1-1	14	3.2	45
RM-2-5	29	3.0	87
RM-3-7	43	2.6	112
RM-3-9	73	2.2	161
RM-4-10	109	1.8	196
RM-4-11	218	1.5	327

Dwelling unit density in **Table 2-1** is based on net area. The net area is measured in acres, and is 80% of the gross area for each residential zone.

2.4 Average Annual Water Demands

For most projects, average annual water demands are determined based on the unit water demand criteria presented in **Table 2-2**.

Table 2-2
Unit Water Demands

Land Use Category	Unit Water Demand
Residential	150 gallons/person-day
Central Business District	6000 gallons/net acre-day
Commercial and Institutional	5000 gallons/net acre-day
Fully Landscaped Park	4000 gallons/net acre-day
Hospitals	22500 gallons/net acre-day
Hotels	6555 gallons/net acre-day
Industrial	6250 gallons/net acre-day
Office	5730 gallons/net acre-day
Schools	4680 gallons/net acre-day

Average annual water demands are calculated as the sum of: (1) the residential water demand, and (2) other water demands for each land use category as follows:

Residential Water Demand (gallons/day) = Residential Population x 150 gallons/person-day

Other Water Demand (gallons/day) = Land Use Area by Category (net acres) x Unit Water Demand for Each Land Use Category (gallons/net acre-day)

Average Annual Water Demand (gallons/day) = Residential Water Demand + Other Water Demands

On some projects, particularly large residential developments, using the unit water demands in **Table 2-2** may generate unrealistically high estimates of water requirements. For these large projects, the DESIGN CONSULTANT or developer may request that the Senior Civil Engineer consider an alternative approach, making use of the City's water demand distribution data developed for macroscale planning purposes. Similarly, the Senior Civil Engineer may also consider alternative unit water demand estimates for specific land use types where such estimates are based on detailed demand evaluations. Recent projects of similar size, nearby location and similar character may be used for comparative demand analysis.

2.5 Peak Water Demands

Unless the project involves a large development that calls for an alternative approach, peak hour and maximum day water demands are estimated using the peaking factors presented in **Figures 2-1 and 2-2**. Peaking day factors correspond to the zones identified in the Public Utilities Department Water System HGL Zones.

Peak water demands are estimated as follows:

Peak Hour Demand = Average Annual Water Demand * Peak Day Factor * 1.5

Maximum Day Demand = Average Annual Water Demand * Peak Day Factor

Figure 2-1 Peak-Hour Demand Factor by Development Type and Size

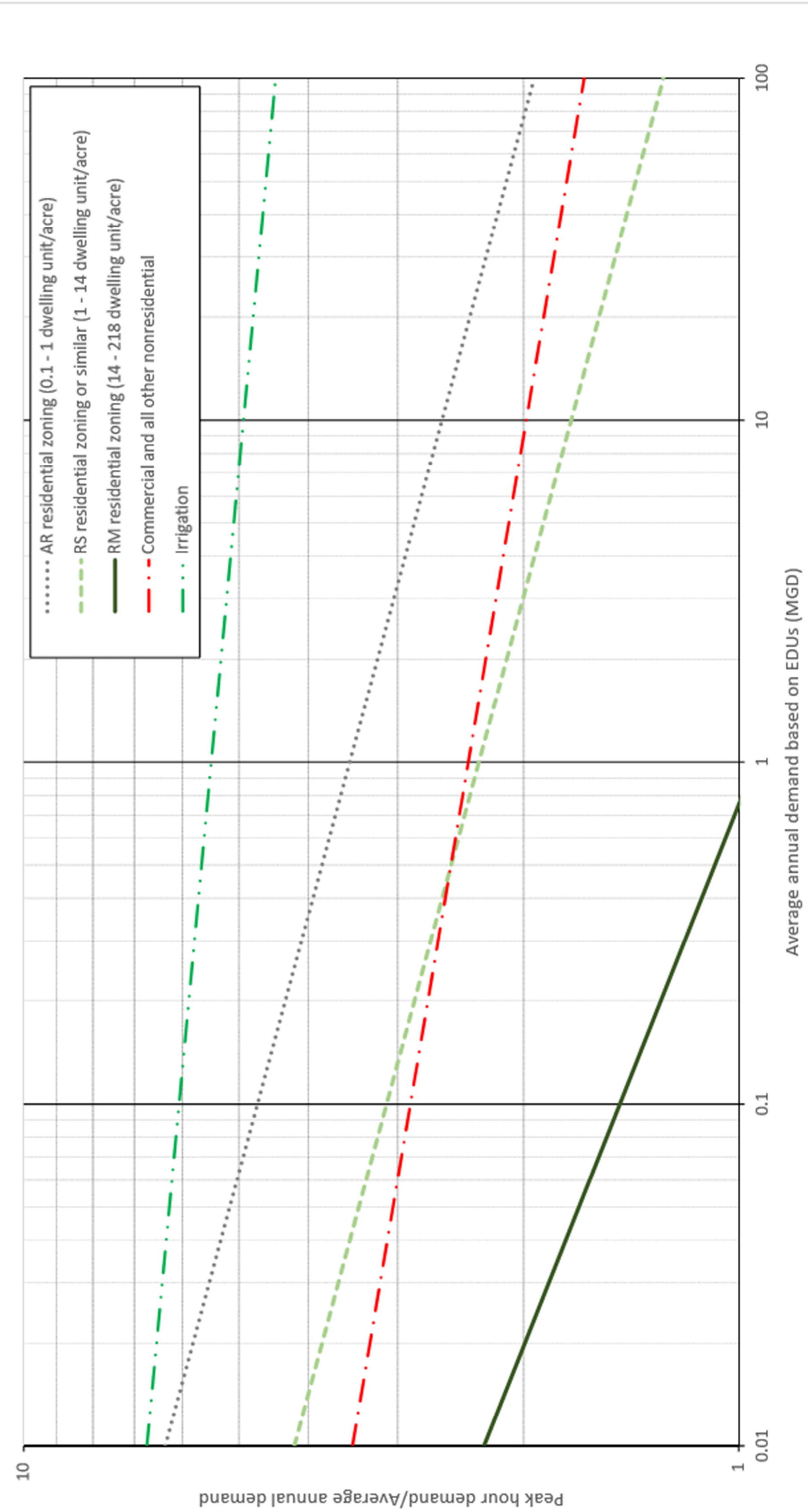
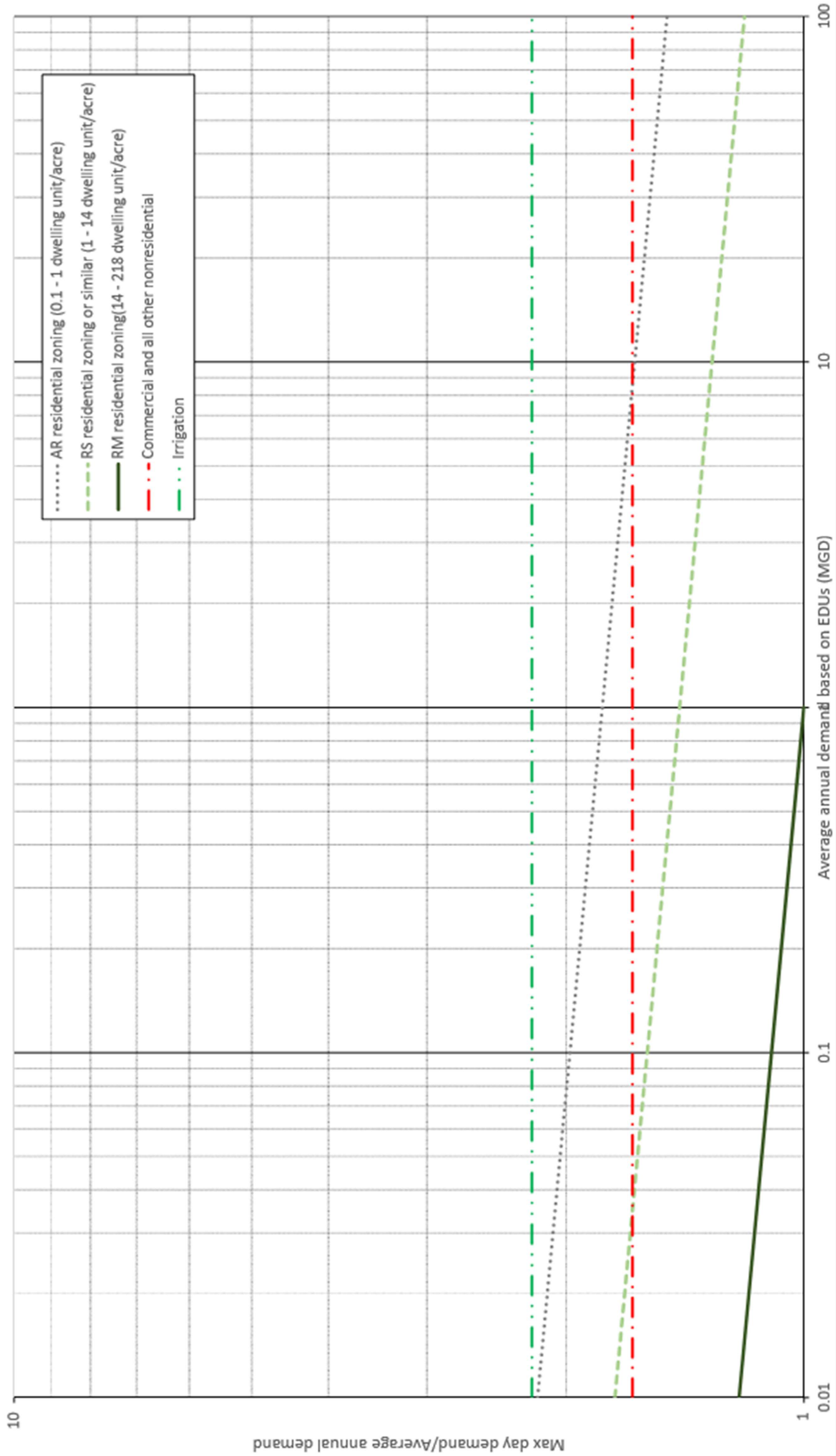


Figure 2-2 Max-Day Demand Factor by Development Type and Size



2.6 Fire Demands

The DESIGN CONSULTANT shall use the minimum required fire demands for design shown in **Table 2-3**. The fire flow duration for planning purposes is at least five hours. Note that the values in **Table 2-3** are the minimum design criteria for public infrastructure. Privately owned facilities shall follow the guidelines described in Appendix B of the California Fire Code (CFC).

Table 2-3
Fire Demands for Design Purposes

Development Type	Fire Demand (gpm)
Single family residential up to Fourplexes	1,500
Condominiums and apartments	3,000
Commercial	4,000
Industrial	6,000

Should application of the CFC Appendix B result in figures lower than those shown in **Table 2-3**, the firm or Civil Engineer, in consultation with the fire department, CIP City Project Manager may approve the CFC figures on a case-by-case basis following submittal of supporting calculations. In no case shall the approved fire flow rate and flow duration be less than the flow rate and duration values required by Appendix B of the CFC based on the anticipated or proposed type of building construction and total building floor area.

The required fire demand must be supplied from public and private on-site fire hydrants located as required by CFC Appendix C.

2.7 Pressure Criteria

2.7.1 Design Pressures

Water systems must be designed to provide the minimum residual pressures under:

- Maximum day demands plus fire demand conditions, or
- Peak hour demand conditions.

In analyzing the supply to a pressure zone, the minimum hydraulic grade line elevation available from the water source is used, a level that typically occurs during dry weather conditions. A water supply source is defined as a treatment plant clearwell, flow control facility, pump station, pressure regulating station or reservoir. Supply sources occur at discrete points in a system of water mains and control both flow and pressure at the supply point. Water mains are not supply sources but rather conveyance facilities. The maximum static pressure in gravity systems is determined from reservoir overflow elevations and/or the discharge control setting on pressure reducing valves, whichever is greater. The maximum static pressure in pumped systems is determined from reservoir overflow elevations or pump shutoff levels, whichever is greater. There are two important pressure criteria used in water system design: Domestic Pressure and Fire Pressure. For systems supplying only domestic demand, only the Domestic Pressure criteria will apply. Similarly, for systems providing only fire demand, only the Fire Pressure criteria will apply. Systems supplying both types of demand, both criteria will apply and must be independently checked.

2.7.2 Domestic Pressure Criteria

The domestic pressure criteria for water system design are shown in **Figure 2-3**. Every water main in each pressure zone must be capable of supplying a minimum static pressure of 65 psi. Domestic pressures must fall no more than 25 psi below the static pressure, and residual water main pressure must be at least 40 psi. Domestic pressures are determined in the distribution system pipelines, excluding losses through service connections and building plumbing, and are measured relative to adjacent building pad elevations.

When analyzing a system with one source of supply out of service, domestic pressures may fall more than 25 psi below static pressure, but the domestic pressure shall not fall below 40 psi.

2.7.3 Pressure Requirements During Fires

For the simulation of fire conditions, a minimum operating pressure of 20 psi is required at the fire hydrant locations.. The residual pressure is determined given the fire demand among one or more hydrants and with the simultaneous water consumption occurring at the maximum day demand. The hydrants considered in this simulation must be sufficiently near to the fire location to be classified as “available” to that location as defined by the California Fire Code.

For water systems with available storage, the residual pressures in the distribution system during a fire are maintained given the following conditions:

- The water level in the storage facility at the time of the fire is at or near the minimum operating level
- The prescribed fire duration set by the California Fire Code, occurring under maximum day conditions.

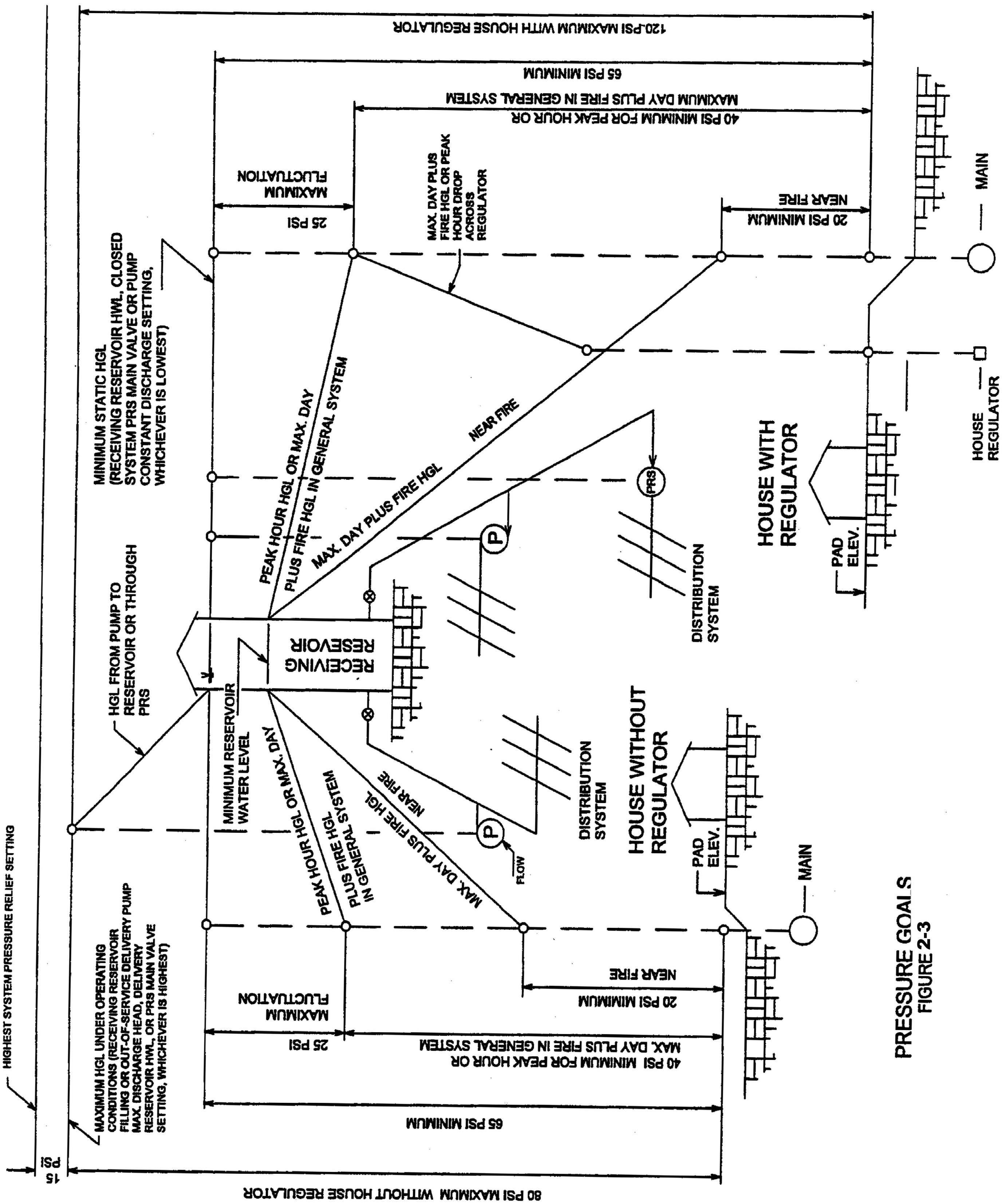
2.8 System Reliability

Water systems must be designed to meet the operating pressure criteria with one critical source out of service. Water mains must be designed so that no more than one, average-sized city block (approximately 30 homes) is out of service at any time, and no more than two fire hydrants (excluding fire services) are on a dead end or are out of service at any time. These provisions do not apply under earthquake conditions.

Water mains serving more than two hydrants or more than 30 homes must be looped, fed from two sources, or provided with a reservoir of sufficient capacity to supply the emergency needs (contingency and fire storage) as described below in **subsection 2.9**.

All water mains relied upon for looping and source redundancy shall be in separate streets. Dual mains in the same street or alignment require the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document. Where dual mains are relied upon for looping or source redundancy, the mains shall be spaced at least 10 feet apart from outer edge to outer edge.

For City CIP work in already-built-out areas, where looping of mains or connection to two sources of supply is not feasible, water mains may be constructed require the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document. Additional design considerations shall be made to minimize the chance of pipe breakage, such as use of a higher class of pipe.



PRESSURE GOALS
FIGURE 2-3

2.9 Storage Criteria for Water Systems

There are three basic types of water storage in the City's system: regulating reservoirs, forebays and clearwells. Regulating reservoirs balance supply and demand for a pressure zone and/or service area. Pressure zones are normally designated by the overflow elevation of the regulating reservoirs. Forebays are used to balance supply and pumping demand to provide a stable suction head for a booster pump station. Typically, a clearwell is a regulating reservoir to store filtered water in a water treatment plant. The shape and material of the storage vessel (elevated tank, standpipe, circular, rectangular or trapezoidal ground level steel, prestressed or reinforced concrete reservoirs) is generally determined by the amount of water storage required, topography of the available site and the economy of construction. All water storage systems shall be designed individually based on the City approved water planning study and may only be modified if proper justification is provided from the DESIGN CONSULTANT. During the planning process, Public Utilities evaluates storage reservoirs individually based upon the intended purpose and design of the reservoir including factors of water system configuration, storage location and connectivity, water system hydraulics, pumping or gravity hydraulics, internal reservoir mixing, external storage turnover, reservoir structural design, physical condition for existing reservoirs, and numerous other factors. These factors include evaluations for the emergency storage sub-components and the operational sub-components of the reservoir. Energy management is an important consideration in planning and hydraulic modeling of water pump stations, pressure regulating stations and storage facilities. Planning and pre-design of water storage reservoirs requires case-by-case evaluation by Public Utilities engineering staff based upon the aforementioned variety of factors that are unique to each facility. Storage systems classified as a combination of regulating reservoirs, forebays and clearwells require special design by the DESIGN CONSULTANT.

Definitions

- Ultimate Maximum Day Demand or Maximum Day Demand (UMDD) is the forecasted maximum day demand (ultimate average day demand multiplied by a peaking factor) for a projected future planning date. This date is selected during the planning phase of the project. The Maximum Day Demand Flow Rate is the uniform flow rate delivering water in a 24-hour period to meet Maximum Day Demand.
- Peak Hour Demand is the forecasted UMDD multiplied by a peaking factor for determining the projected highest hourly consumption during one year.
- Service area includes all pressure zones supplied by a water facility including:
  a) Zone(s) served directly without the need for pumping or pressure reduction,
  b) Pumped zone(s) supplied through pumping station(s), and
  c) Pressure reduced zone(s) downstream of a pressure reducing station(s).
- WTP – Water Treatment Plant

2.9.1 Regulating Reservoirs

The required storage volume within a pressure zone or service area is calculated using the following equation:

Storage Capacity ≥ Operating Storage + MAX [Emergency Storage or Fire Storage]

2.9.1.1 Operating Storage

1. **Definition.** Operating storage is defined as the volume of storage necessary to allow a reservoir's sources of supply to operate at a uniform rate throughout the day while meeting variable water demand. In some cases, operating storage is used to permit the reduction or stopping of supply during peak hour water demand conditions or stopping of pumping operations during hours of peak energy demand. See **Figure 2-4**.

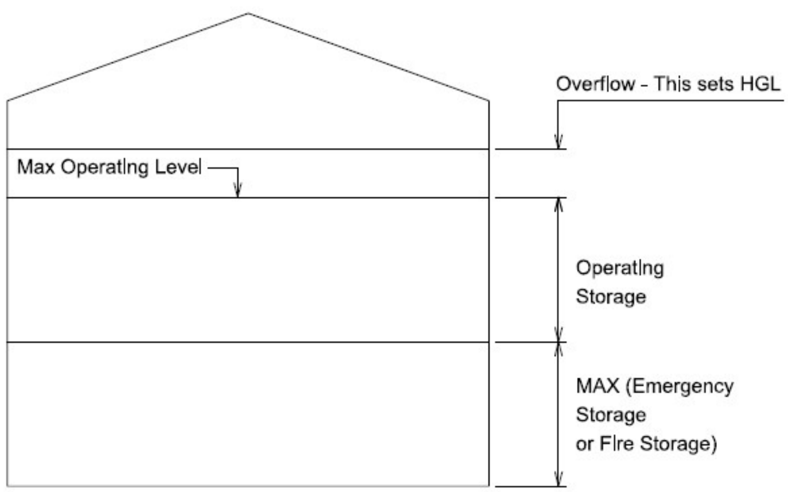


Figure 2-4 Storage Capacity for Regulating Reservoirs

Operating storage may also be defined as the amount of storage necessary to supply Peak Hour Demand with a water supply having a uniform Maximum Day Demand Flow Rate. Operating storage must fluctuate daily in all water storage facilities, like standpipes and elevated tanks supplied by pumps and in ground level reservoirs supplied by gravity pipelines.

In order to optimize the use of transmission facilities and to improve water pressure during peak water demand conditions, pump or gravity inflow must be controlled to achieve top operating levels 2 hours before peak hour demand.

2. **Calculation Procedure.** Operating storage is calculated as 30 % of the ultimate maximum day demand in the service area (one or more pressure zones). The source(s) of supply must

provide for maximum day demand.

To allow the reduction or stopping of supply during peak hour water demand conditions or stopping of pumping operations during hours of peak power demand, additional operating storage volume is required. Assuming that the amount of operating storage was already determined to balance a uniform daily supply with continuously variable demand, the additional operating storage for reducing or stopping of supply due to peak hour water demand or peak power demand management equals the rate of supply reduction times the duration of supply reduction.

If more than one reservoir is planned for the service area, operational storage can be divided between reservoirs, but only when water system modeling shows that minimum pressure requirements are met during peak hour demand.

For existing and substantially developed service areas, the amount of operational storage may be determined by flow measurement. This flow measurement, based on supply and demand curves, must be adjusted for future growth and reasonably anticipated climatic extremes.

The amount of operating storage may be reduced by water supply capacity available in excess of maximum day demand flow rate.

3. **Example.** Assume the expected ultimate maximum day demand in a pressure zone is 6,000 gal/min, then the required operating storage is:

   Operating storage = ((6,000 gal/min x 1440)/1,000,000) x 0.3 = 2.6 mg

   Continuing with the example above, let us assume now that the pumps are shut off for two hours for peak power demand management, the supply is thus reduced by 6,000 gal/min for 5 hours. The additional operating storage required is then:

   Power management storage = ((6,000 gal/min x 60) x 5)/1,000,000 = 1.8 mg
   Use 1.8 mg for power management storage.

   Total operating storage: 2.6 mg + 1.8 mg = 4.4 mg

2.9.1.2 Fire Storage

1. **Definition.** Fire storage is the minimum amount of water required to be stored for firefighting purposes. Minimum fire flow flows and their duration are established by the City Fire Marshall based on *California Fire Code* requirements.

2. **Calculation Procedure.** Fire storage is calculated by multiplying the maximum fire demand expected in the service area by its duration, as stated in Section 2.6. If more than one tank is

planned for a service area, fire storage can be divided between tanks, but only when water system modeling shows that minimum fire flow and pressure requirements are met.

The amount of fire storage may be reduced by water supply capacity available in excess of maximum day demand flow rate with operating storage, or in excess of peak demand flow rate without operating storage.

3. **Example.** Continuing with the example above, let us assume now that the pressure zone is classified as commercial with minimum fire flow of 4,000 gal/min for 5 hours. (For service areas with UMDD of 100 MGD and more, consider that 2 fires are burning concurrently.) The minimum fire storage is:

   Fire storage = ((4,000 gal/min x 60) x 5)/1,000,000 = 1.20 mg

2.9.1.3 Emergency Storage

1. **Definition.** Emergency storage is the amount of water that needs to be stored to satisfy demand when any single component of the system (power, pump, supply pipe, etc.) is out of service.

2. **Calculation Procedure.** Maximum emergency storage is calculated as 12 hours times the ultimate maximum day demand, in gallons per minute. If anticipated total service outage exceeds 12 hours, then a cost/benefit analysis is required to determine the most cost effective solution to meet reliability and water quality objectives.

   The amount of emergency storage may be reduced by water supply capacity available after a single system component is out of service, or by the reduced time it takes to return to full service based on reasonable estimate of time for restoration of system capacity, as determined by Water Operations Division.

   If more than one reservoir is planned, emergency storage can be divided between the reservoirs, but only when water system modeling shows that minimum flow and pressure requirements are met during peak hour and fire demand conditions.

3. **Example.** The minimum amount of emergency storage based on the examples above is:

   Emergency storage = ((6,000 gal/min x 60) x 12)/1,000,000 = 4.4 mg

   If, for instance, there are two pump stations with a 3,000 gal/min capacity each supplying the same pressure zone and one pump station is out of service, the emergency storage is reduced to:

   ((3,000 x60) x 12)/1,000,000 = 2.2 mg

2.9.1.4 Total Storage

For the examples listed above, the total storage would be the sum of operating, fire and emergency storages, or 3.4 + MAX [1.2 or 4.4] = 7.8 **million gallons**.

Note: Water storage volume located in pumped zones of a service area may not be used to reduce the calculated "Total Storage" for the gravity fed portions of a service area.

2.9.2 Forebays

Forebays are usually small tanks located on the suction side of a booster pump station. They balance available supply with pumping demand and provide a stable suction head to the pump station. If a pump station is adjacent to a regulating reservoir, the reservoir also acts as a forebay. Due to the nature of its function, forebays have only one element – operating storage.

The required volume can be calculated as shown in **section 2.9.1.1.2** above.

2.9.3 Clearwells

Typically, a clearwell is a regulating reservoir to store filtered water from a water treatment plant. The required storage volume is calculated using the following equation:

$$\text{Storage Capacity} \geq \text{Operating Storage} + \text{Emergency Storage}$$

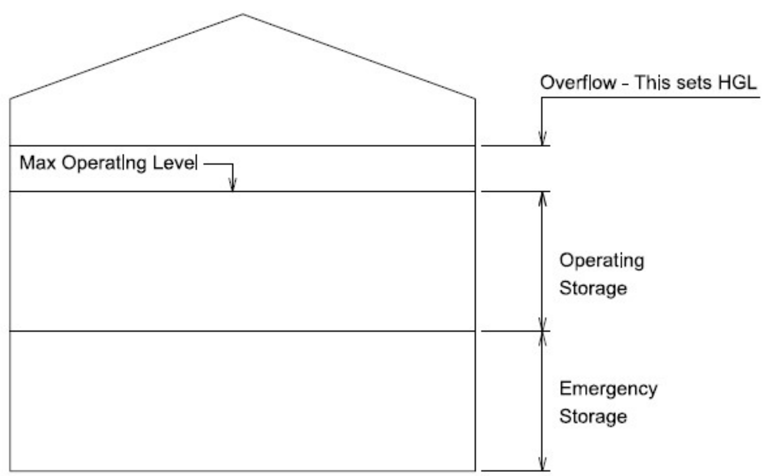


Figure 2-5 Storage Capacity for Clearwells

2.9.3.1 Operating Storage

1. **Definition.** Operating storage is defined as the volume of storage necessary to allow a WTP to operate at a uniform rate throughout the day while meeting variable water demand. See **Figure 2-4**. Operating storage must fluctuate daily in all water storage facilities. In general, the operating storage volume is divided between the potable water reservoirs within the treatment plant service area. The clearwell's share of the operating storage (30% UMDD) will depend on the location and capacity of the other reservoirs within the WTP service area.

2. **Calculation Procedure.** The required volume can be calculated as shown in **section 2.9.1.1.2** above.

2.9.3.2 Emergency Storage/Shutdown Storage

1. **Definition.** Emergency storage is the amount of water that needs to be stored to satisfy demand when any single component of the WTP (sedimentation basin, power, pump, supply pipe, etc.) is out of service.

   It is generally advisable that the raw water supply and treatment facilities are designed with the same reliability and redundancy as the water distribution system for delivery of uninterrupted water supply. That is, with any single component out of service, one at a time. This will allow routine facility maintenance to proceed anytime or, at a minimum, during the winter months without impacting the capacity of the system to meet treated water demand.

   Shutdowns are not unique to water treatment plants, they are just more routine and have more significant impacts due to the complexity and size of the facilities. Shutdowns and emergencies have similar impacts with the difference being that shutdowns are prescheduled and can be anticipated. Therefore, a thorough analysis of the raw water supply and treatment facilities is required to determine those critical facility components resulting in the longest or most significant reduction of treatment capacity when they are out of service, due to either routine maintenance or emergency failure.

2. **Calculation Procedure.** After determination of the critical maintenance shutdown and emergency repair vulnerability of the water treatment plant, the required volume can be calculated as shown in **section 2.9.1.3.2** above**.**

   It is to be noted that operating and emergency storage can be used during WTP shutdowns. As such, additional shutdown storage capacity is only required if shutdown demand is greater than the sum of operating and emergency storage.

2.9.3.3 Total Storage

For the examples listed in **section 2.9.1** above, the total clearwell storage 3.4 + 4.4 = 7.8 **million gallons** for a WTP with 7.8 MGD capacity and without any service area distribution system storage. (Assumption WTP capacity = UMDD).

Note: Water storage volume located in pumped zones of a service area may not be used to reduce the calculated "Total Storage" for the gravity fed portions of a service area.

2.9.3.4 Minimum and Maximum Storage

As a minimum, the clearwell storage should not be less than 25% of the WTP capacity, and not more than the UMDD of its service area for plants 10 MGD and larger.

It is generally more economical to build a reliable WTP to meet UMDD than to provide additional water storage for emergencies and to meet UMDD. Therefore, vulnerability risk analysis and cost/benefit analysis are recommended before deviating from the guidelines outlined above.

Chapter
3

TRANSMISSION AND DISTRIBUTION PIPELINES

3.1 General

The Capital Improvements Program and private developments require the design and construction of new transmission and distribution pipelines. This chapter provides uniform standards on the following for both transmission and distribution pipelines:

- Pipe materials
- Fittings
- Valves and associated structures
- Fire hydrants and services
- Water services
- Water meters
- Flow meters
- Backflow preventers
- Pipe design criteria
- Hydraulic and surge analysis
- Thrust restraint
- Special crossings
- Trenchless construction
- Pipe trench width, bedding and backfill
- Communications

In addition, **Chapter 7** of these guidelines describes the corrosion control design criteria for pipelines and appurtenances.

3.2 Project Presentation

This section on project presentation describes the standards, relevant guidelines and information required to maintain consistency and quality in the drawings and specifications for future water infrastructure.

3.2.1 Preliminary Alignment

Preliminary alignments are generally developed by the City or private developers during a project conceptual or predesign phase and are presented in the Planning Study or Predesign Report. The format used for the preliminary drawings may not necessarily represent the format required for the final design drawings.

For most CIP projects, topographic mapping is provided by the City of San Diego, Engineering & Capitol Projects Department, Survey Section. If the DESIGN CONSULTANT provides the topographic mapping, the survey data will be in U.S. Customary Units. The DESIGN CONSULTANT updates the topographic base to include any development or physical changes that have occurred after the date of survey. If a preliminary horizontal alignment is provided, the DESIGN CONSULTANT reviews and recommends changes in the design to accommodate utility conflicts, the design's constructability, permitting requirements, or easement/right-of-way needs. The proposed horizontal alignment changes must be submitted in writing prior to any design work being performed, or presented in the Basis of Design Report (BODR) but before the 30% submittal.

The vertical alignment is established by the DESIGN CONSULTANT in the design to accommodate utility and permitting requirements, pipe installation criteria, geotechnical requirements, and local, state, and federal standards.

3.2.2 Contract Specifications

The standard specifications used for water infrastructure projects are the latest adopted edition of the GREENBOOK Standard Specifications for Public Works Construction, and the WHITEBOOK – Standard Specifications for the City of San Diego. The DESIGN CONSULTANT also prepares special provisions as necessary to meet the additional requirements of the project as needed.

3.2.3 Contract Drawings

The DESIGN CONSULTANT develops contract drawings to meet the specific needs of a project. Preliminary drawings, when provided to the DESIGN CONSULTANT, are used initially as the basis of design and are amended as necessary. The contract drawings must conform to the requirements of the Citywide Drafting Standards.

3.3 Sizing, Alignment, Easements, and Landscaping

3.3.1 Sizing and Alignment Criteria

Generally, water mains are located 10 feet southerly or easterly of the centerline of streets. For alleys, narrow streets, and private driveways (less than 36 feet curb to curb), water mains may be located less than 10 feet, but not less than 6 feet, from the centerline. When there is a raised center median with curb, water mains are located a minimum of 5 feet from the face of the median curb but within the center 6 feet of a traffic lane (see City of San Diego Standard Drawing SDM-111).

3.3.1.1 Horizontal and Vertical Curves

Curves for smaller diameter jointed pipe are accomplished using straight lengths of pipe with selected bends and fittings. Curves for larger diameter welded steel pipe are accomplished using beveled joints. Curves are based on industry standards for minimum radius of curvature.

3.3.1.2 Utility Separations

A minimum of 5-foot horizontal separation is recommended between water mains and other utilities except for sewer mains. Parallel water and sewer mains require a minimum of 10-foot horizontal separation (edge to edge), in accordance with State Water Resources Control Board, Division of Drinking Water criteria. Reclaimed water mains, are considered as sewer mains for separation purposes. Review and written approval shall be required from the California State Water Resources Control Board, Division of Drinking Water, for separation deviations between water, sewer or reclaimed water.

For parallel water mains, lines should be located in lanes on opposite sides of the street. Separations less than 10 feet apart shall be preapproved by Public Utilities Department, Water System Operations.

3.3.1.3 Water Main Abandonment

The abandonment of existing water mains and appurtenant structures should be in accordance with the construction drawings and the most current approved edition of the Standard Specifications for Public Works Construction (SSPWC or GREENBOOK) and WHITEBOOK, as adopted by the City.

3.3.1.4 Transmission Mains

Transmission water mains (16-inch in diameter and larger) are sized to provide all current water needs of the area they supply, with sufficient reserve capacity to allow future expansion and development. When possible, transmission mains should be planned so that each area is supplied by a minimum of two transmission lines, each capable of providing the water needs of the area being served, under the 25% emergency water conservation mandate.

Acceptable sizes for transmission mains are 16-inch, 20-inch, 24-inch, 30-inch, 36-inch and larger (increasing in 6-inch increments).

Transmission water mains shall not be tapped directly for water services (domestic or irrigation) or fire services (including hydrants), except for 16-inch or the DESIGN ENGINEER prepares a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document. To receive water from a transmission main, a connection to a distribution main must be tapped or built into the transmission main.

3.3.1.5 Distribution Pipelines

Distribution water mains (16-inch in diameter and smaller) should be sized to meet the pressure criteria and the required fire flow plus maximum day demand at a maximum velocity of 15 fps. In lieu of specific calculations for minor losses, calculated head losses are increased by 10% for fittings and other minor losses.

Acceptable sizes for distribution mains are 8-inch, 12-inch, and 16-inch only.

Water mains in commercial and industrial areas are a minimum of 12 inches in diameter.

3.3.1.6 Prohibited Locations

Water mains shall not be installed within 10 feet of trees or shrubs that mature naturally to a height of over 3 feet. If that cannot be avoided, then the trees shall have root barriers installed or replanted in above ground planters.

Water mains shall be installed in paved city streets. Water mains installed in unpaved streets require the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document.

3.3.2 Pipeline Profile Criteria

The DESIGN CONSULTANT develops the pipeline profile to minimize costs while still meeting the needs of the project. Factors to be considered include:

- Pipe material, fabrication, and installation costs
- Potential conflicts with existing and future utilities or other improvements
- The safety and security of the pipeline
- Geotechnical conditions
- The requirements of governing agencies
- Maintenance requirements

The profile of water mains should include stations and elevations at grade breaks. Abrupt vertical grade breaks resulting in upward thrust should be avoided. Profile requirements for special crossings are discussed in **subsection 3.13**.

For a pipe diameter of less than 12 inches, only the pipe invert need be shown in the profile. For pipes 12 inches in diameter and larger, the pipe invert and the top of the pipe should be shown, and the pipeline stationing should be the centerline of the pipe.

Minimum cover for pipelines is described in **paragraph 3.8.3**, or as shown in the City of San Diego standard drawings.

3.3.3 Easements

Permanent easements, where the pipe is located outside the right-of-way are not allowed unless there are no public right of way (public street) options. Water easements, if approved, shall be located entirely within one lot or parcel and adjacent to the property line.

Sixteen-inch diameter and smaller water mains require a minimum 15-foot wide easement. The main should be positioned 5 feet from the property line. A minimum 20-foot wide easement is required for 20-inch to 36-inch diameter mains and a minimum 25-foot wide easement is required for larger than 36-inch diameter mains. Wider easements may be required when the pipe is placed at depths greater than normal (3 to 5 feet to the top of the pipe for water mains). All existing substandard easements must be brought up to current standards prior to the approval of any new improvement permit by the Public Utilities or Development Services Departments.

A minimum of 5 feet of additional easement width (beyond that described above) is required for water mains located in canyons, "open space" areas, and other areas that are difficult to access such as between buildings.

Water service taps are not allowed on easement water mains except where the easement is a paved traveled way and is at least 24 feet wide.

Easements serving more than one utility require a minimum of 5 feet of additional width for each additional utility.

3.3.3.1 Private Street Easements

Easements located in private streets, private driveways, industrial complexes, apartment complexes, and condominiums that are required for access of water vehicles, water meter readers and fire protection equipment, must be a minimum of 24 feet wide and paved the full width of the easement are approved on a case-by-case basis. Easements for fire service mains may be unpaved with a minimum 15-foot width, provided there are no metered water services connected to the fire service main. A separate 24-foot minimum width paved access easement to any connected hydrant must be provided.

3.3.3.2 Access Easements

Vehicular access easements for water meter readers and fire protection equipment must be a minimum of 24 feet wide.

Access roads must be provided to all water main appurtenances (blow-offs, air valves, gate and butterfly valves, manholes, etc.). Access roads must be a minimum of 20 feet wide with a maximum 8% slope, and have a minimum 4-inch decomposed granite surfacing. Access roads with slopes of 8% to 15% require the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document and, if approved, must have a minimum 3-inch, asphaltic-concrete surfacing.

Easements secured by fencing must have a locked vehicular access gate. Keys to the lock must be provided to the various utility agencies with facilities inside the fenced area.

3.3.3.3 Fire Hydrant Easements

Fire hydrants must be provided with a minimum 24-foot paved access easement. Access to onsite and easement fire hydrants shall be approved by the Fire Department.

3.3.3.4 Abandonment of Water Easements

In cases where water facilities are proposed to be completely relocated or abandoned from any existing water easement, and there are no other water facilities using or contemplated in the future for the easement, the water easement shall be abandoned per Section 125.1001 of the Municipal Code as part of the work to be done. Where water facilities are to be completely relocated or abandoned from any mixed-use or general utility easement, the easement shall be abandoned per Section 125.1001 of the Municipal Code as part of the work to be done if it is determined that there are no other utilities using or contemplated in the future for the easement. This requirement for easement abandonment shall apply to all private development projects and Capital Improvement Projects.

All easements required to be abandoned shall be accomplished through a Process 5 easement abandonment application with the Development Services Department pursuant to the State of California Streets and Highways Code or, if applicable, pursuant to the Subdivision Map Act.

As part of the easement abandonment process, the proposed abandonment shall require the approval of the Senior Civil Engineer of Water Systems Operations Division, Public Utilities Department.

3.3.4 Landscaping

New trees should not be planted within 10 feet of existing water pipes. If that cannot be avoided, then the trees should be planted with root barrier or installed in above ground planters.

3.4 Pipeline Materials, Linings, and Coatings

This section references pipe materials, linings, and protective coatings for water pipelines. For specific corrosion control design criteria, refer to **Chapter 7**. For general seismic criteria, see **Chapter 8**.

3.4.1 Materials

The material for water mains is selected in accordance with the current issue of the City of San Diego Public Utilities Department Water Approved Materials List. PVC pipe is generally unacceptable when buried with less than 3 feet or more than 8 feet of cover. Steel pipe (STL) and steel cylinder rod-wrapped pipe (SCRW) is acceptable for water mains 24 inches in diameter or larger. The use of PVC C-905 pipe may be acceptable for use from 16-inch diameter up to 36-inch diameter requires the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document.. For general design guidelines for material selection to account for seismic conditions, see **Chapter 8, Section 4.2**.

3.4.1.1 Asbestos Cement (AC) Pipe

AC pipe is no longer an acceptable material for water pipes.

3.4.1.2 Ductile Iron (DI) Pipe

Thickness design must conform to AWWA C-150 and C-151. Rubber-gasket joints must conform to AWWA C-111. The installation of DI pipe and its appurtenances must conform to AWWA C-600.

3.4.1.3 Polyvinyl Chloride (PVC) Pipe

PVC pipe 4 inches through 12 inches in diameter must conform to AWWA C-900. The dimension ratio (DR=Outside Diameter/Pipe Wall Thickness) for PVC pressure pipe must not exceed 18.

Solvent cement or mechanical joints are not acceptable for pipe-to-pipe connections. Use bell and spigot pipe or gasketed couplings. Pipe-to-fitting connections are mechanical joint only.

PVC pipe 16 inches through 36 inches in diameter used for transmission purposes must conform to AWWA C-905. However, pipes used for distribution purposes must have a safety factor of 2.5 per AWWA C-900.

Concrete encasement with PVC pipe is not allowed.

3.4.1.4 Steel (STL) Pipe

STL pipe must conform to AWWA C-200. Field welding must conform to AWWA C-206.

3.4.1.5 Reinforced Concrete Steel Cylinder (RCSC) Pipe

Reinforced Concrete Steel Cylinder (RCSC) pipe is no longer used for new installations (AWWA C-300). Portions of the existing system are composed of this type of pipe. When connections are made to existing RCSC pipe, special consideration must be made to construction details and system downtime.

3.4.1.6 Steel Cylinder Rod Wrapped (SCRW) Pipe

The design of SCRW pipe must conform to AWWA C-303. This pipe material is for buried services and is not acceptable for aboveground installations. Bell and spigot connections of SCRW pipe 24 inches in diameter and larger are "buttered with mortar" by hand from inside the pipe. Hand-holes with split butt straps are allowed only for field closures.

3.4.2 Linings and Coatings

In selecting materials for use in a water and soil environment, two main factors must be considered. The materials must be capable of performing the desired function in a safe and economical manner, and the materials must operate satisfactorily over the design life of the facility. As corrosion-caused deterioration of materials is a likely mode of failure select materials capable of withstanding the aggressive environment to which they are exposed. The following discussion focuses on the implications of corrosion on materials selection for water pipelines to be constructed.

The term "coatings" refers to materials applied to the exterior of the pipe including tape coatings for corrosion protection. The term "linings" describes materials applied to the pipe interior for corrosion protection. Linings and coatings requirements are more specifically described in **Chapter 7 Corrosion Control Design Criteria**.

3.4.3 Cathodic Protection

Cathodic protection is discussed in **Chapter 7 Corrosion Control Design Criteria**.

3.5 Valves, Appurtenances, and Structures

Pipeline appurtenances/structures include mainline valves, outlets, air release/vacuum relief structures, blow-off stations, access structures, communications, and pipeline markers. Each item is discussed in the following sections. **Table 3-1** at the end of this section provides a summary of the design criteria. The DESIGN CONSULTANT should refer to the City of San Diego's most current Approved Materials List when selecting materials.

3.5.1 Valves

Mainline valves are used only if required for safety, maintenance or operation. The location, size and type are as recommended by the DESIGN CONSULTANT and approved by the Public Utilities Department. Unless otherwise approved, mainline valves are the same diameter as the pipeline.

On distribution mains, valves are placed at street intersections and on each smaller main as it leaves the larger main. In general, crosses are to have valves in 3 directions; tees in 2 directions. In commercial, industrial, and high density locations, all tees and crosses are to have valves on all sides. Valves for fire hydrants are perpendicular to the water main and in line with the fire hydrant; no offsets are allowed. Note that butterfly valves are not allowed on fire services ~~and distribution mains.~~

Distribution water mains are to have valves so that the maximum distance between valves is about one average city block (approximately 30 homes) for 8-inch diameter mains; about 1,200 feet for 12-inch diameter mains; about 1,600 feet for 16-inch diameter mains. The maximum spacing of valves along transmission mains is one-half mile. However, all of the above notwithstanding, valves in the distribution system are placed so that no more than 2 fire hydrants or one average city block is out-of-service at any one time in the event of a main break (in accordance with Fire Department policy). All fire services including hydrants are to have valves at the main (see SDRSD SDW-104).

Where future water main extensions are anticipated, or are deemed possible, valves are placed, where possible, so that no customers are out of service for the connection work. In most cases, this calls for a flanged valve 20 feet from the end of the main. The drawings must specify, either by general note or direct callouts, that valves are flanged to crosses and tees. Valves used with PVC pipe must have mechanical joint ends. Large valves (24 inches in diameter or greater) are always flanged. In-line valves should be located downstream of each major turnout. In-line valves should be adjacent to and outside of areas of known high potential for PGDs.

Valves must be of the size, type and class indicated on the drawings and/or specifications. Unless otherwise specified, all valves must be a minimum of Class 150 and only gate, resilient-seated gate, and butterfly valves are allowed.

All valves for buried service must be factory-coated and lined.

3.5.1.1 Gate and Resilient-Seated Gate Valves

Gate valves must conform to AWWA C-500 and SSPWC City Supplement, Section 209. Resilient-seated gate valves must conform to AWWA C-509. Valve key extensions (SDRSD SDW-109) for buried valves are used whenever the top of the valve is 25 inches or more below the ground or pavement surface.

Unless otherwise specified on the plans, all valves for distribution mains 12” and smaller, and for all fire services, shall be gate or resilient-seated gate valves. The use of other types of valves on distribution mains 12” and smaller may be allowed with special approval from the water operations Senior Engineer.

Sixteen-inch gate valves must have a 3-inch bypass when the maximum operating pressure is 80 psi or greater; larger gate valves must have bypasses per AWWA C-500.

AWWA C-509 does not require 12-inch resilient-seated gate valves to have a bypass when the operating pressure is less than 165 psi.

3.5.1.2 Butterfly Valves

Butterfly valves and operators must conform to AWWA C-504. Class 150B butterfly valves may be specified for 16-inch through 48-inch sizes (see SSPWC City Supplement, Section 209). Class 250B butterfly valves may be specified for 16-inch through 54-inch sizes (see SSPWC City Supplement section 209). The use of Class 250B butterfly valves larger than 12 inches require the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document..

Butterfly valves 16-inch and larger on transmission mains shall have a bypass installed. The bypass shall be installed on transmission mains only, unless otherwise indicated by PUD. The bypass shall be sized and installed per the latest Standard Drawings, or as approved by PUD.

Valve key extensions (SDRSD SDW-109) must be installed for all buried butterfly valves.

Butterfly valves are not allowed on fire services.

3.5.1.3 Plug Valves

Where plug valves are specified, Class 205 shall be required, for all sizes 16 inches and larger, any deviation requires the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document. This grouping includes cone valves, ball valves, and eccentric plug valves. Plug valves are specified with supplemental specifications. Ball valves must conform to AWWA C-507. All plug valves should be installed in a vault due to maintenance issues.

3.5.1.4 Combination Air and Vacuum Valves

Air valve assemblies are used to provide adequate ventilation during filling and draining of a pipeline, to permit the release of small quantities of air that would otherwise accumulate at high points in the pipeline, and to protect the pipeline from vacuum pressures caused by surge conditions or a pipe break. The locations of air valve structures are generally determined by the topography of the pipeline system and, accordingly, should be installed at high points and at long down sloping gradients. Air valves are also installed on the low side of the line. These valves allow for air intake and release from that portion of the line. Combination air and vacuum valves should also be placed down slope of a permanently closed valve separating two different pressure zones.

Air valve assemblies should consist of the following valve types: combination type (AV/AR); air release valve (AR), air vacuum valve (AV); or a multiple valve (AV and AR). All these valves (or combinations of valves) are installed aboveground and housed in an approved structure out of traveled ways within a right-of-way or an easement. A typical AV/AR type assembly consists of parallel combination air vacuum/air release valves, isolation valves, slow closing check valves, and a parallel stem piping from a single outlet at the crown of the pipe. Typical air/vacuum assemblies are not redundant.

Critical valves are those which, if removed or not functional, could create adverse air buildup or negative pressures under certain operational, filling, draining or catastrophic failure conditions, any of which could damage the pipeline or connected facilities.

Combination air and vacuum valves should be placed at high points on water mains 12 inches in diameter and larger. For water mains on very steep slopes and for pipe sizes 12 inches and larger in diameter, calculations to determine the size of combination air and vacuum valves are required.

The system standard for combination air and vacuum valves is 2-inch for up to 48-inch diameter pipe, and 4-inch for greater than 48-inch diameter pipe.

Air valves for water mains 12 inches in diameter and smaller may be excluded if a manual air release (SDW-158), water service or fire hydrant is located near the high point. In general, a 2-inch combination air and vacuum valve, automatic type (SDRSD SDW 159), is adequate for water main sizes up to 48 inches in diameter.

3.5.1.5 Sizing of Air Valves

Air valves are sized as needed to release air during filling of the pipeline, to release small quantities of air during operation, to admit air as the pipeline is being drained, and to admit air if a pipeline break or surge condition occurs.

Air and vacuum valves are sized for the air evacuation rate associated with maximum water discharge rates at affecting blow-offs in accordance with the air valve manufacturer's recommendations. However, in no case may the design differential pressure for air entering the pipeline be greater than 5 psi or the differential pressure which could collapse the pipeline using the factor of safety recommended in AWWA M11.

The drawings or specifications must state the design pressure range for each air and vacuum valve.

3.5.1.6 Motorized Seismic Valves

Motorized seismic valves are used to provide closure of valves in response to an earthquake event that ruptures a pipeline. This mechanism isolates undamaged facilities from damaged facilities to limit further disruption from draining water, contamination, etc. Typical applications include reservoir inlet/outlets and pipelines that cross active faults.

Isolation valves (butterfly, gate, ball or plug valves) are installed with motorized actuators suitable for connection with seismic detectors. Seismic detectors with interlocks to flow and pressure devices are installed at or near the isolation valve. A combination of events causes a signal to be sent to the valve, which closes automatically. A seismic event that triggers the seismic detector combined with a high flow indication sends a signal to close the valve. A seismic event that triggers the seismic detector combined with an indication of a low pressure sends a signal to close the valve.

A second type of seismic valve consists of a swing check valve with an acceleration-sensitive triggering device. During an earthquake, an acceleration-sensitive ball moves and strikes a reacting cylinder that closes the valve. This is a mechanical mechanism and is similar to that used in the California Gas Shutoff Valve.

The location, size, and type of the seismically actuated valve system is as recommended by the DESIGN CONSULTANT and approved by the Public Utilities Department. A detailed description of the seismic isolation valve system for reservoirs is provided in **Chapter 5, paragraph 5.4.4.4**. **Chapter 8, paragraphs 8.4.2 and 8.4.3** provide guidance of when automatic (electric or hydraulically actuated) or manual valves should be placed in pipelines near liquefaction, landslide or active fault zones.

3.5.2 Appurtenances

3.5.2.1 Blowoffs

Blowoffs should be sized and located to drain their influential reach of a pipeline in approximately 8 hours. The locations for blowoffs should be at low points along pipelines or at critical points for flushing, i.e., if it takes longer than 8 hours to drain, additional blowoffs should be added to the line. See **Table 3-1** for a more detailed listing of the design criteria.

The downstream receiving system (including erosion potential) should be evaluated as to its suitability to accept the maximum flow from all affecting blowoffs.

The blowoff discharge point should be located out of the traveled way and, if protruding aboveground, should be housed in an approved structure/enclosure. Where deemed appropriate by the Deputy City Engineer, blowoff stations should include a pumping chamber to permit further withdrawal of water below the normal blowoff surface elevation, and energy dissipaters at the discharge point.

A 2-inch blowoff assembly, as shown on SDRSD SDW-143 and SDW-146, is placed on water mains up to 12 inches in diameter. Larger pipe sizes require either a 4-inch or 6-inch blowoff assembly (SDRSD SDW-144, SDW-145 and SDW-146), depending on the size of the main and the distance between blowoffs. For mains 12 inches in diameter and smaller, blowoffs may be excluded if a fire hydrant is located near the low point. Blowoffs shall be installed at dead-ends (SDRSD SDW-106).

3.5.2.2 Side Outlets

A side outlet (future or current) is simply a specified diameter tee or outlet branching off the main transmission line to allow future branch connections without taking the main pipeline out of service. See **Table 3-1** for a more detailed listing of the criteria used for side outlets.

Outlets for future connections have a buried isolation valve followed by a short spool pipe and a blind flange or dished head.

3.5.2.3 Cutoff Walls

In unpaved areas with steep terrain, water mains and backfill shall be protected from erosion by cutoff walls (SDRSD WP-05) as follows:

- 20% - 35% slope Cutoff walls each 50 feet
- 35% - 45% slope Cutoff walls each 40 feet
- 45% - 55% slope Cutoff walls each 30 feet
- 55% - 65% slope Cutoff walls each 20 feet
- 65% - 100% slope Cutoff walls each 20 feet with cement-treated sand encasement around the pipe

Slopes greater than 100% require special design and approval.

3.5.2.4 Fire Hydrants

Fire hydrants must conform to AWWA C-503 and to the requirements of the Fire Department and the Public Utilities Department.

In general, fire hydrants are located at street intersections, but no more than 450 feet apart in single-family residential areas, no more than 350 feet apart in multifamily residential and commercial areas, and no more than 250 feet apart in industrial areas. Should application of the California Fire Code (CFC) Appendix C methodology result in spacing requirements greater than those shown above, the firm or Civil Engineer, in consultation with the fire department, City Project Manager may approve the CFC spacing requirements on a case-by-case basis following submittal of supporting calculations. In no case shall hydrants be spaced further apart than what is required by the CFC. Fire hydrants in the middle of blocks shall be located on lot lines. Fire hydrants are installed using the following criteria:

- When new water mains are extended in areas where fire hydrants are not needed for protection of structures, fire hydrants shall be installed at a spacing not to exceed 1,000 feet, as measured along the centerline of the main.

- For 8-inch or larger diameter dead-end mains, a maximum of two fire connections with either fire hydrants and/or fire services is allowed.
- For 8-inch or larger diameter mains when looped, two or more fire hydrants can be installed.
- No more than two fire hydrants (or fire services) are allowed on dead-end mains or out-of-service at any time.
- Fire hydrant flow on a private fire hydrant located off a fire service may be reduced per the Uniform Fire Code analysis, assuming a static pressure of 65 psi at the main line.

In general, when a water main is replaced by a parallel main, the fire hydrant is moved 3 feet in either direction from its original location. When the main is replaced in place, the fire hydrant is replaced in its original location.

Fire hydrants in residential areas must have one 4-inch port and one 2½-inch port. Fire hydrants in commercial and anticipated high fire demand areas (e.g., the downtown area, schools, hospitals, and heavy industrial areas) must have two 4-inch ports and one 2½-inch port. Alignment of fire hydrant ports must be in accordance with SDRSD SDW 104. Fire services connected to fire hydrants are typically 6-inch in diameter. The DESIGN CONSULTANT should check (on a case-by-case basis) if an 8-inch diameter fire service is necessary to supply such fire hydrants.

Fire hydrants placed in unprotected (unimproved) areas must have protective posts (SDRSD SDW-104 and WM-04) installed around them. Services to fire hydrants must be installed perpendicular to the water main, and may not be installed in cul-de-sacs.

Per SDRSD SDW-104 (fire hydrant locations), requirements for fire hydrant locations under different conditions are shown. Alternate locations require approval by the Senior Civil Engineer.

3.5.2.5 Fire Services

Fire service requirements are determined by the Fire Marshal. All fire services or private water mains must have valves installed at the main per SDRSD SDW-118 and have an approved backflow prevention device after it enters the property (see SDRSD SDW-120). Reduced pressure detector assembly devices are installed and include a factory installed detector meter assembly.

Fire service plans must show all existing onsite fire hydrants. The complete onsite water network must be approved by the Fire Department before a Fire Service Permit is issued.

When a water main is being replaced or relocated, existing unused fire services to fully developed lots may not be replaced or reconnected. Conversely, existing active fire services to vacant lots may be replaced or reconnected, unless a permitted building plan for the lot shows otherwise. Fire services must be replaced and reconnected in accordance with Section 306-15 of the City of San Diego Contract Documents (specifications).

3.5.2.6 Water Services

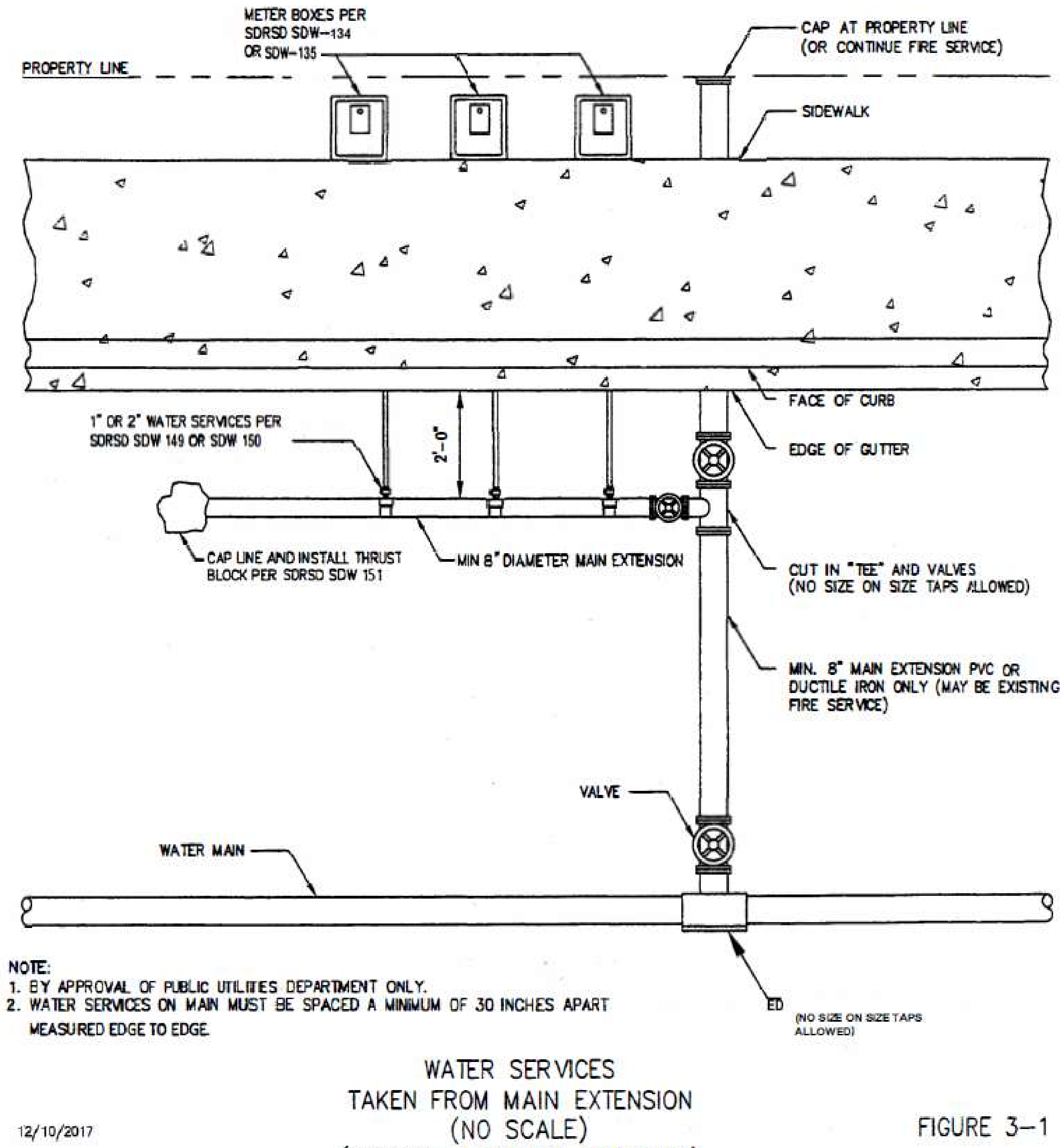
Water services must be 1-inch minimum size; 1½-inch and 3-inch services are not allowed. All water service connections to PVC pipe are made with a saddle for the following diameter services:

- 1-inch water services (SDRSD SDW-150) must be copper pipe. If the improvement plans do not state the type of material to be used, copper pipe is specified.
- 2-inch water services (SDRSD SDW-149) must be copper. If the improvement plans do not specify the type of material to be used, copper pipe is specified.
- 4-inch or larger services must be DI or PVC pipe and require an aboveground meter installation with bypass per SDRSD SDW-119 to be included on the improvement plans. Irrigation services are similar but do not require a bypass.

The City adheres to the requirements of the California Plumbing Code, which states that a pressure regulating valve must be furnished on any individual water service having a maximum pressure greater than 80 psi. This maximum pressure is commonly the static pressure. However, for pressure zones supplied by pumps, the pump shutoff pressure is the basis for determining the maximum static pressure at the water services.

Water services must be installed perpendicular to the water main and tapped not closer than 30 inches apart, measured edge to edge. Taps to the end of a capped pipe must be a minimum of 15 inches away from the cap. In high-density areas (apartments and condos) high traffic areas, and other locations where services are not allowed, water services may also be taken from a main extension (i.e., fire services as shown in **Figure 3-1**), subject to approval by the Public Utilities Department, to reduce the number of taps being made into the water main.

Size-on-size wet taps (6-inch to 6-inch, 8-inch to 8-inch, etc.) are not allowed. Size-on-size taps must be made with in-line "Tee" fittings.



WATER SERVICES
TAKEN FROM MAIN EXTENSION
(NO SCALE)
(SPECIAL APPROVAL REQUIRED)

FIGURE 3–1

When a water main is being replaced or relocated, the existing unused water services to fully developed lots may not be replaced or reconnected. Existing water services to vacant lots may not be replaced or reconnected unless a permitted building plan for the lot shows otherwise. In areas of anticipated urban redevelopment, existing water services serving vacant lots should be deleted from the drawings of replacement plans. To ensure proper credit for capacity for the property at the time of redevelopment, an adequate record of all services must be kept. Credit is not given for service renewal. The cost for reinstallation or new service is paid by the owner/developer. The DESIGN CONSULTANT should check that the latest drawings for the water services in the area are used. An existing plan showing the services to be deleted and their addresses should be sent to the Information and Application Services Division of the Development Services Department, Geographic Information Systems (GIS) Section.

Common water services serving two or more lots are not allowed unless the lots are under a maintenance association and a copy of the Covenants, Conditions, and Restrictions (CC&R) covering maintenance of the services and payment of the water bills is provided.

Water services should not cross lot lines unless CC&R (covering maintenance) is provided. When this is impractical, a private easement sufficient to maintain and repair the service must be dedicated to the lot benefiting from the service.

Encroachment water services may be allowed for single family residential units when all the following conditions are met:

1. Installation of a fire hydrant is not warranted (per Fire Department)
2. The lot does not front on a public main
3. Ownership of the adjacent lot(s) does not belong to the subject lot owner
4. A temporary service agreement is recorded against the subject lot

Duplexes and higher density developments without frontage on an existing water main are required to extend the main to their own frontage if (a) there is a possibility of further main extensions, or (b) there are other lots that could connect to the new main at a later date.

Water services may not be tapped into easement mains except where the easement is 24 feet wide and is a paved, traveled way.

3.5.2.7 Water Meters

Water meters must be located in the public right-of-way (SDRSD WS-03) or in an adequate easement. All new water services shall be located outside parking areas, driveways, or other traveled ways, with the following exception: if the service already exists, or sufficient area is not available outside of driveways to relocate the service (cul-de-sacs, etc.), the installation of the water meter must be according to **Figure 3-2** with a heavy traffic meter box.

Water meters 2 inches in size and smaller, must be installed in accordance with all current regional and City of San Diego directives and standard drawings (SDRSD SDW-134, 135, 136, 137, 149, 150, WS-03). See **Figure 3-3**. Note that polymer concrete meter boxes are used in lieu of the standard concrete meter boxes.

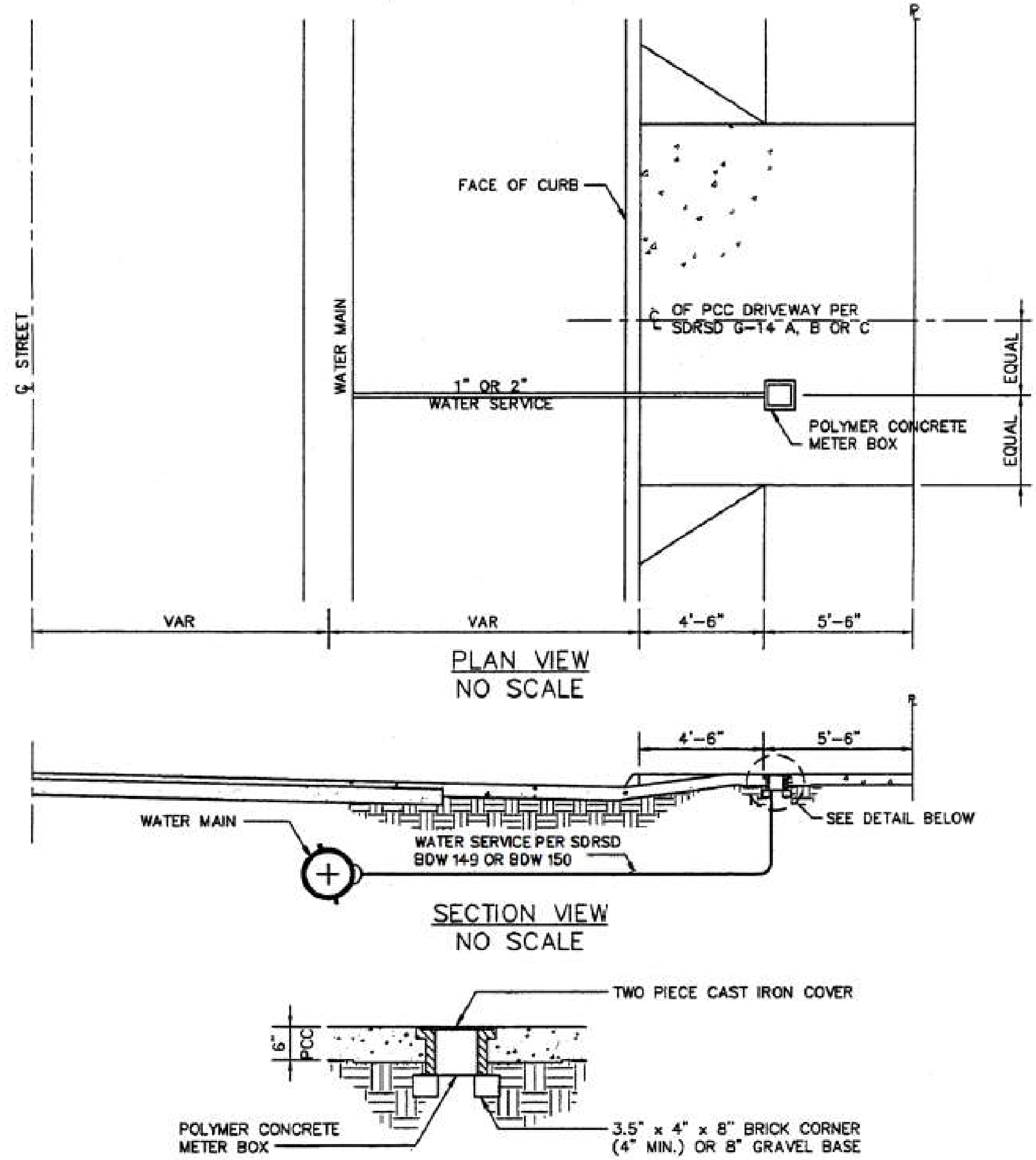
Manifolded 2-inch meters must be located in the same vault (SDRSD SDW-114). Manifolded meters must have read holes with caps and chains situated over each meter (SDRSD SDW-115). When services and meters are to be manifolded, reference the appropriate standard drawing or a detail must be included on the drawings. Meters may not be manifolded on the side of the meters facing the water main. Manifolded meters must meet all flow requirements.

A detail similar to SDRSD SDW-119 is required on improvement plans for meters 3 inches and larger. All meters 3 inches in size and larger require backflow devices. These meters must be built in an aboveground installation with reinforced concrete slab and protective fence.

Construction meters are assembled as shown in **Figure 3-4** for meters 3 inches in size and larger. Smaller meters may be used with prior Public Utilities Department approval of meter installation details.

All details for meter installation for meters larger than 2 inches must be approved by the Public Utilities Department prior to plan approval by the Development Services Department. Written approval, either on the drawings or by memorandum (referring to I.O.#, drawing number and development title) is required.

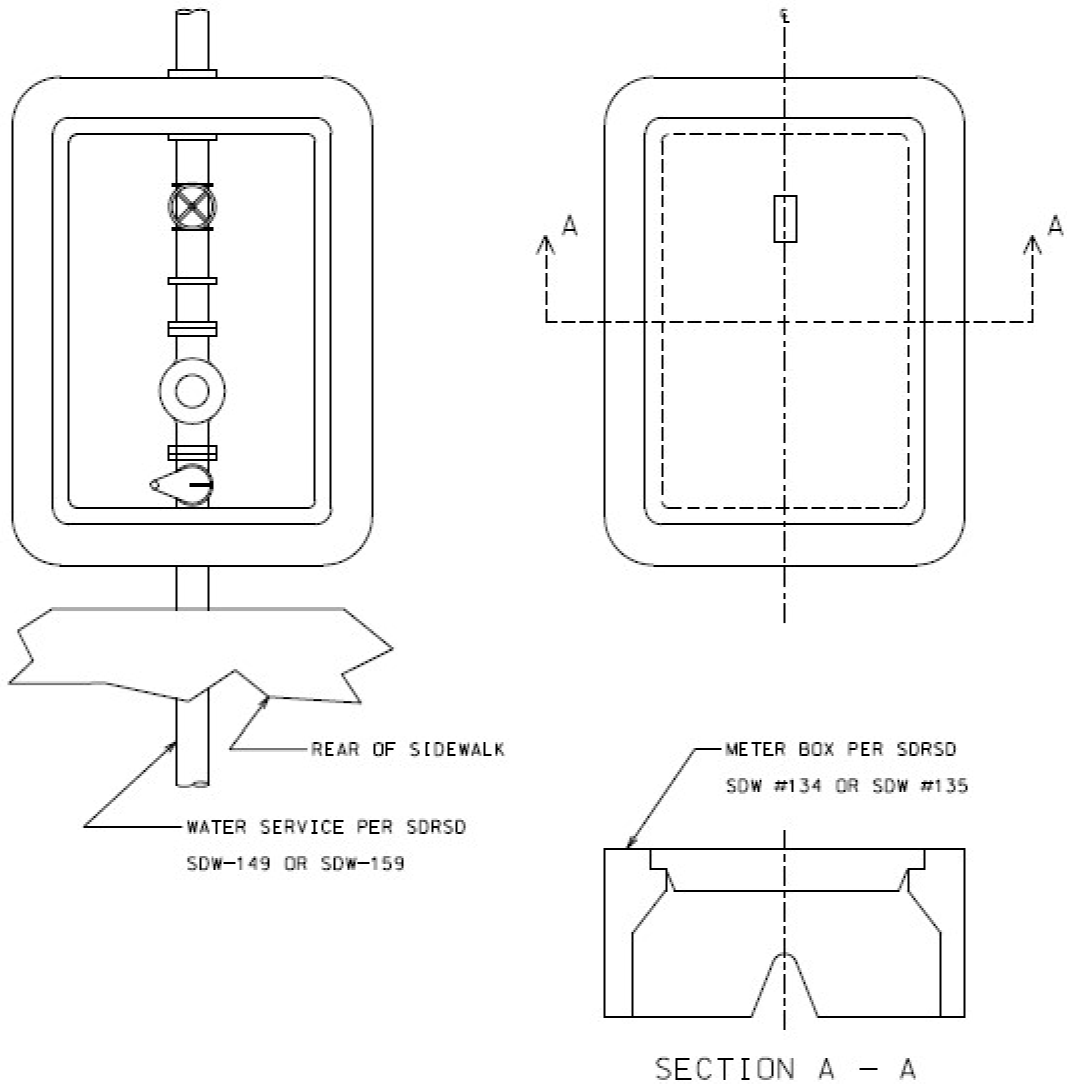
Requirements for backflow prevention must be in accordance with Public Utilities Department standards, and all details must be approved by the Public Utilities Department prior to construction.



12/10/2017

WATER METER IN DRIVEWAY
(SPECIAL APPROVAL REQUIRED)

FIGURE 3–2



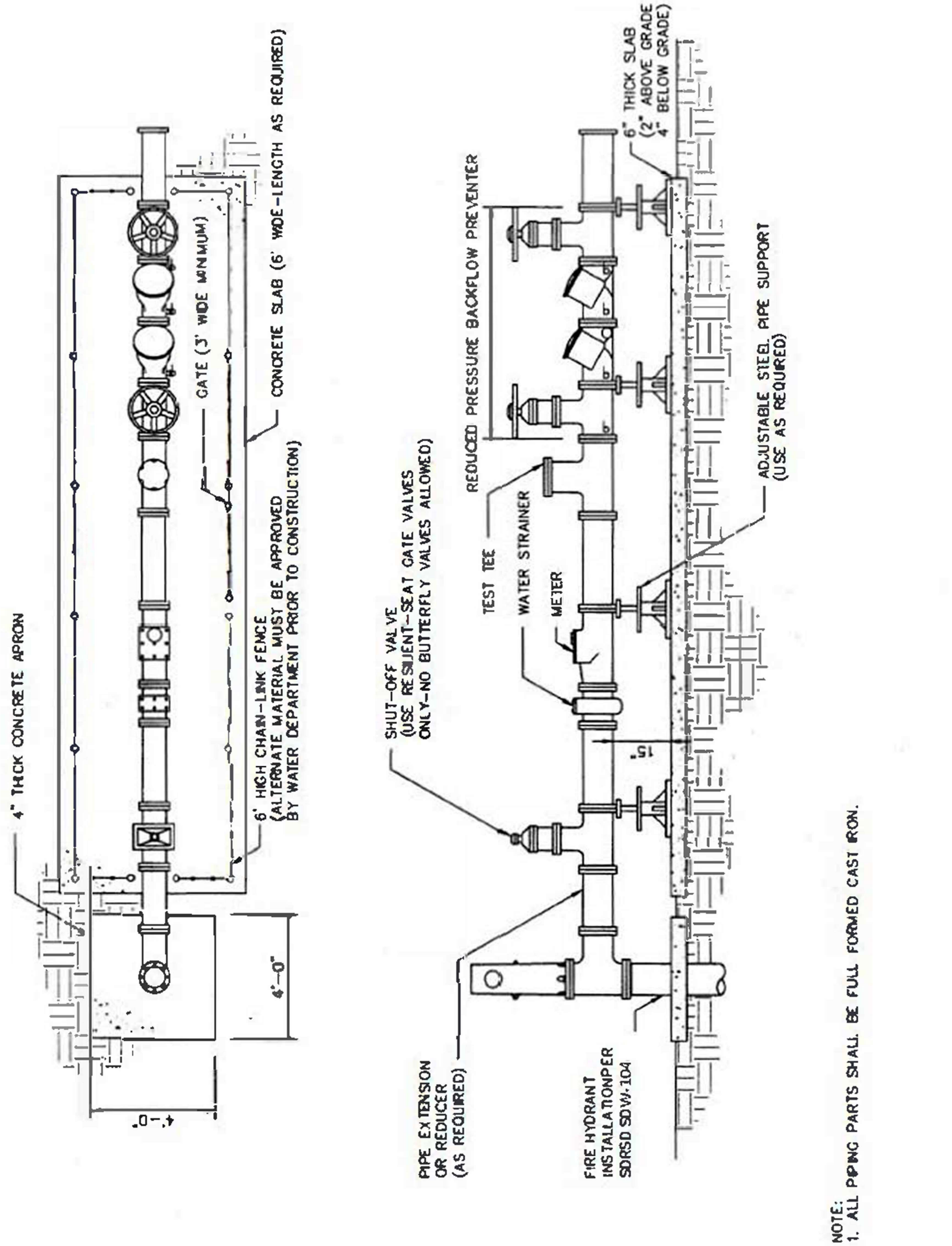
NOTE:

1. ALL METER INSTALALTIONSSHALL BE APPROVED BY WATER DEPARTMENT METER SHOP.
2. FOR LOCATION OF METER BOX. SEE SDRAS WS-03.
3. METER BOXES LOCATED BEHIND SIDEWALK MUST BE INSIDE EASEMENTS.

WATER SERVICE 2" AND SMALLER

4/1/2019

FIGURE 3-3



CONSTRUCTION METER — 3" METER AND LARGER

FIGURE 3-4

3.5.3 Appurtenance Structures

3.5.3.1 Access Manholes

Size-on-size access manholes (SDRSD SDW-103) are required on water mains 20, 24, and 30 inches in diameter. 36-inch access manholes are required on water mains 36 inches in diameter and larger. The maximum spacing between access manholes shall be 1,600 feet. Access manholes and air valves should be combined if practical.

In general, full structures are located at approximately 1,600-foot intervals in developed areas and at approximately 3,200-foot intervals in undeveloped areas, with the partial structures located at the intermediate points between the full structures. In other words, there is an access structure approximately every 1,600 feet, but they alternate between a full structure and a partial structure in undeveloped areas. Actual access structure spacing depends on the topography along the pipeline. Proposed locations for the access structure are approved by the Public Utilities Department. See **Table 3-1** for a more detailed listing of the criteria used for the access structures.

3.5.3.2 Sampling for Water Quality

A 1-inch service should be tapped into the water line to enable sampling of the water to test for water quality. A minimum of one sample station shall be installed per pressure zone or as specified by Water Production Superintendent. A sample station shall be installed if a new pressure zone is created. It is important that the sample stations are connected directly to the main so that water quality results are representative of the water quality within the main. The City should avoid the connection of sample stations to service lines. Also, when installing sample station, it is important to try and direct water flow from the station to permeable surfaces to avoid runoff to the storm drain system. Projects replacing mains where sample stations are installed shall reconnect the service to the main when work is complete. Sample stations shall be installed in accordant to the City's Standard Drawings.

Table 3-1
Appurtenance Criteria

Description	Criteria
A. General Appurtenance Design Criteria	
1. Consistency between design packages	Be consistent with overall project concepts for air valves, blowoffs, and manholes.
2. Standard engineering practice	Prepare the appurtenance designs in accordance with common standard engineering practices and industry standards, City of San Diego standard drawings, and per these guidelines and standards.

Description	Criteria
B. Air Valves	
1. Valve types	a. Air release valves b. Vacuum valves c. Combination air/vac valves Combination valves are the most common valve type proposed.
2. Valve placement	a. Place air valves at all high points (combination valve). b. Place air valves at grade breaks on steep slopes (combination valve). c. Place air valves on long downward sloping sections (air release or combination).
3. Valve size	Size air valves as noted in **section 3.5.1** and per manufacturer's recommendations.
4. Valve number	Required valve capacity can be made up from a combination of smaller, less expensive valves.
5. Valve enclosure	Air vacuum valves are located aboveground in their own enclosures.
6. Pressure class	The valve pressure class to match the pressure class of the adjacent pipe.
7. Isolation valve	Each air valve has a separate isolation valve to allow removal under pressure.
C. Blowoffs	
1. Blowoff types	Major blowoff - Located at key drainage discharge points to be used for initial blowoff. Minor blowoffs - Located at low spots to drain off small residual amounts of water.
2. Blowoff placement	a. Place blowoffs at all low points. b. Place blowoffs at appropriate drainage crossings.
3. Blowoff sizing	Size blowoffs as noted below: a. Major blowoffs - 24 inch diameter pipe or larger. b. Size major blowoffs (4-inch minimum) to drain the pipeline in 8 hours) c. Minor blowoffs - 12 inch diameter pipe or smaller (2-inch minimum blowoff diameter).
4. Energy dissipation	If blowoff water is discharged into open ditches or other waterways, an energy dissipation system is to be included with the discharge pipe. Design dissipation systems to effectively integrate with City streets, roadside ditches or waterways as applicable.

Description	Criteria
5. Vault	A vault for the blowoff is not required. All elements (except the energy dissipation) can be buried.
6. Pressure Class	The pressure class for all piping, valves, and fittings shall match the pressure class of the adjacent pipe.
7. Pipe connection	The main pipe connection to be an inverted or tangential tee with flange sized to match blowoff pipe.
D. Line Valve	
1. Valve size and type	Match pipeline diameter; butterfly type valve unless recommended otherwise.
2. Valve placement	a. As recommended by DESIGN CONSULTANT and approved by the City Project Manager. b. Locate valves at 1/2 mile maximum spacing for transmission mains.
3. Bypass piping system	Provide a bypass piping system with valving for the mainline valve if appropriate.
4. Valve actuation	Manual actuator. Provide 2-inch operating nut; valve actuator gears to be sized to close the valve within the acceptable surge closure time.
5. Valve vault	A valve vault to be provided at the mainline valve for plug valves. Butterfly valves are buried unless the DESIGN ENGINEER prepares a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document.
6. Pressure class	The valve pressure class to match the pressure class of the adjacent pipe.
7. Thrust restraint	Provide thrust restraint.
E. Outlets	
1. Outlet type	Tee with isolation valve and blind flange or bumped head.
2. Location	As required by Public Utilities Department
3. Outlet size	As required by Public Utilities Department
F. Access Manholes	
1. Manhole types	a. Manhole with access (includes manhole and access housing). b. Manhole - buried (direct buried).

Description	Criteria
2. Manhole access locations	a. Manhole access to be provided at approximately 1600-foot intervals. b. Alternate manhole with access structures and manhole-buried (in undeveloped areas). c. Place manhole with access at all crossing locations that are difficult to access from the surface (i.e., in casing or concrete encasement). d. Do not place access manholes over steeply sloping sections of pipe where an entering worker would not have safe footing.
3. Manhole size on water mains 36-inches in diameter and larger.	36-inch diameter manhole, vertical tee with flange and blind flange (hinged for the manhole with access).
4. Air valves	Locate air valves (where called out at a manhole) on the blind flange.
5. Pressure petcock	Provide a pressure petcock where appropriate to check line pressure.
6. Pressure class	The manhole pipe and fitting pressure class to match the pressure class of the adjacent pipe.
7. Sump pit	Provide a dewatering sump pit in the manhole access structures.

3.6 Fittings

3.6.1 Iron Fittings

Ductile iron (DI) fittings with double-thick cement linings are used for DI and PVC pipe and conform to AWWA C-110 C-111 and C-153. All materials should be in accordance with the City of San Diego's Approved Materials List.

Corrosion control for iron fittings shall be in accordance with **Chapter 7**.

The only acceptable joint for PVC pressure class water pipe-to-fitting connections is the mechanical joint (AWWA C-110 and C-111). Push-on joints and solvent cement fittings are not acceptable.

Crosses and tees are the same size in the run (straight) directions.

Use 11¼°, 22½° 45°, and 90° bends which are stocked locally.

3.6.2 Steel Fittings

Steel fittings must comply with ANSI/AWWA C208. Flanges must comply with ANSI/AWWA C207. Flanges are selected in accordance with design pressure, test pressure, surge pressure, and the drilling pattern of the adjoining equipment flange (i.e., valves).

Corrosion control for steel fittings shall be in accordance with **Chapter 7**.

Fittings for welded steel pipe are designed in accordance with standard practice as stated in AWWA M11 and other applicable industry standards. Bolt holes on flanges must straddle the vertical centerline. Welded steel pipe elbows are as follows: 0 to 30 degrees - two-piece; 30 to 45 degrees - three-piece; 45 to 60 degrees - four-piece; and 60 to 90 degrees - five-piece. Joints for fittings are welded or flanged.

Reinforcement and wall thicknesses of steel fittings must conform to AWWA M11 and other applicable industry standards.

Field welding of all steel pipe must be in accordance with AWWA C-206 and the following City standard drawings:

SDW-101 Typical Outlet for SCRW Pipe Steel Pipe and Pipe Specials
SDW-103 Access Manhole
SDW-108 Field Welded Joints
SDW-111 Spigot Ring and Gasket Joint for Welded Steel Pipe
SDW-139 Split Butt Strap

3.6.3 PVC Fittings

PVC pipe may be joined by a bell-and-spigot push-on joint in large diameters for straight segments. In the push-on method, either (1) a rubber gasket set in a groove in the bell end or (2) a double bell coupling provides the necessary seal.

3.7 Joints for Steel Transmission Lines

Pipe joints for steel pipe are flanged, grooved, or plain end, depending on the pipe diameter, longitudinal force, flexibility requirements, the type of adjoining end, and the need to disassemble the joint. When lap-welded slip joints (commonly referred to as bell and spigot joints) are used, joint preparation must be in accordance with ANSI/AWWA C200 and the specifications must require that the pipe bell be shaped with an expanding press or by moving the pipe axially over a die. Shaping the pipe bell using offset rollers which move around the pipe end is not permitted. Joints in small-diameter pipe (less than 24 inches) associated with fittings must be welded, flanged, or grooved end. Rubber gasketed joints may be used for special design conditions.

Depending on the longitudinal force due to thrust and the effect of temperature, large-diameter transmission pipe joints may be lap welded or butt welded. The procedure for design of the joint to resist longitudinal forces is discussed in **subsection 3.9**. Butt strap joints may be necessary on closure sections or to connect to existing sections of the pipeline.

Closure joints as recommended by AWWA M11 section 8.6 should be included in the design of steel pipelines to minimize the effect of contraction due to changes in temperature.

3.7.1 Joint Welds

Joint welds may be lap welds, butt welds, or butt strap welds.

3.7.1.1 Lap Welds

The allowable force on a lap weld is computed by the DESIGN CONSULTANT. Note that the AWWA M11 procedure assumes minimal space between the bell and spigot surfaces. This space and the resulting eccentricity must be in accordance with the requirements of AWWA C200.

If the actual force is greater than the allowable force, three options should be considered:

1. Increase the wall thickness.
2. Use a double lap weld (one weld inside and one weld outside the pipe) instead of a single lap weld with a seal weld.
3. Use a butt weld instead of a lap weld.

3.7.1.2 Butt Joint Welds

Full penetration butt joint welds with appropriate inspection and nondestructive testing can resist a longitudinal force equal to the force resisted by the pipe wall.

3.7.1.3 Butt Strap Welds

The allowable force on a butt strap weld is computed in accordance with the procedure used for lap welds.

3.7.1.4 Seismic Design

See **Chapter 8, paragraphs 8.4.2 and 8.4.3** for design guidelines for steel pipes where they cross active faults, liquefaction or landslide hazards. Depending on pipeline configuration, these guidelines may control the pipe wall thickness, welded joint designs and other construction details for steel pipelines used in these situations.

When a new pipeline must be routed across an active fault (such as the Rose Canyon fault), the pipeline should be designed with recognition that surface faulting may occur. Fault offset hazards to be considered include the primary fault offset, and the zone in which secondary fault offset might occur. An acceptable level of fault-offset displacement is that based on a 16% chance of exceedance at the particular pipe location, given that a characteristic earthquake on the fault occurs. Lacking site-specific data, it may be reasonable to design a pipe to accommodate a fault offset of the Rose Canyon fault for 5 feet of right-lateral movement, accompanied by 0.5 feet of vertical movement.

Pipelines that traverse the liquefaction zones should either be relocated, or if this is not feasible, designed in accordance with **Section 8.4**.

Utilities and pipelines penetrating basement walls are especially vulnerable. Measures should be taken to provide adequate flexibility and / or ductility at such penetrations. The potential for settlement at a site should be investigated by the geotechnical engineer concurrently with the investigation for liquefaction.

3.8 Bedding, Backfill, Cover and Surface Restoration

3.8.1 Bedding

When unstable soils are encountered and over-excavation is required, foundation stabilization material must be specified for use at the base of the trench. The pipe zone is considered to include the full width of the excavated trench from the bottom of the trench to a point at least 12 inches above the top outside surface of the barrel of the pipe. The minimum depth of bedding material beneath the pipe should be selected based on the expected unevenness of the trench bottom and the diameter of the pipe. Typically 6 inches is adequate; however, the DESIGN CONSULTANT selects the appropriate thickness to be used. Particular attention should be given to the area of the pipe zone from the invert to the centerline of the pipe to ensure that firm support is obtained to prevent any pipe lateral movement during final backfill of the pipe zone. Using controlled low strength material (CLSM) in this area can mitigate this concern. Hand tamping with approved tamping bars, supplemented by compacting with mechanical tamping equipment, is allowed.

3.8.2 Trench Backfill

The DESIGN CONSULTANT shall review the trench backfill provisions in the in the latest standard specifications for Public Works Construction "GREENBOOK" and the WHITEBOOK – Standard Specifications for the City of San Diego.

3.8.3 Cover

The standard depth of cover on water distribution mains, up to and including 16-inches in diameter, is 3 to 5 feet. Transmission water mains (i.e., 16-inches in diameter and larger) require a minimum of 5 feet of cover to the top of the pipe. Less cover may be acceptable when supported with engineering calculations and approved by the Public Utilities Department. The maximum depth of cover for distribution and transmission mains is 8 feet. Less than 3 feet or more than 8 feet of cover require loading, deflection, and safety calculations. When supported by calculations, special design must be submitted to the Public Utilities Department for approval.

3.8.4 Surface Restoration

The DESIGN CONSULTANT refers to City of San Diego standard drawings. Surface restoration is required to match or exceed existing conditions according to the requirements of each agency with jurisdiction in the project area.

3.9 Pipe Design

All pipes are designed by the DESIGN CONSULTANT. Steel pipe specials and fittings may be designed by the pipe manufacturer.

3.9.1 External Loads

External loads on a pipeline include dead loads (the weight of the soil and any improvements constructed above the pipe), live loads (caused by construction traffic and/or vehicular traffic traveling above the pipe), vacuum pressures, and pressures from groundwater.

3.9.1.1 Dead Loads

Dead loads attributable to the weight of the backfill are computed in accordance with AWWA standards as per specific pipe material using the compacted soil weight determined in the geotechnical investigation. Dead loads caused by improvements constructed near or above the pipeline are computed by standard geotechnical engineering practices.

3.9.1.2 Live Loads

Live loads caused by standard highway loadings (HS-20) or railroad loadings (E-80) are computed in accordance with applicable AWWA standards. Live loads from heavy construction vehicles should be analyzed. Construction loads may be present when the pipeline has no or only minimal cover.

3.9.1.3 Vacuum Pressure and Groundwater

The DESIGN CONSULTANT computes the allowable internal vacuum pressure using the formulas described in AWWA standards for buried pipeline. For non-buried pipeline (e.g., above grade crossings or pipelines in casings without control density fill or similar situations), use the applicable AWWA standards. If the calculations indicate that the backfilled pipe could be collapsed by a full vacuum, the DESIGN CONSULTANT must notify the City Project Manager in writing. The pipe must be designed to resist external pressure and uplift from groundwater when such conditions exist.

3.9.2 Internal Pressure

3.9.2.1 Operating Pressure

Operating pressure is typically determined from the hydraulic grade line for the facility under static hydraulic conditions. However, if conditions warrant (e.g., for the discharge line from a pumping station), the DESIGN CONSULTANT investigates the combination of the operating and surge pressures and designs the facility accordingly. When not included in the pre-design study, the City Project Manager provides both the static and operating hydraulic grade lines, except where the operating hydraulic grade line is to be determined from pump selection by the DESIGN CONSULTANT. Pressure calculations reflect the difference in elevation between the hydraulic grade line and the centerline of the pipe.

3.9.2.2 Field Test Pressure

Since field air pressure tests of all welded pipe joints and field hydrostatic pressure tests of a completed pipeline are conducted after pipelines are installed, the DESIGN CONSULTANT incorporates those factors into the pipeline design. The hydrostatic test pressure is typically equal to the maximum anticipated surge pressure, the pump shutoff pressure (where applicable), or 1.25 times the operating pressure, whichever is greater. The hydrostatic test pressure must not produce a hoop stress in the pipe wall exceeding that recommended by AWWA M11. Valves (body and seat) must not be subjected to test pressures greater than manufacturer's recommendations. In some cases, this may require an increase in the valve pressure class.

3.9.2.3 Surge Pressure

See **subsection 3.10, Hydraulic and Surge Analysis**.

3.9.3 Design Procedures

The design procedures to determine wall thickness consider the following conditions:

- Material type
- Minimum thickness for handling
- External loads
- Internal design pressure
- Internal surge pressure
- Maximum allowable deflection
- Longitudinal thrust forces caused by valves or changes in alignment
- Longitudinal forces resulting from changes in temperature

- Combined stress (hoop and longitudinal)

The pipe wall thickness selected must be the greater of the thicknesses computed for the loading conditions listed above. The design procedure at the joints is discussed in **subsection 3.11, Thrust Restraint**.

3.9.3.1 Minimum Wall Thickness for Handling

The minimum thickness for handling is calculated by the DESIGN CONSULTANT and as specified by AWWA standards.

3.9.3.2 Design for External Loads

Two conditions for external loads are considered:

- Live load plus dead load with full depth of cover.
- Live load plus dead load with minimal cover. The minimal cover used in the calculation must be coordinated with the specifications. The specifications must state the amount of cover required prior to operating heavy equipment above the pipe. The live loads must represent the heaviest equipment expected for use in compaction or hauling material above the pipe.

3.9.3.3 Design for Internal Pressure

The minimum wall thickness for internal pressure is determined by using AWWA standards. The allowable hoop stress at design pressure for cement mortar-lined and -coated steel pipe is limited to manufacturer's recommendations to minimize the potential for cracking of the coating as the pipe expands under pressure.

3.9.3.4 Design for Internal Surge Pressure

Minimum wall thickness for surge pressure is determined by using AWWA standards.

3.9.3.5 Thrust Forces Caused by Valves or Changes in Alignment

Longitudinal thrust force is calculated by using the method described in AWWA standards and as required by these Guidelines. Closed valves create the full "P x A" (pressure times area) force. This force may cause tension or compression in the pipe wall, depending on the location of the resisting forces. Bends in the alignment create forces as shown in AWWA standards.

3.9.3.6 Longitudinal Force Due to Change in Temperature

When pipe joints are welded, the temperature of the steel is probably higher than when the pipe is in service and conveying water. The stress in the pipe wall is a function of a change in temperature. The specifications must state the maximum allowable temperature of the steel when the closure joints are welded. The minimum temperature of the steel shall be considered 50°F. The force due to a drop in temperature, between the time the joints are welded and the pipe is placed in service, always creates tension in the pipe wall.

3.9.3.7 Longitudinal Force Due to Effect of Poisson's Ratio

Should the pipe be restrained from contracting, the maximum magnitude of the longitudinal stress induced by internal pressure is given by the formula:

Longitudinal Stress = (Hoop Stress) x Poisson's Ratio

For steel, Poisson's ratio is assumed to be 0.303. The longitudinal stress resulting from the effect of Poisson's ratio should be added to the stress caused by any change in temperature. The DESIGN CONSULTANT is advised that situations may occur where the total longitudinal stress includes the temperature stress, Poisson’s stress, and bulkhead thrust stresses.

3.9.3.8 Earthquake Loads

See **Chapter 8, Section 8.4** for design guidelines for buried pipes under earthquake loading.

3.9.3.9 PVC Pipes

The minimum pipe rating shall be DR18, Class 235, unless otherwise shown on the plans. For Design-Build contracts, the operating pressure, depth of cover, soil and groundwater conditions determine the class of pipe required in conformance with the applicable AWWA requirements for the type of pipe selected.

3.9.3.10 Ductile Iron Pipes

The minimum pipe rating shall be Class 150, unless otherwise shown on the plans. For Design-Build contracts, the operating pressure, depth of cover, soil and groundwater conditions determine the class of pipe required in conformance with the applicable AWWA requirements for the type of pipe selected.

3.10 Hydraulic and Surge Analysis

3.10.1 Hydraulic Analysis

The City Project Manager supplies the DESIGN CONSULTANT with available information regarding system and project hydraulics. The information covers design capacity, sizing criteria, system head losses, and design assumptions. The DESIGN CONSULTANT reviews this information for completeness and adequacy.

Typically, transmission pipelines are designed using Hazen-Williams equation with C = 135. Calculations should include minor losses for valves and bends on the pipeline. For transmission lines, typical maximum pipeline velocity is 8 fps for 60-inch and larger pipeline, and 5 fps for pipelines smaller than 60-inch diameter.

Distribution water mains (16 inches in diameter and smaller) should be designed to meet the pressure criteria and required fire flow plus maximum day demand at a maximum velocity of 15fps. Calculations should be based on C = 120 in the Hazen-Williams equation. In lieu of specific calculations for minor losses, calculated head losses are increased by 10% for fittings and other minor losses.

The DESIGN CONSULTANT shall request any additional information necessary for the complete design before beginning the final design. The City Project Manager is notified of any conflicts or necessary changes that may affect the validity or accuracy of the hydraulic information provided.

The DESIGN CONSULTANT prepares the final design hydraulic calculations to verify that the final design is in conformance with the information provided.

3.10.2 Surge Analysis

A surge analysis is normally performed by the DESIGN CONSULTANT in the early design stages. This surge analysis is considered preliminary because certain assumptions must be made to perform the surge analysis. As the final design progresses, some of those assumptions may require modification and the surge analysis must be updated.

The DESIGN CONSULTANT reviews the surge analysis information and coordinates with other designers responsible for pumping stations and reservoirs. Should additional information be necessary or should the assumptions made in performing the surge analysis be modified by final design decisions, the DESIGN CONSULTANT must notify the Senior Civil Engineer of the need for additional information and/or the need to update the surge analysis.

The pipeline DESIGN CONSULTANT verifies that the final design is consistent with the information provided with the surge analysis.

3.11 Thrust Restraint

Thrust at all bends, tees, dead-ends, and reducers must be resisted by thrust blocks, in accordance with SDRSD SDW-151, or a combination of restrained joints and thrust blocks.

The use of concrete anchor blocks for restraining upward thrust is avoided. Upward thrust is restrained by the use of ductile iron or PVC pipe with restrained joints.

Concrete used for thrust blocks must conform to section 201-1.1.2 of the Standard Specifications for Public Works Construction.

Thrust blocks for 16-inch diameter and larger mains are by special design. Calculations must be accompanied by a soil bearing test from a soils engineer. However, in the absence of a qualified soils analysis, a maximum soils bearing capacity of 1,000 psf may be used.

Calculations for an unusual anchorage condition must be submitted to the Senior Civil Engineer for approval. This submittal is accompanied by soils bearing capacity data from a qualified soils engineer. Calculations must be signed and sealed by a California registered civil engineer.

3.11.1 Thrust Restraint Systems

Thrust forces occur at changes in pipeline size or direction such as at elbows, tees, reducers, increasers, caps, plugs, closed valves, etc. Transient pressures caused by water hammer or pump shutoff head should be considered in conjunction with hydrostatic thrust forces.

When buried pressurized pipelines use push-on type bell and spigot joints that can separate (unrestrained joints), external forces are required to resist thrust. These forces could be provided directly by concrete thrust blocking, concrete thrust collars, anchorage to a structure, or by indirectly transmitting the forces to adjacent pipe sections by "restraining" the connecting joints. The forces in the adjacent pipe sections are then transmitted to the surrounding soil by a combination of soil friction and lateral soil pressure.

For large pipe diameters, welded joints are preferred. Therefore, the following discussion focuses on thrust restraint design for a fully restrained joint system. If external restraining forces are necessary, they must be designed using the methods described in AWWA standards.

Unrestrained joint systems are not used for Water transmission pipelines because of the high pressures and large pipe diameters. The concept of restrained joint length is applicable to gasketed joint systems. DESIGN CONSULTANTS must design the complete thrust restraint system as part of the overall project design. A performance specification that requires the pipe manufacturer or contractor to submit a thrust restraint design for review is not acceptable.

3.11.1.1 Restraining Flexible Couplings

Flexible (sleeve) couplings transmit only minor tension and shear forces across pipe joints.

A restraining harness is required for full axial thrust force and must be designed in accordance with AWWA standards.

Where sleeved couplings are used within the required restrained joint length in either direction from an elbow, the following are required:

1. Anchor on each side of each sleeved coupling for the full resultant thrust force
2. Anchor on each side of the elbow for the full resultant thrust force

3.11.1.2 Restraining Fittings

With restrained joint systems, the thrust forces resulting from fittings cause longitudinal stresses in the pipeline. These stresses are most often tensile, but can under special circumstances be compressive.

3.11.1.3 Restraining Valves and Reducers

The requirements for fittings described in the preceding section also apply to valves and reducers. Additionally, valves and reducers can cause tension or compression in the pipe wall.

For a reducer within a system using welded joints, the DESIGN CONSULTANT should also recognize that the unbalanced thrust force can be transmitted upstream or downstream. In this case, the pipe joint system and restraining system is designed to transmit the force in either direction.

When cutoff (seep) rings are embedded in the wall of the structure, they are designed to transmit the full thrust load unless provision is made to prevent such load transfer. For maintenance, valves often require a flexible coupling nearby. If a harness is provided across the flexible coupling, it must not be considered to carry compressive forces.

3.12 Maintenance

Adequate access manholes and space must be provided for maintenance personnel and equipment. The recommended spacing for these structures is discussed in **paragraph 3.5.3, Appurtenant Structures**.

3.13 Special Crossings

3.13.1 Coordination with Agencies

The DESIGN CONSULTANT coordinates with the following agencies, as applicable to the project, to determine any requirements to be included in the Contract Documents for design or construction at special crossings. The DESIGN CONSULTANT verifies permit requirements with the agency prior to submittal.

- Railroads: Metropolitan Transit System (MTS) or North County Transit District
- State Highways: Caltrans

- Streets: Local agencies
- Flood Control: City of San Diego
- Others: Utility companies with permitting requirements for crossings

3.13.1.1 Contract Drawings

1. Agency Standard Details

Any standard details provided by a permitting agency for construction near its facility are included in the Contract Documents in the appropriate permitting section of the specifications, along with specific permit requirements from the agency.

2. Crossing Details

Plan and profile views of all major crossings are provided in the civil drawing section of the contract drawings. Where a similar crossing is used at different locations (such as some highway crossings); only one detail shall be produced. All crossing locations to which the detail applies should be noted on the detail.

Conform to the design requirements of local agencies, including providing the necessary scour, geotechnical, and hydraulic data and analysis.

Unless otherwise approved, provide an access manhole structure/assembly with any special crossing in which the pipeline is tunneled or cannot be easily excavated. Examples include interstate freeway crossings, major drainage way crossings, railroad crossings, and major roadway crossings.

3.13.2 Bridge Crossings

This section provides design requirements, acceptable materials, and special items for water mains traversing bridge crossings. Corrosion control requirements are found in **Chapter 7**.

3.13.2.1 Permits

A City Encroachment Permit is not required to install Public Utilities Department water pipelines or other utilities on City-owned bridges. However, compliance with these Guidelines for pipeline installation on bridges is required. Coordination between the bridge design engineer and the Public Utilities Department is essential. Pre-design meetings are arranged prior to making any final design recommendation on a bridge project.

A Caltrans Encroachment Permit is required to install any pipeline or utility on a Caltrans bridge. This requires conformance with the requirements of the latest edition of the "Caltrans Manual of Encroachment Permits, Encroachments on Bridges."

3.13.2.2 Location

Provide manhole access, materials, and equipment for operation, inspection, maintenance, and repair of all pipelines and appurtenances. See bridge-type details (**Figures 3-5 through 3-8**) for notes on access requirements.

Pipelines and appurtenances must be located under the shoulder or sidewalk area (i.e., between the exterior and first girder; **Figures 3-7 and 3-10**). In box girder type bridges, no other utilities may be installed in the same cell as water and sewer pipelines and appurtenances.

Where adequate access to utilities can be provided for maintenance, pipelines and appurtenances may not be exposed to view.

Consider the use of alternative pipeline locations and configurations, such as routing the pipeline around the bridge or using multiple smaller dimension pipelines, to improve the aesthetic and/or adapt to the physical limitations of the installation.

Use proven and tested engineering and design and construction standards to increase reliability and maintainability and to decrease repair frequency.

Provide piping materials suitable for point support and direct, not buried, exposure.

Provide pressure class and wall thicknesses in excess of that required for the design pressure to provide additional pipe strength and sacrificial wall material (i.e., use a safety factor of 2.25 instead of 2.0; design for pressures 50 to 100 psi greater than anticipated).

Size pipeline facilities in bridges shall accommodate future needs or provide casing to facilitate future expansion. Where required for redundancy, provide multiple pipelines.

During construction of closed cell-type bridges (**Figure 3-5**) with an enclosed ductile iron pipe system, one additional length of DI must be left in each cell. Seal both ends of extra pipe lengths to prevent debris accumulation inside pipe.

Shutoff valves on water mains must be installed at each end of the bridge structure.

Provide expansion joints to accommodate relative expansion and contraction between the bridge and the pipeline, typically resulting from thermal effects. Since this type of movement is only in the axial direction, angular or translational movement expansion joints must be anchored at one location, with the remaining supports allowing axial movement. Pipelines must be anchored at all bends, valves, tees, and other thrust producing fittings, with expansion joints located appropriately.

Provide flexible joints to accommodate differential settlement, rotation, and axial movement between adjacent sections of pipeline where such movement is expected. This type of movement is expected at the junction between bridge and abutment, between abutment and embankment, and between soil masses with differing compaction, loading, and settlement characteristics.

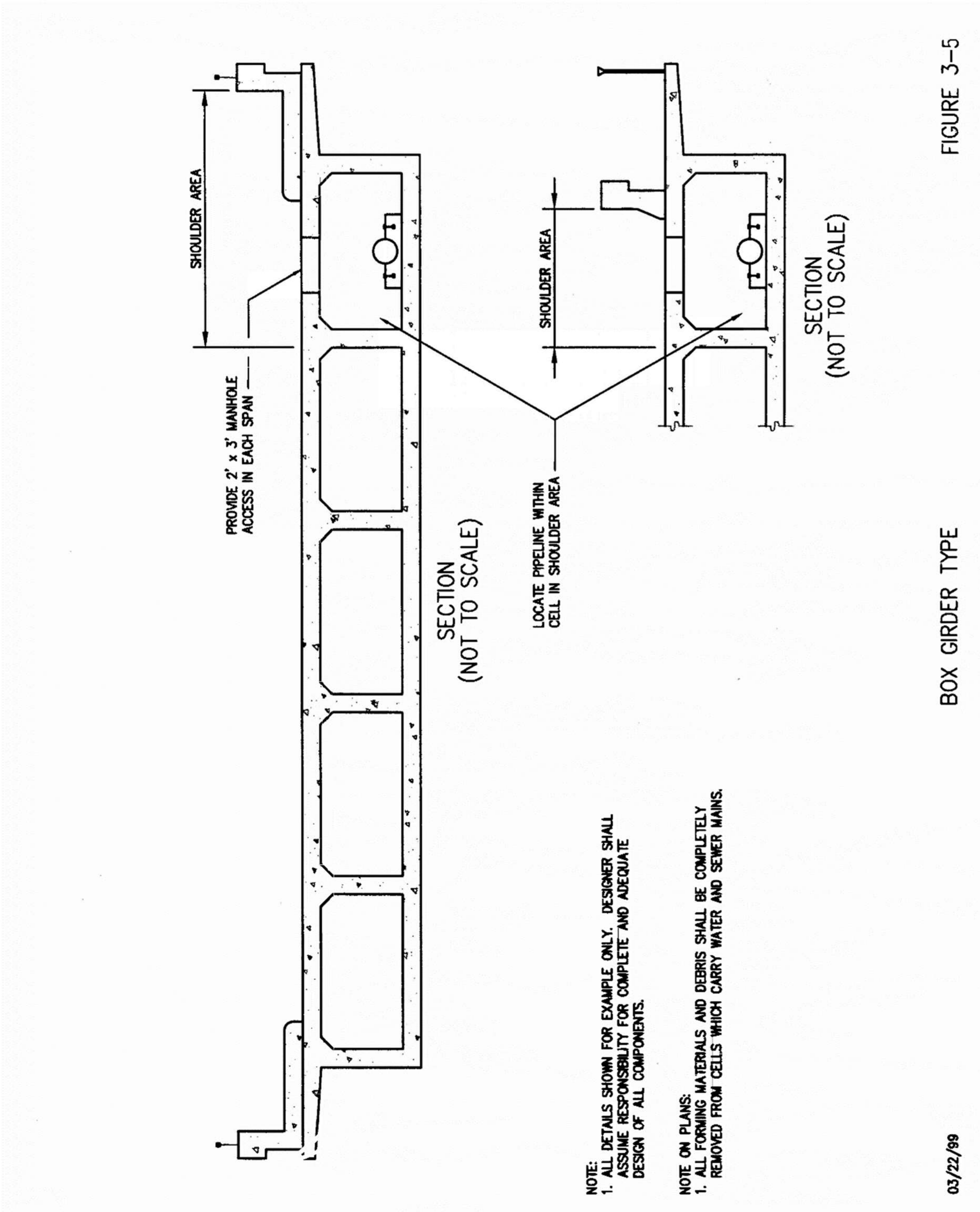
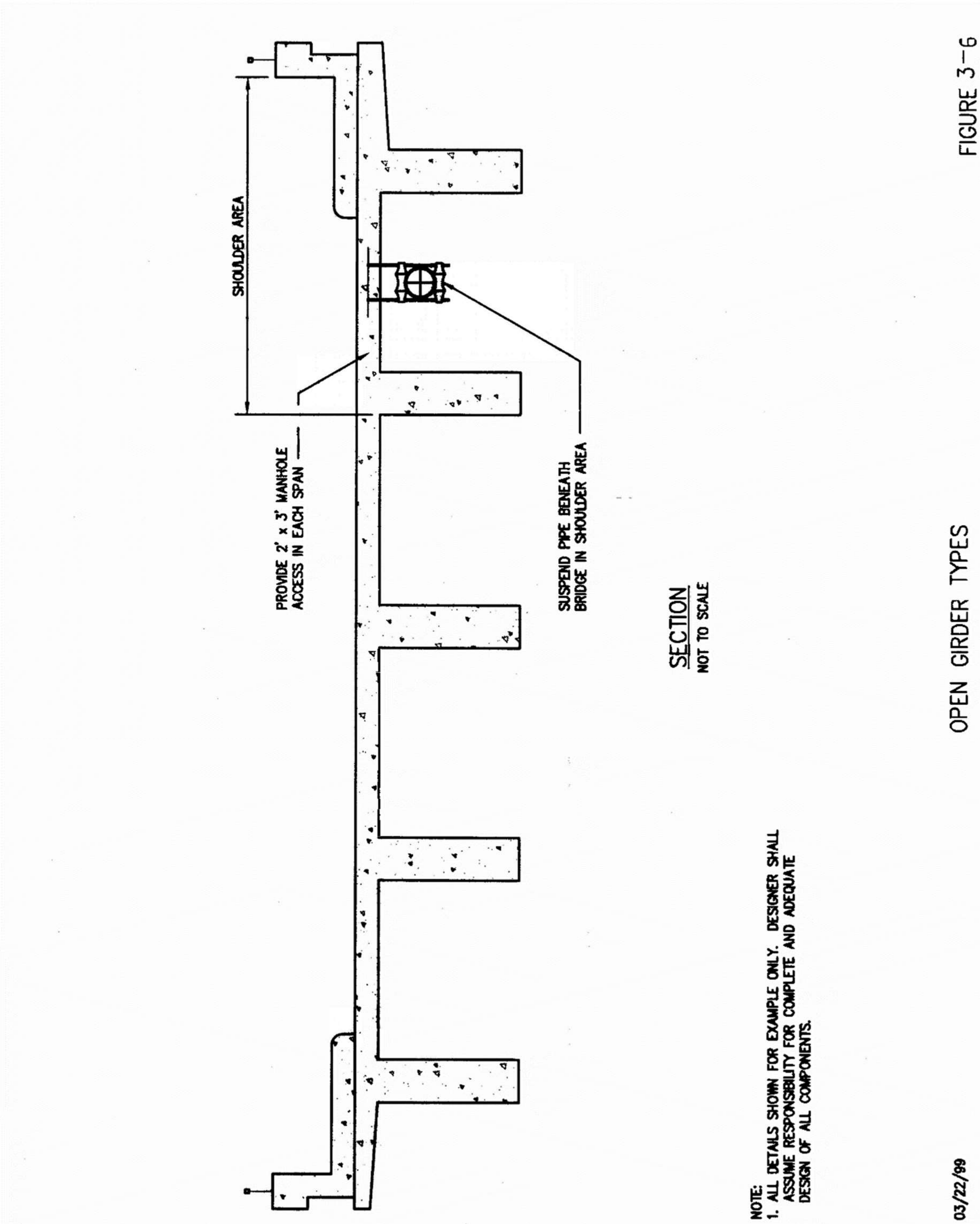
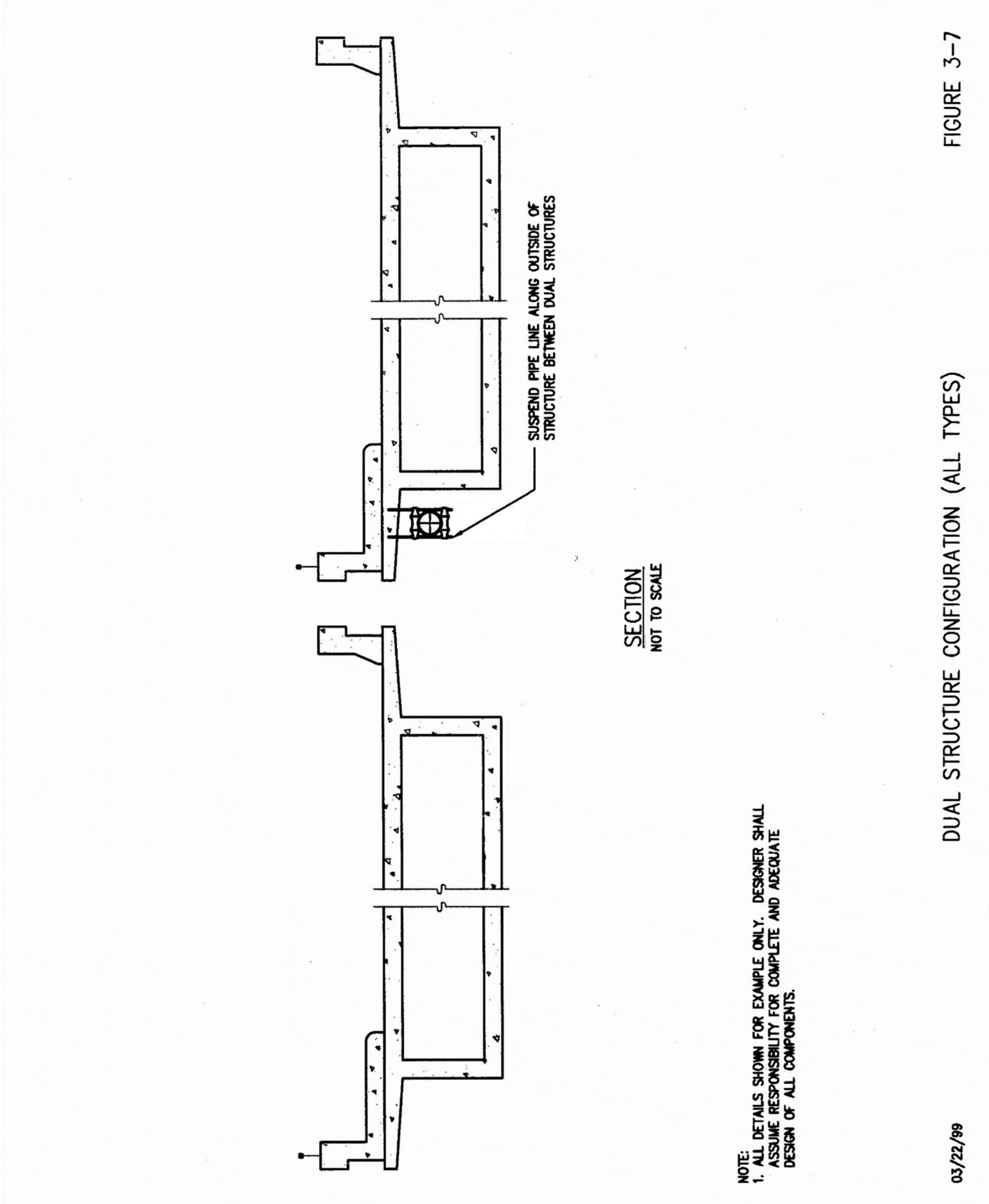
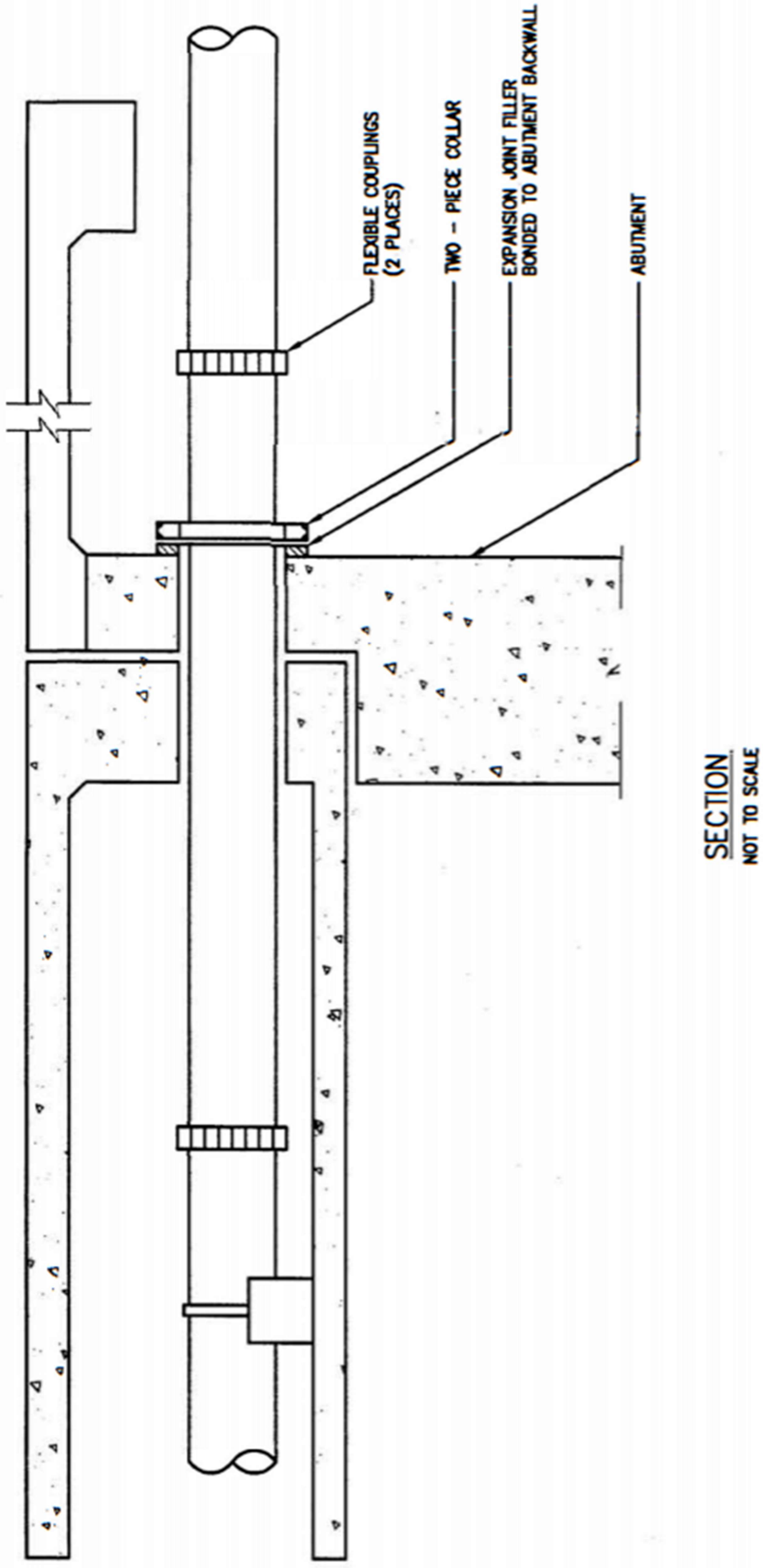


FIGURE 3–5

BOX GIRDER TYPE


SHOULDER AREA
PROVIDE 2' x 3' MANHOLE ACCESS IN EACH SPAN
SUSPEND PIPE BENEATH BRIDGE IN SHOULDER AREA
SECTION
NOT TO SCALE
NOTE:
1. ALL DETAILS SHOWN FOR EXAMPLE ONLY. DESIGNER SHALL ASSUME RESPONSIBILITY FOR COMPLETE AND ADEQUATE DESIGN OF ALL COMPONENTS.
03/22/99
OPEN GIRDER TYPES
FIGURE 3-6


SUSPEND PIPE LINE ALONG OUTSIDE OF
STRUCTURE BETWEEN DUAL STRUCTURES
SECTION
NOT TO SCALE
NOTE:
1. ALL DETAILS SHOWN FOR EXAMPLE ONLY. DESIGNER SHALL
ASSUME RESPONSIBILITY FOR COMPLETE AND ADEQUATE
DESIGN OF ALL COMPONENTS.
03/22/99
DUAL STRUCTURE CONFIGURATION (ALL TYPES)
FIGURE 3–7

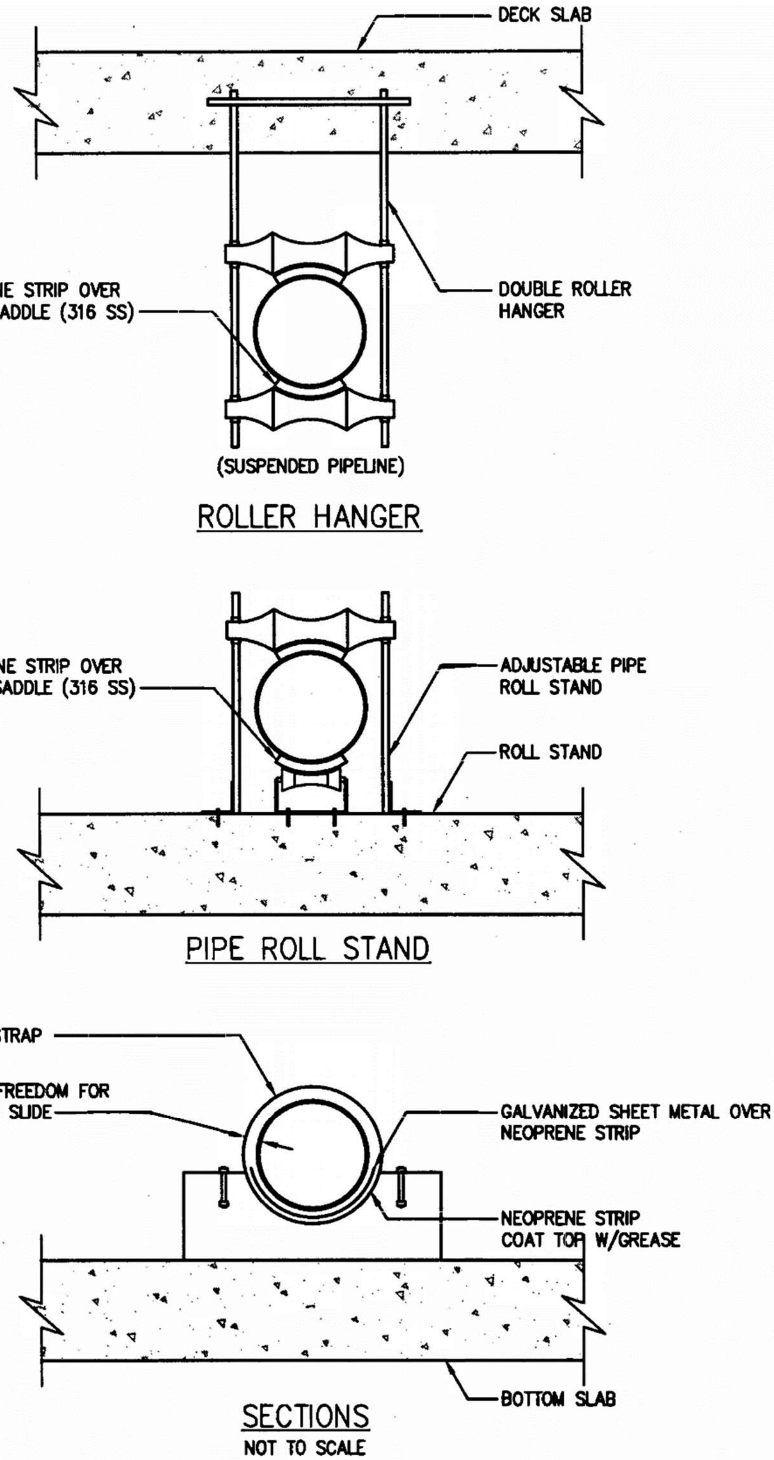


NOTE:
1. ALL DETAILS SHOWN FOR EXAMPLE ONLY. DESIGNER SHALL ASSUME RESPONSIBILITY FOR COMPLETE AND ADEQUATE DESIGN OF ALL COMPONENTS.

ABUTMENT DETAILS

FIGURE 3–8

12/10/2013

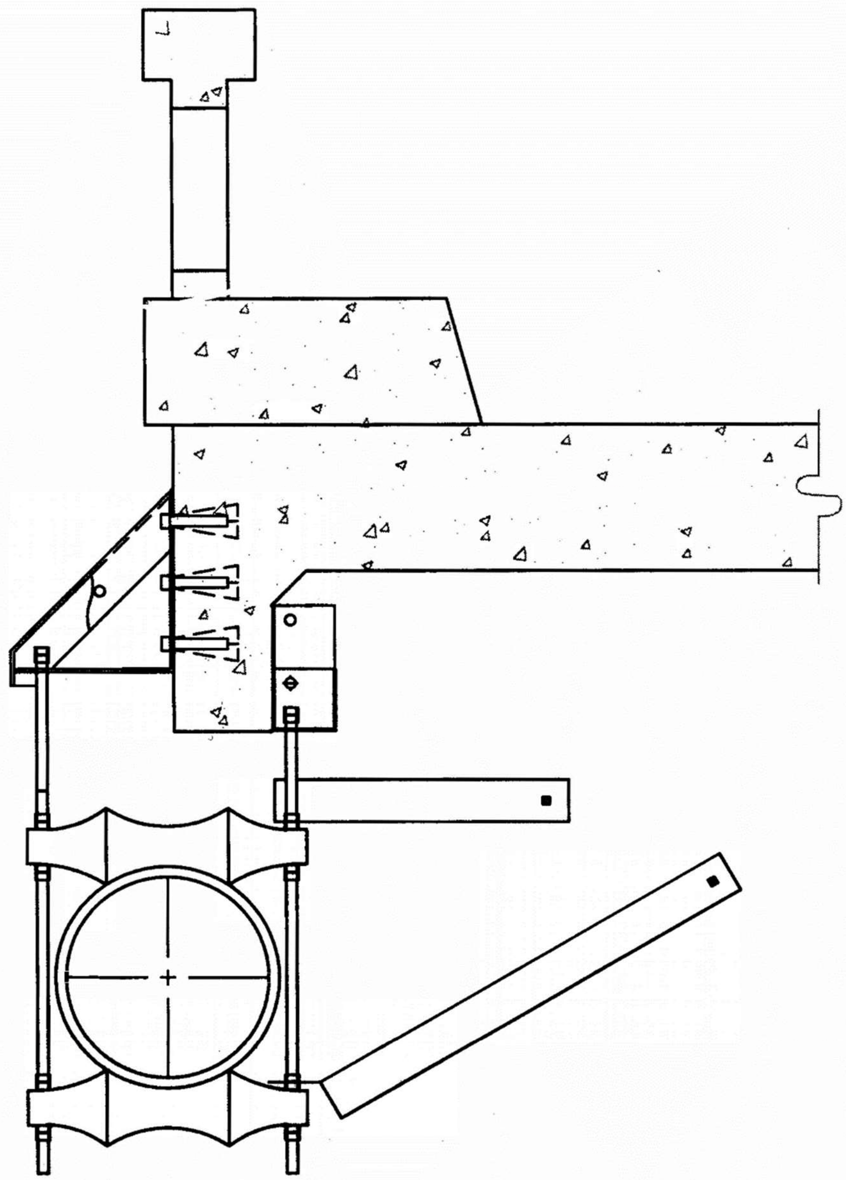


NOTE:
1. ALL DETAILS SHOWN FOR EXAMPLE ONLY. DESIGNER SHALL ASSUME RESPONSIBILITY FOR COMPLETE AND ADEQUATE DESIGN OF ALL COMPONENTS.

03/22/99

CONCRETE SADDLE

FIGURE 3–9



SECTION
NOT TO SCALE

NOTE:
1. ALL DETAILS SHOWN FOR EXAMPLE ONLY. DESIGNER SHALL ASSUME RESPONSIBILITY FOR COMPLETE AND ADEQUATE DESIGN OF ALL COMPONENTS.

03/22/99

TYPICAL DETAIL
WATER TRANSMISSION LINE
(EXAMPLE OF EXISTING INSTALLATION ONLY)

FIGURE 3–10

Design supports to provide free draining conditions and avoid trapping pockets of liquid or air in the pipeline.

Design pipelines for all imposed loads. Calculations should include checks for internal pressure, hydraulic transients, and seismic and wind loads. Longitudinal deflection should be limited to L/360. All thrust forces are calculated and resisted. Maximum thermal expansion and contraction are calculated and accommodated. Check bending, shear, and local buckling at supports.

Confirm that pipelines near an abutment to an embankment transition can accommodate large amounts of differential movement. Submit calculations with plans to the City Project Manager.

3.13.2.3 Pipeline Construction

1. *Pipe Material*

   a. Welded Steel Pipe has a minimum design pressure of 150 psi, a minimum wall thickness/diameter ratio of 0.005, and sufficient wall thickness for welding (minimum 10 gauge, 0.1345 inch). Field welding is in accordance with AWWA C206. Pipe lining and coating shall be per **Chapter 7**. In cases where water and sewer mains occupy the same cell in a closed-cell bridge, welded steel pipe only is used for the water main and may require approval by the State Department of Environmental Health.

   b. Ductile Iron Pipe has a minimum design pressure of 150 psi for water and conforms to AWWA C150 and C151. Pipe lining and coating shall be per **Chapter 7**.

2. *Encasement*

   A pipeline in a bridge passing over a freeway, primary road or railroad must be encased. A box girder cell (**Figure 3-5**) may be considered the encasement if access is available for the full length of the pipeline in the structure, the pipeline is constructed of metal, and provisions are made to adequately drain the cell if the pipeline ruptures.

3. *Available Joint Types and Characteristics*

   a. Flanged: Complete restraint against all movement. Limited tolerance for misalignment.

   b. Welded Steel: Complete restraint against all movement. Tolerance for misalignment varies as follows:

      - Butt weld - None except by trimming pipe ends
      - Lap welded slip - Limited, less than 5 degree angular
      - Butt strap - Large tolerance for misalignment

c. Bell & Spigot Push-on Joint: e.g., Tyton, Fastite, etc. Restraint against movement limited to friction between pipe and gasket. Restraint against axial movement can be increased by using special configurations and accessories. These configurations typically also prevent angular and translational movement, and thus are not suitable where movement other than axial is desired. The tolerance for misalignment is good. Many special configurations require special bell end casting as well, thus special pipe purchases are required.

d. Mechanical Joint: Restraint against movement is limited to friction between pipe and gasket. Restraint against axial movement is increased by using special gasket retainer glands, acceptable to the Public Utilities Department. These products typically also prevent angular and translational movement, and thus are not suitable where movement other than axial is desired. The tolerance for misalignment is good.

e. Grooved Shoulder Joint: e.g., Victaulic, etc. Restraint against axial movement with allowance for limited angular movement. No expansion capability. Limited tolerance for misalignment. Good noise and vibration attenuation.

f. Restrained Push-on Joint: e.g., Super-Lock Tyton, Restrained Tyton, Boltless Restrained Fastite, TR-Flex. Restraint against axial movement with allowance for limited angular and translational movement. No expansion capability. Good allowance for misalignment.

4. Joint Application Considerations

a. Joints for Steel Pipe: Restrained joints may be flanged, grooved shoulder, lap-welded slip, butt strap, or butt-weld type. If restrained joints are used on bridges, the pipeline must be properly anchored and equipped with expansion joints. Intermediate supports must allow axial movement.

Sleeve couplings or rubber gasket joints may be used on bridges if each length of pipe is anchored. Joints must be capable of accommodating the expansion and contraction of each length of pipe and must not be restrained. Anchor supports must be located at the bell end of the pipe. Intermediate supports must allow axial movement.

b. Joints for Ductile Iron Pipe: Restrained joints may be flanged or grooved shoulder type, or other types with appropriate restraint features. If joints restrained against axial movement are used on bridges, the pipeline must be properly anchored and equipped with expansion joints. Intermediate supports must allow axial movement.

Sleeve couplings or mechanical and push-on joints may be used on bridges if each length of pipe is anchored. Joints must be capable of accommodating the expansion and contraction of each length of pipe and must not be restrained. Anchor supports must be located at the bell end of the pipe. Intermediate supports must allow axial movement.

c. Expansion Joints: Expansion joints may be bellows type or slip type with packing. Bellows must be stainless steel or elastomeric if available in the size, pressure class, and movement capability required. Expansion joints may not require limit rods (long bolts spanning the joint) if pipeline sections are properly anchored and single end expansion joints are used. Piping on either side of expansion joints must be properly supported to minimize stresses on the expansion joint itself. A support directly below the expansion joint may be required.

d. Joints at Transitions: Bellows type expansion joints may provide sufficient angular and translational movement capacity for use at the bridge-to-abutment transition, if not restrained against movement in those directions.

   The pipeline near the abutment-to-embankment transition must be capable of accommodating large amounts of differential movement. Where a casing is required, the casing must provide sufficient rigidity to prevent pipe damage, and a flexible coupling must be provided at the end of the casing. Where a casing is not provided, multiple flexible couplings or an expansion joint with ball and socket river crossing joint at each end must be provided.

3.13.2.4 Supports

The spacing of pipeline supports depends on the beam strength and rigidity of the pipe material and on bearing considerations at the supports. Supports must be designed to provide anchorage or axial movement as required by pipeline construction (see **Figures 3-9 and 10**).

Provide neoprene and separate type 316 stainless steel plate saddle supports to electrically isolate the pipe from the bridge in case pipeline cathodic protection is provided as part of the immediate or a future project.

3.13.2.5 Other Design Considerations

The inside diameter of penetrations and casings through pier caps, pile caps, abutments, or other transverse structural components of the bridge must be at least 8 inches larger than the largest pipe dimension (including bells or flanges, etc.), including considerations for future required pipe sizes.

Access hatches for pipelines and other utilities shall be at least 2 ft x 3 ft (**Figure 3-5**), oriented with the long axis parallel to the pipe.

Reasonable measures must be provided to prevent unauthorized access to pipelines.

3.13.3 Trenchless Construction

Trenchless technology construction methods may be required for special crossings and conditions. Examples include:

A. The pipeline depth is excessive due to site conditions, making conventional excavation uneconomical when considering materials handling and shoring requirements.
B. Environmental conditions such as riparian habitat at stream crossings do not permit conventional construction.
C. Disturbance caused by conventional construction to suburban, urban, or business community is not permissible.
D. At congested intersections where, from a traffic or utility standpoint, costly utility relocation, utility support/underpinning, or traffic control is avoided.

Because of increased urbanization, utility networks are growing in size and complexity. As these networks grow, the need for special crossings by trenchless construction methods are becoming more popular due to their inherent advantages. Trenchless excavation construction methods may be divided into three basic categories: pipe jacking, conventional tunneling, and horizontal boring.

The direct costs of trenchless construction are more expensive than conventional cut-and-cover pipe construction. However, social costs, environmental impact, and other indirect costs due to noise, dust, loss of business, parking revenues, traffic delays, etc. make trenchless excavation competitive. Also, problems with settlement, deep shoring, and utility relocation or support are avoided. Nevertheless, the DESIGN CONSULTANT may take advantage of economies of scale by packaging similar trenchless construction technologies together in the same construction package. Moreover, the DESIGN CONSULTANT should not structure bids to favor one construction method but allow flexibility for trenchless construction. For example, having utility relocation or tree removal and replacement in a separate contract biases receiving only cut-and-cover pipeline construction, whereas trenchless construction may be more favorable.

Each of the three basic trenchless construction methods is briefly discussed in the following subsections. The following list of trenchless construction methods is not intended to be all encompassing, and is primarily intended for pipes in the 20-inch to 50-inch diameter range anticipated for the main transmission lines for the City’s water infrastructure.

- Pipe Jacking
- Tunneling
- Horizontal Boring
- Auger Method
- Microtunneling
- Slurry Method
- Directional Drilling
- Compaction/Pipe Ramming
- Percussive Drilling

These categories are chosen for convenience. Many contractor and manufacturer innovations are occurring in this growing industry. Because of the nature of the industry, these categories are not necessarily discrete, but represent more or less a continuum of possibilities. Key to the success of these trenchless construction methods is defining the subsurface conditions; therefore each project is site-specific. Consequently, the DESIGN CONSULTANT should become familiar with possible construction methods and should refer to the latest available within the industry. Included at the end of this section are some technical references as well as sources for additional information. However, the DESIGN CONSULTANT and its geotechnical subcontractors should not provide direction as to the means and methods, but performance requirements and limitations as required for the specific project (as set forth in the guideline specifications).

3.13.3.1 Pipe Jacking

Pipe jacking according to some classifications is distinguished from horizontal boring in that pipe jacking has personnel entry to assist in performing the advance, whereas horizontal boring is without personnel access. On the other hand, horizontal boring methods such as the auger method or microtunneling utilize hydraulic jacks similar to pipe jacking to advance the pipe, carrier pipe, or conductor casing. In essence, microtunneling and auger methods just have a more sophisticated method of advancing the pipe and removal of spoils. Regardless of the nomenclature, the minimum pipe diameter for conventional pipe jacking for personnel entry is about 30 inches for short distances and 6 feet for longer distances. Common sites are 48 inches to 72 inches. Although there is no limit to the size of pipe that can be jacked, the largest is usually about 144 inches. Also, with all these pipe jacking methods, the Contractor must design the jacks to overcome the skin friction developed between the pipe and the surrounding ground.

Friction acting on reinforced concrete pipes jacked through fills typically ranges from 100 to 600 psf of external surface area. Bentonite injected near the cutting edge of the pipe may reduce friction to about 100 psf. The development of special mud polymer lubricants has reduced the skin friction to about 25 to 50 psf where there has been a need. In many situations in firm soil, water alone is used as the lubricant. Because soil friction may increase with time, jacking operations should be uninterrupted. However, maintaining accurate line and grade and proper steering is as much as factor (if not more of a factor) of minimizing jacking forces as overcoming skin friction. After the pipe has been jacked, the lubricant may be replaced with grout.

For most situations, the practical limit for jacking is 1,000 to 1,200 feet. Intermediate jacking stations may be used; however, the shorter stroke length cuts the efficiency of the operations, thus increasing costs. Also, electric modifications, pumping considerations, laser limitations, hydraulic constraints, and reduced production make jacking long lengths uneconomical. Therefore, when long distances are involved, additional shafts should be considered. Alternatively, other methods such as tunneling or directional drilling require consideration.

Typically, the conductor casing or pipe is fitted with a simple cutting shoe or a small open shield to overcut the excavation and protect the leading edge of the pipe. During jacking in firm ground, soil materials are trimmed with care. The excavation face is also not advanced ahead of the jacking operation to minimize soil disturbance and loss of ground around the pipe. Some settlement can be expected, depending on the depth and diameter of the pipe.

Open shields have the advantage of accommodating the removal of cobbles, boulders, and obstructions. For larger diameter pipes above the groundwater table, where soils are susceptible to raveling, running, or sloughing, pipe jacking operations incorporate a shield with breasting tables and/or boards to minimize settlements. In firm ground, even wheel excavators are incorporated.

Spoil removal for conventional pipe jacking is by small muckers, rubber-tire low-profile load-haul-dump vehicles, rail, conveyor, or small cart. For smaller diameter pipes, slushers on pulleys have also been used.

3.13.3.2 Tunneling

Tunneling, like pipe jacking, implies personnel entry according to some classification systems. Unlike pipe jacking, curved alignments can be accomplished and excavation is feasible in hard rock. Also, the length of tunnel is not limited by the thrust of the pipe jacking rams.

As with pipe jacking, the means and methods of advancement and the initial support is the Contractor's responsibility. The DESIGN CONSULTANT and its geotechnical subcontractors are responsible for performance requirements and limitations applicable for each project.

Tunneling excavation and initial ground support methods are broadly classified into hard rock, soft/weak rock, and soils. The methods can be further subdivided under mechanized excavation or conventional excavation. Mechanical excavations may be by tunnel boring machines (TBM), shields, or mechanical excavators, of which there are a multitude of types. Conventional excavations may be by drill-and-blast construction or by hand construction, spaders, or other small equipment.

The smallest practical size for conventionally excavated tunnels is about 5-feet wide by 7-feet high, while for a circular shield or TBM excavated tunnel, the smallest practical diameter is about 4.5 to 6 feet, depending on the length of the tunnel. With the availability of used TBMs, drive lengths of less than 2-miles are competitive with conventionally driven small tunnels. TBMs also have the advantage of causing less disturbance to humans compared with drill-and-blast excavations when advancing through hard rock. While the guideline specifications provide for controlled blasting to limit peak particle velocities and damage to adjacent structures, the vibrations can disturb nearby residents. Where required, the DESIGN CONSULTANT should make a concerted effort and public outreach to educate affected parties about potential impacts. Nevertheless, unless there are special overriding considerations, as with all means and methods of trenchless construction, the DESIGN CONSULTANT should specify the use of either conventional or mechanized excavation. The marketplace, the Contractor's experience, and the Contractor's equipment dictate the methods.

Initial ground support depends on ground conditions. In hard rock, common support types are no support, patterned or random rock bolts and wire mesh, mine straps as required by ground conditions. In soft or weak rock, common support types include patterned or random rock bolts and wire mesh or mine straps as required; shotcrete; ribs and lagging; segmented concrete or steel liner; steel casing spilling and/or crown bars; and other combinations of these, as required by ground conditions. Soil requires similar initial support systems as for soft or weak rock; however, rock bolting methods and sparse support are generally not acceptable. The standard tunnel design practice is to not specify initial support unless incorporated into the final liner. Standard practice is for the DESIGN CONSULTANT to require submittal of the Contractor's tunnel work plan including initial support (to verify that the submittal meets industry standards without accepting responsibility for means and methods) under the category Review Submittal.

The conveyance of spoils depends on the excavation method but is typically performed by rubber-tire low-profile load haul dump vehicles, conveyors, or rail cars for the anticipated tunnel diameter.

After tunnel excavation is complete, the pipe is installed or placed on saddles, cradles, or rollers, and backfilled with cementitious materials such as grout or cellular concrete. Since in some situations, the diameter of the final pipe is small in comparison to the diameter of the tunnel, the DESIGN CONSULTANT should investigate any cost savings or other benefits to be derived using this corridor for other utilities. In very special circumstances, a utility corridor with access may be considered or even required.

3.13.3.3 Horizontal Boring

Horizontal boring is common in earth. Recently, horizontal boring methods have also been used in rock; however, there are practical limitations for rock. Horizontal boring methods are distinguished from pipe jacking and tunneling in that personnel do not enter the excavation. From this standpoint, horizontal boring methods would classically limit the diameter of such operations to less than about 30 inches. With the advent of computerized steering and guidance systems, horizontal boring by the non-personnel entry definition have encompassed projects up to 12.5 feet in diameter.

Horizontal boring techniques briefly described in the following paragraphs include: auger method, microtunneling, slurry method, directional drilling, compaction/pipe ramming, and percussive drilling.

Auger Method: The auger method is a pipe jacking method in which removing spoils is accomplished by a continuous flight auger. The auger also transmits torque to the cutting head from the power source in the jacking/bore pit. The auger may be powered pneumatically, hydraulically, or by an internal combustion engine through a mechanical gearbox. Similar to conventional pipe jacking, the leading edge of the pipe is typically equipped with a cutting shoe. Bentonite is also used to lubricate the pipe and minimize sloughing. The Contractor must carefully monitor the position of the casing and the advance of the auger and cutting head to minimize the risk of unsupported excavated ground and potential settlements.

A steering apparatus attached to the outside of the casing at the cutting head and a water level sensing device for vertical control are commonly used to make minor grade adjustments. The horizontal alignment can be corrected to a minor amount on larger casings by withdrawing the augers and sending personnel through the casing to the leading edge to manually excavate and install wedges on the appropriate side. Water lines are sometimes added behind the steering head to facilitate spoil removal.

The horizontal boring equipment is commonly mounted on a track, but in some applications where large rights-of-ways are available, it is supported by a cradle suspended from a crane. Cradle-type horizontal boring operations are commonly referred to as "side boom" or "swinging" methods. Consequently, the jacking/bore pit construction is not as critical as for a conventional pit, since all preparatory work is done outside the pit and no workers are permitted to enter the pit. No foundation or thrust reaction structures are required; however, a jacking lug or deadman is installed at the bore entrance. Water level and steering apparatus systems for track-type horizontal boring is not appropriate for the cradle-type method. Cradle-type operations require pressurized steering systems. In urban and suburban areas, cradle-type operations are not feasible. Also, water utility lines tend to run parallel to roads and then turn, and large right-of-ways are not available.

Microtunneling: Microtunneling machines have taken sophisticated, hydraulically operated, and automated soft-ground tunnel boring machines such as slurry tunneling machines and scaled them down for diameters as small as 8 inches for excavation and spoil removal. Microtunneling, as with horizontal boring, in some classification systems, has evolved to encompass non-personnel entry of pipe jacking operations for which the record is about 12.5 feet in diameter. Microtunneling is considered a misnomer by some and is simply pipe jacking with an automated miniature tunnel boring machine ahead of the jacked pipe.

With the numerous manufacturers of microtunneling machines worldwide and the advent of trenchless construction, microtunneling is particularly advantageous for difficult ground conditions without the use of expensive dewatering systems or compressed air. Microtunneling also has extremely accurate alignment tolerances for long drives, making conventional horizontal boring and pipe jacking competitive for only the best of soil conditions and the shorter drives. Although most of the microtunneling equipment is designed to operate in soft ground soil conditions, there has been an increased demand for microtunneling machines which can also excavate soft/weak rock and even hard rock (within certain limitations).

Soft-ground microtunneling machines use the principle of "earth-pressure balance" TBMs in which the pressure applied to the cutting face equals the pressure from the ground against the cutting face, thereby providing full face control and preventing loss of ground and settlement. Some machines use pressurized water to assist in excavation. In competent firm ground this may be acceptable; however, in loose, running, or flowing ground, the principle of earth-pressure balance is not achieved and can lead to unacceptable settlements.

Because microtunneling machines are jacked, they have the same limitations with respect to jacking distances (1,000 to 1,200 feet) and curves as for pipe jacking.

Cobbles and boulders can make excavation difficult if not planned. Microtunneling machines can handle boulders and obstructions typically 1/5 to 1/3 of the diameter of the cutterhead depending on the type of cutterhead. To handle coarse-grained materials, microtunneling machines are typically equipped with eccentric cone-type crushers, jaw crushers, strawberry cutters (button bit carbide inserts), or multidisc kerf-type cutters with carbide inserts to break up cobbles/boulders prior to ingestion behind the cutterhead. The cutterhead is also armored with hard facing.

For the smaller diameter machines (less than about 4.5 to 6 feet), minidisc cutters 6 inches in diameter have been employed for short drives in hard rock. These disc cutters if worn, cannot be replaced without removing the entire machine or installing a rescue shaft. The small bearing area of minidisc cutters has experienced problems with their mounts and bearings in the past.

Torque is applied through an auger and thrust through the casing. The life of the cutter depends on the hardness and abrasiveness of the rock. The longest successful mini-hard rock TBM drive is less than 300 feet. The smallest diameter is about 24 inches. Although this technology is evolving and improvements are being made, where longer drives are anticipated in hard rock, the DESIGN CONSULTANT should consider conventional tunneling. Moreover, means and methods are the responsibility of the Contractor.

Spoil removal for soft-ground microtunneling machines is typically by slurry using smaller slurry conveyance pipes and pumps as required. Another method is by auger similar to the horizontal boring auger, only a bentonite slurry is also injected at the cutterhead and conveyed by the augers to a holding tank (volume equal to one-shove) beneath the thrust jacks in the pit.

Spoil removal and rotation of cutterhead is accomplished by an auger for hard rock mini-TBMs (less than about 4.5 feet).

***Slurry Rotary Drilling (SRD)*:** This method of horizontal boring is similar to the auger method in that it is typically executed using boring and receiving pits and is intended for straight line boring. However, a drill bit and tubing are used rather than a cutting head and auger. Drilling action is accomplished by rotating and pushing the drill tubing. A drilling fluid is also used which can be water, air, or bentonite slurry. The drilling fluid keeps the rotating bit clean and aids in spoil removal. Drilling fluid is delivered through the drill tubing and spoils return to the boring pit through the bore hole. In unconsolidated, non-cohesive soils, bentonite slurry aids in preventing borehole collapse and much of the slurry cuttings remain in the bore hole. Pilot holes are typically drilled first. Then reaming bits are employed to enlarge the bore for the desired carrier pipe diameter. The drill bits are not directionally controlled and intermediate access pits are sometimes employed to ensure proper alignment of the bore path. Since the bit is unguided, the accuracy of the bore hole depends largely on subsurface conditions. Obstacles can deflect the drill bit off course, and operator experience plays a significant role in the bore's success and accuracy.

This method is most effective for bore holes from 2 to 12 inches in diameter. However, 48-inch bores have been successfully completed in stable soil conditions. Pipe installation is independent of the boring operation and thus any pipe material that is suitable for jacking or pulling can be installed. Installing pipe spans in the range of 40 to 75 linear feet is most common with this method. As pipe spans increase, so does the chance of unacceptably aligned bore holes due to the unguided nature of this method.

***Directional Drilling*:** Many innovative features from the oil drilling industry have been applied to horizontal earth boring and have advantages over SRD. The terms horizontal directional drilling and directional boring apply to a wide range of techniques and applications. Two key features of directional drilling differentiate it from SRD. The first is that a drill motor powered by pressurized cutting fluid operates the drill bit rather than a rotating drill string. The second is that the drill bit is steerable and thus can be maneuvered around obstacles or to correct the bore path. These characteristics give directional drilling superior capabilities and wider applicability over SRD. Thus, it is the more common method of the two employed.

The steering ability of directional drilling results from the chisel shape of drill bits used which deflects it in the direction oriented. When the bit rotates, it progresses straight. Controlling rotating and push allows for drill bit steering. Drill string position is accomplished with a guidance system mounted in the drill bit assembly, and by magnetically tracking it from the ground surface above the bore. For hard rocks and boulders, a rotary percussion cutterhead can be used.

Once a pilot hole is excavated, larger diameter bores are created by pulling back a large diameter cutter with the drill string (back reaming). The hole may be back reamed in a succession of increasingly larger diameters to achieve the desired final diameter. Special back reamers are available for hard rock or gravels. On the final back reaming, the finished desired pipe is pulled through. The use of directional drilling is particularly advantageous for river crossings.
Large percentages of gravels, cobbles, and boulders make drilling difficult and expensive. Steering accuracy is also an important consideration.

Compaction/Pipe Ramming: Impact moles or pipe ramming techniques, as the names imply, use a pneumatic system which punches through soil by a percussive action. The driving head is typically cone shaped using a stepped cutting head or a series of open steel tubes which punch through the ground, and is subsequently blown through, flushed free or emptied by reamers.

Another technique is to drive the pipe or casing directly without a cutting head. If the line is 6 inches in diameter or greater, the head is driven with an open face, with a band installed around the leading edge for reinforcement. This also reduces the friction from the following pipe. In some cases, water or bentonite slurry can be applied to the outside of the pipe for lubrication.

Diameters obtainable by pipe ramming vary from less than 2 inches to as much as 4.6 feet. Smaller diameter bores (less than 7 inches) are common in the United States while Europe and Japan have had great success with larger diameter impact moles.

Larger diameter pipe ramming can accommodate cobbles and boulders since there is no equipment is inside the casing for obstruction of these obstacles. Pipe ramming techniques used to install a smaller diameter pipe may not offer the same amount of flexibility in excavation.

Pipe ramming is worth considering because it is reported to save time and money in equipment and labor time compared with pipe jacking or other microtunneling techniques.

***Percussive Drilling*:** Combining percussion action with rotary drilling has proven to be an effective means of drilling through hard rock and has been applied in some trenchless methods. Applying a down-the-hole (DTH) percussive drill in conjunction with a track-type auger set up has been used to horizontally bore through hard rock. The largest DTH bit available is 43 inches in diameter and is reported to have been applied in lengths in excess of 1000 feet.

DTH hole percussive bits are pneumatically powered for percussion energy, and rotation and thrust are supplied by the drill rig. Hole cuttings are removed by the air supplied to the bit and are guided back to the bore pit in the annulus between the drilling shaft and the casing. Drilling hammer accuracy improves with harder ground conditions. This method is non-steerable and thus initial setup and alignment are critical to boring to the receiving pits. Large diameter bores are typically accomplished by drilling a small pilot hole and then opening the hole with larger bits in subsequent passes. The limitations of this method are the environmental impact during initial startup due to the percussive impact at the surface and dust control from cuttings blown out by the compressor throughout the operations.

3.13.3.4 Pipe for Trenchless Construction

With all these trenchless scenarios, a carrier pipe or conductor casing is jacked and installed. Typical pipe is reinforced concrete pipe, corrugated metal pipe, or sheet steel pipe in 10- to 20-foot sections. Crossings under county or state highways require a steel conductor casing. The final pipe is installed on saddles (by rollers, cradles, or slurry) which are later backfilled with cementitious materials such as grout or cellular concrete.

Alternative one-pass liners with a sacrificial steel liner cast with an internal steel liner have also been manufactured in the past. Other one-pass linings for potable water pipes are available. These specially coated linings have a sacrificial layer in addition to normal corrosion protection. They are patented and offer a flush bell with an interlocking joint that seals pressures to greater than 300 psi.

Directionally drilled one-pass lining installations use welded steel pipe, also with a sacrificial coating for installation.

Trenchless constructed pipes may have special transition pipelines or vaults required on either side of the bored subsurface crossing. The DESIGN CONSULTANT should refer to **subsection 3.5** of this chapter for design criteria for valves, appurtenances and structures.

3.13.3.5 Jacking Pit

Minimum size jacking pits depend on the size of the pipe being installed. For the 20-inch to 50-inch diameter range, the minimum width for jacking pits range from about 8 feet to 15 feet, and the minimum length will vary from about 20 to 40 feet, depending on equipment and pipe length. Minimum size receiving pits will vary from about 6-foot to 10-foot diameter.

With directional drilling, a jacking it is not necessarily required. With any trenchless method, however, a small staging area is required adjacent to the work area and is typically a minimum of 5,000 square feet.

Although the Contractor is responsible for these items, the DESIGN CONSULTANT and its geotechnical subcontractors should provide geotechnical criteria that enable the Contractor to design the shoring and foundation for its equipment. Also, the DESIGN CONSULTANT should consider the Contractor’s staging requirements and need for jacking and receiving pits when planning special crossings.

3.13.3.6 References

Substantial material (e.g., manuals, guidelines, videos, and references and associations) has been published about trenchless construction. The American Society of Civil Engineers has a draft “Standard Construction Guidelines for Microtunneling” (November 1998) that are under committee review. The following are a few sources provided to the DESIGN CONSULTANT as a primer and introduction to trenchless construction references.

- Boyce, G.M, and Cross, T.R., 1997, A 10-year review of microtunneling in North America, in J.E. Carlson and T.H. Budd, eds., Proceedings of the Rapid Excavation and Tunneling Conference, Society of Mining Engineers, Las Vegas, NV, June, 22-25.

- Hancher, D.E., White, T.D., Iseley, D.T., 1989, Construction specifications for highway projects requiring horizontal earth boring and/or pipe jacking techniques, Joint Highway Research Project No: C-36-672, File 9-11-26, Conducted for Indiana Department of Highways for Purdue University.

- Iseley, D.T., 1990, Trenchless excavation construction: microtunneling the United States experience, in R. Sinha, ed., Proceedings of the International Symposium on Unique Underground Structures, Colorado School of Mines and U.S. Bureau of Reclamation, Denver, Vol. 2, Chap 92, June.

- TRB (Transportation Research Board), 1997, Synthesis of Highway Practice, 242, Trenchless Installation of Conduits beneath roadways, National Cooperative Highway Research Program, Iseley D.T., and S.B. Gokhale, eds., National Academy Press, 76p.

Associations:

- North American Society for Trenchless Technology
  1655 N. Ft. Myer Drive, Suite 700
  Arlington, VA 22209
  phone: (703) 351-5252 fax: (703) 739-6672

- Directional Crossing Contractors Association
  One Galleria Tower, Suite 1940
  13355 Noel Road, LB 39
  Dallas, TX 75240-6613
  phone: (972) 386-9545 fax: (972) 386-9547

- Trenchless Technology Center
  Louisiana Tech University College of Engineering
  P O Box 10348
  Ruston, LA 71272
  phone: (800) 626-8659, (318) 257-4072
  fax: (318) 257-2777

- National Utility Contractors Association
  4301 N. Fairfax Drive, Suite 360
  Arlington, VA 22203
  phone: (703) 358-9300 fax: (903) 358-9307

3.13.4 Railroads and Freeways

For pipe sizes 24 inches and greater, the pipe shall be steel pipe, cement mortar lined and tape coated with a rock shield. Pipe thickness shall be ¼ inch thicker than the calculated design thickness. The inside pipe diameter shall be, at a minimum, 6 inches larger than the design pipe diameter. Pipe shall be reinforced and concrete encased. Steel reinforcement shall be designed to prevent cracking and to give sufficient strength to the concrete to withstand accidental damage due to future excavations. All joints shall be double welded. The horizontal alignment of the pipe crossing shall be straight from outside edge to outside edge of the right-of-way being traversed. The pipe vertical alignment shall be designed so that there are no high or low points within the right-of-way. No appurtenances shall be located within the right-of-way. Valves and access manholes shall be located at each end of the right-of-way. In addition to these requirements, construction must meet all local regulations and standards.

3.14 Pipe Trench Width and Handling

The DESIGN CONSULTANT determines the appropriate trench width by considering the pipe size, depth of cover, type of material to be removed, the space required to install the pipe and operate equipment, and general construction practices.

The trench should be as wide as necessary for proper installation of the pipe and backfilling, and should provide adequate room to meet safety requirements for workers.

3.14.1 Field Control of Trench Width

The method and equipment used to excavate a trench depends on the type of material to be excavated, trench depth, and space available for trenching operations. The choice of method and equipment is typically left to the Contractor. The contract specifications should include provisions for corrective measures to be used by the Contractor if allowable trench widths are exceeded, except when safety requirements dictate a wider trench. The DESIGN CONSULTANT reviews the trench width provisions in the latest standard specifications for Public Works Construction "GREENBOOK," the WHITEBOOK – Standard Specifications for the City of San Diego, and applicable Standard Drawings.

The DESIGN CONSULTANT should ensure that the Contract Documents provide for verification that pipe wall design is adequate to meet loading requirements for the actual trench configuration.

3.14.2 Effect of Trench Width on Pipe Loading

Excavating trenches in natural or undisturbed soil and backfilling the trench is called "open-cut" construction. The pipe is subjected to a vertical soil load resulting from two major forces. The first is produced by the mass of the prism of soil within the trench and above the top of the pipe. The second is the friction or shearing forces generated between the prism of soil in the trench and the sides of a shallow or rectangular trench. The width of the trench affects both forces.

Backfill settles at a faster rate than the undisturbed soil surrounding the trench. This downward movement of backfill induces upward shearing forces that support a part of the weight of the backfill. The resultant load on the horizontal plane at the top of the pipe within the trench is equal to the weight of the backfill minus these upward shearing forces. Unusual conditions, such as poor natural soils, may change these conditions.

For rectangular trenches and embankment conditions, the width of the trench affects the dead load calculations. Refer to **subsection 3.9.1, External Loads**, for the determination of pipe wall thickness on the basis of external loading and internal pressure conditions. Trench width determination should also consider the size of pipe to be installed, soil conditions, equipment to be used for trenching operations, and safety considerations.

3.14.3 Trenching

The DESIGN CONSULTANT shall review the trench excavation provisions in the latest standard specifications for Public Works Construction “GREENBOOK” and the WHITEBOOK – Standard Specifications for the City of San Diego.. The DESIGN CONSULTANT reviews and amends these provisions as needed to meet the needs of the specific project.

Trenching must also conform to the applicable standards of the agency with jurisdiction in the area that construction occurs. Refer to the latest standard specifications for Public Works Construction “GREENBOOK,” the WHITEBOOK – Standard Specifications for the City of San Diego for additional requirements regarding contaminated soils or groundwater.

An adequate shoring safety system must be designed for trenches exceeding 5 feet in depth or trenches in unstable soil for any depth. The safety system must meet the requirements of applicable local and state construction safety orders and federal requirements. Contract Documents must require that the Contractor submit a trench excavation plan showing the design of the shoring, bracing, sloping, or other provisions for worker protection from the hazards of caving ground during construction.

3.15 Signal Communications

Instrumentation requirements are based on the needs of the project, as specified by water operations.

Chapter 4

PRESSURE CONTROL STATIONS

4.1 Definition

Pressure control stations serve the following functions:

- Regulating/reducing stations maintain constant downstream pressure regardless of changing flow rates and/or varying inlet pressures. They are typically used to supply an area of lower pressure from an area of higher pressure.

- Sustaining stations throttle flow rate when the upstream pressure approaches the set pressure on the upstream side of the station and close completely if the set pressure cannot be maintained. They are typically used to prevent demands in an area of lower pressure from depleting the pressure in the area supplying it.

- Relief stations maintain constant upstream pressure by relieving flow (and excess pressure) to the downstream system. They are typically used to prevent pressure surges in pumped, closed, or failed systems, but commonly used by the Public Utilities Department.

4.2 Locations of Pressure Control Stations

Pressure control stations are located within the public right-of-way and easements granted in perpetuity to the City of San Diego, but not in vehicular corridors or curbside parking areas. If at all possible, access hatches for pressure control stations are located outside of streets and away from normal pedestrian paths (e.g. behind sidewalks), for ease of access for inspection and maintenance. If above ground pressure control station and/or SCADA equipment is recommended by the Public Utilities Department, it must be presented to the community. Above ground pressure control stations must include a building with adequate sound mitigation measures or may be located on a concrete pad inside a fenced or caged area (with adequate noise mitigation). Any locations other than those described above must have approval from the Public Utilities, Water System Operations Division.

In evaluating the need or site for a pressure control station, extreme care must be taken to ensure that all hydraulic standards within each of the connected pressure zones is maintained at all times. This is especially important in the case of pressure regulating/reducing stations where the potential to deplete the hydraulic energy of the upstream area is particularly acute. In the specific case of a pressure relief station, particular care should be taken to ensure that the downstream area and pipeline grid can accommodate the variable influx of flow, usually highest during low demand periods. Every pressure zone should have a minimum of one relief valve. If relief valve station is needed, DESIGN CONSULTANT shall take nuisance water discharge location into account, and design either must comply with current storm water and drinking water system discharge regulations, which ever applies. Pressure relief valves are by special approval and should generally discharge to lower pressure zones.

Unless inhibited by physical or hydraulic barriers, or if operational improvements and annual cost savings can be identified, pressure regulated/reduced areas may not receive primary service from pumped areas. Emergency connections are the exception. However, such emergency connections must be analyzed to ensure that emergency flows do not overwhelm the capacity of the pumps nor the capacity of the pipeline grid supplying the emergency connection. Emergency and/or backup supply regulating stations are discouraged in favor of looped water mains.

4.3 Configuration and Sizing Criteria

Pressure control stations must be designed to handle maximum, minimum and emergency (including fire) demands. The highest static pressure to be provided at any customer service anywhere within the system is 120 psi (Refer to Section 2.8). Pressure relief valves to protect the water system should be set 15 psi above the normal maximum pressure at each mechanically operated source such as a pump station or pressure control station. Relief valve settings must be reviewed by Public Utilities Department, Water System Operations Division.

A complete pressure zone modeling study will be required prior to assigning design pressure and flow conditions to individual pressure regulating stations and individual valves within the stations. All pressure control stations will be justified by a hydraulic study and the proposed capacities for duty valves, lead, lag, fire flow, low flow, etc. will be assigned under a zone study. In pressure zones supplied by more than one pressure control station (without available storage), each station is sized so that any one of the pressure control stations can be totally removed from service without reducing the supply capacity to the entire pressure zone.

In general, large pressure control valves (greater than 10 inches nominal size) may not be used to handle both maximum and minimum flows. Small pressure control valves, are used to handle minimum flows. The DESIGN CONSULTANT must provide the peak and average flow rate for both the station and each valve in gallons per minute (GPM) on the construction contract documents (D-drawings).

- Peak Flow – The peak demand on the station with a critical source out of service, or the max-day demand with a fire, whichever is highest. This is obtained from the Public Utilities' water modeling.

- Average Flow – The average annual flow recorded on SCADA if available, or obtained from the water modeling.

- The DESIGN CONSULTANT must demonstrate on the design drawings that the main regulating valves and low-flow regulating valves are normally operating within their manufacturer-recommended flow ranges. Oversizing of valves and improper lag of set pressures will result in cavitation, excessive noise and unnecessary wear and tear on the valves.

All pressure regulating/reducing valves must be equipped with a check valve feature to protect against undesired backflow due to a failed pressure regulating/reducing valve in another part of the same pressure zone. Each pressure regulating station should include a bypass line of an equal or greater diameter than the supply line to the station and an adequate high-pressure relief valve to protect the regulated water system.

Pressure control stations serving a pressure zone must be equipped with the proper number of valves and valve capacities to meet all foreseeable operating and emergency conditions. Public Utilities Engineering in cooperation with Water System Operations will study each pressure zone and station design, including hydraulic modeling and field testing, to make planning-level recommendations for station location, quantity of stations, number of valves per station and preliminary sizing. The DESIGN CONSULTANT is to further refine the individual station design per applicable industry standards and these standards must be applied with basic principles of engineering mechanics and application of sound engineering judgment in order to provide appropriate designs. The size and number of valves must be coordinated with the Public Utilities Department and the City Project Manager.

Pressure control valves must be housed within a concrete vault (except by special approval), either precast or cast-in-place, with a minimum inside vertical clearance (floor to roof) of 5 feet. The concrete can be Type V ASTM C150 Portland Cement. The valves must be elevated and supported by appropriate means (see **Figure 4-1**) with their centerlines at least 2 feet above the finished floor elevation. All pressure control valves in the vault must have not less than 2 feet of clear distance between individual valves and also between valves and walls. Station design must follow Occupational Health and Safety Administration (OSHA) requirements to include all features necessary to protect the health and safety of operators and to protect equipment. Adequate space must be provided for access and working room around valves. Horizontal vault joints shall be sealed with butyl resin sealant. Exterior walls/base of the vault must be waterproofed with crystal seal or approved equal asphalt compound.

In general, pressure control valves are aligned so that all associated piping passes perpendicularly through the walls of the vault. For large-pressure control stations, where thrust conditions from pressure and/or flow may dictate special design, the alignment of pressure control valves may be skewed (e.g., 45 degrees) to the walls of the vault. However, any such special design must be approved by the Public Utilities, Water System Operations Division.

All connected water conveying equipment and appurtenances within the walls of the vault must be flanged. Restrained flexible coupling required on the low pressure side of the pressure control valve.

Each pressure regulating valve (PRV) must have preferably a gate valve or a butterfly valve on both sides (butterfly valves need to be approved by Public Utilities, Water System Operations Division). In addition, pipe supports are needed to provide vertical support to the control valves.

4.4 Appurtenances

Pressure control stations must have a by-pass line of equal or greater size than the supply line to the station, with an in-line gate or butterfly valve that remains closed during normal operating conditions. Appropriate thrust restraint against the closed valves and fittings must be applied.

Each pressure control valve must be isolated on either side by gate or butterfly valves. In general, the isolation valves are located outside the vault, buried with risers to the ground surface and valve covers per applicable standard drawings. Each control valve must have a pressure gauge upstream and downstream of the valves to assist operators in setting the control valves.

The vault needs to have sufficient floor slope to the sump. A sump measuring minimum of 18-inch x18-inch with depth of at least 18 inches covered by removable grate must be included in the floor of the concrete vault at any location. The sump must be accessible for portable pumping to collect and dispose of unwanted water and either must comply with current storm water and drinking water system discharge regulations, which ever applies. Installation of permanent drainage system shall be designed where possible, with approval from Public Utilities Engineering.

Vault covers (access hatches) must be water tight to avoid rain or storm water from precipitating into the vault, have recessed locking hasp capable of securing all panels, must be hinged and spring-assisted to accommodate “one person operation,” must have hold open stay bars and safety railings when doors are in the open position, and must be designed to withstand continuous H-20 heavy traffic loadings. If vault cover is located outside of the paved right of way, cover must have 2 percent slope to let runoff move away from vault. Any individual cover panel must not be longer than 8 feet in any direction. Checkered pattern aluminum plate access hatches recommended. Vault to have 4-inch I.D. PVC pipe sleeve for sump discharge pipe. Vault cover frame shall be outfitted with a weep hole in the lowest corner of the vault. Runoff can be directed to from the hatch frame to the sump.

Ladders in vaults must be equipped with retractable safety extension devices per OSHA requirements. Ladders should be Fiberglass Reinforced Plastic FRP material.

Mechanical pressure gauges are required on both high side and low side of regulating valves and clearly labeled with “high side pressure” and “low side pressure.” These are independent of any instrumentation. Flow direction arrows must be clearly and permanently marked on piping. A permanent plate should be affixed to one wall with label boxes for “high side pressure setting,” ”low side pressure setting,” and “date of last adjustment” for each valve.

4.5 Materials

Pressure control valves, piping, isolation valves, and all other appurtenances associated with pressure control stations must conform to the latest edition of the City of San Diego's Water Approved Materials List. Pipe supports shall be adjustable with stainless steel anchors hardware.

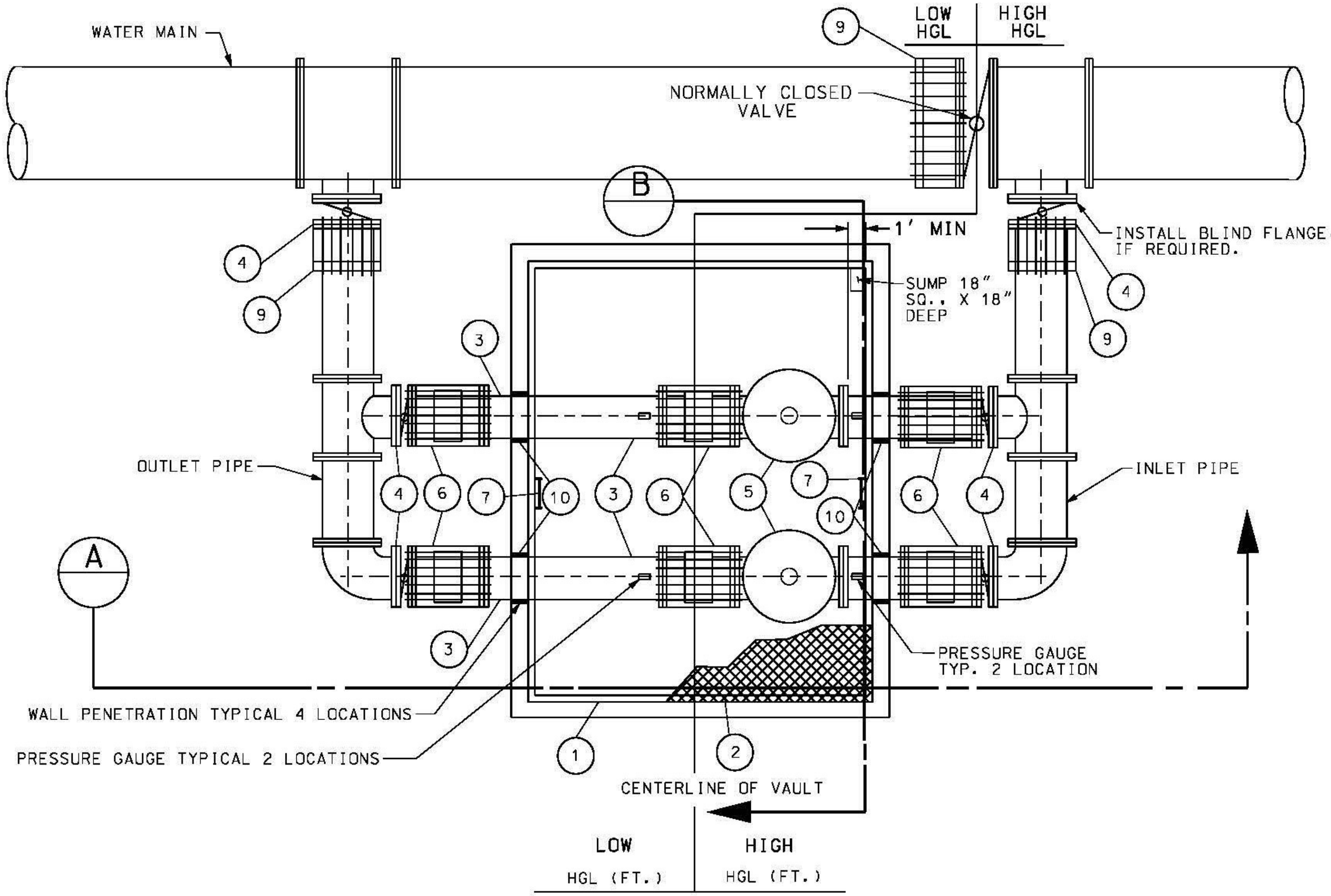
Concrete vaults must be designed to accepted engineering standards with a 28-day concrete compression strength of not less than 4,000 psi. Prefabricated vaults within these same design parameters are acceptable. In high ground water situations, the vault may not rely on restraint from protruding pipes or other appurtenances to mitigate buoyancy.

4.6 Instrumentation and Control

Critical pressure control stations, as determined by Public Utilities, Water System Operations Division, must be equipped with telemetry equipment on both the high- and low-pressure sides of the pressure control valves per the direction of the Public Utilities, Water System Operations Division, CIP Project Manager, and the applicable standard drawings for telemetry. The DESIGN CONSULTANT must coordinate power supply details and phone service, if applicable, with utility companies.

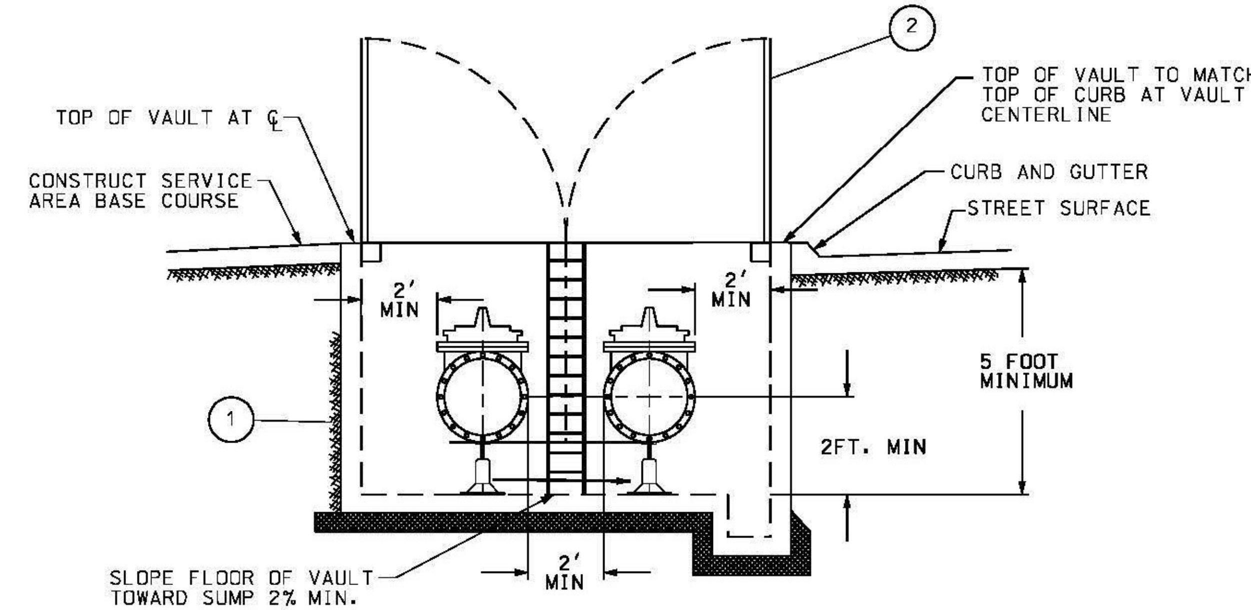
Electrical and SCADA equipment are not recommended to be installed in any station without special design to prevent flooding and maintain a dry and ventilated operational environment.

Suggested pressure settings for the pressure control valves must be noted on the construction drawings, with the additional notation: "*Subject to change based on actual field operating conditions*."



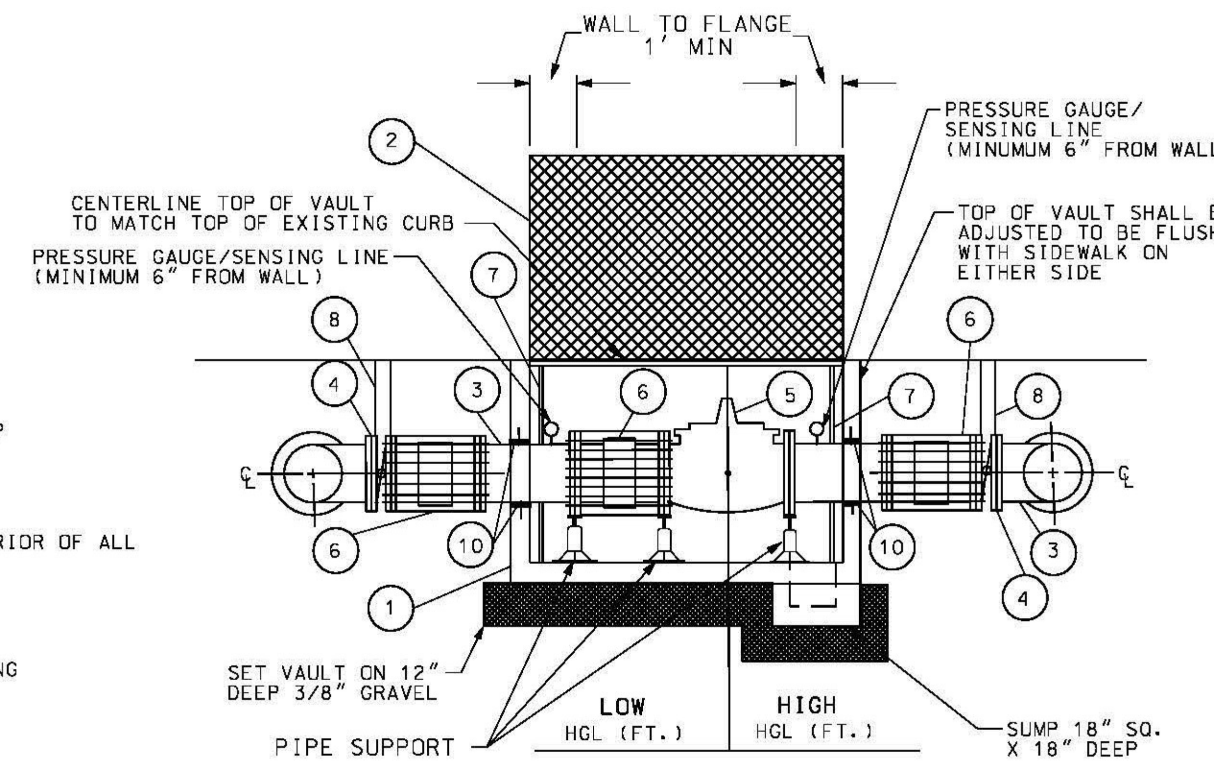
PLAN VIEW

N.T.S.



SECTION - B

N.T.S.



SECTION - A

N.T.S.

ITEM	DESCRIPTION
1	PRECAST CONCRETE VAULT, RATED FOR H20 TRAFFIC LOADING. COAT OUTSIDE OF VAULT WITH CONCRETE CURING COMPOUND. SEAL JOINT WITH WATERPROOF MASTIC.
2	ALUMINUM CHECKERED PLATE, FULL OPENING, SPRING ASSISTED, HINGED COVER, RATED FOR H20 TRAFFIC LOAD. THE COVER SHALL BE DOUBLE LEAF HATCH, WITH LOCKING MECHANISM.
3	DI PIPE SPOOLS.
4	RESILIENT SEATED GATE VALVE.
5	PRESSURE REDUCING VALVE WITH VALVE POSITION INDICATOR.
6	FLEXIBLE COUPLING WITH FLANGE TO FLANGE HARNESS LOGS AND TIE-RODS.
7	FIBERGLASS REINFORCED PLASTIC LADDER W/ LADDER UP SAFETY
8	VALVE OPERATOR EXTENSION AND VALVE CAN. CONSTRUCT PER THE CURRENT CITY STANDARD DRAWING.
9	FLEXIBLE RESTRAINED COUPLING ADAPTER.
10	"LINK SEAL" TYPE WALL PENETRATION DEVICE.

NOTES:

1. PROVIDE A SINGLE, HINGED ACCESS, RECESSED LOCKING HASP CAPABLE OF SECURING ALL PANELS. FULL OPENING EQUIPMENT MAY BE MET WITH A REMOVABLE ALUMINUM CENTER SUPPORT BEAM.
2. PROVIDE PETROLATUM WAX-TAPED AND PLASTIC WRAP ON EXTERIOR OF ALL BURIED DI PIPES AND FITTINGS.
3. PROVIDE EPOXY COATING ON EXPOSED PIPING AND VALVES INSIDE VAULT. COLOR TO MATCH REGULATOR VALVE.
4. INSULATING FLANGE LOCATION WILL BE DETERMINED DEPENDING ON THE PIPE MATERIAL. CONSULT WITH CORROSION SECTION.
5. IF SCADA IS REQUIRED: A FLOW METER, INTRUSION ALARM, AND SUMP PUMP IS NEEDED. INSTRUMENTATION AND CONTROL PANEL SHOULD BE LOCATED NEXT TO VAULT.
6. LOCATION AND ELEVATION OF CONNECTION TO BE VERIFIED BY CONTRACTOR PRIOR TO FABRICATION OF PIPES

TYPICAL PRESSURE CONTROL STATION FACILITY

FIGURE 4-1

Chapter 5

STORAGE FACILITIES

5.1 General

Water storage facilities provide for operational, emergency and fire storage, as applicable. Whenever possible, potable water storage facilities, not defined as a dam per the California Water Code, shall be circular or non-circular tanks constructed of steel or concrete, or both. If the potable water storage facility is designed as a dam as defined by the California Water Code, it shall be sized as a non-jurisdictional dam as specified by the Division of Safety of Dams. This chapter provides guidance for the design of storage facilities, including steel tanks, steel standpipes, and reinforced concrete storage facilities. This chapter also provides guidance for the design of projects that demolish or rehabilitate existing steel tanks and steel standpipes. A standpipe is defined as a storage facility where the height is greater than the diameter. The design of circular prestressed concrete tanks is not covered in this chapter. However, the Public Utilities Department has this type of tank in their system and it is considered acceptable for new tanks.

During the design process, and at the time of the Basis of Design Report (BODR) submittal, the DESIGN CONSULTANT submits a written verification to the City Project Manager that the design complies with these Guidelines and other criteria established by the Engineering Section of the Water Operations Division. This certification can be by a letter which includes a list of the criteria with a check beside each item to be incorporated in the design. A notation should be made in the margin indicating the specific design submittal when the DESIGN CONSULTANT expects this item to be incorporated into the Contract Documents. The DESIGN CONSULTANT also references and discusses any criteria in this listing to which it takes exception and does not recommend implementing.

This document does not apply to the design of the following types of facilities:

- Dams and associated components under California Division of Safety of Dams (DSOD) jurisdiction. The DSOD should be consulted regarding seismic evaluation / design criteria for the particular component under their jurisdiction.

5.2 Project Presentation

As described below, the project presentation is intended to promote uniformity of the Contract Documents between the various water CIP projects.

A predesign report is normally developed by the Public Utilities Department. Although the preliminary concepts for storage facilities are developed before the DESIGN /CONSULTANT is authorized to start work, changes in the design are still required to incorporate site-specific constraints and considerations that become evident during detailed design. The concepts presented in this guideline also apply to revisions of the Predesign Report.

5.2.1 Basis of Design Report

A Basis of Design Report (BODR) for storage facilities is developed in accordance with latest City requirements.

5.2.2 Contract Specifications

The standard specifications used for water infrastructure projects are the latest adopted edition of the GREENBOOK Standard Specifications for Public Works Construction, and the WHITEBOOK – Standard Specifications for the City of San Diego. Beyond these, the DESIGN CONSULTANT changes, modifies, or edits the guide specifications to meet the specific requirements of the project. The DESIGN CONSULTANT also develops any additional sections not included in the guide specifications.

The DESIGN CONSULTANT includes in the special provisions of the construction Contract Documents a listing of all shop drawing submittals required from the construction Contractor. The listing includes a reference to the specification section number and title where each item is described.

The special provisions of the construction Contract Documents require that the construction Contractor submit proposed equipment to the Construction Manager for approval of materials, fabrication, assembly, foundation, installation drawings, and operational information. Review and approval of submittals is normally conducted by the DESIGN CONSULTANT.

5.2.3 Contract Drawings

The DESIGN CONSULTANT develops contract drawings to meet the needs of each project. Preliminary drawings included in the BODR, when provided to the DESIGN CONSULTANT, may be used initially as the basis of the design and may be amended for incorporation into the Contract Documents. The contract drawings must conform to requirements of the Citywide Drafting Standards.

5.2.4 Permits

The DESIGN CONSULTANT prepares all support information required to obtain permits for the project.

5.3 Codes and Standards

Codes and standards used in the design of storage facilities include selected codes and standards issued by the following organizations:

Abbreviation	Code or Standard Organization
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CBC	California Building Code
CPC	California Plumbing Code
CCR	California Code of Regulations
FAA	Federal Aviation Administration
IEEE	Institute of Electrical and Electronics Engineers
ISA	Instrument Society of America
MSS	Manufacturers Standardization Society, Inc.
NEC	National Electric Code
NACE	National Association of Corrosion Engineers
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
OSHA	Standard of the Occupational Safety and Health Administration
PCA	Portland Cement Association
SEAC	Structural Engineers Association of California
UL	Underwriters Laboratory, Inc.
UMC	Uniform Mechanical Code

In addition, other applicable codes and requirements, as adopted by local permitting agencies, are observed for the design. The version of these reference documents, effective at the time of receipt of the Notice to Proceed with the design phase, is used for design purposes.

5.4 Steel Tanks and Standpipes

5.4.1 Site Design Guidelines

The DESIGN CONSULTANT reviews the Predesign Report provided by the Water Department, which includes a preliminary evaluation of constraints that may affect the site layout and design. The DESIGN CONSULTANT ensures that the designated site has sufficient area, is located at the proper elevation, and has adequate drainage.

The DESIGN CONSULTANT evaluates the following issues when situating the storage facility on the site:

- Access and parking
- Flood protection
- Grading and drainage
- Yard piping
- Land ownership and zoning
- Setbacks
- Landscaping and irrigation
- Overflow piping
- Subdrain system
- Site lighting
- Site utilities
- Geotechnical conditions
- Aesthetics
- Conveyance of overflow offsite
- Space provisions for future telecommunications tower(s) B (case-by-case basis)

Construction drawings for storage facility site improvements must include the following information:

- Project location map and vicinity map.

- Survey controls identifying the site by map number, lot number or other identifier linked to the most recent legal title document, and other control features including benchmarks. Survey control must be in accordance with the latest City requirements. In addition, two temporary benchmarks and two horizontal control points must be set near the site, and shown on the plans, at locations that cannot be disturbed during construction.

- Site plan, showing the proposed civil works at the site, the existing site topography, and the site boundary.

5.4.1.1 Access and Parking

Adequate right-of-way must be provided for vehicular access and turnaround, and for the supply pipeline and drain. A 10-foot minimum width strip area must be provided around the standpipe, on the turnaround area, and on the driveway to the street or the access area. Pavement design is based on a 4-inch plant mix pavement with a seal coat. Curbs and gutters are designed in accordance with the City of San Diego Standard Drawings SDG-150 through SDG-154.

Access roads at storage facilities must allow positioning a truck-mounted crane of the size required to remove the largest piece of equipment on the site. Sufficient space must also be provided to park two 3-ton maintenance trucks. The DESIGN CONSULTANT should avoid placing access roads and parking over piping penetrations through storage facility walls to avoid shear loadings.

5.4.1.2 Flood Protection

The floor elevation of buildings at the storage facility must be at least 2 feet above the 100-year flood elevation, as determined by the Federal Emergency Management Agency.

5.4.1.3 Grading and Drainage

The grading plan must be developed in accordance with the requirements of the latest edition of the California Building Code (CBC) and the City of San Diego Grading Ordinance. Recommendations of the site geotechnical report are incorporated in the grading design. Where conflicts exist between the code and ordinance and the geotechnical report, the more stringent requirements must be adopted. Overall grading for the site is conservative and allows flexibility to allow future modifications or facility expansion at the site.

The site is graded with a slope downward from the tank or standpipe in all directions. The storage facility is positioned and the site developed to ensure a uniform soil bearing condition. The footing and floor are placed on either native earth material or structural fill, and the storage facility may not be situated with a portion on native material and a portion on fill. Over-excavation of the site may be required to provide placement of the storage facility on similar materials.

Drainage design must conform to the latest edition of the City of San Diego Drainage Design Manual.

5.4.1.4 Yard Piping

Yard piping must be either steel or ductile iron pipe, as described in **Chapter 3**. Exposed piping at storage facilities must be steel or ductile iron pipe, as described in **Chapter 6**. Linings and coatings of piping must conform to the requirements in **Chapter 7**.

Water service to the site must be equipped with a reduced pressure backflow protection device installed after the water meter. The site water piping system should include a 3/4-inch diameter water riser and hose bibb in a protected location as required for site washdown. Parking posts must be provided around the reduced pressure backflow prevention device.

Mainline valves are shall be of the same diameter as the pipeline. Any deviation from this requirement requires the DESIGN ENGINEER to prepares a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document.

5.4.1.5 Land Ownership and Zoning

Storage facility sites may not be located on easements, but should be entirely located on City-owned land. A zoning variance is generally required for storage facility sites.

5.4.1.6 Setbacks

Adequate setback from property lines must be provided to conform to local ordinances and codes. The distance between structures is determined by access requirements, piping requirements, and future expansion plans. Sufficient setback is also provided to allow for fill, cut, or fill transition to existing contour elevations at property lines.

5.4.1.7 Landscaping and Irrigation

Storage facility sites are landscaped in a manner to meet community standards and conform to the City's *Landscape Standards-Land Development Manual*. The landscape design should extend the concepts established for the materials and form of the storage facility and blend with adjacent areas. Landscape designs must be developed by a Licensed Landscape Architect.

The landscape development of storage facility sites is kept to a minimum and should be low maintenance. Irrigation systems and plant material are installed outside the City's security fence unless it is absolutely necessary to screen objectionable views of a facility from the community or to prevent the erosion of manufactured slopes.

Landscaped areas must have automatically-activated irrigation systems with a reduced pressure backflow prevention assembly and water service meter at the connection to the water main. A framed, laminated, control schematic drawing of the irrigation system must be mounted inside the cabinet door of the irrigation controller.

Landscaping areas shall maintain brush management policy per local agencies to prevent a potential fire from approaching a steel tank.

5.4.1.8 Security Fencing

For specific security and fencing design criteria, refer to **Chapter 8.**

5.4.1.9 Site Lighting

Storage facility site lighting is controlled by a photocell equipped with a manual on/off controller. Outdoor lighting is selected to reduce glare over the surrounding area and is vandal-resistant. The DESIGN CONSULTANT coordinates with the Federal Aviation Administration regarding the need for lighting the top of the tank.

5.4.1.10 Site Utilities

Coordination with representatives of local utility agencies is required during the design process. The Predesign Report for the project presents available information on utilities which might be affected by construction of the project.

5.4.1.11 Geotechnical Conditions

The geotechnical consultant develops and implements a program of geotechnical testing to provide relevant design parameters for the storage facility.

5.4.1.12 Aesthetics

Views of the facility from areas surrounding the storage facility site are analyzed and alternatives evaluated to harmonize the appearance of the storage facility with its surroundings, which needs to be approved by the community.

5.4.2 Structural Guidelines

Structural review is performed by the Development Services Department, Building and Safety Plan Review. New Building Regulations are adopted by the City of San Diego Municipal Code on a regular basis. Information for Building Safety Plan Review can be found at Sandiego.gov/development-services.

5.4.2.1 Reference Standards and Codes

The latest editions of the following standards and codes apply to the design of steel tanks and standpipes:

- Building Code Requirements for Minimum Design Loads in Building and Other Structures, ASCE 7 by the American Society of Civil Engineers.

- Title 24, Part 2, California Building Code.
- California Building Code (CBC) of the International Conference of Building Officials, as adopted by the City of San Diego Municipal Code.
- American Institute of Steel Construction, Specification of the Design, Fabrication, and Erection of Structural Steel for Buildings, AISC Publication No. S-326.
- American Institute of Steel Construction (AISC) Manual of Steel Construction, Allowable Stress Design (ASD).
- Specification for the Design of Cold Formed Steel Structural Members by American Iron and Steel Institute (AISI).
- Standard Specifications for Open Web, Longspan, and Deep Longspan Steel Joists and Joist Girders.
- API documented rules for the design and construction of large welded, low pressure storage tanks, API STD 620.
- The boiler and pressure vessel code (ASME).
- Standards for Welded Steel Tanks for Water Storage, ANSI/AWWA D100.
- Welded Steel Tank for Oil Storage, ANSI/API STD 650.
- Structural Welding Code B Steel, ANSI/AWS-D1.1.
- Specifications for Welding Sheet Steel instructions, ANSI/AWS D1.3.
- Building Code Requirements for Reinforced Concrete, ACI 318, and commentary ACI 318R, as contained in the CBC and as adopted by the City of San Diego Municipal Code.
- Concrete Manual by the U.S. Bureau of Reclamation.
- Concrete Reinforcing Steel Institute (CRSI) Handbook.
- “Formulas for Stress and Strain” by Roark and Yong.
- Standard of the Occupational Safety and Health Administration (OSHA).

- AWWA Standard for Coating Steel Water Storage Tanks, ANSI/ AWWA D102 and NSF Standard 61.

- AWWA Standard for Automatically Controlled Impressed-Current Cathodic Protection for the Interior of Steel Water Tanks, ANSI/AWWA D104.

- Steel Tanks for Liquid Storage by American Iron and Steel Institute (AISI).

- **Chapter 8 Seismic Criteria**.

5.4.2.2 Design Loads

The following criteria define the minimum design loads to be used in the design of steel tanks and standpipes. Without limiting the applicability of other criteria, all design loads must conform to or exceed the requirements of the CBC, ASCE 7, and all applicable requirements of other documents referenced above.

1. *Dead Loads*

Dead loads, are defined as the weight of all permanent construction, including equipment and piping permanently connected to the tank.

Dead loads include allowances for the following items:

- All equipment and piping permanently attached to and considered part of the structure, including future equipment and piping.

- Structural steel platform framing and floor plates.

- Heavy beams or girders, such as those required to carry loads other than platform live loads.

- Piping 12-inches in diameter and smaller is treated as a uniformly distributed load.

- Piping larger than 12-inches in diameter is treated as a concentrated load.

2. *Live Loads*

Live loads in addition to concentrated loads are determined as follows:

- Roof Loads: in accordance with ASCE 7, CBC, ANSI/AWWA D100 or local code, whichever is more stringent.

- Stairs, Platforms, and Walkways: ASCE 7 or local code, whichever is more stringent.
- Minimum concentrated load on ladders and stairs: in accordance the requirements of ASCE 7, OSHA, Cal-OSHA, or local codes, whichever is greatest.

3. *Wind Loads*

Wind loads must be in accordance with ASCE 7, CBC, ANSI/AWWA D100 and ANSI/AWWA D103, or on the requirements of local code, whichever is more stringent. The design is governed by maximum wind or maximum seismic load, whichever is greater.

4. *Hydrostatic and Hydrodynamic Loads*

Hydrostatic loads are based on water when the tank is filled to overflowing. Hydrodynamic loads are determined in accordance with the seismic loads described in this section.

5. *Lateral Soil Loads*

For all yielding structural components, lateral soil loads are determined by using active soil pressure conditions as recommended in the geotechnical report.

For all non-yielding structural components, lateral soil loads are determined by using passive soil pressure conditions as recommended in the geotechnical report.

A minimum surcharge pressure equal to an additional 2 feet of soil is used for all structures adjacent to traffic loading conditions.

Seismic soil loads are determined in accordance with the Seismic Loads described below.

6. *Seismic Loads*

Seismic loads are established in accordance with **Chapter 8 (Seismic Criteria)**. The following criteria provide the basic guidelines for determining design ground accelerations and seismic forces:

- Seismic loads as described in Chapter 8, Seismic Criteria.
- Seismic soil loads are determined in accordance with the recommendation given in the geotechnical report.

- Response spectra with damping factors of 0.5%, 2.0% and 5.0% are used for the seismic design for the appropriate level of shaking and type of structure.

- Site-specific ground acceleration, response spectra, and design recommendations presented in the geotechnical report are used to determine seismic loads.

- Hydrodynamic loads are determined in accordance with the methods presented in **Chapter 8, Seismic Criteria, paragraph 8.6, Water Retention Structures**

7. *Miscellaneous Loads*

The following are considered in the design:

- Miscellaneous loads of a special nature, such as thrust from expansion joints, and special appurtenances.

- Surcharge loads, such as those due to adjacent structures and vehicular loads.

- Thermal loads, where applicable.

- Operating pressure forces and test forces and loads.

- Construction loads and conditions.

5.4.2.3 Loading Combinations

Loading is calculated for different conditions. As a minimum, the following loading conditions are determined:

- Full tank or standpipe: hydrostatic loading, plus hydrodynamic loading, plus seismic forces due to dead loads.

- Empty tank or standpipe: static soil pressure (active or passive) plus seismic soil pressure plus seismic forces due to dead load plus permanent surcharge.

5.4.2.4 Allowable Stresses

Allowable stresses must conform to the following:

- For steel plate and structural steel, allowable stresses are in accordance with the requirements of ANSI/AWWA D100.

- For tank concrete footings, allowable stresses are in accordance with the requirements of ACI 318.

5.4.2.5 Roof Design

The roof must be a structural-steel-supported, steel-cone roof with a slope of 1 in 12. The DESIGN CONSULTANT selects the roof type. If the appearance of the roof is of sufficient importance to justify the additional cost, an elliptical "water bearing" type of roof may be specified. If the roof is supported on a central column which requires lateral bracing, the design must include separate trolley tracks below each set of lateral braces.

The roof is designed for the loading and allowances in accordance with the requirements of **paragraph 5.4.2.2**.

The roof plate that is not in contact with water is at least 3/16-inch thick; the roof plate submerged in water during normal operations is 3-inch minimum (knuckle or cone type). A corrosion allowance is not required for the roof plate. The roof plate construction must be in accordance with the standard practice of ANSI/AWWA D100, by continuous fillet weld at the top side only. Full penetration welds are used to join the roof knuckle together. The roof plate is not connected to the support members.

Roof supports are hot-rolled structural shapes with a minimum thickness of 3/16 inch. Shapes, bar, and plate submerged in water are at least 3-inch thick. Lateral bracing of the roof rafter compression flanges is assumed to be provided by the roof plate.

Bolts, washers and nuts installed inside the storage facility are type 316 stainless steel.

Columns are fabricated from a sealed steel pipe welded at both ends. The column base is fabricated from steel plate and designed for a maximum allowable soil bearing in the geotechnical report. The column base is not welded to the bottom plate**,** but must be restrained from any lateral movement.

5.4.2.6 Wall Design

The wall design must be in accordance with ANSI/AWWA D100 and ANSI/ AWWA D103 standards. Applicable loadings and allowable stress must be as described in **paragraphs 5.4.2.2 and 5.4.2.4**, respectively.

All wall plate is rolled, regardless of material thickness.

The design fabrication and inspection requirements specified in ANSI/AWWA D100 and ANSI/AWWA D103 are considered, except that only steel that complies with ASTM A-36 or ASTM

A131 material requirements is used. The lowest 1-day mean ambient temperature at the tank site is generally 45°F.

A corrosion allowance shall be specified for the tank inside and outside of the shell plate in AWWA D100. Minimum tank wall thickness must be in accordance with the requirements of ANSI/AWWA D100 and ANSI/AWWA D103. Welds shall be in accordance to AWWA D100..

The tank wall is designed for stability without the requirement for intermediate girders on the inside or outside surface of the wall.

Freeboard between maximum fluid level and the top half of the roof shell is provided to accommodate for the sloshing of fluid induced by seismic loading so as not to overstress the roof plate, roof members, and the connection.

5.4.2.7 Floor Design

Floor plates are lap welded continuously from the top of the plate with a minimum thickness of 5/16 inch. Sketch plates are 1/16 inch thicker than the rest of the floor plates. The floor plate is extended a minimum of 1 inch beyond the exterior of the wall. The joint between the wall and the bottom plate is continuously welded from inside and outside of the tank wall.

A corrosion allowance, if required, is added to the minimum requirements of the standards.

5.4.2.8 Anchor Bolts

Anchor bolts are designed to safely resist the uplift resulting from the overturning moment about the axis of the base of the tank or standpipe. See **Chapter 8, paragraphs 8.6.1** for additional guidance on anchor bolt design. Anchor bolt nuts are torqued after filling the storage facility and again before acceptance by the City.

5.4.2.9 Footings and Foundations

A ring wall footing is used. The top of the ring wall footing is approximately 6 inches above finished grade. The minimum depth of the ring wall footing below the bottom of the tank is not less than 2 feet.

The ring wall footing is reinforced to resist the lateral soil pressure of the confined earth. The width and height of the ring footing is sized for the loadings in **paragraph 5.4.2.2** and the allowable soil bearing pressure recommended in the geotechnical report. The minimum width is not less than 2.5 feet.

A compressive strength of 4,000 psi is used for the concrete, and 60,000 psi yield strength is required for reinforcing steel. Concrete cover for reinforcing bars must be in accordance with the requirements of ACI 318. The alternative design method is recommended for the design reinforcement.

5.4.3 Mechanical Design Guidelines

5.4.3.1 Storage Facility Hydraulics and Piping

The DESIGN CONSULTANT refers to the Predesign Report prepared by the Public Utilities Department for available information on the storage facility piping configuration and capacity, storage facility size, high water elevation, and the adequacy of the overflow and drain pipes. Valves and piping are provided to meet special conditions at the site. Required anchors, supports and thrust blocks are provided as required to resist all loads and forces imposed by the conditions of service. Piping and valves are tested to 150 psi. The tank is electrically insulated from the attached pipeline by means of insulating couplings or sections of PVC pipe.

A concrete vault containing altitude valve(s) is provided adjacent to the tank. The vault should be similar in design to the regulator system with appurtenances shown in **Chapter 4**. The vault must be adequate to carry an H-20 loading and have a ladder and sump. Altitude valves must be of the type listed in the Public Utilities Department's Water Approved Materials List. If needed, two-way valves are acceptable. A bypass is to be provided around the altitude valve.

See **Chapter 8 paragraph 8.6.1** for guidance on design of critical piping for earthquake loads.

1. *Inlet and Outlet*

Inlet and outlet piping is designed to maximize water circulation inside the tank. As a general rule, separate inlet and outlet pipes are required on all tanks. Both the inlet and outlet pipes penetrate the bottom plate and are separated as much as practical on opposite sides of the storage facility to promote circulation. Provision of a diffuser on the inlet is desirable to disperse inflow to the tank and encourage circulation. The pipe penetration opening through the bottom plate must be reinforced in accordance with the requirements of ANSI/AWWA D100.

For steel tanks, the inlet and outlet pipes penetrate the floor. For standpipes, the inlet and outlet pipes are on the side of the tank. At all wall penetrations, a double ball type flex coupling is to be provided on the exterior wall.

Reinforced concrete vaults are provided to house rubber-seated isolation valves on inlet and outlet piping. Inlet and outlet valves may be equipped with backup battery-powered electric actuators for automatic isolation following an earthquake. Seismic systems actuators shall include sufficient signal options to fully integrate to the local control systems for automatic operation and remote monitoring features including local manual override options (See **paragraph 5.4.4**). Valve vaults must be designed for H-20 traffic loads and must be easily accessible for storage facility shutdown. A storage facility bypass pipeline is provided to accommodate shutdowns. In-line valves are the same diameter as inlet/outlet piping. Piping under the storage facility is encased in concrete. If valves are located away from the storage facility, there is a flexible coupling in the inlet and outlet lines with sufficient flexibility to accommodate differential settlement.

A restrained Dresser type coupling is provided on the vertical riser of the inlet pipe. The coupling is located above pavement grade. A 125-pound flanged overflow nozzle must be installed, with a 1-inch, extra heavy threaded coupling and plug in the bottom of the nozzle for testing. A 1-inch, extra heavy outlet coupling and corporation stop are also provided in the lower ring of the standpipe.

2. *Drain*

A drain pipe is installed at the bottom of the tank. The drain pipe is of adequate size and has sufficient slope to dispose of drainage water. The pipe is of a suitable type and pressure class to accommodate operation under pressure, if required. If the tank is unanchored, the location of the penetration in the bottom plate must conform to the requirements of the ANSI/AWWA D100. The drain line may be discharged to a drainage structure or facility common with the overflow pipe. DESIGN CONSULTANT is required to provide control methods for all discharges, including hydrostatic water discharges emitted from the storage facilities as necessary to comply with the current Regional Water Quality Control Board (RWQCB) or State Water Resources Control Board (SWRCB) discharge permits.

An eccentric plug valve is installed on the drain line. A vault adjacent to the ring wall footing is required for housing the drain valve. A hand railing is added around the inlet to the drain. The handrails are steel. The use of aluminum handrails is not permitted.

3. *Overflow*

The overflow pipe is sized to discharge the maximum fill rate of the tank. The overflow is located in an internal location. The overflow pipe should be braced against the tank wall. The DESIGN CONSULTANT designs the overflow system to ensure that water in the storage facility is protected from cross-contamination with surface water. The overflow pipe has an air gap separation, with flap gates and/or bug screening and low pressure flapper-type closure at overflow/drain piping outlet. Overflow structures should include level float sensors to detect overflow conditions and serve as a backup warning. The overflow float sensors should be fully integrated in to the local control system (See **paragraph 5.4.4**).

The overflow funnel is not less than 6 inches below the bottom of the shell vents. The overflow pipe flange clears the tank shell by 14 to 16 inches.

4. *Recirculation Piping and Pumps*

Where recommended in the Predesign Report or directed by the City Project Manager, recirculation piping and pumps is provided to afford additional circulation in the storage facility. Pumps and drives are suitable for outdoor installation, and are housed in a locked security cage. The pumping system is designed to recirculate the entire volume of the storage facility in less than 3 days. The recirculation piping draws water from the tank outlet and conveys water to the tank inlet. Where there is a common inlet/outlet line, recirculation is from the inlet/outlet line to 75% of the height of the tank. Recirculating pumping systems shall include sufficient signal options to fully integrate to the local control systems for automatic operation and remote monitoring features including local manual override options (See **paragraph 5.4.4**).

5. *Wall Washdown System*

A washdown piping system is mounted on the interior wall of the storage facility. The minimum design flow rate is 25 gpm per nozzle. It is assumed all nozzles are operating simultaneously per basin. Maximum size of nozzle is 1 ½ inches, unless otherwise approved. Minimum design pressure is 50 psi (static) at the hose connection.

6. *Sample Taps*

Sample taps are provided at various levels in storage facilities. A locked access to the sample taps is provided at the exterior base of the tank or standpipe.

A minimum of four 3/4-inch sampling taps are provided. Three of the taps must protrude a distance of 1 foot into the tank and be separated vertically to represent water quality from the bottom to the top of the tank. A fourth sample point is located near the bottom of the tank, flush with the inside face of the tank. An additional sample tap is provided in the recirculation piping if recirculation piping is used. It is recommended that the sample ports be labeled, by height. Also, depending on the configuration and location of the sample lines, it may be recommended that recirculation pumps be installed to obtain representative samples and reduce biofilm growth within the sample lines.

7. *Chlorine Injection Points*

Chlorine injection points are provided and equipped with locking covers. Injection points are located on the inlet pipe to the storage facility.

8. *Pump Connection*

A 6-inch diameter flanged pump connection is provided on the side of the tank. The connection is located 18 inches above the adjacent ground on aboveground tanks and on the pipe upstream of the altitude valve on buried tanks. A 6-inch flanged plug valve is provided on connections.

9. *Baffling*

The DESIGN CONSULTANT, as part of the Basis of Design Report, determines if internal baffling is recommended to improve circulation and water quality in the tank. On tanks greater than 10 million gallons, it may be necessary to computer model to identify improvements that optimize flow patterns, reduce short-circuiting, and minimize water age. The need for computer modeling is determined on a case-by-case basis.

5.4.3.2 Re-Chlorination

Water quality and level of chlorine residual maintained in the storage facilities are issues of concern. Storage facilities are to be maintained in accordance to the Nitrification Action Plan (refer to **Attachment 5-1**) and AWWA M56 specification. The need to provide re-chlorination of the water entering the reservoir is considered on a case-by-case basis. The DESIGN CONSULTANT verifies the need for re-chlorination facilities with the Public Utilities Department and in consultation with the Water Production Superintendent.

At a minimum, the design includes chlorine analyzers, sampling ports and a flanged connection for future chlorine injection. The chlorine analyzer is to be housed in a NEMA 4X enclosure.

The sampling and monitoring system allows the return of sample water back to the storage facility to minimize water waste. It is required to monitor chlorine residual at the distribution storage facilities. The preferred method for continuous inline Chlorine monitoring is by amperometric means. Amperometry is an electrochemical technique that measures the change in current resulting from chemical reactions taking place as a function of the analyte concentration. Amperometric sensor cells require continuous water flow. The DESIGN CONSULTANT is responsible for determining adequate flow-rate regulation entering the cell to mitigate fluctuations and head pressure as well as avoiding flooding the chlorine sensor cell. The discharge water of the sensor cells (Processed water) should be temporarily stored on an adequately sized storage holding tank to be pumped back in to the distribution reservoir. The DESIGN CONSULTANT is responsible for determining the storage holding tank size on a case-by-case basis. The holding tank placement should never be in direct sunlight. The stored water in the holding tank should be pumped back into the reservoir in a timely manner as agreed upon by the DESIGNER and Public Utilities Department to avoid any possible water stagnation thereby reducing the possibility of bacterial growth. The DESIGN CONSULTANT is responsible for adequately sizing the pump system to the height of the reservoir. Amperometric chlorine sensor systems shall have sufficient signal options to fully integrate to the local control systems for automatic operation and remote monitoring features including local manual override options (See **paragraph 5.4.4**).

5.4.3.3 Access

A minimum of three access manways must be provided. Two 36-inch diameter (minimum) hinged-type manholes are provided at the bottom shell course. One 36-inch diameter access hatch is provided in the roof. The design of the manway and reinforcement around the openings must conform to the requirements of ANSI/API Standard 650.

A galvanized steel ladder is provided at the outside of the tank and should extend to the roof. Safety climbs are provided instead of safety cages at all ladders. Anti-climb provisions are also provided on all ladders.

A platform with galvanized steel grating and railing is provided and installed on the roof adjacent to the ladder. The roof manway and ladder are provided near the roof platform for access to the tank interior.

The revolving roof ladder is galvanized and designed to clear the roof manhole, all electrical conduit and cathodic protection equipment on the roof. Roller wheels are provided at the pivot end.

Ladders, safety climbs, platforms, and guardrails must meet Cal-OSHA General Industry Safety Orders and the following requirements:

- Provide interior catwalk at the spider rod level.
- Spacing between vertical members on ladder guard cage should be no greater than 15 inches center-to-center.
- Ladder rungs must have a minimum diameter of 3/4 inch.
- Distances between the first rungs of ladders and top steps are no more than 12 inches. Where there is no step, the first step is no more than 18 inches above grade.
- Rungs clear width is greater than or equal to 16 inches.
- Clearance on the climbing side of the ladder to the nearest obstruction is at least 36 inches.
- Clearance between back of ladder and the tank is over 7 inches.
- The dismount railing at the roof is 42 inches tall and 18 to 24 inches wide. A chain is provided between dismount railings.

- Rails are not less than 2 inches by 3/8 inch.
- Safety climb devices with a pivot dismount pole are provided on all exterior and interior ladders where required.
- Provide D-rings, hold-downs and other safety hook-up points on exterior and interior for attachment of safety cables and harnesses.

5.4.3.4 Vents

A vent is installed at the center of the tank roof. The vent is sized to prevent pressure buildup during the inlet and outlet operation at the maximum hydraulic rate. A type 316 stainless steel insect screen is provided in the vent.

A rotary ventilator is provided on the center of the roof. The ventilator is 3 feet in diameter, made of aluminum, and provided with cross braces and a type 316 stainless steel screen in a detachable frame.

Side ventilators with galvanized frames and type 316 stainless steel screens are placed in each top shell plate above the maximum water surface in the tank. Side ventilators should be provided with drip troughs to intercept condensed enamel fumes from the inside of the roof and prevent the same from running out of the vents and down the outside wall of the standpipe.

5.4.3.5 Tank Appurtenances

Appurtenances at steel tanks and standpipes include the following equipment:

- Inside and outside painters' trolley rails are constructed to set out from the tank shell for drainage. The trolleys should be constructed so that they can be operated on the inside or outside track.
- Spider rods are installed permanently by welding, above the painter's trolley track, and the rods are left in place upon completion of the tank.
- A davit crane and winch system is installed on access platforms over 25 feet in height. The davit crane and winch are rated for a minimum load of 1,000 pounds. The working platform and railing at the davit location provides for safe operation, with a minimum platform size of 6 feet by 5 feet. The railing around the platform is at least 42 inches tall with a lower kickplate of 4-inch minimum height above the platform and a 24-inch opening in the railing for access.

5.4.4 Instrumentation and Control Guidelines

Instrumentation and control systems at storage facilities consist of level monitoring, storage facility inlet and outlet valves, isolation valves, altitude valves, position monitoring, flow monitoring, a seismic isolation valve system, chlorine disinfectant and injection control system, recirculation systems, intrusion alarm systems, stratification layer(s) temperature measurements, and external weather stations. For water quality monitoring system layout, refer to **Figure 5-1** Water Quality Monitoring System.

5.4.4.1 Telemetry/Control and Communications

Telemetry/control and communications must be in accordance with the latest City requirements for supervisory control and data acquisition (SCADA) remote terminal units (RTUs). A programmable logic controller (PLC) or Programmable Automation Controller (PAC) interfaces between the facility processes instruments and the radio transceiver/router and/or commercial cellular circuit. The storage facility RTU is polled by the Human Machine Interface (HMI), which is programmed in accordance with the storage facility Control strategy and process instrumentation thresholds. Process circuits are loop powered and produce a 4-20 mA current, our existing legacy standard electrical interface, equally in proportion to the process variable. Instrumentation and process threshold set points should be prepared by the DESIGN CONSULTANT, as defined in the contract documents. This strategy should be originally defined in the Predesign Report and the detailed control strategies should be prepared by the DESIGN CONSULTANT in coordination with the Public Utilities Department's System Operations and SCADA Administrator.

5.4.4.2 Level Monitoring

The below grade storage facilities primary level sensor is an ultrasonic, radar, laser, or head pressure level transmitter, which is a proportional analog measurement of the physical water level of the storage facility. The sensor is interfaced to the local PLC/PAC via analogous process circuits. The sensor head is mounted on a 3-inch ANSI flange or customized bracket at the top of the storage facility and the transmitter control box is mounted 4.5 feet above finished ground and centered away from the walls. The control box integral digital level readout indicates the tank level in feet and inches. The secondary backup reservoir level is read with another similar level sensor transmitter. The pressure level transmitter should be below ground. A submersible type pressure level transmitter is acceptable as work around for above ground storage facilities.

High and low level switches (discreet devices) are provided as a back-up to the level transmitter. The level switch is of the inductive type with cable-suspended electrodes held by an electrode holder mounted on a 3-inch ANSI flange or a customized bracket at the top of the storage facility. The switches and the level transmitter are connected to the PLC/PAC. Dual cell storage facilities are provided with level instrumentation in each cell.

Above grade storage tank and standpipe level transmitters are equipped the same type level sensor transmitters as below ground reservoirs as mentioned above. The transmitter is provided with an integral digital display calibrated to feet of water level.

Above grade tanks and standpipes requiring local level indication are provided with a target and gauge board assembly. The vertical moving pointer is actuated by an internal float riding on two bottom-anchored guide cables. All components in contact with water must be of type 316 stainless steel.

5.4.4.3 Inlet/Outlet Valves

Storage facility isolation butterfly valves are provided with valve position limit discreet switches to report valve status to the HMI. Storage facility altitude valves require localized hydraulic pilot control as a primary means of operation. Altitude valves hydraulic pilot control set points should be prepared by the DESIGN CONSULTANT. Altitude valve should provide status feedback to the local PLC/PAC for remote monitoring. The minimum required feedback and control interfaces for altitude valves are OPEN and CLOSED states. Altitude valve diaphragms and stems are required to be interfaced with the percentage position indicator via a proportional and analogous position transmitter. Additional override electrical features should be provided to alternatively control the altitude valve via the interfaces to the local PLC. Include 24VDC solenoids on the pilot controls high side and low side of the altitude valve to control the valve via the PLC/PAC. In addition, the bidirectional flow rate monitoring is accomplished by a flow transmitter. This transmitter also reports to the PLC/PAC for remote monitoring.

5.4.4.4 Seismic Isolation Valve System

There are three primary functions of a seismic isolation valve:

1) Provide automated control with override option to open/isolate a tank under normal or seismic conditions

2) Isolate a tank from the pressure zone, should the operator deem it suitable to withhold the water inventory in the tank from leaking out of broken distribution system pipes. The water in the tank can then be made available for firefighting at some time after the seismic event has occurred, but before the pressure zone can be re-supplied with additional water; i.e. water treatment plants

3) Isolate the tank from the distribution system to prevent rapid loss of water due to broken pipes that could result in loss of life and/or property damage

Unless a credible life safety or other threatening situation occurs, it is not generally advisable for seismic isolation valves to automatically close and isolate all water from a pressure zone. This type of automatic closure could leave a pressure zone with no available source of water to fight fires immediately after an earthquake. This guideline could be relaxed if fire department and public utilities department emergency coordination capability can be demonstrated to be reliable under post-earthquake conditions. In this case the isolated tank could be opened within, at most, 1 or 2 minutes, once it is deemed that the situation warrants the need for fire flow water from the isolated tanks. The DESIGN CONSULTANT is responsible for preparing a controlled strategy to operate seismic devices. The DESIGN CONSULTANT is also responsible for determining the seismic thresholds to operate seismic devices automatically.

For pressure zones which are served by two or more tanks, it is acceptable to isolate the tanks automatically (or remotely) under seismic conditions, except for the largest tank. Assuming pipeline damage has occurred in that zone, the non-isolated tank can be expected to drain (go empty) within hours, depending on the nature and location of the pipeline damage and hydraulics of the zone, and assuming, also, no manual intervention (manually closing valves) has taken place in this time frame. If a fire ignites in that zone after the time the first tank goes empty, but before the zone can be re-supplied with additional water from water treatment plants, the isolated tank(s) can be overwritten remotely opened to provide fire flows for that fire.

For tanks where it is deemed suitable to add seismic isolation valves, the valves should have the following attributes:

<u>Remote Seismic Isolation Valves</u> Two sensors should be used to detect situations where operators (via SCADA) decide to close (or partially close) a valve. One signal should indicate that a large earthquake has occurred. This can be demonstrated by sensing that a suitably high and long duration level of shaking has occurred. This can be measured by ground acceleration, velocity or shaking-energy-type sensors. The settings to indicate that a large earthquake has occurred should be set such that high frequency short duration accelerations (truck vibration, shock loads) do not falsely indicate a large earthquake. The second signal should indicate a sudden loss of pressure or increase in flow of water leaving the tank. A PLC/PAC can be developed to automatically determine if both conditions have occurred. If both conditions have occurred, then the PLC/PAC can send a signal to the isolation valve to close completely or partially. The partial closure could be used to throttle back the water flows. There should be an alternate power supply to operate the instrument sensors, the SCADA system, and to actuate the isolation valve, which does not depend on electric or gas supply from San Diego Gas and Electric, under post-earthquake conditions. The power supply should be sized to provide 4 full valve cycles (i.e., two closures and two openings). Prominently placed instructions should be located at the valve to allow manual override of the seismic isolation valve.

<u>Automatic Seismic Isolation Valves</u> Two sensors should be used to make the decision to automatically close a valve to isolate a tank. One signal should indicate that a large earthquake has occurred. This can be demonstrated by sensing that a suitably high and long duration level of shaking has occurred. This can be measured by ground acceleration, velocity or shaking-energy-type sensors. The settings to indicate that a large earthquake has occurred should be set such that high frequency short duration accelerations (truck vibration, shock loads) do not falsely indicate

a large earthquake. The second signal should indicate a sudden loss of pressure or increase in flow of water leaving the tank. A programmable logic controller (PLC) can be developed to automatically determine if both conditions have occurred. If both conditions have occurred, then the PLC can send a signal to the isolation valve to close completely. There should be an alternate power supply to operate the instrument sensors and actuate the isolation valve, which does not depend on electric or gas supply from San Diego Gas and Electric, under post-earthquake conditions. The power supply should be sized to provide 4 full valve cycles (i.e., two closures and two openings). Prominently placed instructions should be located at the valve to allow manual override of the seismic isolation valve.

A fire hydrant or similar type outlet should be placed between the tank and the seismic isolation valve to allow the fire department to draft directly from the tank under emergency conditions.

Design details for the seismic isolation valve may include the following:

- The seismic detector, upon verification that a seismic event with a magnitude higher than its set point has occurred, closes the storage facility isolation valves by actuating the inlet and /or outlet isolation valve electric actuators. If the isolation valve is a single altitude valve, Cla-Valve or similar, the valve should be provided with a valve closing solenoid to be tripped by the seismic controller, in addition to the specified valve position limit switch.

- The seismic detector is connected in a "voting" scheme, where the valve closure command is issued only when an additional signal B either high flow or low pipeline pressure B denotes that a pipeline failure has occurred. A strategic location is selected for a pressure transmitter and/or flow transmitter on the inlet or outlet pipeline to suit each storage facility design.

- The seismic detector is provided with a back-up 24 VDC battery pack to sustain operation for at least 12 hours. The seismic detector control unit is installed in the RTU control panel with the PLC/PAC and telemetry equipment. Seismic sensors should ideally be mounted in a "free field" condition in a suitable enclosure or may be mounted on a suitable high frequency structural wall or column. The seismic sensor(s) are connected to the control unit with manufacturer-furnished cables. Alarm contacts are provided and connected to the PLC/PAC. Through the PLC/PAC, the seismic detection system accepts the remote valve closure command from the HMI as well as "system disarm" and reset command.

- The isolation valves electric motor actuators are 24 VDC type, connected to a 24 VDC battery and charger with sufficient power to actuate the valves four times (two closures and two openings).

5.4.4.5 Site Intrusion Alarm

The storage facility site is provided with intrusion switches on hatches, maintenance access openings, entrance gates, and electrical panels as well as motion detection. Intrusion switches are connected to the PLC/PAC which is programmed with an adjustable time delay upon entrance to allow the operator to disable the alarm before it is broadcast by the telemetry system. The disarm/reset controls are located in a convenient location for authorized personnel operation.

5.4.4.6 Chlorine Injection Instrumentation

Residual chlorine is monitored in a continuous sample stream by a Amperometric type chlorine analyzer. Provide a holding tank to temporarily store the chlorine analyzer process water. Include a small pumping system to recirculate the process water back in to the storage facility.. The transmitter produces an isolated 4-20 mA output to the PLC/PAC proportional to chlorine residual. Field selectable ranges are between 0 and 5 mg/l. The PLC/PAC is programmed with a 3-mode proportional integral derivative controller to pace the chlorine injection pumps.

A liquid level indicator is required and is a direct reading gauge with a type 316 stainless-steel float inside the tank and an indicator board mounted on the outside of tank.

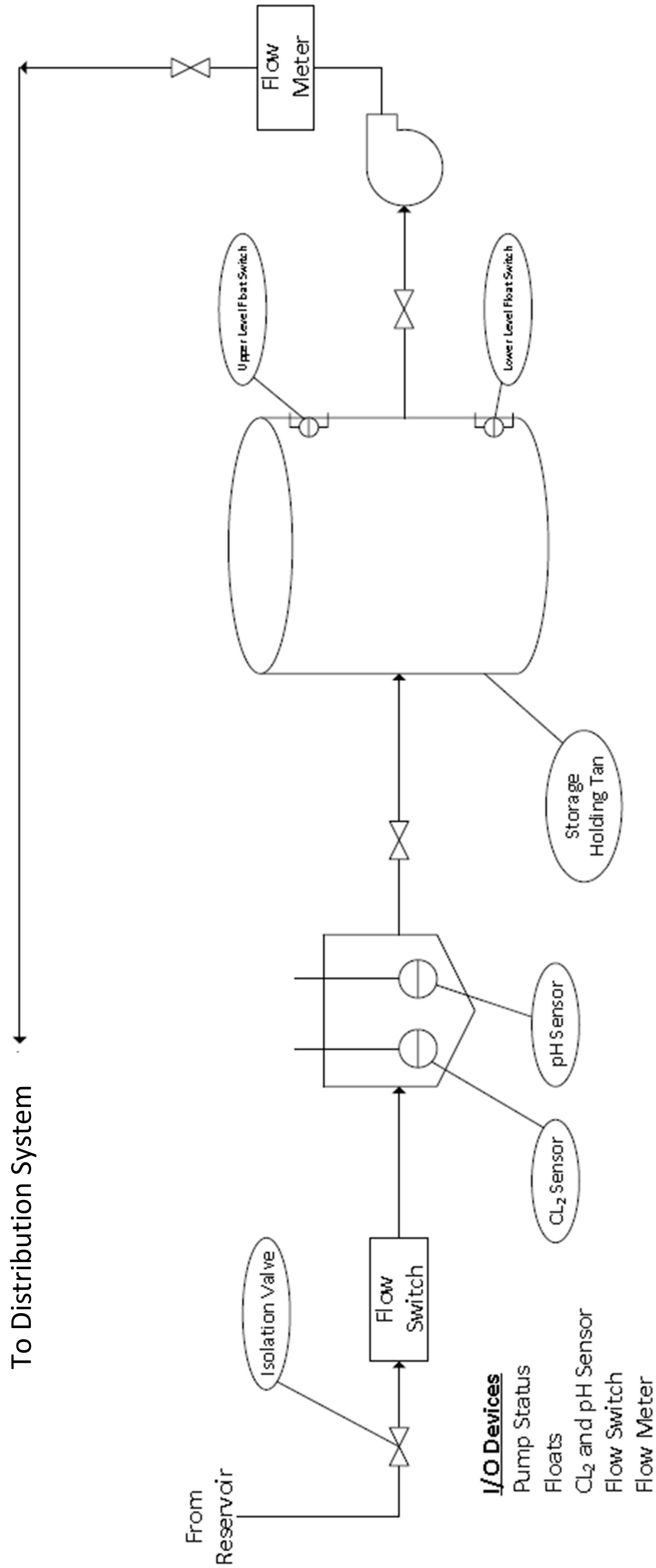
5.4.4.7 Temperature Measurements

Provide three temperature sensors that are proportionally analogous to the water temperature. Place each sensor on the center of the storage facility and vertically spaced equally to yield three temperature readings. The temperature sensors should be insertion type sensors with a 4-20 mA current interface each to the local PLC/PAC.

5.4.4.8 Weather Stations

It is crucial to measure ambient weather conditions such as rainfall, temperature, humidity, and wind speed and direction. This data is used to assist in performing analysis and forecasting future trends in water demand. Mounting location of weather station sensors is site specific and will require a case by case assessment.

Figure 5-1: Water Quality Monitoring System



5.4.5 Cathodic Protection Guidelines

Impressed current cathodic protection shall be designed and installed to protect all submerged steel surfaces per NACE SP0388. Selection of materials and coatings must be in accordance with the latest City requirements.

5.4.6 Electrical Guidelines

5.4.6.1 Purpose

This section provides guidance in the design of electrical facilities for storage facilities and the conduct of special studies (including protective device coordination, short circuit study, arc flash hazard analysis, harmonics, load flow/voltage drop and motor starting analysis). Arc fault energy levels shall be considered to ensure all personnel are protected in the event of an arc flash incident.

5.4.6.2 Electrical Codes and Standards

These guidelines are in addition to the requirements of the following applicable articles of the latest Codes and Standards listed below:

- National Electrical Code (NEC, NFPA 70)
- California Electrical Code
- National Electrical Safety Code
- Institute of Electrical and Electronics Engineers (IEEE)
- American National Standards Institute (ANSI)
- National Electrical Manufacturing Association (NEMA)
- Underwriter's Laboratory Standards (UL)
- California Occupational, Safety, and Health Administration (CAL OSHA)
- Federal Occupational, Safety, and Health Administration (OSHA)
- National Fire Protection Association Standard (NFPA 70E)

These guidelines are the recommended minimum requirements and shall not be used as a substitute for sound electrical engineering judgement.

5.4.6.3 Electrical Criteria

Electrical designs promote the commonality of hardware, the use of proven hardware, and the use of current technology. All electrical service cabinets and other free-standing equipment must have seismic braces to satisfy code requirements.

All electrical material and equipment shall be labeled or listed by UL or by another Nationally Recognized Testing Laboratory (NRTL).

The bus, wiring and transformer systems shall be designed to limit overall voltage drop from source (incoming switchgear) to load to 5%.

Allowable steady state voltage drops shall be:

- Main Feeders 2%
- Motor Feeders 3%
- Transformer Feeders 3%
- Panelboard Feeders 2%
- Branch Circuits 2%

Allowable transient voltage drop during motor starting shall not exceed 15% of rated bus voltage on any 480V or greater.

Transient voltage shall not dip below 85% of rated motor terminal voltage at motor terminals.

Utilization voltage ratings are as follows:

- Motors smaller than 3/4 hp are 120 volts, single phase, 60 Hz.
- Motors 3/4 hp and larger are 480 volts, 3 phase, 60 Hz.
- Miscellaneous non-motor loads of 0.5 kW and less are rated at 120 volts.
- Non-motor loads larger than 0.5 kW are rated at 480 volts, 3-phase, unless this voltage rating is not available for the equipment selected.
- All ac control power circuits are 120 volts.
- All instrumentation power supplies are 120 volts ac.
- Special purpose dc control circuits may be 125 volts, 48 volts, or 24 volts.

Motors must have the following features:

- Heavy duty, 100,000 hour rated bearings.
- Oil-lubricated motors are equipped with a visual oil level indicator.
- Locked rotor must comply with NEMA Code “F” or better.

- Motors for water pumps are solid shaft type for ease of adjustment of impeller by means of adjusting a nut at the top of the impeller. The Construction Contractor is required to submit a detail showing how adjustment of the pump impeller using upper end of motor for City approval.

- Motors have winding over-temperature safety switch.

- Motors have strip-type heater elements that automatically disconnect.

5.4.6.4 Interfaces

At storage facilities with a pumping station, electrical facilities must also comply with the provisions outlined in **Chapter 6**. The electrical design is coordinated with the cathodic protection system to avoid possible interference between the storage facility grounding system and the cathodic protection system.

5.4.6.5 Electrical Service and Distribution

Distribution (utilization) voltages at the storage facility site are 480 V, 208 V, and 120 V unless other voltages are required for special cases. Incoming service voltages must be coordinated with SDG&E.

The storage facility power distribution system is designed such that no single fault or loss of the preferred power source results in disruption (either extended or momentary) of electrical service to more than one of the vital components. Vital and non-vital components serving the same function are divided as equally as possible between at least two MCCs or distribution panels.

The electrical power distribution system incorporates redundant power sources. The requirement for redundant supply is waived only in consultation with the City Project Manager. Incoming power metering has the capability for remote reading via telemetry.

Outdoor installations have non walk-in, weatherproof enclosures.

5.4.6.6 Electrical Equipment

Electrical equipment is sized to continuously carry all electrical loads without overloading. Equipment and materials are rated to withstand and/or interrupt the available fault currents, with at least a 20% reserve margin for electrical load growth. Electrical power conductors are sized according to the heating characteristics of conductors under fault conditions.

1. *Distribution/Lighting Panels*

All panels have non-fusible disconnects in the main panel to open circuits during repair work. All breakers have "lockout" safety switches. 25% spare breakers are provided for future expansion.

2. *Motor Control Centers*

Motor control centers at storage facilities must conform to the requirements described in **Chapter 6**.

3. *Switchgear*

Switchgear requirements must conform to the requirements described in **Chapter 6**.

5.4.6.7 Grounding

The grounding system shall be designed for personnel safety and to protect equipment in case of apparatus failure, lightning and static electricity.

All feeders have an equipment grounding conductor in the same raceway. Noncurrent carrying metal parts of equipment, all enclosures, and the raceway are grounded by an equipment ground conductor contained in the raceway, cable or run with the circuit conductors in the same raceway. Equipment grounding conductors must be sized according to NEC Article 250.

The grounding system in the storage facility area is coordinated with the cathodic protection system design to ensure that grounding does not hasten corrosion of pipe, tanks, and equipment.

5.4.6.8 Instrument Power

All 120 V power to instruments and instrument panels is derived from a dedicated instrument power panel from a shielded transformer. A general lighting and convenience receptacle panel may not be used to serve above loads. Instrument panels must be in a NEMA 3 or NEMA 4 enclosure.

An uninterruptible power supply (UPS) is provided for all main control panels, RTUs, RIOs, PLCs, and all other process controllers to provide continuous conditioned power. The UPS is sized to provide 30 minutes of standby power.

5.4.6.9 Emergency Power

Requirements for emergency power are generally described in **Chapter 6**. Diesel engine units may be installed with special approval from the Water Operations Division Senior Civil Engineer. If required, an automatic transfer switch is provided.

5.4.6.10 Lighting

The California State Energy Conservation Standards apply where applicable. Voltage for lighting systems is as follows:

- Outdoors: LED, 277 or 120 volts, with a photoelectric cell and a timer in parallel and a manual override.

Suggested illumination levels are as follows, and should comply with latest IES guidelines:

- Electrical equipment rooms: 40 footcandles
- Exterior lighting: 0.1 to 1 footcandle
- Mechanical equipment rooms: 30 footcandles

Lighting adjacent to stairs and ladders is switched. The pathway to the main lighting switch is lighted with non-switched lighting fixtures.

All other outdoor lighting around storage facilities is controlled by photoelectric cells with a parallel timer and a manual bypass with key-operated switching.

Exterior lighting with 90-minute capacity emergency battery back-up packs is provided at the property entrance gate to unattended storage facilities.

5.4.6.11 Receptacles

The convenience GFCI receptacles throughout the outside of the facility must be 20-amp, NEMA 5-20-R, 120-volt grounding type located so that all working areas can be reached by a 50-foot extension cord. 480 V, 3-wire, 4-pole twist lock receptacles are provided so that the receptacles can be reached by a 50-foot-long cord. All outdoor receptacles in wet areas are in weatherproof enclosures installed in secured locations.

5.4.6.12 Additional Requirements

The contract documents shall include the requirements for:

- Provision for testing and written certification of ground fault testing.

- Spare parts and service for all major electrical equipment, including motors, emergency generators, electrical switchgear, and MCCs, available in Southern California within 24 hours of notification.

- If required by the Federal Aviation Administration (FAA), obstruction lights, wiring and conduit are provided.
- Building design shall comply with the regulations and standards associated with the California Electric Code (Part 3) and the California Energy Code (Part 6) of the 2016 California Building Standards (Title 24).

5.4.7 Architectural and Landscaping Guidelines

Each storage facility structure should be evaluated based on its surroundings, designed to fit the local setting, and complement surrounding adjacent land use. The DESIGN CONSULTANT should consider the following:

- The design approach is flexible and creative, adapted to the unique conditions at each storage facility site. There is no single theme/style for storage facility structures.
- Construction material and plantings should be evaluated and selected according to requirements of function such as durability, aesthetics, maintenance, and cost-effectiveness.
- The design is well conceived and of lasting aesthetic value, putting public funds to good use.
- Color is in accordance with local community input.
- DESIGNER to coordinate with Project Manager for art requirements.

5.4.8 Storage Facility Construction, Filling, Disinfection and Testing

5.4.8.1 Storage Facility Construction

In addition to the requirements of AWWA D100, ANSI/AWS D1.3, ANSI/API STD 650, and any other relevant AWWA specifications, all intersections of horizontal and vertical welds in the standpipe shell must be inspected by radiographic methods and provisions made to deliver the film to the Construction Manager upon completion of the work.

Sand for the cushion under the standpipe is thoroughly dry, where the use of dry sand is practicable. Under unusual conditions and when necessary, the sand may be pre-oiled, in which case the cushion must be rolled with a heavy roller and finished slightly higher than is required if dry sand is used, to take into account the compaction of the cushion under load, which might result in the standpipe floor being lower than the top of the foundation.

A clearance of 1/4 inch is provided between the outside edge of the floor plate and the side of the sand cushion depression in the foundation.

In testing the floor with hot oil, the oil should be injected very slowly to avoid displacing the sand and ensure complete coverage. This test is performed only in the presence of the City Inspector.

5.4.8.2 Filling, Disinfection and Testing

Before filling the standpipe for testing, the walls are thoroughly washed and the tank disinfected, per AWWA C652.

The overflow pipe is tested by filling it with water before filling the standpipe and before connecting to the drain line. Considerable time and large quantities of water have been lost due to leaks discovered in overflow pipes after standpipes are filled.

After the standpipe is filled, the plug on the bottom side of the overflow nozzle is removed to determine whether leaks have occurred in the overflow pipe since the original test was made.

Anchor bolt nuts shall be torqued after filling the standpipe and again before acceptance by the City.

Site piping and valves shall be pressure tested in accordance with the provisions of **Chapters 3 and 6**.

5.5 Reinforced Concrete and Prestressed Concrete Storage Facilities

This guideline governs the design of buried and partially buried, cast-in-place, reinforced concrete storage facilities. The function of partially buried storage facilities is identical to that for buried concrete storage facilities. Partially buried concrete storage facilities have features similar to those for buried storage facilities, except that the structures are designed to be backfilled to a level below the roof elevation.

Storage facilities may consist of a single or dual basin configuration with hopper-shaped bottom(s). A dual basin design separated by a common wall is the most common storage facility configuration.

5.5.1 Site Design Guidelines

Site design guidelines for buried and partially buried reinforced concrete storage facilities are essentially identical to those for steel tanks as described in paragraph 5.4.1. Site grading prevents site drainage from gaining access to the top of buried storage facilities and the earth blanket on the top of a buried storage facility provides a minimum of 1% grade from the roof ridgeline to the perimeter of the storage facility.

The underdrain system provided consists of a grid of drain pipes beneath the floor of the storage facility and around its perimeter. The underdrain system reduces the uplift forces that occur when the storage facility is drained and detects excessive leakage from the storage facility. The underdrain system needs to be laid out in zones, no bigger than 20,000 ft^2 each, so a leak can be located in a specific area. Water collected in the drain piping system is discharged to an underground vault. An inspection manhole is provided at the vault for direct observations of leakage. Drain rock is provided beneath the storage facility and pea gravel is placed around the underdrain piping.

As part of the storage facility design, volume calculations are required to establish the volume of the storage facility at 0.1-foot increments between the high water level and the floor level at the sump. The reduction in volume attributed to the overflow device and the roof columns is included in the calculations.

5.5.2 Structural Guidelines

Structural review is performed by the Development Services Department, Building and Safety Plan Review. New Building Regulations are adopted by the City of San Diego Municipal Code on a regular basis. Storage facilities may require permits issued by both the City Engineer and Chief Building Official (Development Services Department). Discuss the type of City permits that will be required with the City's Project Manager. Information for Building Safety Plan Review can be found at Sandiego.gov/development-services.

5.5.2.1 Reference Standards and Codes

The latest editions of the following standards and codes govern the design of buried and partially buried reinforced concrete storage facilities:

- Building Code Requirements for "Minimum Design Loads in Buildings and Other Structures," ASCE 7 by the American Society of Civil Engineers
- Title 24, Part 2, California Building Code.

- CBC of the International Conference of Building Officials, as adopted under the City of San Diego Municipal Code.
- Building Code Requirements for Reinforced Concrete, ACI 318, and commentary, ACI 318R, as contained in the CBC and as adopted under the City of San Diego Municipal Code.
- Environmental Engineering Concrete Structures, ACI 350.
- "Concrete Manual," U.S. Bureau of Reclamation.
- Concrete Reinforcing Steel Institute (CRSI) Handbook.
- "Rectangular Concrete Tanks," Portland Cement Association (PCA).
- "Moments and Reactions for Rectangular Plates," Engineering Monograph No. 27, U.S. Department of the Interior Bureau of Reclamation.
- Structural Welding Code - Steel, ANSI/AWS-D1.1.
- Recommended Lateral Force Requirements and commentary (commonly known as "Blue Book"), Seismology Committee of the Structural Engineers Association of California (SEAOC).
- "Formulas for Stress and Strains," Roark and Young.
- Standards of the Occupational Safety and Health Administration.
- State of California Construction Safety Orders, Cal-OSHA.
- **Chapter 8 Seismic Criteria.**

5.5.2.2 Design Loads

The following criteria define the minimum design loads for buried and partially buried concrete storage facilities. Without limiting the generality of the other requirements of these criteria, all design loads must conform to or exceed the requirements of the CBC, ASCE 7, and all applicable requirements of the documents referenced in **Section 5.5.2.1** above.

1. *Dead Loads*

In addition to the dead load of the basic structural elements, the following items are included in the dead load:

- All equipment and piping permanently attached to and considered part of the structure, including future equipment and piping.
- Piping of 12-inch diameter and smaller is treated as uniformly distributed loads.
- Piping larger than 12 inches in diameter is treated as concentrated loads.

2. *Live Loads*

Live loads, in addition to concentrated loads, are determined as follows:

- Roofs that require vehicular access for maintenance require H-20 traffic loads.
- Roof Loads: in accordance with the ASCE 7 CBC, or local code, whichever is more stringent.
- Stairs, Platforms, and Walkways: ASCE 7 or local code, whichever is more stringent.
- Minimum concentrated load on ladders and stairs: in accordance with the requirements of ASCE 7, OSHA, Cal-OSHA, or local codes, whichever is greatest.
- Mechanical and electrical equipment areas are designed for a minimum of 100 psf live load. Additional consideration is given for the type, size, and weight of specific equipment and the maintenance equipment in determining the actual design live load and concentrated loads.

3. *Wind Loads*

Wind loads must be in accordance with the ASCE 7, and the CBC or on the requirements of local code, whichever is more stringent. The design is governed by maximum wind or maximum seismic load, whichever is greater.

4. *Hydrostatic and Hydrodynamic Loads*

Buried and partially buried storage facilities are considered environmental engineering structures and are designed for hydrostatic forces imposed by the fluid contained in them. All environmental engineering structures are designed for hydrodynamic forces using ground acceleration and the response spectra identified in the project geotechnical report and the requirements of **paragraph 5.5.2.2.6**.

5. *Lateral Loads*

Buried and partially-buried concrete storage facilities are designed for the following applicable pressures:

- For all yielding structural components, lateral soil loads are determined using active soil pressure conditions recommended in geotechnical report.
- For all non-yielding structural components, lateral soil loads are determined using passive soil pressure conditions recommended in the geotechnical report.
- A minimum surcharge pressure equal to an additional 2 feet of soil is used for all structures adjacent to traffic loading conditions.
- Hydrostatic pressure imposed by the contents of the storage facility is considered.
- Hydrostatic pressure imposed by groundwater conditions, in addition to lateral soil pressure, is considered in the design. Lateral pressure distribution is as recommended in the geotechnical report.
- Seismic soil pressure is in accordance with the requirements of **paragraph 5.5.2.2.6.**

6. *Seismic Loads*

Seismic loads shall be developed in accordance with **Chapter 8, Seismic Criteria**:

- When selecting ground motions for seismic design, consider requirements for uninterrupted operation after a major earthquake.
- **Chapter 8 paragraph 8.5.1** provides requirements for seismic loading on underground structures.
- **Chapter 8, paragraph 8.6** provides guidance for application of seismic loads for water retention structures, including hydrodynamic effects.
- **Chapter 8, paragraph 8.6.3** provides specific guidance for design of water retention basins for earthquake loads.
- **Chapter 8 paragraph 8.6.4** provides specific guidance for design of internal structures in water retention basins for earthquake loads.

7. *Impact and Vibration Loads*

For structures carrying live loads that include impact, the assumed live loads are increased in accordance with the Specification For Structural Steel for Buildings, AISC 360. All forces produced by the equipment or machinery that vibrates are considered in the design of supporting structures and information on the magnitude of these forces is obtained from the respective equipment suppliers. Impact forces due to operations, including surging fluid, are considered in the design.

8. *Miscellaneous Loads*

Miscellaneous loads of a special nature, such as thrust from expansion joints or loads at special appurtenances, are considered in the design. Other examples of miscellaneous loads include:

- Surcharge loads, such as loads due to adjacent structures and vehicular loads.
- Thermal loads, where applicable.
- Operating pressure forces, forces due to moving fluids, and test forces and loads.
- Construction loads and conditions.
- Equipment load caused by removal of valves, etc.

5.5.2.3 Loading Conditions

Structures are designed for various loading conditions. As a minimum, the following load combinations are determined:

- Tank Full Without Backfill: Dead load plus hydrostatic loading plus hydrodynamic loading plus seismic forces resulting from dead loads.
- Tank Empty Without Backfill: Dead load plus seismic forces resulting from dead loads.
- Tank Full With Backfill: Hydrostatic loading plus static soil pressure plus dead load and live load plus hydrodynamic pressure plus seismic soil pressure plus seismic force due to dead load and soil cover.
- Tank Empty With Backfill: Dead load plus static soil pressure (at rest) plus seismic soil pressure plus seismic forces resulting from dead loads, including earth blanket on roof.
- Equipment loads where truck or other equipment are loaded on roof for removing equipment.

5.5.2.4 Allowable Stress

Allowable stress for reinforced concrete and prestressed concrete structures must be in accordance with ACI 350 and AWWA D110.

5.5.2.5 Structural Design Requirements

Reinforced concrete storage facilities are considered environmental engineering (hydraulic) structures and are designed for strength and serviceability. Designs are prepared using the strength design method or, as an alternative, the working stress design method. Designs must meet the following requirements:

- Structural designs of reinforced concrete environmental engineering structures and support facilities are in accordance with the general requirements of ACI 350.
- Design criteria are established within the limitations of the CBC and the ACI.

1. *Strength Design Method*

The following guidelines govern the strength design method:

- All concrete support facility structures not considered environmental engineering structures are designed by the strength design method.
- All conventionally reinforced concrete environmental structures should be designed for strength and include the Environmental Durability Factor as defined in ACI 350.
- Serviceability requirements for support facilities and environmental engineering structures must be in accordance with the provisions of ACI 350 and ACI 350.

2. *Working Stress Design Method*

If the working stress design method is adopted, the design must be in accordance with ACI 350, including the exceptions.

3. *Minimum Strengths*

Minimum strength for concrete and reinforcing steel is as follows:

- Concrete: 28-day compressive strength of 4,000 psi.
- Reinforcing steel: Yield strength of 60,000 psi per ASTM A615.

4. *Joints*

Expansion, contraction, and construction joints must be provided in accordance with ACI 350 to afford flexibility and accommodate differential movement, temperature stress, and shrinkage stress. All joints in environmental engineering structures where watertightness is required are provided with waterstops and sealant. All joint detailing, types, and locations must be in accordance with ACI 350. The locations of all joints are shown on the construction drawings. Joints for prestressed concrete tanks shall meet the requirements of AWWA D110.

Expansion joints are provided at abrupt changes in the structural configuration If storage facilities remain empty for extended periods, a closer spacing should be used.

Contraction joints are used to dissipate shrinkage stresses, where required. Where used, the spacing of contraction joints is at intervals of less than 24 feet, unless additional reinforcement is provided in accordance with ACI 350. For environmental engineering structures in seismically active zones, partial contraction joints are used where 50% of the reinforcement passes through the joint.

Construction joints are positioned to cause the least impairment of the strength of the structure, to provide a logical separation between sections of the work, and to facilitate construction. All reinforcement is continued across or through the joint unless designed as a contraction or expansion joint.

5. *Prestressing*

Structural design and materials of prestressed concrete tanks shall conform to requirements AWWA D110.

Strand used as base restraint cables or primary circumferential prestressed reinforcement shall be hot-dipped galvanized seven-wire strand and shall be manufactured in accordance with ASTM A416 prior to galvanizing, and ASTM A475 for galvanization and stranding. Wires shall be individually galvanized prior to stranding. The minimum weight of zinc coating per unit area of uncoated wire surface area shall be no less than 0.85 oz/ft^2.

5.5.2.6 Detailing

Detailing is performed in accordance with the seismic provisions of the following codes and references:

- CBC
- Provisions in ACI 318
- Provisions in ACI 350
- Provisions in AWWA D110

Detailing of different structural elements ensures that ductility and other requirements are in accordance with the requirements of the CBC and the SEAOC “Blue Book.”

5.5.2.7 Watertightness and Cracking

To maintain watertightness of the structure, cracking and crack widths must be kept to a minimum. Cracking can be kept to a minimum by proper design, reinforcement distribution, and spacing of joints. Requirements in ACI 350, and recommendations in 350R commentary should be followed to minimize crack width. Specifically, bar spacing, bar size, and joint detailing should follow ACI 350.

5.5.2.8 Design Requirements for Major Elements

1. *Roof*

The following guidelines are used when designing below-grade or exposed reinforced concrete roof systems:

- Use a flat slab system with a suggested column spacing of 20 feet, center-to-center.
- Consider the effect of relative rigidity when the concrete storage facility roof is rigidly connected to the tank walls. The effect of daily temperature fluctuation on exposed concrete roof slabs is a consideration for partially-buried storage facilities.
- For large, exposed, storage facility roof structures where expansion joints are required, provide ductile moment resisting frames or the combination of sheer walls and ductile moment frames to resist seismic forces.
- Reinforcing required by structural design and reinforcing required to meet minimum code requirements run continuously through roof construction joints.

2. *Walls*

Walls are designed in accordance with the following:

- For a single-story closed storage facility, the wall acts as a vertical slab with continuity at both top and bottom. Moment distribution can be used to obtain the effects of continuity with the base and top slab. Reinforcing details at corners should be considered to handle the local effect of continuity around the corner.
- Walls should be designed for the loading conditions given in **paragraph 5.5.2.3**.
- The walls should be designed for passive pressure due to retained soil.
- Joints shall conform to **paragraph 5.5.2.5**.
- Prestressed walls shall follow AWWA D110.

Provide adequate freeboard between the maximum fluid level and the top of the wall to accommodate for the sloshing of fluid induced by an earthquake to prevent excessive stresses at the roof and connections with the roof.

3. *Foundations and Floor Slabs*

Unless groundwater or other geotechnical requirements dictate a mat foundation, the foundation should consist of a spread footing cast monolithically with the floor slabs. Design floor slabs as a membrane-reinforced concrete slab carrying all loads (i.e., concrete, water, superstructure, etc.) to the foundation. This floor slab is provided with construction joints detailed and spaced and to adequately tolerate differential settlement and shrinkage stresses. Joints must be in accordance with the recommendations of ACI 350. All floor slab joints shall be provided with water stops.

Slab-on grade storage facility floors are designed and detailed as a mat foundation, carrying all loads except for the water, which is directly carried by soil to permit foundation and concrete volume change movements while carefully controlling crack widths. The bottom of the slab should be a reasonable level for ease in excavation and the top surface should slope a minimum of 1% along the longer dimension for cleaning and drainage. Column footings are placed monolithically and on top of the membrane slab to reduce stress concentration and to permit slab curling while controlling cracking. Give careful attention to corner detail to maintain continuity between walls and base slab.

5.5.3 Mechanical Design Guidelines

5.5.3.1 Inlet and Outlet

Inlet and outlet piping must be steel pipe, mortar-lined and coated, conforming to the requirements of ANSI/AWWA C200 and C205. Yard piping must conform to the requirements described in **Chapter 3** and exposed piping must conform to the requirements described **in Chapter 6**.

Design the inlet pipe to ensure water circulation inside the storage facility. Provide baffles if necessary. Valve vaults are provided for inlet and outlet control valves as described in **paragraph 5.4.3.1.1**.

Provide grating over the outlet pipe to protect piping from plugging due to a roof collapse. Space reinforced concrete piers to support the pipe and to protect against uplift of the pipe, due to buoyancy.

Place the outlet pipe in the outlet sump, located away from the inlet pipe, to accomplish maximum water circulation within the storage facility.

Place the outlet sump near the corner of the basin diagonally opposite the inlet valves to promote water circulation within the storage facility. The DESIGN CONSULTANT designs the outlet to be non-vortexing under maximum flow rate (pumps at full capacity) and with the water level at 5 feet above the top of the curb at the outlet sump. The slope from the toe of the 5:1 slope to the top of the outlet sump may vary from 1% to 0.5%, depending on the size of the storage facility. The elevation of the finished floor at the sump is determined by the DESIGN CONSULTANT. A curb with mud gates is provided around the outlet sump. A stainless steel handrail is placed around the perimeter of the outlet sump and a permanent stainless steel ladder is provided for access to the sump. The top of the sump is the lowest part of the storage facility floor. The sump is at least three column lines from the nearest wall.

A submerged emergency shut-off (sluice gate or butterfly valve) is provided in the outlet sump. In the event of an outlet pipe failure, the emergency shut-off provides a means for preventing the storage facility from draining completely, thus preventing structural damage to the storage facility.

5.5.3.2 Overflow System

A rectangular overflow weir structure cantilevered from the wall is provided. A steel pipe located at the invert connects the overflow to an appropriate point of discharge. The size of the overflow and the pipe is designed for the maximum fill rate. For dual basins, flow is through an opening in the dividing wall within the overflow structure. An air vent connected to the overflow pipe is provided to vent the trapped air in the pipe. The end of the pipe has a flap gate or insect screen.

The overflow pipe is sized to discharge the maximum fill rate of the tank. The overflow is located in an internal location. The overflow pipe should be braced against the tank wall. The DESIGN CONSULTANT designs the overflow system to ensure that water in the storage facility is protected from cross-contamination with surface water. The overflow pipe has an air gap separation, with flap gates and/or bug screening and low pressure flapper-type closure at overflow/drain piping outlet. Overflow structures should include level float sensors to detect overflow conditions and serve as a backup warning. The overflow float sensors should be fully integrated in to the local control system. (See **paragraph 5.4.4**). DESIGN CONSULTANT is required to provide control methods for all discharges, including hydrostatic water discharges emitted from the storage facilities as necessary to comply with the current Regional Water Quality Control Board (RWQCB) or State Water Resources Control Board (SWRCB) discharge permits.

5.5.3.3 Storage Facility Access

Access through the roof to the floor and the overflow structure is required. A concrete stairway, cantilevered from the wall, is the recommended access to the storage facility floor. A stainless steel ladder is recommended for reaching the floor of the overflow structure. Aluminum hatches with locking devices are provided to limit unauthorized access. The hatches are designed for the anticipated live loads. Where applicable for vehicular access, use H-20 loading.

5.5.3.4 Roof Vent

A minimum of four vents is provided for each basin. Vents are sized for the maximum inflow or discharge rate to prevent pressure buildup inside the storage facility. A bumped head, with mesh screen, is located on top of the vent above the finished grade.

5.5.3.5 Sample Taps

Sample taps are provided at various levels in the storage facility. A locked access to the sample taps is provided at the exterior of the storage facility at ground level.

A minimum of four 6-inch diameter sample ports are provided that extend through the concrete wall of the storage facility. These sample ports are all at the same elevation at the bottom of the storage facility. Sampling taps (3/4-inch diameter) are located on each sample port. Three of the taps must protrude a distance of 1 foot into the storage facility and be separated vertically to represent water quality from the facility at different heights. The fourth tap draws samples from near the bottom of the tank and is flush with the inside face of the tank. It is recommended that the sample ports be labeled, by height. Also, depending on the configuration and location of the sample lines, it may be recommended that recirculation pumps be installed to obtain representative samples and reduce biofilm growth within the sample lines.

A fifth 3/4-inch sample tap is provided in the recirculation piping if recirculation piping is used.

5.5.3.6 Washdown System

A washdown piping system is mounted on the interior wall of the storage facility. The minimum design flow rate is 25 gpm per nozzle. It is assumed all nozzles are operating simultaneously per basin. Maximum size of nozzle is 1 ½ inches. Minimum design pressure is 50 psi (static) at the hose connection. Any deviation from these requirements requires the DESIGN ENGINEER to prepare a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document.

5.5.3.7 Disinfection

Facilities are provided for rechlorination of water in concrete storage facilities as described in **paragraph 5.4.3.2** Chlorine injection points are provided and equipped with locking covers.

5.5.3.8 Recirculation Piping and Pumps

Recirculation piping and pumps are provided as described for steel tanks and standpipes in **paragraph 5.4.3.1.4**.

5.5.3.9 Appurtenances

Davit crane and winch systems must conform to the requirements **in paragraph 5.4.3.5**.

5.5.4 Instrumentation and Control Guidelines

Instrumentation and control systems for buried and partially buried reinforced concrete storage facilities must conform to the requirements in **paragraph 5.4.4**.

5.5.5 Electrical Guidelines

Electrical systems for buried and partially buried reinforced concrete storage facilities must conform to the requirements in **paragraph 5.4.6**.

5.5.6 Architectural and Landscaping Guidelines

Architectural design for buried and partially buried reinforced concrete storage facilities must conform to the requirements in **paragraph 5.4.7**.

5.5.7 Storage Facility Construction, Filling, Disinfection, and Testing

Storage facility construction, filling, disinfection and testing must conform to applicable portions of **paragraph 5.4.8**.

5.6 Demolition of Existing Storage Facilities

Design for the demolition of an existing storage facility includes removal and disposal of the concrete or steel storage facility, concrete foundation, and aboveground appurtenances. Buried utilities are abandoned in-place. Any deviation from this requirement requires the DESIGN ENGINEER to prepares a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document.

Removal of the existing coating and recoating may require that the site be classified as a lead paint removal project, depending on the lead content of the original paints used. If the site is classified as a lead paint removal site, the DESIGN CONSULTANT incorporates the procedure developed by the City Asbestos and Lead Management Program (ALMP) for removal of lead-based paints from the exterior and interior surfaces of the standpipe. The ALMP manages and directs all aspects of lead-based paint removal from the facility. The DESIGN CONSULTANT also provides for the removal of asbestos or other hazardous material from the site.

Final features of the site are decided on a case-by-case basis. Improvements largely depend on the anticipated future use of the land such as a park or parking area, or the site may be prepared for sale of the property. The DESIGN CONSULTANT coordinates the final site features with the Public Utilities Department Project Manager.

5.7 Rehabilitation of Existing Storage Facilities

Rehabilitation of an existing storage facility is intended to include all the design features described in earlier sections of this Chapter 5, including:

Site Design Guidelines

Structural Guidelines

Mechanical Design Guidelines

Instrumentation and Control Guidelines

Cathodic Protection

Electrical Guidelines

Architectural Guidelines

Storage Facility Construction, Filling, Disinfection and Testing

Site improvements may include repairs or improvements to existing pavement, fencing, lighting and security. The DESIGN CONSULTANT performs a structural analysis that meets the intent of **Chapter 8, Seismic Criteria**. **Paragraph 8.10 in Chapter 8** may be used for seismic evaluation and upgrade of existing structures. Removal of the existing coating and recoating may require that the site be classified as a lead paint removal project, depending on the lead content of the original paints used. If the site is classified as a lead paint removal site, the DESIGN CONSULTANT incorporates the procedure developed by the City Asbestos and Lead Management Program (ALMP) for removal of lead-based paints from the exterior and interior surfaces of the standpipe. The ALMP manages and directs all aspects of lead-based paint removal from the facility. The DESIGN CONSULTANT also provides for the removal of asbestos or other hazardous material from the site.

All electrical conduit and appurtenances are upgraded to meet current code requirements, including the installation of weatherproof conduit, fittings, receptacles, and appurtenances, and the installation of ground fault circuit interrupters (GFCIs).

Improvements for each reservoir are approached on a case-by-case basis. The DESIGN CONSULTANT coordinates improvements with the Public Utilities Department and the City's Project Manager.

Appendix 5-1
Nitrification Action Plan

THE CITY OF SAN DIEGO

City of San Diego
Nitrification Action Plan
(CDPH SYSTEM NUMBER 3710020)

JANUARY 21, 2011

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

Water Operations Branch; System Operations Division
Wastewater Branch; Environmental Monitoring and Technical Services Division

Certified
ISO 14001

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Background

General

The City of San Diego (City) has developed this Nitrification Action Plan to provide both an early warning of impending nitrification, and an operational means to prevent/minimize nitrification episodes within the City's potable water system. Guidelines and practices have been developed to ensure a uniform approach to nitrification control. The most important components of these guidelines are the monitoring of existing system facilities, investigation and mitigation of nitrification episodes, and measures to minimize future nitrification.

Nitrification Overview

Nitrification is a biological activity, not a chemical reaction. Ammonia Oxidizing Bacteria (AOB) use ammonia as a nutrient/food. The biological process converts ammonia to nitrite. During extensive nitrification episodes, chloramines are also used as a nutrient and AOB convert the chloramines to ammonia then nitrite. Direct measurement of AOB is not practical due to the time and complexity required to perform the analysis. Nitrification can be detected by measuring the nitrification byproduct nitrite, which can be easily and quickly measured. Once nitrification starts, nitrite is present and chlorine residuals degrade quickly causing rapid drops in disinfection residual and possible increase in heterotrophic plate counts.

Factors affecting nitrification have been well documented. Water age, source water quality, bio films and chlorine residual are major factors influencing nitrification. Additional water quality parameters influencing nitrification include pH, temperature, nitrifying bacteria, and water velocity. Increased water age results in a decline of chloramine level. Water with chloramine levels < 2 mg/L has significantly higher incidences of nitrification. As water ages, the chloramine degrades and free ammonia is released into the water. Source water with high free ammonia concentrations provides nutrients for nitrifying bacteria. An accumulation of biofilm protects nitrifying bacteria from chloramines and free chlorine.

AOB and other nitrifying bacteria can be killed or inactivated by exposure to a Free Chlorine residual. Once AOB become established they are not killed or inactivated by chloramines, even at high dosages. AOB have been shown to be resistant to chloramine at residuals > 10 mg/L. Free chlorine is approximately 150 times as effective as chloramines in killing or inactivating bacteria. Mitigation of nitrification within storage facilities is accomplished by breakpoint chlorinating to 2 mg/L free chlorine residual.

Distribution storage facilities within the City's potable water system have experienced significant episodes of nitrification. The source water quality, facility and distribution system design and system operation impact the occurrence of nitrification. Storage facilities with a single inlet/outlet structure experience increased water age due to decreased mixing. Less than optimal water cycling results in stratification and increased water age. High free ammonia levels in the source water provide a nutrient for AOB. Nitrification increases with water temperature. Source water with a total chlorine residual of < 2 mg/L increases the potential for nitrification.

Description of System Facilities

Sources of Supply and Distribution System

The City imports on average 85 – 90% of its water from the San Diego County Water Authority (CWA) via the Metropolitan Water District of Southern California. The City's water is a blend from the Colorado River, State Water Project, and local sources. The percentages of source waters vary year to year and also over the course of a year depending on numerous factors, including imported operations/restrictions, volume of water available from local sources, the treatment plant water sources, and customer demand. The City's potable distribution system currently consists of over 130 pressure zones and about 3,300 miles of distribution pipelines. The City stores potable water in 30 storage tanks/reservoirs, 7 of which are clearwells located at three treatment plants.

Operating Parameters of Distribution Storage Facilities

The City's basic operating plan for its distribution storage facilities includes ensuring sufficient supply of water, minimizing electrical pumping costs, monitoring for water quality, specific turnover rate goals, total chlorine residual targets, and mitigation of nitrification events. The following distribution system reservoirs are hydraulically connected and may need additional investigation and/or preventive chlorination, if sample readings require corrective actions and Lab send out notification:

- Point Loma Reservoir to Catalina Standpipe,
- Scripps Ranch Tank to Stonebridge Tank,
- Rancho Bernardo Reservoir to Pomerado Tank,
- Bayview Reservoir to Soledad Reservoir,
- La Jolla View Reservoir to La Jolla Country Club Reservoir.

Monitoring Program

General

Extensive monitoring is conducted by the City including but not limited to:

- Distribution storage facilities are monitored weekly for pH, temperature, free chlorine residual, total chlorine residual, total ammonia, nitrate, nitrite and Heterotrophic Plate Count (HPC).
- Individual pressure zones are monitored weekly or monthly (depending on size) for pH, temperature, free chlorine residual, total chlorine residual, Total Coliform, and Escherichia Coli.
- Approximately 24 pressure zones are monitored weekly for total ammonia, nitrate, and nitrite.

- The water treatment plants perform continuous monitoring of plant effluent for total chlorine residual. Free ammonia is monitored daily.

The City maintains historical monitoring data and reports monitoring results to designated staff. With each sampling, the City reviews the results to determine the courses of action to take.

Water Treatment Plants are equipped with on-line continuous monitors for total chlorine residual. Plant operators collect grab samples every two hours and perform chlorine residual analysis. Free ammonia is monitored daily to maintain the appropriate ammonia feed rate.

Nitrification Control

Nitrification Prevention Strategies

Treatment Plants
- Maintain plant effluent free ammonia level between 0.01 and 0.10 mg/L
- Adequately maintain and calibrate equipment used for monitoring chlorine, ammonia, and water levels
- Maintain plant effluent chloramine residual between 2.0 and 2.6 mg/L
- Provide effective corrosion control
- Monitor water quality on a continuous basis

Distribution System
- Monitor water quality on a routine basis
- Maintain a sufficient chlorine residual to minimize the nitrification process
- Adequately maintain and calibrate equipment used for monitoring chlorine and water levels
- Routinely inspect and clean water tanks and reservoirs
- Provide effective corrosion control
- Minimize water age by cycling of water storage facilities in three to seven days with a goal of no more than five days.
- Maximize hydraulic mixing by use of separate inlet/outlets and/or mechanical mixers
- Chlorinate storage facilities past breakpoint when nitrification occurs
- Flush distribution system mains if water quality degrades

Storage Facility Chlorination Practices

The City chlorinates storage facilities with the addition of a 12% sodium hypochlorite solution when the total chlorine residual level falls below the guideline level, or the HPC or nitrite levels exceed guideline levels. This chlorination process is scheduled for non-peak demand timeframes.

For storage facilities that cannot be hydraulically isolated:

The City calculates the quantity of 12% sodium hypochlorite solution needed for the water tank to have a 3.0 ppm total chlorine dose based on its filling level. City SCADA operators

lower the level of water in the storage facility to the lowest operating level, and then crews add the 12% sodium hypochlorite solution into the storage facility as the water level rises to its filling level.
To ensure highly chlorinated water does not exit the storage facility during waiting period, the following steps are to be taken:

1. SCADA operators are notified to start filling the tank simultaneously with chlorination process
2. Crews are in constant contact with SCADA operators during the chlorination and filling process
3. SCADA operators are pumping and trending the reservoir's levels continuously to insure water does not leave the tank

The day after each sodium hypochlorite addition, the total chlorine residual is measured. If the free chlorine residual in the tank is less than 1 ppm, the sodium hypochlorite addition and measurement processes are repeated.

For storage facilities that can be hydraulically isolated:

The City calculates the quantity of 12% sodium hypochlorite solution needed for the water tank to achieve a free chlorine residual of 2.0-3.0 mg/l based on its filling level. City SCADA operators lower the level of water in the storage facility to the lowest operating level and then crews add the 12% sodium hypochlorite solution into the storage facility as the water level rises to its filling level. The reservoir is then isolated at its filled level until the following day. Free and Total Chlorine residual are taken before the reservoir is put back in service. Free chlorine residual must be > 1.0 mg/l.

<u>Distribution System Storage Facility Cycling</u>

The City's guideline is to cycle its storage facilities in three to seven days with a goal of no more than five days. The cycling of the storage facility varies depending on the system demands, hydraulic constraints and operational needs.

<u>System Flushing</u>

The City conducts flushing of the potable water system in areas where chlorine residual is low, or there are other water quality issues such as taste, color and/or odor. Samples are collected throughout the distribution system and monitored for water quality

<u>Distribution System Storage Facility Cleaning</u>

The City System Operations Reservoir and Tank crews inspect and clean the water tanks every three to four years. Inspections of the storage facilities by engineers are frequently performed during the cleaning. The City documents any maintenance issues and scheduled repairs.

Nitrification Action Plan Triggers

The Nitrification Action Plan impound facilities triggers are based on a combination of heterotrophic plate counts (HPC), total chlorine residuals, and nitrite levels. Depending on the levels of these triggers found, the guideline actions are identified below.

Parameter	Level	Action
HPC	< 100 CFU/ml	no action required
	> 100 and < 200 CFU/ml	Resample within 1 day
	> 200 and ≤ 500CFU/ml	Immediately Isolate Facility from the Distribution System, Chlorinate Facility, Resample
	≥ 500 CFU/ml	Immediately Isolate Facility from the Distribution System, Investigate the Source of Contamination, Chlorinate Facility, Resample
Total Chlorine Residual	> 1.25 ppm	no action required
	> 0.4 and ≤ 1.25 ppm	Sample 3 times per week. Cycle Facility weekly. Resample 3 times per week.
	≤ 0.4 ppm	Sample daily. Cycle Facility daily. Chlorinate Facility, if after cycling trend does not show improvements. Resample 1 day after chlorination
Nitrite as **NO_2**	< 0.25 ppm	no action required
	≥ 0.25 and < 0.70 ppm	Lab Sample twice a week. Cycle Facility every day. Resample twice a week
	≥ 0.70 ppm	Chlorinate Facility upon results of the test are known, Resample. Collect and analyze a confirmatory sample 1 day after chlorination.
	≥ 3.29 ppm	Notify the California Department of Public Health within 24 hours.

Nitrification Trigger Selection

Nitrification being a biological process can result in rapid changes within the water. Several water quality parameters are impacted by nitrification including chloramine residual, nitrite, nitrate, dissolved oxygen, alkalinity reduction, pH reduction, HPC, Ammonia oxidizing bacteria, and nitrite oxidizing bacteria.

Ammonia Oxidizing Bacteria and Nitrite Oxidizing Bacteria were eliminated as triggers due to the length of time and complexity of the analysis. Dissolved oxygen was eliminated due to dissolved oxygen being influenced by several factors not related to nitrification. Nitrate was eliminated due to low levels of nitrate naturally occurring in the water.

Nitrite (as NO_2) was selected due to nitrite being absent in the treated water entering the distribution system from the water treatment plants. The presence of nitrite in the water is close to 100% certainty that nitrification is occurring. Analysis for nitrite can be conducted both in the field and the laboratory. Nitrite ≥0.70 mg/L indicates severe nitrification is occurring. Nitrite ≥ 0.25 and < 0.70 mg/L indicates significant nitrification is occurring. Nitrite < 0.25 mg/L indicates no or moderate nitrification is occurring. Since Nitrite ≥ 3.29 mg/l exceeds the treatment plant effluent MCL, notification of the California Department of Public Health and collection of a confirmatory sample must be completed within 24 hours.

Total chlorine residual rapidly decreases when nitrification is occurring. Total chlorine residual was selected for five factors: One, total chlorine residual rapidly decreases when nitrification is occurring. Two, total chlorine residual is desirable to prevent microbial growth. Three, total chlorine residual is monitored as part of the Total Coliform Rule. Four, total chloramine residual > 2.0 mg/L inhibits the start of nitrification. Five, total chlorine residual is quick and easy to monitor. Total chlorine residual ≤ 0.4 mg/L is significantly decreased from the source water residual and increases the possibility of microbial contamination. Total chlorine residual > 0.4 and ≤ 1.25 provides conditions for nitrification to initiate. Total chlorine residual ≥ 1.25 mg/L is in an acceptable range.

Heterotrophic Plate Count (HPC) was selected due to HPC may increase when total chlorine residual decreases and provides a general indication of the level of microbial activity. HPC is typically at very low or at not detectable levels in the distribution system. HPC ≥ 500 CFU/ml represents an unacceptable level. HPC >200 and ≤ 500 CFU/ml are significantly elevated from normal distribution system levels. Addition of chloramines by cycling the impoundments may decrease the HPC level. HPC >100 and ≤ 200 CFU/ml require verification by resampling. HPC < 100 CFU/ml do not require additional actions and will be resampled at the next routine sample date.

Communication Protocol for Nitrification Alert

Communication between System Operations and Water Quality Lab (Lab) is as follows:

1. Lab sends Water Quality Impound Report to System Operations staff, including Water Production Superintendant (WPS) in charge of the water distribution system operations, weekly.
2. Lab notifies WPS in charge of the water distribution system operations of the potential need to chlorinate a tank(s).
3. WPS reviews water quality results, chlorine residual, HPC and determines the need of chlorination.
4. Crews are directed by WPS to chlorinate the tank(s) and Lab is notified about this planned activity.
5. After chlorination process, crews submit Chlorination Treatment Report to the Lab.

References:
The City used the following references for developing its Nitrification Action Guidelines:

1) Fundamentals and Control of Nitrification in Chloranimated Drinking Water Distribution Systems AWWA Manuel M56, American Water Works Association, first edition, 2006
2) "Using Nitrification Potential Curves to Evaluate Full-scale Drinking Water Distribution Systems," Fleming, *et.al., J*ournal AWWA, October 2008.

Chapter 6

PUMPING STATIONS

6.1 General

This chapter covers the design of raw water, treated water, and reclaimed water pumping stations. These facilities are referred to here as pumping station(s). Raw water pump stations provide for inlet screening and the problems associated with the existence of mussels as appropriate. The DESIGN CONSULTANT's pumping station design incorporates these operational and feature guideline requirements into the project Contract Documents.

Before the design of any pumping station begins, the City Project Manager contacts the Water Operations Division to schedule a design conference meeting to discuss and review the specific design and equipment requirements for the project. The DESIGN CONSULTANT participates in this conference. These conferences also determine which Special Pumping Station Requirements, if any, are required in the project design.

Special Pumping Station Requirements are optional and are not required for all pumping stations. Special Pumping Station Requirements are typically for pumping station designs with high lift or high flow pumps, special environmental concerns, or other special design requirements, .

At the time of the Basis of Design Report (BODR) submittal, the DESIGN CONSULTANT submits a written verification to the City Project Manager that the design complies with the required Public Utilities Department Guidelines and agreed design conference criteria. This verification can be in the form of a cover letter attached to a list of these criteria with each item to be incorporated into the design of the pumping station checked off. A notation should be made in the margin indicating the specific design submittal when the DESIGN CONSULTANT expects this item to be incorporated into the design drawings and specifications. Note: This annotation assists reviewers of design submittals. The DESIGN CONSULTANT also references and discuss any criteria in this listing to which it takes exception and does not recommend implementing.

6.2 Project Document Presentation Guidelines

These Guidelines are intended to promote uniformity of report drawings and the Contract Documents between the various Water projects during the design phase of implementation.

6.2.1 Basis of Design Report Drawings

The Predesign Report is normally developed by the Public Utilities Department. The DESIGN CONSULTANT develops the BODR in accordance with requirements the latest City requirements. The format requirement for preliminary drawings used in the BODR may not be required to completely match that required for Contract Documents.

6.2.2 Contract Specifications

The standard specifications used for water infrastructure projects are the latest adopted edition of the GREENBOOK Standard Specifications for Public Works Construction, and the WHITEBOOK – Standard Specifications for the City of San Diego. Beyond these, the DESIGN CONSULTANT changes, modifies, or edits the guide specifications as necessary to meet the requirements of each project, and develops any additional sections not included in the guide specifications, as required.

Equipment specifications prepared by DESIGN CONSULTANT avoid sole source equipment requirements and ensure competitive pricing for major equipment to be supplied by the Construction Contractor, such as pumps, motors, and emergency power generation equipment.

DESIGN CONSULTANT includes in the special provisions, a list of all shop drawing submittals required from the Construction Contractor for review and approval. This listing includes a reference to the specification section number and title where each item requiring review and approval is described.

The special provisions require that the Construction Contractor make submittals of proposed equipment to the Construction Manager for approval of materials, fabrication, assembly, foundation, installation drawings, and Operation and Maintenance Manuals. Review and approval is by the DESIGN CONSULTANT.

The Construction Manager routes shop drawing submittals to the Water Utilities Water Distribution Division Engineering Section for review of the following major equipment: pumps; motors; valves; emergency power generation system; electrical equipment and controls, prior to their return to the Construction Contractor.

6.2.3 Contract Drawings

The DESIGN CONSULTANT develops contract drawings to meet the needs of each project. Preliminary drawings included in the BODR, when provided to the DESIGN CONSULTANT, may be used initially as the basis of design and may be amended for incorporation into the Contract Documents. The contract drawings must conform to the requirements of the Citywide Drafting Standards. The DESIGN CONSULTANT may change or modify the guidelines as necessary to meet the requirements of each project, and develop any additional as required.

6.3 Codes and Standards

Codes and standards to be used in the design of pumping stations include the following:

Abbreviation	Code or Standard
AASHTO	American Association of State Highway and Transportation Officials
ABMA	American Bearing Manufacturers Association

ACI	American Concrete Institute
AGMA	American Gear Manufacturers Association
ANSI	American National Standards Institute
ASHREA	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CalTrans	California Department of Transportation
FS	Federal Specifications
HYI	Hydraulic Institute Standards
IEEE	Institute of Electrical and Electronics Engineers
ISA	Instrument Society of America
MSS	Manufacturers Standardization Society, Inc.
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SSPC	Steel Structures Painting Council
CBC	California Building Code
UFC	Uniform Fire Code
UL	Underwriters Laboratory, Inc.
UMC	Uniform Mechanical Code
CPC	California Plumbing Code

Specific structural design codes and standards to be used in structural design for pumping stations are included in **paragraph 6.12.1** of this chapter.

The DESIGN CONSULTANT also observes all applicable codes and other requirements adopted by local permitting agencies. The current version of these documents effective at the time of receipt of Notice to Proceed with design phase is used as reference for design purposes. In case of conflict between the requirements of these reference documents and any code adopted by a local permitting agency, the code requirements prevail.

6.4 Pumping Station Hydraulics and Piping

6.4.1 Station Hydraulics

The DESIGN CONSULTANT refers to the Predesign Report provided by the Public Utilities Department for information on system hydraulics, design capacity, system head curves, net positive suction head (NPSH), pump operating curves, piping configuration, transient surge analyses and control. The DESIGN CONSULTANT reviews this information and prepares hydraulic calculations for the BODR based on the following:

1. System head curves
2. Pump operating curves
3. Available NSPH
4. Piping configurations
5. Pump controls
6. Transient surge analyses

The BODR includes a figure showing both the system head curve and pump operating curves as described in **paragraph 6.5.5** of this chapter. Where variable frequency drives (VFDs) are used, pump operating curves must also indicate pump operation at various speeds.

6.4.2 Piping Materials

All pumping station suction and discharge piping are ductile iron (DI) or engineered shop fabricated steel. Avoid the use of pipe threads on ductile iron pipe flanges. Where the use of threaded flanges is unavoidable, the thread must be assembled with epoxy and coated on the interior and exterior as described in **Chapter 7**.

Select piping systems which are appropriate for the type of fluid being conveyed. Prepare a piping schedule presenting materials, pressure rating, and test requirements.

For acceptable linings and coatings and other corrosion control requirements for pump station piping, see **Chapter 7**.

6.4.3 Flow Velocities

The DESIGN CONSULTANT sizes suction and discharge pipe so that the maximum suction velocity is 5 fps and the maximum discharge velocity is 8 fps. The minimum recommended discharge piping velocity is 3 fps.

6.4.4 Bolts and Fasteners for Piping

All bolts and pipe fasteners for piping shall be in accordance with **Chapter 7**.

6.4.5 Dissimilar Metal/Isolation Connections

Small piping, fitting, and appurtenances 2 inches and less in diameter connected to the pump suction and discharge piping must use PVC bushings and stainless steel pipe. Galvanized steel pipe is not acceptable.

Insulating PVC bushings and gaskets must be placed between connections of brass and ferrous piping and between any other pipes made of dissimilar metals.

The DESIGN CONSULTANT indicates any other isolation fittings required to isolate pumping station piping from sections of buried piping that are protected by a cathodic corrosion control system.

6.4.6 Fittings for Differential Settlement

Flexible Dresser-type couplings, mechanical joints, or other flexible type fittings with restraining devices are provided where both inlet and discharge piping connect to a pumping station or valve vault wall to allow for differential settlement. The fittings or couplings must have a fusion bonded epoxy coating on both the inside and outside surfaces.

6.4.7 Schedule of Pumping Station Piping Materials

The DESIGN CONSULTANT includes in Contract Documents a schedule of piping materials for all exposed and buried piping over 2 inches in diameter within the property limits of the pumping station. The schedule includes the following information:

Item No.	Diameter	Description	Units	Quantity	Remarks

6.5 Selection of Main Pumping Units

6.5.1 General

The DESIGN CONSULTANT refers to the Predesign Report provided by the Public Utilities Department with information on the vertical turbine pump configuration.

Pumping systems are normally controlled by a level control system (with a set discharge storage level using constant speed pumps) or a closed zone system (where a set pressure is maintained using variable frequency drives on pumping units).

6.5.2 Selecting the Type of Units

If the Predesign Report does not indicate which pump configuration should be used, the DESIGN CONSULTANT presents in the BODR a comparative evaluation of cost, operability, and constructability issues. This analysis includes general arrangement drawings and cost estimates for the pumping station with various configurations. Based on this analysis and the DESIGN CONSULTANT's recommendation on pump configuration, the City Project Manager directs the

DESIGN CONSULTANT as to which configuration to use before proceeding with final design of the pumping station.

6.5.3 (NOT USED)

6.5.4 Vertical Turbine Pumps

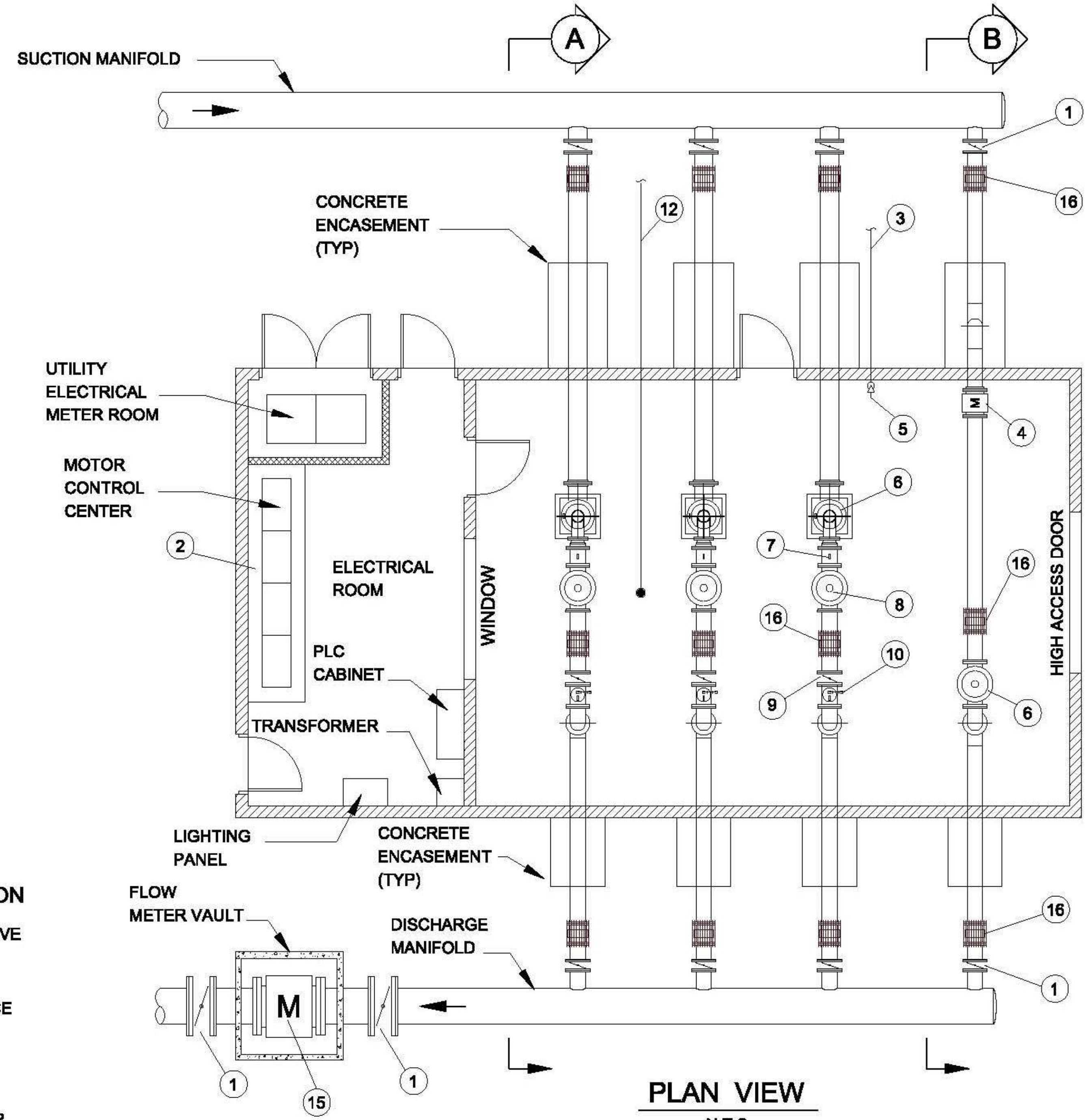
If vertical turbine pumps are selected for use at the pump station, the DESIGN CONSULTANT includes the following features of pump construction:

- Type: Vertical canned turbine.
- Barrel or Can: Heavy-duty steel epoxy coated for mounting in concrete encasement, designed to support the unit without vibration at any operating speed. Barrel or can is provided by the pump manufacturer
- Bowls: Cast iron with amine cured epoxy coated water passages.
- Impellers: Cast bronze, enclosed single plane type, balanced to operate within acceptable field of vibration limits.
- Shaft: Line shaft, type 316 stainless steel.
- Shaft Couplings: Type 304 stainless steel.
- Wear Rings: Bronze.
- Seals: Mechanical with flushing water.
- Bearings: Heavy-duty, grease lubricated, bronze. Minimum L-10 bearing life

The pump motor coupling must allow for adjustment of the pump impeller at the upper end of the motor.

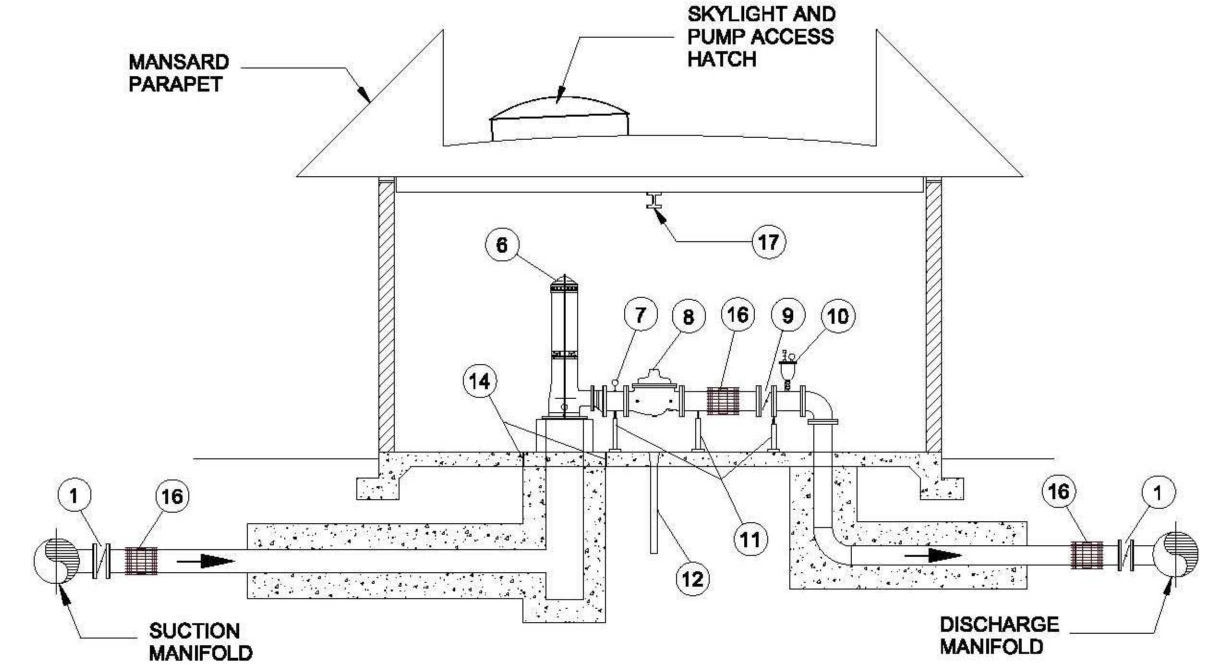
The vertical turbine pump discharge head, sole plate, column and cans are to be provided by the pump manufacturer as a package.

Typical pumping station general arrangement drawings for the vertical turbine pumping configuration is provided for the DESIGN CONSULTANT'S consideration in **Figure 6-1**.



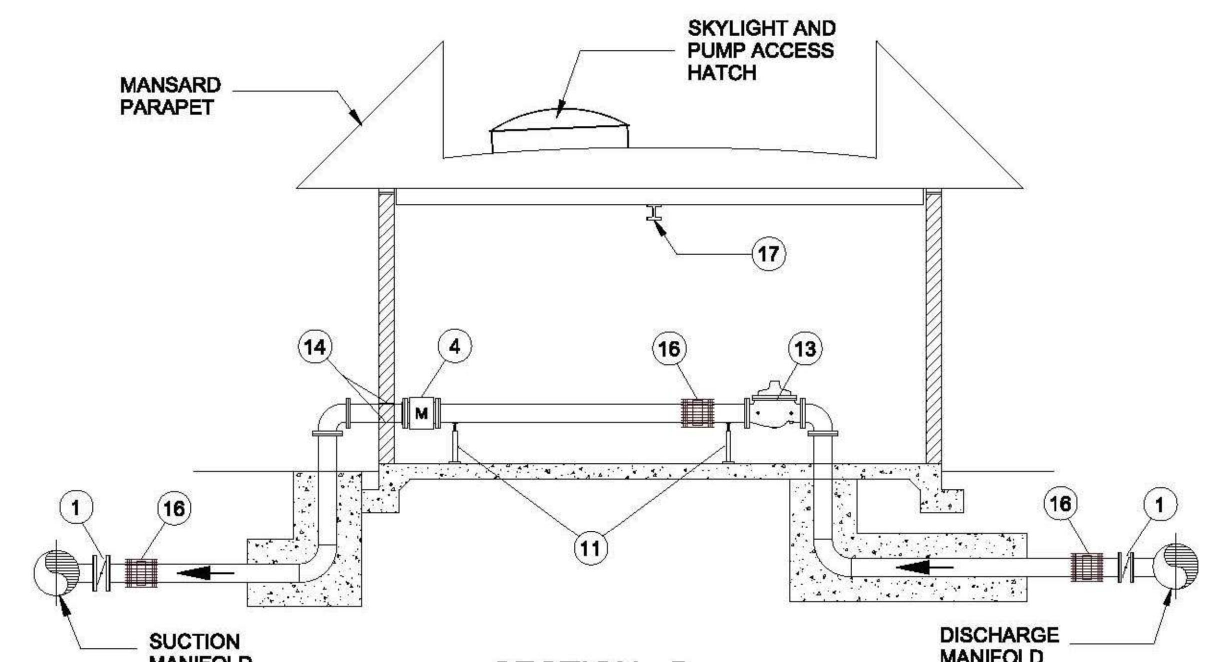
PLAN VIEW

N.T.S.



SECTION - A

N.T.S.



SECTION - B

N.T.S.

ITEM	DESCRIPTION
1	ISOLATION VALVE
2	PAD
3	WATER SERVICE
4	FLOW METER
5	HOSE BIBB
6	PUMP & MOTOR
7	PRESSURE INDICATOR
8	PUMP CONTROL VALVE
9	GATE VALVE
10	COMBINATION AIR VALVE
11	PIPE SUPPORT
12	DRAIN TO SANITARY SEWER
13	PRESSURE RELIEF VALVE
14	EXPANSION JOINT FILLER
15	PUMP STATION FLOW METER
16	FLANGE TO FLANGE FLEXIBLE COUPLING WITH HARNESS AND TIE ROD
17	TRAVELLING MONORAIL

NOTES:

1. SURGE TANK TO BE INCLUDED IF REQUIRED BY DESIGN.
2. COMPRESSORS ARE REQUIRED WHERE SURGE TANKS ARE REQUIRED.
3. ELECTRICAL ROOM ELEVATED AT LEAST 4 INCHES.
4. EMERGENCY GENERATOR TO BE INCLUDED IF REQUIRED BY DESIGN.
5. REDUCERS TO BE INCLUDED ON PRESSURE RELIEF VALVE IF REQUIRED BY DESIGN.
6. MINIMUM 3-FOOT HORIZONTAL CLEARANCE IS REQUIRED BETWEEN PUMP PIPING AND APPURTENANCES, AND AWAY FROM ALL WALLS, STAIRWAY, LADDER, ETC.
7. BYPASS WITH PRESSURE GAUGE AND AIR/VACUUM VALVE TO BE INCLUDED ON PRESSURE RELIEF VALVE IF REQUIRED BY DESIGN.
8. VERTICAL CLEARANCE BETWEEN OVERHEAD HOIST SYSTEM AND VALVES, PIPES, ETC. IS REQUIRED FOR LIFTING AND MOVING EQUIPMENT TO THE STATION ACCESS DOOR.

TYPICAL PUMP STATION
VERTICAL TURBINE CONFIGURATION
FIGURE 6-1

6.5.5 Pump Operating and System Head Curves

The DESIGN CONSULTANT prepares a combined system head curve and pump operating curve showing all pumps running, with both Hazen-Williams coefficients of 110 and 140 to determine friction loss. Curves represent both maximum and minimum pressures to be experienced by the pumping system. These curves are shown as a figure in the BODR and be repeated on the contract design drawings. When as-built drawings are prepared, the DESIGN CONSULTANT places the actual pump operating curves on the contract design drawings.

When selecting pumps, the DESIGN CONSULTANT considers the following items:

1. Select a pump operating curve where the required operating point is near the maximum efficiency point (optimally just to the right of this point) of the pump curve.

2. Select a pump operating curve where the operating point is near the minimum value of radial thrust.

3. Avoid pumps with "flat" pump operating curves where a small change in total dynamic head (TDH) results in a large change in pump flow.

4. Specify a pump/impeller located near the center of the pump operating curve recommended operating range. To facilitate modifying the pump with a different impeller to change pumping performance. This modification may be required based on information determined during station startup operational testing when the pump is discharging into the system.

5. In specifying the pump operating point, specify an operating flow at the required head that is 105% of the design requirement to allow for loss of operating capacity from pump wear and increased pipe friction.

6.5.6 Vibration and Cavitation

To minimize vibration and resonance, the mounting pedestal, floor or inertia block must be of sufficient mass, typically 3 times greater than the mass of the pumps. The DESIGN CONSULTANT must require level installation of the pump base and anchor bolts, and dynamically balanced pumps to prevent vibration. Vibration amplitude must be less than limits set by the Hydraulic Institute standards. The DESIGN CONSULTANT selects suction and discharge piping to prevent cavitation or excessive vibration. The DESIGN CONSULTANT also selects a pump that operates within a stable operating range on pump operating curves to prevent cavitation.

6.5.7 Net Positive Suction Head (NPSH)

The net positive suction head available (NPSHA) is calculated for all pumps pursuant to standard engineering practices, less a 2-foot factor of safety. The NPSHA should always be more than the net positive suction head required (NPSHR) for the selected pump at maximum speed conditions.

6.5.8 Pump Motors

DESIGN CONSULTANT requires pump motors with the following characteristics:

- Minimum electrical efficiency of 93% at the specified operating point.
- Nameplate horsepower that exceeds the maximum required by the pump under all operating conditions. For best efficiency, the motors specified should operate in a range within 90% to 100% of its rated power (avoid oversizing motors since efficiency and power factor drop in motors running below load rating).
- Provide a 1.15 service factor at ambient temperature plus 50°C of the nameplate voltage.
- The temperature rise rating may not exceed class "B" temperature limits as measured by the resistance method when the motor is operational at full load of 1.15 service factor continuous in a maximum ambient temperature of 40°C.
- Provide an Underwriter's Laboratory (UL), Factory Mutual (FM) rating, and National Sanitation Foundation (NSF/ANSI 61).
- Provide totally enclosed fan cooled squirrel cage induction type.
- Provide vertical turbine pump motors that have a solid shaft shaft for ease of adjustment. The Construction Contractor is required to submit a detail showing how adjustment of the pump impeller using upper end of motor for City approval.
- The frame is cast iron.
- Windings are copper. Aluminum windings are not acceptable.
- Insulation is class "F" with epoxy coating.
- Provide heavy-duty 100,000 hour rated bearings. If bearings are oil lubricated, provide a visual oil level indicator.
- The starting code letter/locked rotor kVA shall comply with NEMA code "F" criteria or better.

- Provide an overtemperature safety switch installed in the motor windings.

- Provide a heater element installed to reduce condensation. The motor heater element is strip type that automatically disconnects when the motor starts.

- Equip with antireverse rotation ratchet. Also install a lockout limit to prevent motor start if the pump control valve is not closed.

- Motor shall be inverter duty rated when used with variable frequency drives.

6.5.9 Variable Frequency Drives

Unless otherwise indicated in the Predesign Report, variable frequency drives (VFDs) are normally used on pumping units to maintain a specific target pressure on closed zone systems.

For stations requiring VFDs, and when multiple pumping units are provided, the system is to provide a minimum of two VFDs and the rest of the pumps have constant speed motors.

For each VFD unit, provide a manual bypass connection to allow manual across the line motor start operation (i.e., full voltage start and constant speed motor operation).

Each VFD unit shall have the capability of locally controlling motor speed manually by adjusting a potentiometer or via the keypad incorporated onto the VFDs.

Each VFD unit shall be capable of interfacing with a Programmable Logic Controller (PLC) via the following standard interfaces.

- Discrete Inputs - Discrete inputs interface the VFD with control devices such as pushbuttons, selector switches, and PLC discrete output modules. These signals are typically used for functions such as start/stop, forward/reverse, external fault, preset speed selection, fault reset, and PID enable/disable.

- Discrete Outputs - Discrete outputs can be transistor or relay. Typically, transistor outputs drive interfaces to PLCs, motion controllers, pilot lights, and auxiliary relays. Relay outputs usually drive ac devices and other equipment with its own ground point, as the relay contacts isolate the external equipment ground.

- Analog inputs 0 to 10 Vdc or 4 to 20 mA signals

- Analog outputs 0 to 10 Vdc or 4 to 20 mA signals - These signals can represent a speed set point and/or closed loop control feedback. An analog output can be used as a feedforward to provide set points for other VFDs so other equipment will follow the master VFD's speed; otherwise, it can transmit speed, torque, or current signals back to a PLC or controller.

- Ethernet interface VFD - Ethernet interface with a built in web server that allows users to configure and control the VFD from any web browser. Ethernet protocols such as Modbus TCP/IP and EtherNet.

6.5.10 Hydropneumatic Tank/Surge Tank (Special Station Requirements)

The DESIGN CONSULTANT may consider use of a hydropneumatic tank (which provides storage for low demand periods and/or surge protection) or a surge protection tank as required in the design.

If a hydropneumatic tank or surge protection tank is used, it must include all controls and appurtenances supplied by a single vendor as unit responsibility.

A hydropneumatic tank is typically controlled as follows:

- Stage first call pump on by pump on pressure transducer or pressure switch (i.e., provide tank differential pressure transmitter to indicate tank level).

- Pump off by pump off level probe (near center of tank) or in stilling well.

- Add/vent air pressure by solenoid valves as required after each pump call cycle to obtain desired set point pressure in the tank at the pump off level.

- Low/high level probe alarms and low/high pressure switch alarms.

Alarm conditions must be telemetry alarm points. These alarm conditions also start/stop pumps and add/vent air as required to reestablish the required tank level and pressure conditions.

If used as a surge protection tank, controls include similar level probes, add/vent air pressure solenoids, and pressure switches to continuously maintain the water level near the center of the tank.

6.5.11 Pump Base Plate Installation

Provide a detail on the drawings showing how the pump base plate is bolted to the top of the suction can for vertical turbine pumps.

Provide type 316 stainless steel anchor bolts, nuts and washers for securing the pump base.

6.5.12 Pump Head Mounting to Base Plate/Sole Plate

Design and construction shall be such that the pump head is mounted to the base plate/sole plate assembly. The bolts used in the assembly must be oriented so that the bolt head is on the pump head side of the mounting configuration. The sole plate and/or the base plate holes shall be threaded. Nuts on the underside of the base plate are not allowed. Threaded inserts are not allowed and studs are not allowed.

6.5.13 Spare Parts and Manuals to be Supplied

The DESIGN CONSULTANT indicates that the Construction Contractor provides the following spare parts for each size of pump installed:

- Impeller
- wear ring set
- bearing set
- couplings
- mechanical seal
- set of gaskets and O-rings
- complete set of dowels
- keys and pins for fastening all parts
- complete set of any special tools required for dismantling the pump

The Construction Contractor supplies a manual for the operation, maintenance, and repair of the pump as published by the manufacturer for each size of pump installed.

6.6 Pumping Equipment Layout

The DESIGN CONSULTANT refers to the Predesign Report for any requirements for pump arrangement and/or pump spacing at the pumping station. Should the Predesign Report have no requirements, the DESIGN CONSULTANT refers to **Figures 6-1** of this chapter. **Figure 6-1** provides a typical pumping equipment layout for pumping stations with vertical turbine pumps.

In general, the pumping equipment layout provides convenient access for operation and maintenance personnel, equipment installation, adjustment of component parts, maintenance and equipment removal utilizing conventional general purpose tools. Equipment is arranged to provide minimum clearances on at least 3 sides. Clearances are actual to most exterior dimension, not nominal.

The DESIGN CONSULTANT allows a minimum 3-foot clearance between pump piping and appurtenances and away from all pumping station walls, stairways, ladders, etc. Placing conduit, piping panels, etc. in any designated clear spaces is prohibited. Vertical floor to overhead obstructions must be a minimum of 7 feet -6 inches. Where equipment manufacturers recommend a minimum clearance for maintenance, the DESIGN CONSULTANT provides an additional 1 foot.

For pumping stations with an electrical room and pump room in the same building, the electrical room is elevated at least 4 inches to provide positive drainage in the event of a pipe failure. The room has a window in the wall between the pump room and the electrical room for safety and to view pump operation.

Any changes the DESIGN CONSULTANT considers appropriate to the above pump arrangement or pump spacing are referred to the City Project Manager. The DESIGN CONSULTANT presents the agreed upon layout in the BODR.

6.7 Pump Inlet Configuration and Piping Layout

6.7.1 Pump Inlet Configuration for Vertical Turbine Pumps

If the vertical turbine pump configuration is used for the pumping station, the DESIGN CONSULTANT may use **Figure 6-1** as a guide in configuring the inlet manifold and suction piping to each pump. **Figure 6-1** illustrates acceptable inlet configurations for a pumping station system located inside a building and one located outside on slab. The DESIGN CONSULTANT may suggest deviations to the piping configurations shown in **Figure 6-1** to the City Project Manager before issuing the BODR.

6.7.2 (NOT USED)

6.7.3 Pump Discharge Header Configuration Vertical Turbine Pumps

If the vertical turbine pump configuration is used for the pumping station, the DESIGN CONSULTANT may use **Figure 6-1** as a guide in configuring the discharge manifold and discharge piping from each pump. **Figure 6-1** illustrates acceptable discharge configurations for a pumping station system located inside a building and one located outside on a slab. The DESIGN CONSULTANT may suggest deviations to the piping configurations shown in **Figure 6-1** to the City Project Manager before issuing the BODR.

6.7.4 (NOT USED)

6.7.5 Relief/Bypass Line to Suction (Special Station Requirement)

Install a bypass line with a pressure relief valve to relieve the discharge manifold to the suction manifold in a pump operation overpressure condition. This line must have a vacuum relief valve after the pressure relief valve. This line can also be used to recirculate fire pump test flows when appropriate. DESIGN CONSULTANT provides for installation of the pressure relief valves and a flow meter on this line in a valve vault or aboveground to determine the amount of water being recirculated. The relief valve has a valve position limit switch to alarm in the PLC when the valve opens.

6.7.6 Bypass Line to Discharge (Special Station Requirement)

As a special station requirement, the DESIGN CONSULTANT may include a bypass from the suction supply manifold to the discharge manifold through a hydraulic check valve to protect against suction surge pressures or to supply low pressure flow in a pumping station failure. The bypass line is the same size as the suction line to the pumping station. DESIGN CONSULTANT provides for installation of a pressure gauge and air/vacuum valve on the bypass line located in a valve vault or aboveground.

6.7.7 Discharge Piping Assembly

DESIGN CONSULTANT designs exposed pumping station discharge piping using spool sections, tie-rod restrained coupling adapters, or restrained Dresser-type couplings (not with studs). Discharge piping is fitted and connected so that no lengths of pipe are too long to remove from the pumping station building using the hoist equipment provided. Provide unions for the removal of all small piping appurtenances.

6.7.8 Pipe Restraints

The DESIGN CONSULTANT indicates thrust “kick” braces at 90° elbows and all other bracing required to resist seismic forces, operational pressure and surge pressures on exposed piping installations. Indicate locations of thrust blocks and restrained joints in the contract drawings.

The DESIGN CONSULTANT designs all piping joints and thrust restraints to withstand maximum anticipated surge pressure. Base elbow fittings are not designed to carry any side thrust loading. Indicate wall pipes with intermediate flanges for thrust restraint where piping enters valve vaults or underground pumping station walls.

6.7.9 Couplings

The selection of pipe joints or couplings and the care with which they are installed are important considerations for the DESIGN CONSULTANT. Sleeve couplings, mechanical joint couplings, rubber-gasket push-on joint couplings, field-weld joints, grooved and shouldered couplings, butt straps, and flanges are commonly used with steel water pipe. Screwed joints are used on small steel, cast-iron, bronze, stainless, etc. The DESIGN CONSULTANT may consider patented joints if the application fits the recommended use and design data from the joint manufacturer.

6.7.9.1 Restrained Couplings

Flanged adapters, sleeve-type compression couplings or grooved-end couplings should be provided with a suitable harness for longitudinal restraint. For bolted flanges, the DESIGN CONSULTANT ensures that flanges of different materials and pressure classes are compatible.

6.7.9.2 Flexible Couplings

On exposed piping inside the pumping station, the DESIGN CONSULTANT avoids rigid connections in flanged piping between the pump and fixed discharge manifold piping. Flexible couplings provide ease of assembly/disassembly of piping, minor adjustment in assembled piping, pump vibration isolation and strain relief at flanged fittings.

6.7.10 Pressure Gauges

Provide a compound pressure gauge (combination vacuum and pressure) on the suction piping and a pressure gauge on the discharge pipe of each pump installed. Typical locations for these gauges are shown in **Figure 6-1**. Gauge assemblies are mounted off the piping on a separate stand to isolate the gauges from pump vibration with the following fittings connecting to the pumping station piping:

- Stainless steel nipple
- Corporation stop
- Flexible hose off the piping to the gauge mount location
- Isolation ball valve
- Air release cock
- Diaphragm seal/pulsation dampener (to prevent corrosion and pressure surges on the gauge(s), fill the diaphragm seal and gauge with glycerin and provide a fitting for refilling)
- Stainless steel gauge snubber

Gauges must have a built-in safety plug for blowout protection in an overpressure condition. Pressure transducers have a 4 to 20 mA signal output for transmitting pressure information to the pump controls and to a pressure display panel, in accordance with **subsection 6.15** of this chapter.

6.8 Expandability

If the Predesign Report indicates that a pumping station is planned to be expanded in the future, the DESIGN CONSULTANT ensures that adequate space is provided to accommodate the installation of future equipment. The suction and discharge piping manifold is sized and arranged to accommodate future flows without having to take the pumping station out of service when expansion is required. If it appears to be impractical or not economical to construct the pumping station building to house future equipment, the DESIGN CONSULTANT presents a comparative evaluation of cost, operability, and constructability issues in the BODR. This evaluation addresses alternative means of providing the desired capacity to meet future capacity requirements. Based on this analysis, the City Project Manager directs the DESIGN CONSULTANT before proceeding with final design of the pumping station relative to future expansion.

6.9 Standby Pumps and Equipment

All pumping stations are designed with one standby pumping unit having a capacity equal to the largest pumping unit in the station.

Compressed air systems for pumping stations are provided with one standby air compressor.

6.10 Transient Surge Analysis and Surge Control

The DESIGN CONSULTANT performs the surge analysis and designs a surge control system in accordance with its analysis.

6.10.1 Transient Surge Analysis

The DESIGN CONSULTANT evaluates pumping stations to determine the potential for hydraulic transients. Computer programs for transient analysis are approved by the City Project Manager on a case-by-case basis. State-of-the-art computer programs for transient analysis such as LIQT developed by Stoner Associates, Inc., or other programs approved by the City of San Diego, are used to evaluate all transient phenomena and proposed surge control measures. Each program, including those listed above, has unique capabilities and must be assessed for each situation to make sure it can handle the complexity of the analysis involved for the particular pumping station. The DESIGN CONSULTANT obtains from the City Project Manager any information necessary to properly evaluate transient phenomena in water pipeline(s) connected to pumping station(s) or reservoir(s) that is not included in the DESIGN CONSULTANT'S scope of work.

6.10.2 Surge Control

Surge protection is normally required at all pumping stations. Surge control measures suitable for raw water and treated water pipelines are also employed for reclaimed water pipelines.

Before initiating the detailed design of pumping stations, the hydraulic transient calculations prepared by the DESIGN CONSULTANT are submitted as an appendix to the BODR together with a description of any potential for hydraulic transients and a list of steps the DESIGN CONSULTANT recommends for further action or mitigation of the hydraulic transients. Based on the contents of this documentation, the City Project Manager directs the DESIGN CONSULTANT to design the necessary means to mitigate hydraulic transients.

Transient control measures may be considered independent of or in combination for water systems and are limited to the following:

- Water pipeline alignment revisions to eliminate potential column separation zones.
- Globe-type pump control valves on inlet or discharge pipelines. Both the valve body and flanges are rated to withstand the shutoff head of the pump or maximum surge pressure, whichever is greater. During normal starting and stopping of the pumps, each pump must start against a closed valve. The valve must open slowly to control upsurge. During the pump stopping sequence, the control system initiates closing of the valve. At the completion of the closing cycle, a limit switch confirming complete closure of the valve signals the pump to stop. During emergency power failure, the valve shall automatically closes. Closure time is set to reduce surges in the pipeline. All opening and closing times are independently adjustable, with closing times initially set as recommended in the final surge analysis.
- If surge tanks on discharge pipelines are required, size the tanks to reduce incremental surge pressure increase to a maximum of 33% of the discharge pipeline design pressure. The surge tank is designed, fabricated, and tested in accordance with the ASME Code for Unfired Pressure Vessels, and is equipped with a compressed air system controls to maintain the air-to-water ratio and initiate alarms. Surge tanks are equipped with level probes add/vent air pressure solenoids and pressure switches to maintain water level near center of the tank.
- Installation of a surge anticipator relief valve which senses a loss of power and/or pressure surge wave and opens on set time delay or high pressure respectively. Install piping and valves to provide pressure relief from the pump discharge side to the suction side.
- Installation of a pressure relief valve from discharge manifold to suction manifold for routine pressure rises due to rapid changes in system demand. Operation of relief valve cannot rely on a mechanical actuator or diaphragm.
- Standpipes are not permitted for surge control on Water projects.

6.11 Valves

6.11.1 General

All valves are shown on the design drawings, except small valves which are part of packaged equipment or instrument systems required by the codes or indicated in the equipment specifications. The DESIGN CONSULTANT shows all valves that are normally used by maintenance personnel to isolate equipment or sections of piping, or which are used for normal operation or control procedures. All valves 4 inches and larger are numbered and a schedule for all numbered valves is prepared by the DESIGN CONSULTANT. The valve schedule is shown on the drawings and includes the valve number, pressure rating, type of actuator, type of valve, associated fluid abbreviation, and sheet number of the drawing where the valve is shown. Unless otherwise approved, all mainline valves are the same diameter as the pipeline.

The DESIGN CONSULTANT selects materials for valves to be compatible with the fluid being conveyed and conform to requirements for valves included in the City of San Diego Approved Materials List where possible. The DESIGN CONSULTANT shall choose appropriate valves so that the number of valve types in the pumping station are minimized.

6.11.2 Isolation Valves

In general, all isolations valves are the full-resilient seated gate valves included on the City of San Diego Approved Materials List. Subject to approval by the City Project Manager, butterfly valves conforming to AWWA C504 may be used as an alternative to gate valves to isolate equipment if the DESIGN ENGINEER prepares a request for deviation using the format of ATTACHMENT 1, which is included as a part of this document..

Isolation valves are installed on the pump inlet, pump discharge line, pump manifold lines, bypass lines and surge protection line for removal and maintenance of pumps and other accessory equipment. Discharge isolation valves are installed a minimum of 3 pipe diameters downstream of pump control valves.

Buried valves are approved for buried service with a watertight bonnet and buried service actuator. Install buried valve actuator extensions, valve wells and valve frames and covers as required and conforming to CSD SD SDW-109 for operation with 7 foot valve keys. All exterior valves are sited within the site security fence.

6.11.3 Pump Control Valves

Pump control valves have an emergency shutdown power check feature for surge protection when power fails. This valve effects controlled closure when flow stops as a result of power failure before flow reversal. The flow control valve also provides pump reverse anti-rotation protection. Pump control valves are provided for controlled valve opening and closing during pump startup and shutdown. Provide a limit switch on the valve to alarm and prevent a pump from starting if the valve is open at the pump “on” call signal and also shut down the pump if the valve does not open within a specific time-delay period. Provide an emergency closing feature to close the valve at the controlled rate in the event of motor power loss. The valve should also provide for manual operation in the event of VFD equipment failure. At this time, the valve becomes a regulating valve so the pumps can operate as constant speed pumps.
During starting of the pumps, each pump pumps against a closed valve. The valve opens slowly to control upsurge. During power failure, the check feature in the valve closes automatically. All opening and closing times are independently adjustable with closing times as recommended in the final surge analysis.

On constant speed only, pumping stations provide wide open when running globe valves.

6.11.4 Air/Vacuum Relief Valves

Air release, air vacuum release or combination air release and vacuum valves are provided at critical locations in the pumping station piping. These valves serve to prevent small quantities of air from being captured inside the piping system, to vent large quantities of air during filing of the piping, and to prevent piping collapse because of vacuum conditions caused by rapid drainage of the piping.

Three air/vacuum relief valve configurations are used to alleviate these conditions. Air vacuum valves must be capable of venting large quantities of air while piping is being filled and allow air to re-enter while the piping is being drained. Air release valves vent accumulating air while the system is in service and under pressure. Combination air valves combine the characteristics of the two previous configurations.

These valves are placed at the end of suction or discharge manifolds or on each pump's suction or discharge pipe as required to prevent air accumulation or to provide vacuum relief.

Provide 2-inch diameter air bleeds (gauge cocks) on each pump suction line if an air release valve is not provided in the line.

On each pump discharge line, provide a gauge cock before the pump control valves and an air release valve after the pump control valve.

All air/vacuum relief valves are connected to the piping manifolds with PVC isolation bushings and stainless steel nipples and are equipped with stainless steel isolation valves and unions to allow easy removal for maintenance.

6.11.5 Drain Valves

Provide a capped fitting on the suction and discharge side of each pump to drain pumps and check for residual pressure during maintenance prior to opening fittings.

6.11.6 Check Valves

Unless otherwise required by a surge analysis, the discharge side of all pumps are provided with pump control valves in lieu of check valves as described in **paragraph 6.11.3** of this chapter.

Check valves for pumping station support systems, such as potable water or drainage systems, are heavy-duty swing type check valves with an outside spring and lever.

6.11.7 Corporation Stops for Flow Meters

Provide 2-inch corporation stops on each pump discharge line downstream of the pump control valve for the connection of a pitot tube and/or insertion flow meter to be used for flow measurement. The corporation stops are located a distance at least equal to 8 pipe diameters downstream and 2 pipe diameters upstream of any fitting in the pipe layout which might cause turbulence. Also provide a 2-inch corporation stop on the discharge manifold before leaving the station or, if buried, in a valve vault on the discharge line to allow for measuring total pumping station flow. For flow metering devices, see paragraph 6.15.8 of this chapter.

If the pump discharge piping arrangement does not allow for proper location of the corporation stop, provide the corporation stop for flow measurement in the pump suction line in a vault.

6.11.8 Hand Operated Valve Actuators

All gate valves and butterfly valves (except buried valves) are wheel operated for ease of operation. Wheel actuators are installed in readily accessible positions. Chain wheel actuators are provided with hammer blow starting when located more than 6 feet above floor. Butterfly valves 6 inches in diameter and larger are equipped with enclosed gear actuators and handwheels.

As a special pumping station requirement, the City Project Manager may consider electric actuators for isolation valves 16 inches in diameter and larger. AC reversing-type electric actuators are used for electrically operated isolation valves. Electrical actuators on buried piping are installed in valve vaults for ease of maintenance.

Actuators for pump control valves are described in **paragraph 6.11.3** of this chapter.

6.11.9 Electrical Operated Valve Actuators

Acceptable Electrical Valve actuator interfaces.
For each Electrical actuator unit, provide a bypass connection to allow manual operation.

Each Electrical actuator unit, shall have the capability of locally controlling actuator motor speed manually by adjusting a potentiometer, discrete incremental rotary step or via the keypad incorporated onto the Electrical actuator user interface.

Each Electrical actuator unit, shall be capable of interfacing with a Programmable Logic Controller (PLC) via the following standard interfaces.

- Discrete Inputs - Discrete inputs interface the V Electrical actuator unit, with control devices such as pushbuttons, selector switches, and PLC discrete output modules. These signals are typically used for functions such as start/stop, forward/reverse, external fault, preset speed selection, fault reset, local remote, hand, off auto and PID enable/disable.

- Discrete Outputs - Discrete outputs can be transistor or relay. Typically, transistor outputs drive interfaces to PLCs, motion controllers, pilot lights, and auxiliary relays. Relay outputs usually drive ac devices and other equipment with its own ground point, as the relay contacts isolate the external equipment ground.

- Analog inputs 0 to 10 Vdc or 4 to 20 mA signals

- Analog outputs 0 to 10 Vdc or 4 to 20 mA signals - These signals can represent a speed set point and/or closed loop control feedback. An analog output can be used as a feedforward to provide set points for other VFDs so other equipment will follow the master VFD's speed; otherwise, it can transmit speed, torque, or current signals back to a PLC or controller.

- Ethernet interface VFD - Ethernet interface with a built in web server that allows users to configure and control the Electrical actuator unit, from any web browser. Ethernet protocols such as Modbus TCP/IP and EtherNet.

Reference ISA standard 96.

6.12 Structural Guidelines

Structural review is performed by the Development Services Department, Building and Safety Plan Review. New Building Regulations are adopted by the City of San Diego Municipal Code on a regular basis. Information for Building Safety Plan Review can be found at Sandiego.gov/development-services.

6.13 Sitework

6.13.1 Site Constraints

The DESIGN CONSULTANT reviews the Predesign Report from the Public Utilities Department for site constraints that may affect the design appearance, character, materials selection, earthwork, and location on the pumping station site. Views of the facility from areas surrounding the project site are analyzed, and alternatives discussed to harmonize the appearance of the facility with its visual context. Regardless of the visual circumstances, the pumping station operating floor is in all cases located above the 100-year flood elevation.

Pumping station sites may not be located on easements, but must be entirely located on City of San Diego-owned land.

6.13.2 Construction Sequencing

Where bypass pumping for an existing pumping station is required, the DESIGN CONSULTANT provides a sequence of construction on the drawings and in the special provisions of the specification, describing the required construction sequence for performing the bypass operation.

6.13.3 Site Utilities

The DESIGN CONSULTANT identifies and coordinates with appropriate local utility agencies representatives. The DESIGN CONSULTANT also refers to the Predesign Report for any available information on utilities that might be impacted by each project.

The DESIGN CONSULTANT designs the water service with a reduced pressure backflow protection device installed after the water meter, in accordance with City Standards. The site water piping system should include a 3/4-inch water riser and hose bibb placed inside the pumping station building for cleaning the building and adjacent site. The design includes parking posts placed around the reduced pressure backflow prevention device to protect it from damage due to traffic.

6.13.4 Access and Parking

A vehicle access road at the pumping station site allows the positioning of a crane truck of the size required for removal of the largest pumping station equipment through roof hatches when appropriate.

The site also includes sufficient parking space for two 3-ton maintenance trucks.

Avoid locating truck or crane truck access road and parking over inlet discharge piping penetrations into the pumping station walls to avoid pipe shear loadings at these locations.

All vehicle access roads to pumping stations are asphalt paved and a minimum of 24 feet wide.

6.13.5 Security

For specific security and fencing design criteria, refer to **Chapter 8.**

6.13.6 Site Lighting

The pumping station site lighting is controlled by a photocell equipped with manual on/off control. For outdoor lighting, the DESIGN CONSULTANT selects luminaries that produce the least glare over the surrounding area. LED lighting is preferred when installing CCTV security systems. LED minimizes glare and starbursting at night.

Exterior fixtures are vandal-resistant.

6.13.7 Landscaping

All pumping stations are landscaped in a manner that meets community standards and conforms to the City of San Diego Landscape Standards–Land Development Manuel. The landscape design must be perceived as an extension of the concepts established for the materials and form of the building selected to blend with adjacent areas. Landscape designs must be developed by a licensed landscape architect.

The landscape development of pumping station sites is kept to the minimum and is low maintenance. Irrigation systems and plant material are installed outside the City's security fence unless it is absolutely necessary to screen objectionable views of the facility from the community or to prevent the erosion of manufactured slopes. Recommend all vegetation be installed in a manner that when fully mature, a minimum 3 foot separation is maintained between the security fencing and landscaping.

The DESIGN CONSULTANT conforms to the requirements of the latest current edition of the following City-approved documents:

- Landscape Standards, City of San Diego Land Development Manual.
- Rules and Regulations for Reclaimed Water Use and Distribution within the City of San Diego, Clean Water Program.
- Consultants Guide to Park Design, Rights-of-Way and Open Landscaping, City of San Diego Park and Recreation Department.
- Recommend the Landscaping Designer additionally follows Crime Prevention Through Environmental Design Standards to integrate the landscaping into the overall security efforts.

Landscaping selected by the DESIGN CONSULTANT should be drought tolerant. Landscaped features on the pumping station site should be low maintenance and low irrigation (xeriscaping) types.

Landscaped areas are provided with an automatic irrigation system. A reduced pressure backflow prevention assembly is placed in the irrigation piping system to protect the domestic water supply from pollution. A framed, laminated control schematic drawing of the installed irrigation system is mounted in the door of the controller cabinet inside the pumping station.

6.14 Station Support Systems

6.14.1 Ventilation

The DESIGN CONSULTANT designs ventilation to cool the facility using outside air as a cooling medium. The DESIGN CONSULTANT calculates the total sensible cooling load for the pump station building/structure, including both external loads (building/structure envelope) and internal loads (motors, occupancy, lighting, and miscellaneous heat generating equipment). The required ventilation rate must be based on ASHRAE HVAC Applications, Chapter Ventilation of the Industrial Environment, paragraph Ventilation Airflow for Temperature Control, latest edition. The calculation formula is:

$$Q = qs/1.08\ \Delta t$$

Where:

Q = required ventilation rate, cfm
Qs = total sensible heat to be removed, Btu/hr
Δ = temperature rise of the air, °F

The DESIGN CONSULTANT must use ASHRAE Weather Data for Region X for the project location, summer 2% Dry Bulb Temperature column (°F as design outdoor air temperature, and Δt = 10°F).

If no significant sensible cooling load is encountered, the DESIGN CONSULTANT uses 6 air charges per hour or 1.5 cfm/sf, whichever is greater, as a minimum with ASHRAE recommended Outdoor Air Requirements for Ventilation (ASHRAE Standard 62-1981).

The ventilation system must conform to the following codes standards and guidelines unless superceded by more stringent local codes:

- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- Cal-OSHA General Industry Standards
- National Electric Code (NEC)
- National Fire Protection Association Standards (NFPA)
- Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Standards
- California Building Code (CBC)
- California Fire Code (CFC)

- California Mechanical Code (CMC)

Design the ventilation system for noise levels as described in **subsection 6.19** of this chapter. This noise limit includes the sum of fan intake, fan discharge, motor, and casing rotation noise. The maximum fan noise load at 1 meter distance is 85 dBA. Ventilation systems must specify the use of low noise fans.

Provide replaceable dust filter elements on inlet wall louvers or supply air fans. Inlet ventilation dust filters are installed to minimize entry of dust into the station. Filters are located at access doors in the ducting, fan heads, and at convenient locations for maintenance access. Provide a label on the ducting at the filter access location to alert operating personnel to the need to check or replace filters at specified intervals or as measured by a differential pressure gauge. Inlet wall louvers are weatherproof and are equipped with a bird screen or insect screen, as applicable.

Inlet/discharge silencers may be required for noise attenuation. If an inlet/outlet blower system requires noise attenuation, a silencer is provided.

As a special pumping stations requirement, exhaust louvers have motor operated grates that open when the ventilation system is in operation.

Pumping station ventilation systems operate by thermostatic control with manual on/off override.

Underground pumping station areas in coastal and other high-humidity areas are equipped with a wall-mounted dehumidification system.

6.14.2 Overhead Hoist

The DESIGN CONSULTANT designs an overhead hoist system for the installation, disassembly, maintenance, and removal of piping, motors, pumps, valves, flow meters, and other major components in the pumping station. Design of all hoists must be in accordance with the Hoists Manufacturers Institute.

On pumping stations using vertical turbine pumps, the DESIGN CONSULTANT provides roof access hatches or operable skylights for removal of pumps and motors using truck-mounted mobile cranes. A travelling monorail or jib crane system with manual or electric hoists is provided for maintenance and repair over control valves and flow meters.

Install a high access door at the end of the crane rail to allow for positioning a truck-mounted crane inside the station for the removal of equipment.

On some pumping stations, embedded eyebolts may be provided to assist in equipment removal.

6.14.3 Water Supply and Toilet Facilities

The potable water supply is protected by a reduced pressure principle backflow preventer in accordance with local code requirements. The DESIGN CONSULTANT requires the Construction Contractor to obtain the water permit and pay all installation costs for a 1-inch meter service (meter to be installed by the City) per RSD SDW-134, SDW-150, and WS-03. The Construction Contractor is also required to pay water billings until final acceptance of the pumping station by the Public Utilities Department.

As a special pumping station requirement, stations may be designated for inclusion of toilet facilities. No station has toilet facilities that cannot be discharged to a municipal sewer system. All sanitary drains designed by DESIGN CONSULTANT must be in conformance with California Plumbing Code (CPC) and all local codes.

6.14.4 Instrument Air

Instrument air systems, when required, are designed for a maximum system pressure of 60 psig. Compressors are non-lubricated, air- or liquid-cooled, sized for not less than 12 cfm per unit, but in any case, at least 20 times the anticipated maximum air demand. The maximum compressor noise level at one meter distance is 85 dBA. A redundant compressor is provided. ASME-approved receivers are sized to provide a run time of not less than 15 minutes. Compressed air is aftercooled and dried using a regenerating desiccant air dryer. Dryers are installed on the system side of receivers and are sized for not less than twice the anticipated air demand.

6.14.5 Pump Room Drainage System

The drainage system consists of a floor drain, hub drain, cast iron drain pipe, holding sump and sump pumps. The drainage system is designed to handle drainage from the pump seals, power check valves, air release valves, and housekeeping. Floor drains are located and floor slopes designed so that equipment pads do not interfere with drainage. The drainage system is discharged to the municipal sewer system. The DESIGN CONSULTANT consults with the local governing authority to design the drainage system to meet all applicable codes, including cases where a municipal sewer is not available. If required, the holding sump is designed with adequate volume to prevent the pump from cycling in excess of the number of starts per hour recommended by the motor manufacturer. The sump is covered with aluminum grating.

Sump pumps are duplex-type submersible pumps complete with lifting chain, discharge valve, check valve, and piping, starter, level controls, and automatic alternator. High water level alarms are connected to the main pump station control panel.

6.14.6 Fire Extinguisher

A fire extinguisher rated for Class A, B, and C type fires is installed in each pumping station. If an emergency generator is included in the pump station design, a similar fire extinguisher is also provided in the engine room in the outside generator enclosures.

6.15 Instrumentation and Controls

6.15.1 Pump Control Description

The DESIGN CONSULTANT describes the pump control modes and sequence description, including control valve operation, safety interlocks and control resets. These descriptions are titled “Control Strategies” and are sufficiently detailed to guide the Construction Contractor in programming the programmable logic controller (PLC).

Five types of pumping modes sequence control are covered:

- Pressure Control, normally used for pumps designed to maintain a pressure set point/target in a closed zone.
- Flow Control, used for pumping systems designed to maintain a flow demand set point/target in a closed zone.
- Level Control, where the pump sequencing depends on level set points in reservoirs and standpipes
- Multimode Control, may be required where the pump station serves a closed zone and a reservoir simultaneously. This type of control may combine the requirements of pressure and level control if the pressure and flow rates cannot be met by constant speed pumps alone.
- Time of use permissive mode, used for pumping systems scheduled to operate around predetermined energy conservation schedules

6.15.2 Pressure Control of Pumps

The DESIGN CONSULTANT determines the control philosophy based on the number of pumps, the flow capacity of each pump if different sizes are used, the pump curves, and the pipeline system head curve. To meet the closed zone pressure set point requirements at wide flowrate ranges, the pumps are driven by variable frequency drives (VFDs). The DESIGN CONSULTANT determines the rpm range for controlling each pump by examining the pump efficiency curves versus the flow curves. For instance, driving the pump past, 90% flowrate capacity may cause a disproportional increase in electric power consumption.

Pressure surges caused by the transition from one-pump to two-pump operation, two to three, etc., must be avoided as described in the following control sequence.

6.15.3 VFD Pump Control Sequence

The following pump control sequence assumes a four-pump closed pressure zone, three pumps active, one on standby, same size and driven by VFDs. The pump control sequence is performed by the PLC with a programmed software logic and adjustable software timers. As the minimum pressure set point for pump operation is reached, the first pump starts up at minimum rpm. As the flowrate demand increases and the measured pump station discharge pressure decreases, the pump rpm increases to a programmed maximum. When an additional pump is required, the PLC starts up a second pump at minimum speed and keeps the running pump at maximum rpm. As the flow demand increases, the second pump rpm increases to its maximum and with increasing demand the third pump starts at minimum rpm while the first and second pumps continue to run at a maximum rpm. When the flow demand decreases, the pump sequence reverses order. The fourth pump remains on standby until the pump rotation places it in active duty.

The preceding example assumes a VFD for each pump and all pumps of the same size. This arrangement provides smooth transition when additional pumps are started or stopped. The DESIGN CONSULTANT may propose a control system that uses VFDs and constant speed pumps to reduce cost. However, this proposal must be supported by pump and system curves for the specific pump station and approved by the City Project Manager.

The VFD for each pump is provided with an across the line bypass motor starter selected by a 2-position switch to be used in case of VFD failures or upset conditions.

6.15.4 Pumping Station Surge Control

The DESIGN CONSULTANT provides the means to avoid surges on pump start/stop operation. The means to achieve surge control may consist of pump discharge control valves, hydropneumatic surge tanks, pressure relief valves, or a combination of them. Pump discharge control valves are covered in **paragraph 6.11.3** of this chapter. Control valves are provided with valve position limit switches (open/closed) so that the PLC verifies that the valve is closed before starting and stopping the corresponding pump. If hydropneumatic surge tanks are provided, they must have a complete control system and alarm outputs to interface the local PLC. The alarms must include high or low vessel water level, air compressor trouble, etc. The PLC shall maintain the vessel water level by controlling the supply of air in the vessel. Discrete outputs should interface to the PLC to activate compressed air system by adding air and venting air. The DESIGN CONSULTANT provides and the surge tank vendor verifies calculations defining tank capacity, water/air level ratios, and the connecting pipe size that determines the water flowrate in and out of the surge tank. Both a mechanical gauge for localized reading vessel water column and an electronic pressure transmitter interfaced to the PLC to measure remote vessel water level. The

DESIGN CONSULTANT is responsible for control sequence and strategy of the hydropneumatic surge tank.

6.15.5 Level Control of Pumps

Pump stations designed for reservoir level control are sequenced based on reservoir level set points. The pumps are normally of the same size with solid-state soft start motor starters and bypass contactors.

The reservoir level signal is routed to the pumping station by a process control script in the Human Machine Interface (HMI) remotely via the owners microwave radio infrastructure or leased line telemetry.

6.15.6 Level Control Pump Sequence

Pumping stations designed to feed reservoirs or tanks are provided with single-speed pump motors. The PLC control logic is designed to avoid excessive pump cycling. The start/stop cycles per hour are within the motor manufacturers specifications. The PLC program allows the operator to perform level set points and timer adjustments remotely on the HMI through the local operator interface on the control panel. The timers are intended to delay the start/stop of pumps upon detection of reservoir level set points.

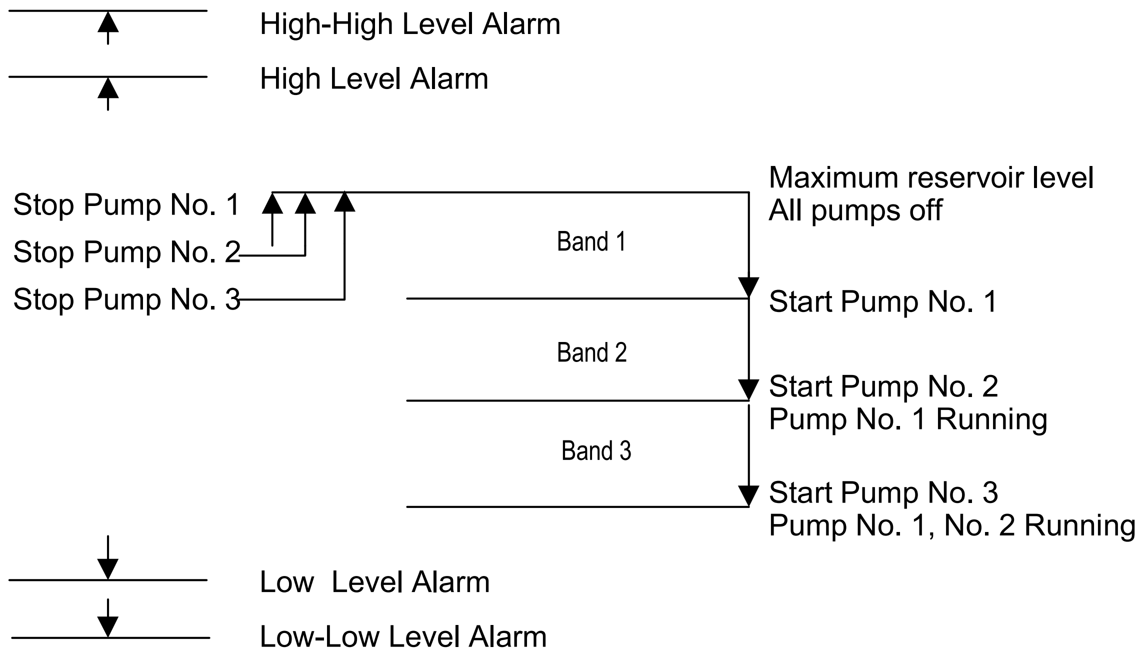
6.15.7 Typical Level Control Sequence

Assume three constant speed pumps filling a reservoir. The PLC interlocks prevent simultaneous pump starts, which could happen after a power failure when two or more pumps are running. In that case, 15-second intervals are allowed between pump starts.

6.15.7.1 Sequence Control Description

Figure 6-2 shows that the reservoir water level has been at the top of band 1 and drops to the bottom of band 1. After an adjustable delay start pump 1. If the level remains within band 1 and 2, continue pumping with pump 1. When the level rises to the top of band 1, stop pump 1. If the level drops below band 2 while pump 1 is on, start pump 2. When the level rises to the top of band 2, stop pump 2. This sequence repeats similarly for pump 3. Pumps are rotated periodically or at each cycle to allow equal wear. Pump rotation is displayed on the operator interface.

Figure 6-2
Typical Pump Level Control Diagram



6.15.8 Flow Measurement and Pressure Instrumentation

In addition to the pump discharge header pressure transmitter, an in-line magnetic flowmeter is installed in new pump stations on the station suction or discharge piping to monitor pumping station throughput. A pressure transmitter and a pressure switch is also installed on the pump station suction header. In the event of low suction pressure, the PLC shuts down the pumps sequentially until the header suction rises to safe levels or until all pumps are turned off.

Flowmeter selection includes an evaluation of the facility criticality, including consideration of a shutdown necessary for meter maintenance. Magnetic flowmeters are preferred for new facilities; however, insertion flowmeters may be permitted by the City Project Manager.

6.15.9 Control Panel Pump Selector Switches

Three position selector switches for each pump are provided on the control panel. The positions are H-O-A. In the "H" (hand) position, the pump runs continuously without PLC control. This mode is for testing or emergency only. In the "O" (off) position, the pump is shut down and cannot be started. In the "A" position, the pump start/stop operation is controlled by the PLC based on the logic programmed by the Contractor.

6.15.10 Control Panel Operator Interface Terminal

To minimize the number of pushbuttons and switches and provide process graphics and alarm data to the operator, an operator interface terminal (OIT) is provided on the control panel. The graphics are configured by the Contractor in coordination with the City's Telemetry Instrumentation and Control Group.

- Range of product Magelis XBTGT
- Product or component Type: Advanced touchscreen panel
- Display type: Backlit color TFT LCD
- Display colors: 65536 colors
- Display resolution: 1024 x 768 pixels XGA
- Display size: 15 inch
- Software type: Configuration software
- Software designation: Vijeo Designer
- Operating system: Magelis
- Processor name: CPU RISC
- Processor frequency: 266 MHz
- Memory description: Back up of data SRAM 512 kB lithium battery
- Application memory: flash EPROM 32 MB
- Integrated connection type: Power supply removable screw terminal block
- Digital input removable screw terminal block
- Composite video input (NTSC/PAL) RCA
- COM2 serial link RJ45 RS485 <= 187.5 kbit/s
- Siemens MPI (187.5 kbits/s)
- COM1 serial link male SUB-D 9 RS232C/RS422/
- RS485 <= 115.2 kbits/s
- Audio output removable screw terminal block
- Audio input mini-jack
- 3 digital output removable screw terminal block
- Ethernet TCP/IP RJ45
- 2 USB type A master port (V1.1)
- Resistance to electrostatic Discharge: 6 kV IEC 61000-4-2 level 3
- Cut-out dimensions 383.5 (+ 1/- 0) x 282.5 (+ 1/- 0) mm

6.15.11 Pump Station Telemetry

Pump station data transmission to the Supervisory Control and Data Acquisition control center at Chollas.

As a minimum, the telemetry data transmitted including:

- Pump running
- Motor high temperature

- Pump circuit breaker/motor starter failure
- Control power failure
- Main power phase unbalance/failure
- Pump control valve failure
- Low suction pressure
- Discharge flow rate and pressure
- Pump room flooding
- RTU/PLC enclosure door alarm
- Generator run status and failure
- Ventilator fan failure, etc.
- Pumping station ambient temperature
- Communication failure
- Automatic Transfer Switch (ATS) Status
- VFD/Drive Fault
- Pump Station Flow Rates

6.15.12 Programmable Logic Controllers (PLC)

The Programmable Logic Controllers are programmed to execute and process the pump station's hard inputs and outputs connections in conjunction with the internal PLC software soft inputs and outputs written within the control algorithm also referred to as the PLC program. The DESIGN CONSULTANT determines the control philosophy also referred to as the control strategy. The CONTRACTOR is responsible for the interpretation of the control strategy and the implementation of the strategy in to the control algorithm (PLC Program). The control algorithm shall be written ether in Derived Function Block (DFB) or Structured Text (ST). Also the CONTRACTOR is responsible for organizing a Factory Acceptance Test (FAT). The CONTRACTOR is responsible for programming, testing, fine tuning, configuration and commissioning of the pump station control system devices. The CONTRACTOR shall closely coordinate with the City's Telemetry/Control group and provide scheduled project updates. The CONTRACTOR must follow City's established hard/soft input output standards in PLC and Control device programming.

- The Programmable Logic Controller is the Unity series processor 140CPU65150 or most current equal.

- The configuration and development software in Unity Pro XL or most current equal with the minimal following features:

    - "All-in-one" software
    - 5 IEC61131-3 languages + Legacy LL984
    - Integrated conversion tools from Concept, Proworks, PL7 Pro
    - FDT / DTM standard for field device integration
    - Standard objects and libraries
    - Customizable integrated Function Block Library (DFB)

- PLC simulator on PC, Built-in test and diagnostic
- Animation tables, Operator Screens and Trending Tool

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6.16 Electrical Design and Emergency Power Generator

6.16.1 Electrical Design Work

The DESIGN CONSULTANT conducts all electrical studies required for the BODR (e.g., protective device coordination, short circuit study, arc flash hazard analysis, harmonics, load flow/voltage drop and motor starting analysis). Arc fault energy levels shall be considered to ensure all personnel are protected in the event of an arc flash incident. The DESIGN CONSULTANT also prepares the technical specification sections necessary to assemble a complete electrical package and develops the electrical drawings for pumping stations necessary to construct a complete electrical package.

At existing pumping stations where additional load is being added to the distribution system, the DESIGN CONSULTANT obtains the maximum electrical demand reading for the past two years from the electrical utility company, and uses this reading as the starting base load.

6.16.2 Codes and Standards

The pumping station electrical system designed by the DESIGN CONSULTANT must comply with the requirements of National Electrical Code, the City of San Diego Electrical Code, California Electrical Code, ANSI, UL, NEMA, IES, and IEEE, as applicable. Building design shall comply with the regulations and standards associated with the California Electric Code (Part 3) and the California Energy Code (Part 6) of the 2016 California Building Standards (Title 24).

6.16.3 Electrical Service and Distribution

Distribution (utilization) voltages are 4.16 kV, 480 V, 208 V, and 120 V unless other voltages are specified for special cases. Incoming service voltages are coordinated with the utility company and the Public Utilities Department.

The DESIGN CONSULTANT designs the pumping station power distribution system so that no single fault or loss of preferred power source results in disruption (extended or momentary) of electrical service to more than one motor control center (MCC) associated with vital components. To meet this requirement, the electrical power distribution system incorporates redundant power sources.

Vital components serving the same function are divided as equally as possible between at least two MCCs. Nonvital components are divided in a similar manner.

Incoming power metering can be remotely read via telephone modem.

Outdoor installations are nonwalk in weatherproof enclosures.

During pump startup, the voltage drop at the motor terminals may not exceed 15%. Feeder and branch circuit conductors are sized so that their combined voltage drop does not exceed 5% with a maximum of 3% in either feeder or branch circuit.

Utilization voltage ratings are as follows:

1. Motors:
   - Smaller than 3/4 hp, 120 volts, single-phase, 60 Hz
   - 3/4 hp and larger (up to 300 hp), 480 volts, 3-phase, 60 Hz

2. Miscellaneous nonmotor loads of 0.5 kW and less are single-phase rated at 120 volts, 60 Hz.

3. Nonmotor loads larger than 0.5 kW are rated at 480 volts, 3-phase, 60 Hz, unless this voltage rating is not available for the equipment selected.

4. Lighting:

   - Outdoors = LED, 277 or 120 volts, single-phase
   - Indoors = LED, 277 or 120 volts, single-phase

5. General-purpose receptacles are rated 20 amps, 120 volts, single-phase.

6. Special purpose receptacles may be 120, 208, or 480 volts, 3-phase as required.

7. All ac control power circuits are 120 volts, single-phase.

8. Special purpose dc control circuits may be 125 volts, 48 volts, or 24 volts.

9. All instrumentation power supplies are 120 Vac single-phase, 60 Hz.

6.16.4 Electrical Equipment

The DESIGN CONSULTANT sizes electrical equipment to continuously carry all electrical loads without overloading. Equipment and materials are rated to withstand and/or interrupt the available fault currents, with at least a 25% reserve margin for electrical load growth. Electrical power conductors are sized according to the heating characteristics of conductors under fault conditions. Electrical equipment panels are provided with cooling fans.

6.16.4.1 Medium Voltage Motor Controllers

Medium voltage controllers are modular design, vacuum contactor type. Where required by the power supply, or if the voltage dip exceeds the required maximum value, reduced voltage motor starters are used. A reduced voltage motor starter may also be used as a surge protection device for the constant speed pump drives. The motors are started slowly to reduce surges in the pipeline.

Indoor enclosures must be NEMA 12 rated.

All MV starters are furnished with electronic protection modules with communication capability.

6.16.4.2 Variable Frequency Drives

Variable frequency drives (VFDs), where required, are provided with the pump and motor to provide unit responsibility for a system that performs over the required head and flow ranges. The VFDs are used to drive induction motors, and are PWM type.

All VFDs have remote control capabilities via a MODBUS(+) communication interface port. Interface features as defined in **section 6.5.9**.

VFDs shall be Active front end type to minimize harmonics and improve power factor.

6.16.4.3 600-Volt Motor Control Centers

Low voltage motor control center (MCC) assemblies must conform to the UL and ANSI standards for NEMA Class 2, type B wiring.

All breaker handle mechanisms have padlocking devices on the off position.

All indicator lights mounted on the MCC are push-to-test type, and shall comply with NEC machine indicating light and icons.

Each Motor circuit on the MCC and including incoming main should be equipped with power monitoring devices. Including the pertinent Voltage Transformers (VT), Current Transformers (CT) and user interface display for the purpose of monitoring power quality and motor efficiency. Each power monitor device should be configured to fit the project electrical configuration. Each power monitor device should interface with the local Programmable Logic Controller (PLC) network via Ethernet. The CONTRACOR is responsible for the configuration of each power monitor device and the necessary PLC code to transfer the telemetry information per device to the remote control center.

All combination magnetic starters have MCPs and time delay mechanisms to prevent the unit from dropping out during momentary utility voltage dips.

A full-length ground bus must be provided.

6.16.4.4 Switchgear

Switchgear assemblies conform to UL and ANSI standards, and comply with the service requirements of the utility company.

For outdoor applications, the switchgear must be weatherproof NEMA 4, nonwalk-in type, with sloped roof.

Busbars are copper, fully insulated and silver-plated at joints. A full-length ground bus must be provided.

6.16.5 Grounding

Grounding electrode system resistance for a single rod should be less than 25 ohms.

All feeders have an equipment grounding conductor in the same raceway.

Equipment grounding conductors must be sized in accordance with NEC table 250-122.

6.16.6 Instrument Power

All 120-volt power to instruments and instrument panels is derived from a dedicated instrument power panel from a shielded transformer, not from a general lighting and convenience receptacle panel. Provide separate fuses for each field device. Instrumentation panels ~~is~~ should be derived from a dedicated and properly sized circuit breaker feed from a stepped down shielded transformer of witch the primary side to power the panels should be 120 volt AC. It is not acceptable to source power form a general lighting and convenience receptacles. Instrument loop or circuit should be powered by a 24 volt DC source. Each loop should be protected for short circuit with an adequately sized fast blow fuse or as needed device isolation circuit breakers.

An uninterruptible power supply (UPS) is provided for all main control panels, RTUs, RIOs, PLCs, and all other process controllers as required for the specified instrumentation and controls.

6.16.7 Emergency Power

6.16.7.1 Emergency Plug-in Connection

In stations without an alternative backup power source (i.e., second service or dedicated onsite emergency power), install a manual transfer switch and an emergency plug-in power connection to the pumping station for use with a portable generator.

The pumping station should also be equipped with a manual transfer system that requires the use of an enable key to sequentially open the line power service and then transfer to the emergency power service connection.

Automatic transfer switches are required when station is provided with a backup generator. Manual switches are sufficient for non-permanent generators/plug-ins.

In station, install a 30 Amp, 240 Volt plug–in power connection for use with portable generator block heaters if any, and a 120 Volt circuit for battery charger.

The transfer switch has the same current amperage interrupt rating (AIC) as the line power main breaker.

The following warning sign is posted on the manual transfer switch panel:

DO NOT TRANSFER POWER UNDER LOAD

6.16.7.2 Emergency Power Generator

Diesel engine generator units may be installed with special approval from the City Project Manager in conjunction with the Water System Operations Division. Need for emergency power is established in the Predesign Report or the BODR.

The preferred fuel tank installation is a frame-mounted fuel tank under the emergency generator unit (surrounded by a spill containment dike) or an aboveground tank installed in an aboveground block-wall enclosure incorporating a confinement dike. An aboveground tank is used where possible. All diesel storage tanks have a desiccant dry-air breather on vents to prevent water condensation in the tank. The fuel tank contains sufficient fuel to sustain a minimum of 24 hours of continuous operation.

The DESIGN CONSULTANT requires that a 1-year standard service contract for the emergency generator be provided by the Construction Contractor. The pumping station has an interlock-protected emergency power automatic transfer switch (ATS) to automatically start the generator in the event of loss of main power (i.e., phase of power, reverse power, or low voltage brownout). The ATS is mounted in sight of the generator control panel or remote status annunciator panel for ease of operation. The ATS is provided with communication provisions for remote annunciation and control via the local telemetry system. As a minimal the following telemetry indicators from the EMERGENCY POWER GENERATOR and the AUTOMATIC TRASFER SWITCH should be interfaced to the local PLC for remote status monitoring:

- Generator running
- Generator fault

- Generator fuel level
- ATS ON load position
- ATS OFF load position

Refer to the **Noise Control Guidelines Appendix 6-1** for Emergency Power noise abatement.

6.16.8 Lighting

Refer to **paragraph 6.16.4** of this chapter for lighting voltages. The State of California Energy Conservation Standards apply where applicable.

Lighting levels are as follows (and should be verified with IES requirements):

Area	Illumination Level
Electrical Equipment Rooms	40 footcandles
Exterior Lighting	0.1-1 footcandle
Pumping Area (dry well)	30 footcandles
Mechanical Equipment Rooms	30 footcandles
Restrooms	30 footcandles

Lighting in pumping stations is switched. The pathway to the main lighting switch is lighted with nonswitched lighting fixtures.

Exterior lighting around unattended pumping stations, is provided with key-operated switching located at the property entrance gate.

Emergency egress lighting in all interior areas of the pumping station is accomplished with emergency battery backup packs illuminating the egress path to the outdoors. 90-minute battery backup capacity is provided.

6.16.9 Receptacles

20 amp, NEMA 20-R, 120-volt grounding convenience receptacles for GFI plugs are provided throughout the pumping station facility so that all working areas, can be reached by a 25-foot-long portable cable (extension cord).

One 200-amp, 480-volt, 3-wire, 4-pole twist lock receptacle is provided so that the receptacle can be reached by a 50 foot long cord where required by water operations.

All receptacles in outdoors are in weatherproof/weather resistant enclosures for GFI plugs.

6.16.10 Electrical Equipment Room

The electrical equipment room is separate from the pump room. It is either located in a separate building or may be separated from the pump room by a divider wall fitted with a fixed viewing window so that the pump room is in a non-hazardous environment.

6.17 Architectural Treatment

This section provides a general basis for the approach to architectural design of pumping stations. The following guidelines and criteria are provided to ensure a consistent and thorough design process for each facility. Although the guidelines described in this section apply to pumping stations, the general concepts could be applied to other Water facilities which incorporate pumping stations and other related buildings/structures (e.g., combined reservoir, pumping station facilities).

6.17.1 Design Performance Guidelines

The DESIGN CONSULTANT meets with the City Project Manager to establish appearance and physical performance criteria for the facility. Areas of focus include the sizes and configurations of the major functional elements to be housed in the facility, and the deployment and interrelationships of supporting mechanical, electrical, and maintenance provisions. Topics also include:

1. Discover, document, and prioritize functional goals for the facility, including spatial needs and hierarchy of importance, public image, the degree or level of security appropriate to the facility location, functions to be housed, the scope of future expansion and flexibility expected, desired links to other functions on the project site, maintenance guidelines, and HVAC, electrical, lighting, and acoustical criteria. The use of the new facility is discussed and documented in terms of intended conformance with, or departure from, existing employee health and safety policies.

2. Discover and document the degree and type of human interaction anticipated to occur within and around the planned facility, including Water Department personnel and public access to the facility in the form of visits by non-Water Department personnel. These considerations have key relevance in the design of the facility within the context of regulations governing handicap access. The building design resulting from these conversations is affected in areas such as the number and location of emergency exits, fire detection and suppression system, the design of zones of safety, horizontal and vertical clearances, and other personal safety, acoustic and lighting safety provisions.

3. Determine locations and sizes of structures and other functional systems which may already exist at the project site, as well as the availability and types of utility services which

may be required. Develop strategies to successfully integrate the design of the new facility into this context.

4. Review the impact of the project on existing drainage patterns. Develop mitigation strategies if necessary.

5. Investigate existing zoning constraints, applicable building codes, and anticipated public and governmental review procedures necessary during the course of the design. Develop strategies and assign responsibilities for their successful negotiation

6. Review and document existing and future planned land uses around the facility site. Determine guidelines for the design and character of the new facility so that it harmonizes as effectively as possible with its visual and social context.

7. Review and incorporate mitigation measures included in environmental documents for the project.

8. The DESIGN CONSULTANT utilizes the minimum criteria for noise control described in **Appendix 6-1** of this Chapter 6. Additional or more strict criteria may be established in the environmental approval process. The DESIGN CONSULTANT shall utilize the most conservative criteria established.

6.17.2 Design Appearance Guidelines

As an extension of the discussions in the preceding paragraphs, the DESIGN CONSULTANT and the City Project Manager establish criteria for the appearance and physical performance of the structural system and building envelope. The architectural design should be developed in character, style, form, color, and materials to harmonize effectively with its surrounding environment. Suggested design parameters to assist in these aspects of the design of the facility include:

1. **Height of Structures.** The facilities are kept as low in profile as is functionally possible. Where appropriate, the design should de-emphasize verticality and encourage the grounding of planar elements of the facility into the natural landscape. Low, horizontal site walls, berming, and the use of sloping wall planes are to be considered in achieving this balance.

2. **Reflective Finishes.** Visible and highly reflective materials and surface finishes should be avoided on the exterior of the facility.

3. **Exterior Walls.** The use of low maintenance indigenous materials such as masonry and concrete for the exterior walls of the facility is encouraged. The use of surface textures and horizontal banding of harmonious colors are some of the techniques to be considered in blending the facility with its environment. Material coloration should be achieved

through the use of integral coloration and, in the case of concrete, pigmented admixtures, rather than applied coloration such as paint, which must be maintained.

4. **Roofs.** Just as with the massing and materials of the exterior walls, the design of roof systems should be carefully developed to harmonize with the visual context of the facility. Where flat roofs are appropriate, they should be predominately hidden by parapet walls. Where pitched roofs are desired, consideration should be given to selecting pitch, materials, and coloration to harmonize with surroundings. Highly reflective roof surfaces must not be visible from adjacent property. Mansard and jogging roof lines should be employed only when appropriate to the setting. The use of securable skylights for natural lighting is encouraged where feasible. Also provide securable skylights or access hatch for ease of equipment removal using a mobile crane. It is preferable the pump station is designed with a mansard type roof so that there is a flat roof around the skylight/pump access hatches allowing an even working surface for moving equipment in and out of the pump station. However, a mansard style roof may not be appropriate in all locations. The DESIGN ENGINEER and architech should take into account community sensitivity to deteremine a roof design that will blend into the surrounding buildings. If there is a community plan that suggests building style, such community plan should inform the designer of the pump station building. The roof will be accessed through an interior ladder with railing and fall arrest equipment. Pitched roof with tiles around the skylights or portable ladder should be avoided. If the roof is flat, the roof should have a parapet wall for safety. The new building design should be presented to the community.

5. **Windows.** Where windows are appropriate to the design, they should be selected carefully for energy efficiency, acoustic characteristics, and security. Glazing systems are designed to avoid light leakage to adjacent property as direct glare or reflected glare from sunlight. Glass tinting and window frame colors should be chosen for their consistency with the palette of materials and colors selected for the facility.

6. **Insets, Grills, Trim and Accents.** Insets, grills, trim material, and accents should be employed judiciously and only where necessary or appropriate for compatibility with adjacent structures. Insets, grills, trim, and accents are consistent with the color palette chosen for the facility and should avoid bold, strong, or reflective colors.

7. **Doors and Frames.** Door and frame colors are compatible with the wall surface in which they are located.

8. **Lighting.** Lighting should satisfy functional and security needs while not creating light pollution in the form of point sources of direct glare visible from a distance. Lighting should be sensitive to the privacy of adjacent land uses. Fixtures should be carefully selected for efficiency, cut-off, consistent lamp coloration throughout the project, and effectiveness in delivering only the light necessary to the task, while avoiding unnecessary spill lighting beyond site boundaries. Low-level light fixtures which light immediate areas

are encouraged. Natural lighting of the interior of the building in the form of skylights and clerestory windows is also encouraged.

9. **Equipment and Service Areas.** All mechanical and electrical equipment are screened from public view.

10. **Materials - Safety.** Materials used in the construction of the facility conform in composition and application to all applicable regulations, including those concerning volatile organic content, lead, mercury, CFCs, and asbestos.

The Predesign Report contains discussion of site constraints that may affect the design appearance, character, materials, selection, massing and location on the project site. Traditionally established City preferences and guidelines for material and appearance systems, structural systems, and major building envelope systems are discussed and their appropriateness to the specific application assessed. These preferences and guidelines are developed in the context of the specific location of the project site; therefore, not all facility design should be expected to have the same architectural theme and character. Construction materials and methods are established and defined, in terms of their physical appearance and overall visual effect in harmonizing with the surrounding environment, their emergency from the basic structural system, and their appropriateness in accommodating the deployment of mechanical and electrical systems within the facility.

Weathering systems are also defined in terms of the area's desert climate. The roofing system and the building perimeter envelope are established for optimum durability over the full range of climatic variations typical to the region.

These examinations form the basis of directions to the DESIGN CONSULTANT about the appearance of the new building. From these discussions, the DESIGN CONSULTANT develops specific graphic and written statements defining the architectural theme and character of the new structure, as well as its relationship to other functions on the project site and its harmony with the visual context of surrounding land uses.

6.17.3 Site Constraints

Finally, the DESIGN CONSULTANT reviews the Predesign Report for a discussion of site constraints that may affect the design appearance, character, materials selection, massing, and location on the project site. Views of the facility from areas surrounding the project site are analyzed and alternatives discussed to harmonize the appearance of the facility with its visual context. The DESIGN CONSULTANT ensures that viewsheds are optimized while hydraulic elevations and storm drainage provisions are preserved. Regardless of the visual circumstances, the facility in all cases is located above the 100-year flood elevation.

6.17.4 Space and Function Requirement Program

The DESIGN CONSULTANT documents the topics of discussion and directions established in the facility criteria meeting(s) in a space and function requirements program. This document may be in any form, from a simple memorandum to a bound report, depending on the size and complexity of the project. More significant than its form, the report must thoroughly document the understandings reached in the meeting(s). The document contains a summary establishing gross area and volume requirements, as well as a schematic of the basic functional relationships within the facility. It also completely describes the parameters of appearance, function, size, and layout. As such, the space and function requirements program is a distillation of all the information necessary to allow a competent design to be developed. The Predesign Report serves as the point of beginning for this program.

6.17.5 Program Review and Approval

The DESIGN CONSULTANT submits the space and function requirements program to the City Project Manager, who reviews the material thoroughly and comments on any additional items or corrections that may be required. If the program information is found to be a clear, concise and accurate statement of requirements, the City Project Manager approves the report.

6.17.6 Building Design

After Public Utilities Department approval, the DESIGN CONSULTANT proceeds with design of the facility. Requirements for basic functional relationships and area and volume requirements are developed and refined into plan, elevation, and section views of two separate design schemes. While schematic, the drawings are accurate to scale and incorporate all major program requirements. The DESIGN CONSULTANT meets with the City Project Manager to present both schemes. Each alternative is described in terms of how well it embodies program requirements. Structural systems, building envelope, and major building systems are shown in both schemes. As a part of the DESIGN CONSULTANT'S presentation and description of the schemes, the relative merits, advantages, and potential criticisms of each scheme are discussed. The meeting culminates in a decision by the City Project Manager of the selected scheme and any necessary adjustments. Clear directions are given to the DESIGN CONSULTANT on the final course of development to be pursued.

6.17.7 Construction Documents

After the City Project Manager's decision, the DESIGN CONSULTANT proceeds to develop the selected scheme into Contract Documents.

6.18 Corrosion Control

For corrosion control requirements for pumping stations, refer to **Chapter 7**.

6.19 Noise Control

6.19.1 General

The noise design guidelines outlined in **Appendix 6-1** define the minimum technical requirements to be used by the DESIGN CONSULTANT for the design, material and equipment selection, construction, startup operations and maintenance considerations to control noise from individual pieces of equipment or individual units within the pumping station, at the facility boundary and in the community. Any deviations from the requirements of these noise Guidelines must be completely justified and explicitly requested by the DESIGN CONSULTANT. City Senior Engineer approval of all such deviations is required.

6.19.2 Design Phase

Facility compliance with these noise Guidelines must begin during preparation of the BODR. Paragraphs 2 and 4 of Appendix 6-1 address noise control for the design phase.

6.19.2.1 General Facility Design

The DESIGN CONSULTANT prepares facility designs that result in an operating pumping station in compliance with all local, state and federal noise regulations. Compliance is ensured through the submittal of BODR plans and specifications to the City Project Manager for review and approval. Facility noise predictions are developed during the engineering design phase to predict the pumping station noise levels (at personnel frequented locations), facility boundary line noise levels, and (where appropriate) community noise levels. The sound pressure levels of completed facilities during their operation are guaranteed by the DESIGN CONSULTANT to be within permissible limits of these Guidelines, including a pump station at facility boundary and community sound pressure levels due to facility operations. Locations where noise level limits cannot feasibly be met are identified by the DESIGN CONSULTANT and brought to the attention of the City Project Manager.

6.19.2.2 General Equipment Design

Noise generated by equipment, piping, prime movers and other noise sources is determined and noise information updated during the design period. Updated noise data is incorporated into the facility noise model and properly evaluated by the DESIGN CONSULTANT to avoid the need for corrective noise attenuation measures after completion of facility construction.

6.19.3 Preconstruction Phase

The DESIGN CONSULTANT conducts an ambient noise survey during project design so that existing noise levels within the planned facility boundaries, at facility boundary line, in the community can be considered and incorporated into the design of the facility. The ambient noise survey is discussed in **paragraph 5 of Appendix 6-1** and shall be conducted in accordance with the methods described in **Paragraphs 7.4 and 7.5 of Appendix 6-1**. Ambient noise measurements are made at the same locations approved by City Project Manager and modeled in the design phase.

6.19.4 Maintenance Considerations

The DESIGN CONSULTANT takes care in preparing the design, specification and implementation of noise control measures and devices so that maintenance and safety issues are adequately considered. Maintenance and safety issues are discussed in **paragraph 8 of Appendix 6-1**.

6.20 Pumping Station Operational Testing Facility Acceptance

The DESIGN CONSULTANT provides appropriate information in the Contract Documents to describe the following requirements:

6.20.1 Operational Test Procedures

The DESIGN CONSULTANT prepares a schedule of operational tests to be witnessed by the City and Construction Manager that demonstrate the proper operation of all equipment at the station. The Construction Contractor is required to demonstrate over a 14 consecutive day testing period that the operation of all pump station mechanical equipment, electrical controls, emergency power operations and warning displays. Simulated failure conditions are initiated by the Construction Contractor as required to demonstrate warning displays. Startup plan is required and shall be provided by the Construction Contractor.

6.20.2 Contractor Testing and Equipment Certifications

The DESIGN CONSULTANT prepares specifications that require the Construction Contractor to test and adjust all equipment to ensure proper operation after all construction is completed. The specifications require that the Construction Contractor obtain the following motor and pump test data and equipment installation certification and provide it to the Construction Manager during operational testing.

6.20.2.1 Installed Equipment Certification

The DESIGN CONSULTANT prepares specifications that require the Construction Contractor to submit to the Construction Manager, within 14 calendar days of installation, a letter from each major equipment supplier certifying that the equipment installed at the pumping station was installed and tested to manufacturer's recommendations.The certifications from the Construction Contractor (and/or its equipment suppliers and subcontractors) certifies that major equipment was installed, tested and is operating to manufacturer's recommendations. Certifications are provided for the following major equipment in the station: pumps and motors, variable frequency drives, power check valves, emergency generator units, automatic transfer switches, diesel fuel tanks and day tanks, motor control centers, pump control panels, telemetry panels, flow meters, and pressure switches/transducers.

6.20.2.2 Factory Testing Report Pump Motors

The DESIGN CONSULTANT prepares a specification requiring the Construction Contractor to have the pump motor manufacturer/supplier submit certified factory test information for the supplied units: motor heat run and efficiency test curves.

6.20.2.3 Factory Testing Report - Pump Unit(s)

Certified pump test curves recording the actual performance of installed equipment are prepared for each pump at the Construction Contractor's expense (in accordance with Hydraulic Institute Society test requirements). The test information also includes the following: TDH/GPM, motor current draw, motor RPM, and overall efficiency.

6.20.2.4 Vibration Analysis Report

The Construction Contractor is required to provide a vibration analysis test report for the installed pumping and emergency generation equipment. This analysis and report is prepared by a state of California Registered Professional Mechanical Engineer experienced in this type of work.

6.20.2.5 Installation Testing Report - Pump Efficiency

DESIGN CONSULTANT shall specify within the contract documents that the Construction Contractor shall provide a third party pump efficiency test report as part of the acceptance process.

APPENDIX 6-1
PUMPING STATION NOISE CONTROL GUIDELINES

1. SCOPE

The Guidelines define the minimum technical requirements to be used for design, material and equipment selection, construction, startup operations and maintenance considerations to control noise from individual pieces of equipment or individual units within the facility, at the facility boundary and in the community. Any deviations from the requirements of this noise Guideline must be completely justified and explicitly requested and approvals obtained from the appropriate the City Senior Engineer .

2. REFERENCES

2.1 Noise Regulations

This Guideline includes references to the following noise regulations:

1. California Administrative Code, Title 8, Group 15, Article 105, "Control of Noise Exposure."
2. County of San Diego Code of Regulatory Ordinances, Chapter 4, Sections 36.401-36.443, "Noise Abatement and Control."
3. City of San Diego Municipal Code, Chapter 59, Article 9.5, "Noise Abatement and Control."

2.2 Noise Standards

This Guideline contains references to the following noise standards:

1. American National Standards Institute (ANSI)
   S1.4, Specification for Sound Level Meters
2. American National Standards Institute (ANSI)
   S1.11, Specification for Octave Band and Fractional-Octave Band Analog and Digital Filters
3. American National Standards Institute (ANSI)
   S1.13, Measurement of Sound Pressure Levels in Air
4. American National Standards Institute (ANSI)

5. S1.25, Specification for Personal Noise Dosimeters

6. American National Standards Institute (ANSI)
S1.40, Specifications for Acoustical Calibrators

3. GENERAL

3.1 Definitions

1. Noise - unwanted sound.
2. Sound pressure - small oscillatory pressure variations above and below ambient atmospheric pressure that produce the auditory sensation of sound (in N/m^2, where 1 $Newton/meter^2$ = 1 pascal [Pa]).
3. Sound pressure level - 20 times the common logarithm of the ratio of measured sound pressure over the reference sound pressure, expressed mathematically in decibels (dB), as follows:

   $$\text{Sound pressure level (dB)} = 20\ \text{LOG}_{10} \frac{\text{Measured Sound Pressure}}{\text{Reference Sound Pressure}}$$

   where the reference sound pressure = 20 micropascal (20 μPa).
4. A-weighting - an acoustic frequency adjustment to a sound pressure level which simulates the sensitivity of human hearing. An A-weighted sound pressure level (dBA) results from either manually or electronically applying the frequency dependent A-weighting factors.
5. Noise level, sound level or overall sound level - the single number A-weighted sound pressure level as read on a sound level meter set to A-weighting. This level is also the energy sum of the A-weighted sound pressure level spectrum.
6. Overall sound pressure level - the single number unweighted sound pressure level as read on a sound level meter set to linear. This level is also the energy sum of the sound pressure level spectrum.
7. L_{eq} - the equivalent continuous sound level or energy average sound level over a set period of time (usually one hour).
8. TWA - the 8-hour time-weighted averaged occupational noise exposure level.
9. Octave band - the interval between two frequencies having a ratio of 2 to 1.

4. DESIGN PHASE

4.1 General Facility Design

1. The DESIGN CONSULTANT prepares facility designs that result in operating facilities that comply with all local, state and federal noise regulations. Compliance is ensured through the submittal of plans, specifications and quarterly summary reports for review and approval. The sound pressure levels of completed facilities during their operation are guaranteed by the DESIGN CONSULTANT to be within permissible limits of this Guideline, including in-facility, facility boundary and community sound pressure levels due to facility operations. Locations where the noise level limits cannot feasibly be met are identified and brought to the attention of the City Project Manager.

4.1.2 Facility Noise Modeling

Facility noise predictions are developed during the engineering design phase to predict the in-facility noise levels (at personnel frequented locations and work stations), facility boundary line noise levels, and (where appropriate) community noise levels.

1. For small facilities with only a few (<10) potentially noisy items of equipment, simple spreadsheet-type calculations may be used to predict the composite facility generated noise.

2. For larger facilities with several (10 or more) items of potentially noisy equipment, a facility noise computer model is used to calculate the composite facility generated noise.

3. Noise modeling formulas and software are based on industry accepted practices for source noise prediction, noise propagation and noise attenuation analysis.

4. Equipment Noise Data
   a. For potentially noisy equipment, either the octave band sound pressure levels at a specific distance from the noise source (usually one meter for smaller items and at least one major equipment dimension away for larger equipment) or the octave band sound power levels are obtained and carefully reviewed by the DESIGN CONSULTANT. Both the overall level (dBA) and octave band levels for the preferred octave band frequencies of 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz are determined for each piece of potentially noisy equipment. This information is to be estimated during the preliminary engineering phase and updated throughout the detailed design phase, as equipment selection becomes more definite.

b. Plan and elevation coordinates are identified for each item of potentially noisy equipment and used as source locations in the noise model.
c. Plan and elevation coordinates are identified for each sensitive receptor location and used as receiver locations in the noise model.

5. Where individual pieces of equipment meet a specified noise level limit but are to be located near other noisy equipment, the combined sound pressures are additive. In this case, individual equipment noise level limits must be reduced sufficiently to achieve the employee location noise limit (e.g., 85 dBA TWA for 8-hour exposure).

6. Noise model verification is undertaken by the DESIGN CONSULTANT to ensure that modeled distance versus noise attenuation between facility noise sources and community receiver locations, atmospheric absorption attenuation with distance, noise barrier attenuation and any other excess attenuation factors are consistent with published acoustical data and that the model is calibrated to accurately account for noise level differences at the noise sources, at the facility property lines and at the community sensitive receptor locations.

7. Facility noise levels are predicted and used when addressing the following considerations relevant to facility design:
   a. The technical and economic feasibility of selecting low noise equipment designs and their effect on in-facility, facility boundary line and community noise levels.
   b. Any requirement for additional noise abatement measures to comply with regulated and noise limits.
   c. Locations of in-facility areas that cannot be designed with adequate feasible noise controls and therefore must be designated as high noise areas requiring the use of personal hearing protection and/or noise shelters.
   d. The number of employees potentially affected by excessive noise exposure, without and with the implementation of noise controls.
   e. The management of employee tasks so that their TWA noise exposure is deemed acceptable by Cal-OSHA.
   f. The influence of noise controls on facility operation and maintenance.

4.1.3 In-Facility Non-Industrial Area Noise Planning

1. The DESIGN CONSULTANT designs interior work spaces so that the noise from internal systems and exterior facility noise does not exceed the nonindustrial work area noise limits on Table 1 of this appendix. Architectural acoustic treatments to interior walls, floors, ceilings and special window treatments are considered. In addition, appropriate acoustical and vibration isolation of internal building noise and vibration sources are considered by the DESIGN CONSULTANTS.

4.1.4 In-Facility Occupational Noise Exposure Planning

1. The DESIGN CONSULTANT, in consultation with the Water Department staff, estimates operator and maintenance personnel work locations. They also estimate the normal and worst-case durations at the estimated work locations.

2. The DESIGN CONSULTANT determines area noise levels for all employee frequented areas and occupied locations that might contribute to the TWA noise exposure of personnel.

3. Facility employee TWA noise exposures are predicted by DESIGN CONSULTANT for three conditions:
   a. Facility design with standard equipment.
   b. Conservative facility design featuring quiet equipment or equipment with noise control options to achieve a maximum combined equipment noise level of 85 dBA at or beyond a distance of 1 meter (3 feet) from any equipment surface
   c. Optimized facility design with equipment only having sufficient design noise controls to achieve the state-mandated employee TWA noise exposure compliance. This is more a function of employee position and duration than limiting equipment noise levels. It may require an iterative computational process and may allow higher equipment noise levels. The most recent version of the Cal-OSHA requirements govern in all cases of occupational noise exposure computation.

4. The DESIGN CONSULTANT compares the predicted number of employees with excessive TWA noise exposures for this three-part noise exposure analysis and submits the findings to the City Project Manager for review and comment.

4.1.5 Boundary Line and Community Noise Planning

Sound levels at or beyond facility boundary lines conform to the noise limits of Table 2 or Table 3 of this appendix, depending on the facility proximity to City and County land use. The noise limits of the most recent codes of the City and/or County of San Diego govern their respective land use jurisdictions.

1. Areas in which the sound is expected to be tonal require the allowable overall sound level limit for that area to be reduced by 5 dBA. A tonal sound is one where the sound in a narrow band (1 octave or less wide) is more than 5 dB higher than the level in both of the adjacent side bands.

2. For facility design noise control, the following strategic order of priority is used:
   a. When practical, noisy equipment is located in more remote areas of the unit or facility, where personnel and community noise exposure is reduced due to distance.
   b. Where feasible, equipment that conforms to the noise limits described in this Guideline without add-on external acoustical enclosures, silencers, lagging, etc., is selected.
   c. Equipment that can be externally treated with acoustical enclosures, silencers, lagging, etc., is selected.

3. Noise attenuation treatments or controls, in addition to those furnished by equipment suppliers, are provided to ensure that the completed project equipment, operating individually, collectively, or in groups, conforms to the noise limits of this Guideline.

4. A noise compliance summary report that includes equipment type, manufacturer, operating characteristics, location and predicted noise levels is submitted quarterly to City Project Manager. The first summary report is developed early during the preliminary engineering phase and includes the most recent available data. This preliminary data is updated periodically during the engineering design phase until the final design data is firm. Calculations or computer model input data used to predict sound pressure levels at the facility boundary lines and in the community is included in the quarterly summary reports.

5. Design information is submitted to potential equipment suppliers, including a copy of this noise Guideline and applicable sound pressure level limits. An equipment noise data sheet is also provided the bidding equipment suppliers. The noise data sheet indicates the free-field noise level limit at a specified distance, as determined by the DESIGN CONSULTANT, provides space for the bidder to list its guaranteed specified distance equipment noise levels (overall A-

weighted and octave band sound pressure levels) and the associated noise control costs for:

a. Standard equipment package
b. Optional quiet design version of equipment
c. Equipment with supplier add-on noise controls (acoustical enclosures, upgraded silencers, etc.)

6. Equipment noise data sheets must be completed by bidding equipment suppliers for each type of potentially noisy equipment and returned with their bids.

4.2 General Equipment Design

1. Noise generated by equipment, piping, prime movers and other noise sources is determined and noise information upgraded during the project design. Updated noise data is incorporated into the facility noise model and properly evaluated to avoid the need for corrective measures to attenuate noise after completion of facility construction.

2. Standard designs that do not conform to the requirements of this Guideline may be brought into compliance by a combination of:
   a. Replacement with "quiet" designs
   b. Use of acoustical enclosures
   c. Use of acoustical (or thermal) lagging
   d. Use of upgraded silencers
   e. Use of other appropriate noise control methods.

3. The design of acoustical controls is considered with and conforms to thermal design requirements.

4.3 Equipment Purchase

1. Individual pieces of equipment conform to guaranteed noise limits provided on noise data sheets.

2. Where individual pieces of equipment meet a specified noise level limit but are to be located near other noisy equipment, the combined sound pressures are additive. In this case, individual equipment noise level limits are reduced sufficiently to achieve the desired location noise limit (e.g., 85 dBA).

3. If sound pressure levels and measurement positions are different from the standard conditions normally shown on the noise data sheet, such information is specified by the bidder.

4. Where relevant, the following information is provided to bidding equipment suppliers:
   a. Site conditions, including prevailing wind speeds and directions, size and locations of existing buildings, and size and locations of groves of trees, walls and other visual barriers.
   b. Frequented locations of operating and maintenance personnel.
   c. Other structures and adjacent equipment that may affect the operating sound pressure level of Supplier's equipment.

5. If a supplier's optional noise controls, which could be built into its equipment, would generate excessive costs, the DESIGN CONSULTANT notifies City staff and they jointly determine which is more economical and practical:
   a. Acceptance of the equipment with the optional built-in noise control measures, or
   b. Selecting add-on noise attenuation treatments (enclosures, silencers, lagging, etc.) external to equipment.

5. PRECONSTRUCTION PHASE

5.1 Ambient Noise Survey

1. A noise survey is conducted during project design so that existing noise levels within the planned facility boundaries, at facility boundary lines and, where appropriate, within the community can be considered and incorporated into the design of the facility. The ambient noise survey is conducted in accordance with the methods in subsections 7.4 and 7.5 of this appendix. Ambient noise measurements are made at the same locations approved by City staff and modeled in the design phase.

2. All instrumentation is calibrated before each series of measurements in accordance with ANSI S1.40 and has valid annual calibration certification. Sound measurement instrumentation must conform to the ANSI S1.4, S1.11 and S1.13 standards.

3. The preconstruction baseline noise survey is conducted by a qualified DESIGN CONSULTANT member or a City Project Manager-approved acoustical consultant.

6. CONSTRUCTION PHASE

6.1 Inspections

The construction phase include DESIGN CONSULTANT or approved acoustical consultant quality control monitoring and inspections to ensure that design noise control principals and practices are carefully followed and that noise controls are properly implemented by the respective contractors and subcontractors.

6.2 Construction Noise Monitoring

1. The Contractor plans, oversees or undertakes all construction activities so as to comply with the applicable noise regulations. Construction noise is monitored during the construction phase so that construction noise within the community does not exceed the limits of this Guideline. Construction noise monitoring is conducted in accordance with the methods in subsections 7.4 and 7.5 of this noise design Guideline.

2. Construction noise monitoring is conducted by a qualified member of the Contractor's team or an acoustical consultant approved by the City Construction Manager.

3. The Contractor keeps noise monitoring logs, along with notations of construction activities and times during the noise measurements, which are available for periodic inspection by the City Construction Manager.

7. POST-CONSTRUCTION OPERATIONAL COMPLIANCE CONFIRMATION

7.1 Compliance Confirmation

1. An operating facility noise survey, consisting of in-facility noise measurements, facility boundary line noise measurements and, where appropriate, community location noise measurements, is conducted following facility startup.

2. A written report detailing the results of the noise surveys and any needed corrective measures is submitted to City Construction Manager.

3. Corrective actions are provided by the DESIGN CONSULTANT or an approved acoustical consultant to bring project site into compliance with this noise Guideline.

7.2 Noise Survey After Facility Startup – General

1. During the operating facility noise survey conducted after startup, the facility equipment is in normal operation mode with the highest practical load condition up to a full rated load.

2. The survey is conducted by a qualified, approved acoustical consultant, preferably the same person(s) who conducted the preconstruction noise survey.

3. The survey is performed to demonstrate that the completed facility's equipment, operating individually, in groups, or collectively, conform to the in-facility, facility boundary line and community location requirements of this noise Guideline.

4. If a particular piece of equipment does not meet its guaranteed noise specification limit, as submitted on its noise data sheet, a noise test is required of the equipment supplier and appropriate corrective actions or noise mitigation measures taken at the supplier's expense.

5. To the extent possible, ANSI S1.13 standards of noise measurement apply.

7.3 In-Facility Noise Surveys

A facility nonindustrial area noise survey, a facility equipment noise survey and an employee noise exposure survey are conducted by the DESIGN CONSULTANT or approved acoustical consultant after facility startup.

7.3.1 Facility NonIndustrial Area Noise Survey

The facility nonindustrial area noise survey measures sound pressure levels for at least 15 minutes at several locations in each of the room or location not classified as industrial, such as those typified in Table 1. The noise measurements are taken during a period when the area is not occupied or visited by facility personnel. The results of the area noise survey are compared with the area noise limits on Table 1 and included in the operational facility noise report.

7.3.2 Equipment Noise Survey

The in-facility equipment noise survey measures sound pressure levels as follows:

1. Sound readings are to be taken 1 meter (3 feet) horizontally in all four directions from major equipment surfaces and at a distance of 1.5 meters (5 feet) above the ground, platform, or floor level.

2. If the equipment has a highly directional sound field (i.e., a stronger sound radiation in one or more directions), readings are taken at several locations (all 1 meter [3 feet] from the piece of equipment) to establish the directivity pattern of the noise source.

3. Working areas above, below, or adjacent to equipment normally occupied or frequented by personnel, such as platforms, are measured.

4. Sound readings are taken in control rooms and offices at normal work stations.

5. All sound pressure level readings include the overall sound level in dBA and the octave band sound pressure levels at the nine preferred octave band frequencies of 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. All instrumentation is calibrated just before each series of measurements in accordance with ANSI S1.40 and has valid annual calibration certification. Sound measurement instrumentation must conform to the ANSI S1.4, S1.11 and S1.13 standards.

7.3.3 Employee Noise Exposure Survey

1. On two consecutive workdays during the operating facility noise survey conducted after startup, the DESIGN CONSULTANT or approved acoustical consultant equips each facility employee exposed directly to facility industrial equipment noise with an audiometric dosimeter that complies with the most recent ANSI S1.25 requirements for monitoring occupational noise exposure.

2. Before receiving an installed dosimeter, employees are instructed in the purpose of the survey and the proper wearing of a dosimeter, and are asked to cooperate in the compliance survey by avoiding unnecessary noise producing activities, including shouting, whistling, hitting or bumping the microphone.

3. The employee noise exposure survey is conducted by an acoustical consultant or a certified industrial hygienist, each of which must have prior experience in performing this type of survey.

7.4 Facility Boundary Line Survey

1. The facility boundary line survey measures the overall sound level (dBA) and the nine preferred octave band sound pressure levels at the same boundary line locations approved and modeled in the design phase, including the locations used in the preconstruction noise survey. Include any additional locations which may have become important since the design phase noise modeling and preconstruction noise survey. All instrumentation is calibrated just before each series of measurements in accordance with ANSI S1.40 and has valid annual calibration certification. Sound measurement instrumentation conforms to the ANSI S1.4, S1.11 and S1.13 standards.

2. Hourly average, maximum, L_{10}, L_{50} and L_{90} noise readings are taken for at least a 24-hour period and at least one full day removed from any holiday or weekend day.

3. If highly directional noise sources are present, additional boundary line readings are taken to establish the directional noise pattern.

7.5 Community Noise Survey

If residences are within 150 meters (500 feet) of any facility boundary line, readings similar to those required under section 7.4 of this appendix are taken at nearby representative residential locations.

7.6 Reporting Noise Survey Results

The DESIGN CONSULTANT or approved acoustical consultant prepares and submits an operational facility noise report summarizing the following:

1. In-facility results including the nonindustrial area and industrial equipment noise survey results and the employee noise exposure results.
2. Facility boundary line noise survey results.
3. Community locations noise survey results.

Any noncompliance with the requirements of this Guideline is highlighted along with recommended measures to achieve full compliance.

8. MAINTENANCE CONSIDERATIONS

Care is given to the design, specification and implementation of noise control measures and devices so that maintenance and safety issues are adequately considered.

8.1 Maintenance Issues

Ease of maintenance and housekeeping is considered by the DESIGN CONSULTANT in locating noise control systems and acoustically treated equipment within the facilities.

Ease of removal and reinstallation of noise control systems is given a high priority by the DESIGN CONSULTANT in the design and selection process so that equipment maintenance can be performed with minimal difficulty and the noise control systems remain effective over time.

Thermal issues are duly considered by the DESIGN CONSULTANT to avoid operational difficulties and equipment temperature problems where noise control systems are used.
Robust noise control systems, with long life expectancies, are investigated to reduce untimely replacement costs.

Table 1
Noise Level Limits for Nonindustrial Facility Work Areas

NonIndustrial Facility Work Area[1]	Leq(15 min) Sound Level, dBA
Warehouses	65
Control Open	60
Offices Rooms	55
Laboratories	50
Administrative Areas:	
Receptionist, General Secretarial	50
Conference Rooms, Private Offices	45

1. **Noise limits apply to work space while unoccupied but with normal ventilation and exterior noises.**

Table 2
City of San Diego
Sound Level Limits at or Beyond Facility Boundary Lines

Receptor Land Use Zone[1]	Leq(1h) Sound Level[2], dBA 7am-7pm	7pm-10pm	10pm-7am
1. Residential:			
- All R-1	50	45	40
2. Residential			
- All R-2	55	50	45
3. Residential			
- R-3, R-4 and all other Residential	60	55	50
4. All Commercial:	65	60	60
5. Manufacturing, Industrial, Agricultural, Extractive Industry	75	75	75
6. All Residential Zones due to Facility Construction (Note 1 does not apply)	75	no const. allowed	no const. allowed

1. The sound level limits at a location on a boundary between two zoning districts is the arithmetic mean of the respective limits for the two districts.
2. The requirements of more restrictive City codes apply.

Table 3
County of San Diego
Sound Level Limits at or Beyond Facility Boundary Lines

Receptor Land Use Zone[1]	L_{eq}(1h) Sound Level[2], dBA 7am-10pm	10pm-7am
1. Residential density less than 11 dwellings: R-S, R-D, R-R, R-MH, A-70, A-72, S-80, S-81, S-87, S-88, S-90, S-92, R-V, and R-U	50	45
2. Residential density equal to or greater than 11 dwellings: R-RO, R-C, R-M, C-30, S-86	55	50
3. S-94 and all other Commercial:	60	55
4. M-50, M-52, M-54	70	70
5. S-82, M-58, and all other Industrial	75	75
6. All Residential Zones due to Facility Construction. (Note 1 does not apply)	75	no const. allowed

1. The sound level limits at a location on a boundary between two zoning districts is the arithmetic mean of the respective limits for the two districts.
2. The requirements of more restrictive County codes apply.

REVISIONS	NO	DATE	BY	CK	APP	DESCRIPTION	REVISIONS	NO	DATE	BY	CK	APP	DESCRIPTION

1. Client: ______ Site: ______
Equip. Type: ______ Service: ______
Equip. Item No. ______ No. Required: ______

2. Manufacturer: ______ Model: ______ Style: ______
Size: ______ RPM: ______ HP: ______ Driver: ______

3. NOISE DATA SOURCE:

☐ Noise Measurement Tests (check all that apply):
- ☐ Loaded ☐ Identical Equipment
- ☐ Unloaded ☐ Similar Equipment

☐ Noise Calculation (Attach) ☐ Catalog Data

NOISE MEASUREMENT CONDITIONS:

☐ Free Field Describe: ______
☐ Reverberant
☐ Semi-reverberant
☐ Other Describe: ______

4. NOISE LEVELS

OCTAVE BAND CENTER FREQ [Hz]	A: Equipment Noise Level Allotment – Maximum RMS Lp at __1_ meter(s)	B-1: Maximum RMS Sound Pressure Level (Lp) in dB re: 20 μPa at __1__ meter(s) – Standard Equipment	B-2: With Special Design	B-3: Added Acoustic Treatment	C-1: Maximum Sound Power Level (Lw) in dB re: 1 picowatt (10^{-12} watt) – Standard Equipment	C-2: With Special Design	C-3: Added Acoustic Treatment	OBCF [Hz]
31.5								31.5
63								63
125								125
250								250
500								500
1000								1000
2000								2000
4000								4000
8000								8000
Overall dB(Lin)								dB(Lin)
Overall dB(A)								dB(A)

5. Brief description of Special "Noise Control" Design and/or Added Acoustical Treatment : ______
Special Design: ______
Added Acoustical Treatment: ______
Any Other Means: ______

6. Additional cost(s) for Special Design and/or Added Acoustical Treatment(s), respectively, as bid.
Special Design: ______
Added Acoustical Treatment: ______
Any Other Costs: ______

7. Special equipment noise characteristics (tonal pitch, directional, impulsive, etc.) : ______

8. Sound Pressure Levels (Lp) are to be measured per ANSI-S1.13 - "Measurement of Sound Pressure Levels in Air" and recorded on Sheet 2, along with equipment sketch and test locations. If a different method and/or if catalog data are used, describe and fully reference:

9. Notes, Comments and/or Exceptions: ______

10. Noise Emission Guarantee:

We guarantee that the noise emission from an operating unit of the above equipment, as bid, will not exceed the overall A-weighted sound level or the linear octave band levels stated under Column 4-A, at the specified distance.

Signature: ______ Date: ______

INSTRUCTIONS:
1. Buyer fills in Sections 1 and 4-A.
2. Bidder fills in Secs. 2, 3, 4-B, 4-C, and Sections 5-10, plus Sheet 2 if tested.

EQUIPMENT NOISE DATA SHEET

SHEET	OF	JOB NUMBER
1	2	

DOCUMENT NUMBER	REV

SKETCH OF TEST EQUIPMENT LAYOUT AND NOISE MEASUREMENT LOCATIONS:

NOTE: Noise measurement distances are from the nearest major equipment surface.

OCTAVE BAND CENTER FREQUENCY [Hz]	RMS SOUND PRESSURE LEVEL (Lp) AT NOTED MEASUREMENT LOCATIONS, dB re: 20 μPa								Maximum RMS Lp* per Octave Band (Transfer to Sheet 1-Col. B)
	Location 1 at____meters	Location 2 at____meters	Location 3 at____meters	Location 4 at____meters	Location 5 at____meters	Location 6 at____meters	Location 7 at____meters	Location 8 at____meters	
31.5									
63									
125									
250									
500									
1000									
2000									
4000									
8000									
OVERALL dB (LIN)									
OVERALL dBA									

* Maximum octave band sound pressure level (Lp) for all locations.

REFERENCES AND COMMENTS:____________________________

INSTRUCTIONS: Bidder sketches equipment and noise measurement locations, then fills in noise data under location columns and Sheet 1-Col. B.	EQUIPMENT NOISE TEST DATA SHEET	SHEET 2	OF 2	JOB NUMBER
		DOCUMENT NUMBER		REV

PES-N&V-02-MH(7/98)

REVISIONS	NO	DATE	BY	CK	APP	DESCRIPTION	REVISIONS	NO	DATE	BY	CK	APP	DESCRIPTION

1. Client: CITY OF SAN DIEGO WATER DEPARTMENT — Site: North Side Pump Station
Equip. Type: Centrifugal pump — Service: Potable water distribution
Equip. Item No. SD-CP-07A/B/C/D — No. Required: 4

2. Manufacturer: XYZ Pump Company — Model: KX-500-1800 — Style: Centrifugal
Size: 3500 gpm — RPM: 1800 — HP: 500 — Driver: TEFC Motor

3. NOISE DATA SOURCE:

- [ ] Noise Measurement Tests (check all that apply):
  - [ ] Loaded
  - [ ] Unloaded
  - [ ] Identical Equipment
  - [ ] Similar Equipment
- [ ] Noise Calculation (Attach)
- [x] Catalog Data

NOISE MEASUREMENT CONDITIONS:

- [ ] Free Field — Describe:
- [ ] Reverberant
- [x] Semi-reverberant
- [ ] Other — Describe:

4. NOISE LEVELS

OCTAVE BAND CENTER FREQ [Hz]	A: Equipment Noise Level Allotment — Maximum RMS Lp at 1 meter(s)	B-1: Maximum RMS Sound Pressure Level (Lp) in dB re: 20 μPa at 1 meter(s) — Standard Equipment	B-2: With Special Design	B-3: Added Acoustic Treatment	C-1: Maximum Sound Power Level (Lw) in dB re: 1 picowatt (10^{-12} watt) — Standard Equipment	C-2: With Special Design	C-3: Added Acoustic Treatment	OBCF [Hz]
31.5	93	84	81	88				31.5
63	91	86	84	87				63
125	89	88	85	86				125
250	85	90	86	85				250
500	79	87	84	80				500
1000	74	88	81	74				1000
2000	70	86	79	71				2000
4000	67	82	76	67				4000
8000	67	80	70	65				8000
Overall dB(Lin)	97	96	92	93				dB(Lin)
Overall dB(A)	82	93	87	82				dB(A)

5. Brief description of Special "Noise Control" Design and/or Added Acoustical Treatment :
Special Design: Quiet casing and coupling design
Added Acoustical Treatment: Inlet and discharge pipe lagging to headers
Any Other Means:

6. Additional cost(s) for Special Design and/or Added Acoustical Treatment(s), respectively, as bid.
Special Design: $650 per unit
Added Acoustical Treatment: $225 per unit
Any Other Costs:

7. Special equipment noise characteristics (tonal pitch, directional, impulsive, etc.) :

8. Sound Pressure Levels (Lp) are to be measured per ANSI-S1.13 - "Measurement of Sound Pressure Levels in Air" and recorded on Sheet 2, along with equipment sketch and test locations. If a different method and/or if catalog data are used, describe and fully reference:
Pump Catalog with documented noise data - Catalog No. P9602

9. Notes, Comments and/or Exceptions:

10. Noise Emission Guarantee:
We guarantee that the noise emission from an operating unit of the above equipment, as bid, will not exceed the overall A-weighted sound level or the linear octave band levels stated under Column 4-A, at the specified distance.

Signature: W. E. Agree — Date: 7/15/98

INSTRUCTIONS:	EXAMPLE NOISE DATA SHEET	SHEET	OF	JOB NUMBER
1. Buyer fills in Sections 1 and 4-A.		1	2	112233-90000
2. Bidder fills in Secs. 2, 3, 4-B, 4-C, and Sections 5-10, plus Sheet 2 if tested.		DOCUMENT NUMBER: SD-NSPS-00-ME-10		REV: 0

PES-N&V-01-MH(7/98)

REVISIONS	NO	DATE	BY	CK	APP	DESCRIPTION	REVISIONS	NO	DATE	BY	CK	APP	DESCRIPTION

1. Client: **CITY OF SAN DIEGO WATER DEPARTMENT** Site: **North Side Pump Station**
Equip. Type: **Centrifugal pump** Service: **Potable water distribution**
Equip. Item No. **SD-CP-07A/B/C/D** No. Required: **4**

2. Manufacturer: **XYZ Pump Company** Model: **KX-500-1800** Style: **Centrifugal**
Size: **3500 gpm** RPM: **1800** HP: **500** Driver: **TEFC Motor**

3. NOISE DATA SOURCE:
- [ ] Noise Measurement Tests (check all that apply):
  - [ ] Loaded
  - [ ] Unloaded
  - [ ] Identical Equipment
  - [ ] Similar Equipment
- [ ] Noise Calculation (Attach)
- [x] Catalog Data

NOISE MEASUREMENT CONDITIONS:
- [ ] Free Field Describe: ______
- [ ] Reverberant
- [x] Semi-reverberant
- [ ] Other Describe: ______

4. NOISE LEVELS

OCTAVE BAND CENTER FREQ [Hz]	A: Equipment Noise Level Allotment — Maximum RMS Lp at __1__ meter(s)	B-1: Maximum RMS Sound Pressure Level (Lp) in dB re: 20 µPa at __1__ meter(s) — Standard Equipment	B-2: With Special Design	B-3: Added Acoustic Treatment	C-1: Maximum Sound Power Level (Lw) in dB re: 1 picowatt (10^{-12} watt) — Standard Equipment	C-2: With Special Design	C-3: Added Acoustic Treatment	OBCF [Hz]
31.5	93	84	81	88				31.5
63	91	86	84	87				63
125	89	88	85	86				125
250	85	90	86	85				250
500	79	87	84	80				500
1000	74	88	81	74				1000
2000	70	86	79	71				2000
4000	67	82	76	67				4000
8000	67	80	70	65				8000
Overall dB(Lin)	97	96	92	93				dB(Lin)
Overall dB(A)	82	93	87	82				dB(A)

5. Brief description of Special "Noise Control" Design and/or Added Acoustical Treatment :
Special Design: **Quiet casing and coupling design**
Added Acoustical Treatment: **Inlet and discharge pipe lagging to headers**
Any Other Means:

6. Additional cost(s) for Special Design and/or Added Acoustical Treatment(s), respectively, as bid.
Special Design: **$650 per unit**
Added Acoustical Treatment: **$225 per unit**
Any Other Costs:

7. Special equipment noise characteristics (tonal pitch, directional, impulsive, etc.) :

8. Sound Pressure Levels (Lp) are to be measured per ANSI-S1.13 - "Measurement of Sound Pressure Levels in Air" and recorded on Sheet 2, along with equipment sketch and test locations. If a different method and/or if catalog data are used, describe and fully reference:
Pump Catalog with documented noise data - Catalog No. P9602

9. Notes, Comments and/or Exceptions:

10. Noise Emission Guarantee:
We guarantee that the noise emission from an operating unit of the above equipment, as bid, will not exceed the overall A-weighted sound level or the linear octave band levels stated under Column 4-A, at the specified distance.

Signature: *W. E. Agree* Date: **7/15/98**

INSTRUCTIONS:	EXAMPLE NOISE DATA SHEET	SHEET 1 OF 2	JOB NUMBER 112233-90000
1. Buyer fills in Sections 1 and 4-A. 2. Bidder fills in Secs. 2, 3, 4-B, 4-C, and Sections 5-10, plus Sheet 2 if tested.		DOCUMENT NUMBER SD-NSPS-00-ME-10	REV 0

PES-N&V-01-MH(7/98)

Chapter 7

CORROSION CONTROL DESIGN CRITERIA

7.1 Introduction

Many facilities, both underground and submerged, contain metallic structures and components which, when placed in contact with soil and/or water without protection against corrosion, tend to deteriorate and fail prematurely. This chapter addresses the application of corrosion control methods, such as coatings and linings, the selection of materials, and cathodic protection needed to afford protection from corrosion to such facilities.

7.2 Protective Coatings and Linings

The term "coatings" refers to materials applied to pipe or tank exteriors for corrosion protection. "Linings" describes materials applied to pipe or tank interiors for corrosion protection.

Pipeline and tank coatings and linings must have certain common characteristics to ensure long-term corrosion protection. Characteristics considered during the selection of protective coating and lining systems include the ability to apply with minimal defects, adhesion to the substrate, ability to resist development of holidays as the coating or lining ages, ability to resist cathodic disbondment, ability to withstand normal handling and storage, repairability, cost, availability, and regulatory compliance.

Dielectric (electrically insulating) coatings must provide and maintain effective electrical insulation and resist cathodic disbondment. Dielectric coatings are typically used in conjunction with cathodic protection when soil and water resistivity values are below 5,000 ohm-cm. Conductive coatings and linings, such as cement mortar, must be capable of resisting significant cracking and maintaining an alkaline environment to passivate underlying metal surfaces for a suitably long period of time.

7.2.1 Linings

Linings refer to coating materials used on the interior surface of carbon steel, ductile iron, and concrete structures. Linings are used to prevent internal corrosion and maintain a smooth surface to maximize flow capacity. The linings must not impart any taste or odor to the water and should be approved by the National Sanitation Foundation (NSF) for potable water contact.

The DESIGN CONSULTANT should consider reference materials from NACE, AWWA and manufacturers' trade associations for pipe lining and other methods of corrosion prevention for pipeline interiors.

7.2.1.1 Cement Mortar

Cement mortar is the most commonly used lining for water mains made of ductile iron and steel larger than 3 inches in diameter. Experience has shown that cement mortar is a durable lining capable of providing many years of service with minimal maintenance under most conditions. With a few precautions, cement mortar linings can be expected to be very reliable. Cement mortar protects the underlying metal surface by passivating it through contact with the alkaline cement paste. Under most conditions, the protection lasts as long as the lining is intact.

A. General Considerations

Corrosion protection is provided to metal pipe surfaces by cement mortar for as long as the cement paste is intact. Cement paste can be leached out of the lining by prolonged contact with soft water. The leaching characteristics of water can be predicted by reviewing an accurate analysis of the water to be conveyed. Waters that promote leaching of cement paste are very pure waters low in calcium and alkalinity, and may be low in pH. Waters of this type are generally found in coastal areas with surface water supplies, but rarely in inland areas. High purity water can also be the product of advanced water treatment processes and the use of cement mortar linings must be carefully considered for these applications.

Cement mortar linings are rigid and crack if the pipe has excessive deflection (out-of-roundness). Although small cracks are self-healing, large cracks may expose the metal surface to the water, with resulting corrosion. Therefore, sturdy bracing or stulling is required to maintain the round shape of pipes lined with cement mortar before shipping and installation. The stulling is removed before the pipe is placed in service.

Cement mortar linings may incur cracking under alternating wet and dry conditions. This is due to shrinkage of the lining as it dries. The best service life of cement mortar linings is obtained if the lining is kept in contact with water so that it remains fully hydrated.

Sulfate-resistant cements are generally used where sulfates exceed approximately 300 mg/L. ASTM C150 Type II or Type V are sulfate-resistant Portland cements are typically used.. When sulfate concentration exceeds 1,000 ppm, Type V cement is required.

Cement mortar linings are also susceptible to damage if the pipe is subjected to negative pressure or vacuum, even for brief periods. Therefore, surge protection is important and adequate vacuum relief valves must be provided for cement mortar lined pipelines.

A final important consideration for cement mortar lined pipes is that all joints should be field lined with cement mortar to match the body of the pipe. This is important to provide corrosion protection at the joints. Joint lining is normally done for all steel pipe types.

B. AWWA Specifications

Cement mortar linings are covered by AWWA standards for various types of pipe commonly used to convey water. The AWWA standards govern the thickness, mix design, and installation of the lining. In some cases, joint lining requirements are not included in the standard but are appended or may be obtained from pipe manufacturers.

C. Thickness for Alternative Pipe Materials

The thickness of cement mortar linings varies according to the type of pipe in which the lining is placed. All linings have manufacturing tolerances that allow slightly thinner linings. In concrete pressure pipe types, the cement mortar lining is considered part of the structural wall of the pipe and is included in calculations of pipe strength.

D. Welded Steel Pipe

Cement mortar linings for welded steel pipe are specified in AWWA C205. The minimum acceptable lining thicknesses shall be as defined in this standard. Additional lining thicknesses above the minimum may be considered on a case by case basis as required for special conditions.

Joint lining requirements shall be as specified in AWWA C205.

Cement mortar linings are NSF-approved for potable water contact. However, some fast-setting grout materials used for patching joints and other defects are not NSF-approved and contain compounds that may impart taste and odor in transmission lines with low flowrates. Non-NSF approved compounds shall not be allowed.

Cement mortar linings can be applied to the pipe interior during pipe manufacture or during construction of the pipeline in the field. Plant-applied linings are applied by a centrifugal process. These linings are typically “held back” several inches on the interior of the bell to facilitate pipeline installation. These hold backs at field joints shall be lined with cement mortar grout and troweled smooth with the plant-applied lining.

Cement mortar can also applied in the field after the pipeline is installed. This process provides a continuous lining, and patching of field joints is not required. Steel pipe interiors are not to be painted prior to cement mortar field lining. Steel is left bare. This practice is not preferred over factory applied cement mortar linings.

E. Ductile Iron Pipe

Cement mortar linings for ductile iron pipe are specified in AWWA C104. Minimum lining thickness for pipe and fittings must be double the AWWA requirements.

A seal coat of asphaltic material, which is commonly applied to cement mortar linings in ductile iron pipe is not required for normal potable water service. Special conditions may exist where a seal coat may be desirable All seal coats used in contact with potable water must be NSF approved..

7.2.1.2 Epoxy Linings

Epoxy linings are used less commonly than cement mortar linings for water pipe. Epoxy linings are thin films compared to cement mortar. A typical epoxy lining is approximately 16 mils thick (1 mil equals 0.001 inch). Dry film thicknesses of 10 to 12 mils are sometimes specified for valves to minimize the interference between moving parts within certain types of valves.

Many paint manufacturers produce conventional epoxy coatings that are NSF-approved for potable water contact. Epoxy linings may be used in the following special situations:

- For pipes located in buildings or structures in instances where the pipe is disassembled periodically.
- For pipes with complicated shapes, such as discharge headers for pumps that cannot be cement mortar lined.
- For pipes where velocities are too high for cement mortar linings.
- For fabricated steel fittings, such as flexible couplings and valves.

7.2.2 Coatings

Coatings refer to materials applied to the exterior of pipes tanks, and components. The term "paint" is frequently used as a synonym, but it is less accurate because it sometime refers to materials applied for appearance, whereas coatings are applied primarily for surface corrosion protection.

7.2.2.1 Welded Steel Pipe Coatings

All modern applications of steel water pipelines use protective coatings for buried service. Several types of coatings are commonly used.

A. Cement Mortar

Cement mortar coatings have a long service history for corrosion protection of steel and iron water pipelines. Cement mortar coatings are covered by AWWA C205. As with linings, special field joint coatings procedures are required as specified in AWWA C205

Cement mortar coatings are applied to steel pipe by a pneumatic process during manufacture.

Exterior coatings can be applied up to 1-1/4-inch thick or more and are reinforced with spiral wire, wire mesh, or wire fabric. Field joints are coated with cement mortar grout. A circumferential band or "diaper" is normally placed around the joint to retain the grout. Proper mortar coating of field joints is critical to long-term durability of this coating. Experience has shown that field joints tend to be the weakest points in cement mortar-coated pipelines and are typically the first areas to corrode.

The corrosion protection qualities of cement mortar coatings can be adversely affected by alternating wet and dry conditions. Salts from soil and groundwater can be wicked into the mortar coating and can concentrate under repeated drying cycles. Cement mortar coatings alone are not recommended when soil or ground water resistivity values are below 5,000 ohm-cm and/or chloride ion concentrations exceed 300 ppm. Select, clean, sand backfill of high resistivity (>25,000 ohm-cm) may be used to improve the corrosion resistance of cement mortar coated pipe when these conditions are encountered. In the absence of the use of select sand backfill, the addition of cathothdic protection is required.

The protective qualities of cement mortar can also be compromised if the pipe is struck by hard blows that cause cracking or disbondment between the mortar and the metal of the pipe.

Unlike the other exterior coatings discussed in this section, cement mortar is not a dielectric coating. Pipelines installed with cement mortar coatings require higher current densities for cathodic protection than pipelines with dielectric coatings in good condition. It is often preferred to use cathodic protection in conjunction with dielectric coatings in order to reduce the size and outputs of cathodic protection systems. Also, since the coating is conductive, the effect of electromagnetic coupling (induced voltages) is less on cement mortar-coated pipelines. However, cement mortar-coated pipelines are still susceptible to elevated potentials under powerline fault conditions.

B. Tape and Cement Coatings

Prefabricated, factory applied, three layer, cold-applied polyolefin tape with a cement mortar overcoat (rock shield) should be used when corrosive soils are encountered (<5,000 ohm-cm). The installation of cathodic protection is always required when dielectric coatings are used.

Tape coating for pipelines and fittings should be in accordance with AWWA C214 for pipelines, and AWWA C209 for fittings. Coating thickness shall be as specified by the applicable AWWA standard as determined by the piping diameter. The addition of cement mortar (rock shield) over the dielectric tape shall be as specified in AWWA C205 for cement mortar overcoats..

C. Epoxy Coatings

Epoxy coatings include polyamide or polyamine-cured liquid epoxy coating systems and fusion bonded epoxy coating systems. These coating systems are commonly used to protect exterior surfaces of appurtenances such as valves, couplings, and blind flanges. Epoxy coatings should be in accordance with AWWA C210 for liquid epoxy and AWWA C213 for fusion bonded epoxy systems applied to steel pipe and fittings.

Liquid epoxy and fusion bonded epoxy coatings are typically applied at a minimum dry film thickness of 16 mils for over steel surfaces intended for buried or submerged service. Epoxy coatings are dielectric coatings. The installation of cathodic protection is always required when dielectric coatings are used. To provide a suitable service life, epoxy coatings must be applied to steel with a minimum near-white metal sandblast (SSPC SP-10) surface preparation for immersion or buried service. White metal sandblasting (SSPC SP-5) may be required for specific coating systems and severely corrosive conditions.

D. Wax Tape Coatings

Wax tape coating systems are field applied systems and are used to provide external corrosion protection to buried or submerged bolted flange connections, bolted mechanical couplings, and other bolted connections where polyethylene tape and epoxy coatings cannot be readily applied. The application of wax tape coating systems should be in accordance with AWWA C217

7.2.2.2 Ductile Iron Pipe

A. Epoxy Coatings

Liquid epoxy and fusion bonded epoxy coatings, the same as used for welded steel pipe, can be used for ductile iron pipe and fittings. However, special attention should be used during application because of the surface roughness and the annealing layer of ductile iron pipe and fittings. Ductile iron pipe surface preparation should be in accordance with NAPF 500-3. Epoxy coating are typically applied at a minimum dry film thickness of 24 mils over the external surfaces of ductile iron pipe. The application of fusion bonded epoxy coatings on ductile iron fittings should be in accordance with AWWA C116.

B. Polyurethane Coatings

Ductile iron pipe and fittings may also be coated with a high solids polyurethane coating using a two component, 1:1 mix ratio, heated airless spray unit. These coatings are generally applied in a shop, but they can be applied in the field using special equipment. Shop-applied coatings require 100% holiday inspection with normal field inspection before and after installation. Polyurethane coatings are dielectric coatings. The installation of cathodic protection is always required when dielectric coatings are used.

C. Polyethylene Encasement

External corrosion protection for ductile iron pipe and fittings may also be provided by the use of polyethylene encasement. Polyethylene encasement is applied in accordance with AWWA C105. The use of polyethylene encasement on ductile iron piping is limited to soils with resistivity in excess of 10,000 ohm-cm.

D. Wax Tape Coatings

Wax Tape coating systems are applied to ductile iron piping systems and fittings similar fashion as steel pipe and fittings, It is used primarily as a field applied system for bolted flange connections, mechanical couplings, tapping sleeves, and other fittings.

7.2.3 Welded Steel Tanks and Reservoirs

Exterior coating, interior lining, and where necessary, complete removal and recoating surfaces of steel water tanks, surge tanks and reservoirs must be done in accordance with AWWA D102.

In general, for new steel tanks, AWWA D102, outside coating System No. 5, and inside coating System No. 2 should be used. For conditions requiring additional corrosion protection, outside coating System No. 6 and inside coating System No. 3. Lining material should be approved by the National Sanitation Foundation (NSF) for potable water contact.

Cathodic protection is required for all internal, submerged, carbon steel surfaces of steel tanks and reservoirs.

7.3 Materials Selection

7.3.1 General Exposures

This section outlines the main exposures to materials anticipated at water facilities.

7.3.1.1 Soil Exposures

Some soil environments and groundwaters can be corrosive to buried metal structures. Resistivity measurements, which can be made in the field or the laboratory, indicate how corrosion currents flow through soils or groundwaters. High concentrations of chlorides and sulfates contribute to a reduction in resistivity and an increase in the corrosion activity of a material. In the presence of oxygen, chloride ions can be extremely corrosive to steel. Similarly, high levels of sulfates can reduce soil or groundwater resistivity and corrode steel and concrete.

7.3.1.2 Surfaces Exposed to Fluids

Surfaces exposed to fluids include the interiors of pipelines and equipment such as pumps. Metals in contact with water streams are subject to corrosion, particularly when exposed in splash zones.

7.3.1.3 Atmospheric Exposures

Much of San Diego is exposed to a marine environment. This environment includes airborne salts and locations in which structures may be exposed to direct salt spray. Atmospheric exposure may, therefore, be severe in projects in the San Diego area. The combination of wet/dry cycling in the presence of chlorides found in salt spray can create the potential for significant corrosion activity on all exposed metal surfaces.

7.3.2 Material Considerations

The following paragraphs describe the performance to be expected from various materials used for water facilities in the Greater San Diego area. **Table 7-1** gives supplemental information on acceptable materials.

7.3.2.1 Concrete

Soil Exposure: Concrete is typically a durable material in underground service. It is rarely affected by electrolytic corrosion like metals, and unless the pH of the soil, groundwater or process stream is less than 5.5, the chloride concentration is 300 ppm or more, or the sulfate concentration is greater than 1,000 ppm, concrete is suitable for use in soil exposures. Soils and groundwater found in the San Diego area may contain significant concentrations of chlorides and sulfates which are detrimental to concrete and reinforcing steel. Attack on concrete and steel is likely when soils are acidic. When the pH of the soil is at or below 5.5, barrier coatings may be required to protect the concrete surface. In areas of high sulfate concentrations (greater than 1,000 ppm) modification of water-cement ratio, use of Type V cements (sulfate resistant) and barrier coatings must be considered for all buried concrete.

Reinforced concrete structures are also subject to cracking and spalling due to corrosion of reinforcing steel. Because the volume of corrosion products is much greater than that of the reinforcing steel itself, great pressure is exerted on the concrete, causing it to crack and eventually spall. It is therefore recommended that exposure of concrete surfaces to chlorides be minimized through the use of coatings.

7.3.2.2 Steel

For all exposures, steel should be electrically isolated from dissimilar metals to prevent the formation of unfavorable galvanic corrosion cells. In areas where abrasive materials are likely to damage coatings, cathodic protection by impressed current or galvanic anodes may be desirable.

Soil Exposure: Low resistivities and high chloride concentrations in the soil may lead to corrosion of buried steel pipelines or structures. Cathodic protection shall be installed on all dielectrically coated buried steel pipelines or structures. Cement mortar coated steel pipelines and structures should be installed with cathodic protection when soil resistivity below 5,000 ohm-cm. Where cathodic protection is not provided, corrosion monitoring equipment should be incorporated into the design to allow the operating staff to monitor the condition of the pipelines or structures. Non-welded joints are bonded for electrical continuity.. Coatings may be used alone or in conjunction with cathodic protection depending on the structure type, coating system type, and specific soil corrosivity. Recommendations for coating systems are discussed later in these Guidelines. Most soil environments in the San Diego area contain soil with resistivity values below 5,000 ohm-cm and the use of cathodic protection and protective coatings should be expected.

Fluid Exposure: Bare or galvanized steel is subject to corrosion when exposed to fluids at a water facility. Corrosion is most severe in the splash zone environment where atmospheric oxygen hastens the corrosion process. Steel, if submerged, should be coated or lined with a material suitable for use in the anticipated exposure. Because of concerns regarding the corrosion of steel in contact with the process streams, cathodic protection must be considered for these steel structures considered to be in a corrosive exposure. This type of corrosion control should be incorporated along with suitable coatings or linings.

Atmospheric Exposure: Corrosion of steel structures at water facilities is likely due to exposure to atmospheric chlorides near marine environments or chlorine process streams and protective coatings must be considered.

7.3.2.3 Ductile Iron

Soil Exposure: Ductile iron pipe can be expected to provide performance similar to steel in most exposures. However, because ductile iron generally has a greater wall thickness for a given diameter pipe than steel, the time to reach failure may be increased. Ductile iron pipe is treated in a manner similar to steel with regards to the application of protective coatings and cathodic protection. Polyethylene encasement may be considered for ductile iron pipe when soil resistivity values exceed 10,000 ohm-cm.

Fluid and Atmospheric Exposure: When exposed to fluids or under atmospheric conditions, ductile iron can be expected to corrode at a rate similar to that for bare or galvanized steel. Ductile iron is treated in a manner similar to steel with regards to the application of coatings and cathodic protection.

7.3.2.4 Aluminum

Soil Exposure: In very broad terms, dry, sandy and well-aerated soils are not corrosive to aluminum. However, as moisture and dissolved salts increase, the soil becomes more aggressive to aluminum. Where levels of chlorides, sulfates or pH are high, contact with the soil may be detrimental to buried aluminum. Its use, therefore, is not recommended for underground applications.

Fluid Exposure: When exposed to fluids, aluminum is most stable in the pH range between 4 and 8.5. Because it is an amphoteric material, it is attacked by both acids and bases. Therefore, contact with solutions with pH greater than 8.5 or less than 4 causes corrosion of the aluminum.

Severe pitting of aluminum can occur where iron or copper ions are in a solution in contact with aluminum. A galvanic couple is established in which aluminum is attacked at localized areas. Chloride ions can also lead to pitting in aluminum. This is most likely to occur in crevices and other stagnant areas. The introduction of chemicals like ferric chloride into the process stream causes severe degradation to aluminum and failure can occur rapidly. Due to the wide range of pH values found in wastewater facilities, aluminum is not recommended for use in fluid exposures.

Atmospheric Exposure: Aluminum has excellent resistance to atmospheric pollutants. Its resistance to atmospheric corrosion is due to a tightly adherent oxide film, and destruction of this film by either mechanical or chemical means exposes a very reactive surface. If the protective oxide film is disturbed, the presence of salts, including chlorides, can cause rapid pitting of aluminum. Further, electrical coupling to iron, stainless steel, or copper accelerates this deterioration.

Aluminum is stable only in a small range of pH values. For example, aluminum handrails to be installed in concrete (pH 12 to 13) should be placed in plastic shields, cast into the concrete. In addition, a sealant should be placed between the plastic shield and the aluminum. Under these conditions, aluminum performs acceptably. Alloys typically used include 5052 and 6061, but most alloys show similar atmospheric corrosion characteristics. The aluminum-copper precipitation hardening grades (2000 series) generally show somewhat greater corrosion, and the pure aluminum and al-clad varieties (1000 series) exhibit somewhat less corrosion.

Aluminum is not recommended in areas where spillage of chlorine, sodium hydroxide, or other strong acids or bases may occur.

Anodized aluminum has shown excellent performance in limited applications at water facilities. Although it would most likely be dinged and abraded in uses like handrails, anodized aluminum can be used in a number of other areas, such as electrical switchgear enclosures.

Because aluminum is an electrically active metal (standard potential of -1.66 volts versus standard hydrogen electrode), its use in water is limited. When coupled to any of the common engineering alloys (steel, iron, stainless steel, copper and its alloys), aluminum becomes the anode, and galvanically corrodes. For this reason, aluminum must be electrically isolated from dissimilar materials.

7.3.2.5 Copper and Brass

Soil Exposure: Copper and brass typically perform quite well in underground applications where the pH is neutral to alkaline and the concentration of aggressive ions, such as chloride and sulfate, is low. They are often used for potable water lines and fittings. Copper is a corrosion-resistant material which does not depend on the formation of an oxide or other surface film to be protected from corrosion. Because it is cathodic to iron and aluminum, it hastens their corrosion when coupled to them. Isolation of copper from most materials commonly used in wastewater plant construction is therefore required in buried service. Because copper is an excellent electrical conductor and maintains a low resistivity interface with the soil, bare copper cable is often used for grounding systems. Unfortunately, this can lead to galvanic corrosion of steel and iron, and to very high current requirements for cathodic protection systems.

Various solutions have been proposed, such as grounding cells, which are essentially dielectric until large potential differences (ground faults) occur. When ground faults do occur, the cell short circuits and dissipates the charge. Copper is subject to changes in corrosion resistance with changes in temperature, so electrolytic corrosion can occur on hot and cold water lines buried in a common trench. To prevent this, the two lines should be isolated from each other at points of electrical contact. This can be accomplished with the use of insulating couplings. However, where high concentrations of chlorides (300 ppm or more) or high sulfate concentrations (1,000 ppm or more) or low pH values are found (5.5 or less), copper or brass piping should not be used without a tape wrap coating and cathodic protection. Furthermore, when copper or brass is used in an aggressive environment, it should be electrically isolated from other structures. If copper piping is used to connect copper service lines to plastic mains, brass tapping saddles should be used.

Fluid Exposure: Copper and brass typically have good corrosion resistance in aqueous solutions. Further, if copper is coupled to a less noble metal like steel or aluminum, galvanic corrosion of the less noble metal may result. Because copper is a fairly soft material, it is also subject to erosion corrosion. This type of corrosion is accelerated by high fluid velocities, high temperatures and abrasive particulate matter.

Copper and brass should not be used in streams which allow exposure of the metal to solutions carrying residual chlorine (2 ppm or more). This is especially critical in reclaimed water systems, as chlorine can cause severe corrosion of copper and brass.

Brasses containing over 15% zinc may suffer dezincification. This form of corrosion is especially prevalent in stagnant, acidic solutions. Copper and brass are therefore not recommended for fluid exposures.

Atmospheric Exposure: Copper and brass typically have excellent atmospheric corrosion resistance.

7.3.2.6 Stainless Steel

Soil Exposure: In soil, stainless steel is fairly resistant to uniform corrosion, which occurs over the entire surface. However, it may be subject to pitting corrosion. Stainless steel pipe is most often used in situations where contamination of the material carried in the pipe is the prime concern. However, because pitting of the buried structures might occur where soil conditions surrounding the pipe vary, it is prudent to install stainless steel pipe with a uniform, well-installed backfill where differential oxygen corrosion cells will not occur. Coatings and cathodic protection of buried pipelines in corrosive soils should be provided. In noncorrosive soils, coatings for stainless steels should be considered.

Fluid Exposure: Stainless steels are typically resistant to corrosion in flowing waters. Of the various types of stainless steels, the austenitic grades (300 series) show the best performance. In stagnant waters, however, pitting of stainless steel may occur. Oxidizing metal salts such as ferric chloride may also attack stainless steel. Type 304 and 316 alloys are more resistant to chlorine, hypochlorous acid (HOCl) and hypochlorite ions than other alloys that might be used in the process streams.

Cathodic protection of stainless steel is an option for preventing pitting which might otherwise occur. Although stainless steels are essentially immune to uniform corrosion, pitting has been encountered in many aqueous environments and can be prevented by the use of cathodic protection. By electrically coupling stainless steel to a large immersed structure made of steel, zinc, or other metal which is more anodic to stainless steel, pitting is reduced or eliminated. However, where galvanic couples exist, stainless steel increases the magnitude of corrosion deterioration of the structure to which it is bonded. It is therefore recommended that electrical contact be eliminated where the anode/cathode ratio is not favorable, i.e., small anode to large cathode.

Atmospheric Exposure: Stainless steel has been used with much success in both outdoor and indoor applications. Of the various types of stainless steel, the austenitic grades (typically 302, 304, and 316) generally have the best corrosion resistance. Of these three alloys, 316, although more expensive than the others, is the most resistant to pitting.

The austenitic alloys are resistant to chlorides and moisture likely to be found in water facilities. There are also advantages to using stainless steel in combination with other metals. This is true where the more anodic material has a much larger surface area than the cathodic material. For example, galvanic corrosion has not been a problem where stainless steel fasteners are used to hold down aluminum deck plates. This is because the amount of stainless steel (cathodic material) used to hold down the aluminum (anodic material) is quite small in comparison with surface area ratios. Overall, stainless steel has been demonstrated to provide excellent corrosion resistance in severe atmospheric environments.

7.3.2.7 Polyvinyl Chloride (PVC)

Soil Exposure: PVC is often used in soil exposures. Being a polymeric material, its resistance to corrosion in water and soil is excellent. PVC is widely used for electrical conduits and water pipelines. When buried, mechanical damage is unlikely. Even when buried, further protection can be provided by encasement in colored concrete and/or the use of warning tape. Where it is important that the pipe be located easily, metallized tape or a tracer wire can be routed in the same trench as the PVC pipe to enable detection.

Fluid and Atmospheric Exposures: In wastewater plant applications, PVC has had excellent success. It is unaffected by the levels of moisture and atmospheric chlorides. However, its resistance to many organics is limited (particularly ketones, esters, and aldehydes) so it should not be used to carry these materials. Care should be taken in the use of PVC in contact with chlorine. PVC is suitable for the transport of dilute chlorine solutions; however, its use is not recommended for transporting liquid or gaseous or dry chlorine above 73°F and it is only marginal for dry chlorine at less than 73°F. Similarly, PVC should not be used in applications where temperatures can exceed roughly 140°F. The manufacturer should be consulted prior to using PVC products in chemical exposures or high temperature applications.

7.3.2.8 Other Polymeric Materials (All Exposures)

Most other polymers are resistant to the chemicals normally encountered in water facilities. However, this does not apply to concentrated chlorine (dry or wet gas), which is extremely corrosive. Polyolefins (polyethylene, polypropylene) have very good resistance to corrosion. Chemically, they are essentially inert, and, with the exception of chlorine, should be resistant to the chemicals likely to be encountered. Polypropylene is suitable for temperatures up to 180▪F and polyethylene is suitable up to 140°F.

Most plastics are suitable for burial. Polyolefins are waterproof and may also be buried. Polyethylene is often used for natural gas service due, in part, to its corrosion resistance, toughness and resistance to cutting.

7.3.2.9 Fiber Reinforced Plastics (Fiberglass, All Exposures)

Fiber reinforced plastics have been used successfully in water facilities. These materials are based on glass-reinforcing fibers held in a matrix of a thermoplastic (polyester type) or a thermosetting resin (epoxy type), and are available in a wide variety of structural forms such as tubes, angels, and grates. Both types are extremely resistant to corrosion by water, chlorides and most other chemicals commonly found in a water facility. The exception is chlorine. Polyester-based, fiber-reinforced plastics have somewhat better resistance to wet chlorine than epoxy-based plastics, but manufacturer's application data should be consulted before any material is selected for chlorine service. Depending on concentrations, dilute chlorine solutions may not present problems.

Manufacturers should be contacted for each service application where the use of these materials may be considered. There have been significant failures of this type of material when the material was improperly selected. The DESIGN CONSULTANTS must carefully evaluate the intended application because fiberglass does not have the same structural strength or physical properties as steel.

Table 7-1
General Guidelines for Material Selection

Item	Acceptable Materials of Construction
Buried Pipe	
• Transmission Pipe	DIP[(1) (2)(8)] SCRW[(1))] and CMLTCMC steel[(1))], CMLC steel[(1)] and PVC
• Transmission Pipe Fittings	Steel[(1)(4)(5)] and ductile iron[(1)(2(8))]

Item	Acceptable Materials of Construction
• Distribution Pipe	Ductile iron[2][8] and PVC
• Distribution Pipe Fittings	Cast iron[2][8] and ductile iron[2][8]
• Service Pipe	PVC and copper type K
• Bolts and Fasteners	Stainless steel[6], and galvanized steel
Exposed Pipe	DIP[9], Steel[9], PVC[10]
Water Pipe Valves	
• Body	Cast iron[7], ductile iron[7], and cast steel[7]
• Stem and Trim	Bronze and stainless steel[6]
• Control Tubing	Stainless steel[6]
Pumps	
• Body	Cast iron and ductile iron
• Impeller	Bronze
• Shaft	Stainless steel[6]
Water Reservoirs	Reinforced concrete or steel
Drains, Sanitary	PVC
Culverts and Storm Drains	Reinforced concrete pipe
Structural Concrete	Type V cement, minimum 2-inch cover over reinforcement
Structural Metal	Galvanized steel
Ladders	
• Dry	Aluminum, galvanized steel and fiberglass
• Submerged	Stainless steel and fiberglass
Hydraulic Gates	Cast iron
Handrail	Aluminum, galvanized steel, or stainless steel
Electrical Enclosures	Galvanized steel, stainless steel and fiber-reinforced plastic
Electrical Conduit (low voltage)	
• Buried	PVC
• Exposed	Galvanized steel or PVC coated galvanized steel in corrosive areas

Notes:

1. Provide cathodic protection in immersion services and where soil conditions are corrosive.
2. Cement mortar lined with dielectric coating.
3. Not used in aggressive soils.
4. Cement mortar lined and coated.
5. Cement mortar lined, tape wrapped, mortar coated for corrosive soils.
6. Use type 316 stainless steel in corrosive atmospheric exposures. Buried bolts shall be carbon steel and wrapped with petroleum wax tape
7. Epoxy coated and wrapped in petrolatum/wax tape for buried service.
8. Polyethylene encasement allowed in soil conditions with resistivity greater than 10,000 ohm-cm.
9. Cement lined, aliphatic acrylic polyurethane coated.
10. Acrylic latex coated.

Item	Acceptable Materials of Construction
Abbreviations:	
ABS	Acrylonitrile-Butadiene Styrene
CMLC	Cement Mortar Lined and Coated
CMLTCMC	Cement Mortar Lined, Tape and Cement Mortar Coated
DIP	Ductile Iron Pipe
PVC	Polyvinyl Chloride
SCRW	Steel Cylinder Rod Wrapped
VC	Vitrified Clay

7.4 Cathodic Protection

7.4.1 Buried Piping Systems

Cathodic protection must be considered for all buried transmission, distribution, and facility piping whenever steel or ductile iron materials are used. Cathodic protection is always used in conjunction with protective coatings. Protective coatings may be either dielectric or cement mortar based. Cathodic protection is always required on buried dielectrically coated steel or ductile iron piping systems regardless of soil corrosivity. The use of cathodic protection on cement-mortar coated steel piping systems is optional when soil resistivity values exceed 5,000 ohm-cm or they are encased in structural concrete.

The use of cathodic protection on individual, dielectrically coated, ductile iron pipe fittings used in nonmetallic piping systems is not usually required. It may be required if extremely corrosive conditions exist. Dielectrically coated ductile iron pipe fittings not installed with cathodic protection should be field wrapped with a petroleum wax tape coating system to provide additional corrosion protection.

7.4.2 Welded Steel Tanks and Reservoirs

Cathodic protection should always be provided to protect the submerged internal surfaces of welded steel tanks and reservoirs. For tanks and reservoirs smaller than 0.5 million gallons, galvanic anode cathodic protection systems in accordance with AWWA D106 is required. For tanks and reservoirs 0.5 million gallons or larger, automatic potential controlled impressed current cathodic protection systems in accordance with AWWA D104 is required.

Chapter 8

SEISMIC CRITERIA

8.1 General

8.1.1 Structures Similar to Buildings

Structural/Seismic review is performed by the Development Services Department, Building and Safety Plan Review. New Building Regulations are adopted by the City of San Diego Municipal Code on a regular basis. Information for Building Safety Plan Review can be found at Sandiego.gov/development-services. Seismic design criteria shall comply with the latest adopted version of the California Building Code (CBC) or standards referenced in the CBC.

8.1.2 Structures Not Similar to Buildings

DESIGN ENGINEER is responsible to comply with and produce seismic design for water pipelines in accordance with this chapter and the latest adopted versions of all other applicable codes, standards, and guidelines.

These guidelines are a suggested starting point, but do not take the place of the design engineer's judgment and additional information available for a particular project site. Each design engineer should have the knowledge, experience, and insight into the importance of their facility to select the appropriate seismic design load and subsequently to apply that load in an appropriate manner to the structure. Similarly, these guidelines do not prescribe the procedure or process of analyzing the structure. Again, this is design engineer's responsibility to select the method of analyses that best suit the complexity, criticality, and importance of the facility.

Recommendations for the seismic loading criteria for water pipelines can be found in a guideline prepared for FEMA's and National Institute of Building Sciences (NIBS) by a team representing practicing engineers in the United States' water utility industry and academics through American Lifelines Alliance (ALA).

The design of dams and associated components are under California Division of Safety of Dams (DSOD) jurisdiction. The DSOD should be consulted regarding seismic evaluation/design criteria for the particular component under their jurisdiction.

8.1.3 (NOT USED)

8.1.4 Facility Importance and Performance Goals

The California Building Code (CBC) performance goals have been formulated with the intent of protecting building occupants from life safety hazards resulting from earthquake damage, as opposed to attempting to ensure post-earthquake operability of facilities. Buildings built to the CBC may still suffer significant damage after an earthquake, such that they may not be able to perform their function. In some cases, resultant damage to CBC code-built buildings may be so significant such that repair of the building is not economical, and total demolition is warranted.

The CBC recognizes that some facilities, such as Emergency Operations Centers, Hospitals and similar "Essential Facilities" should have better performance such that they are available for use immediately following an earthquake. In order to accommodate this goal, the CBC specifies somewhat higher design force levels and more rigorous quality assurance measures during the design and construction process. The adjustment in force level is typically obtained with the application of an occupancy Importance, or "I" factor.

The criteria described in this document are intended to provide greater reliability for the City of San Diego Public Utilities Department facilities than would be obtained by straight application of the CBC and other similar standards, when such reliability is economically justified. Depending upon the level of service required after an earthquake, each new facility should be assigned an "I" factor. **Table 8-1** provides three groups of importance.

Where the detailed requirements of this Standard or referenced standards and codes require the application of an Importance Factor, I, such factor shall be determined in accordance with the **Table 8-1**.

Examples. If a pumping plant is the only source of water for a pressure zone, and if maintaining flows to the pressure zone is considered essential, then the non-redundant parts of that pump station should be designed with I=1.5. Elements of the pump station building that are not essential to pumping plant operation, such as lighting and ventilation, could be classified as Important (I=1.25). If there are two water tanks within a pressure zone, then each of the water tanks could be classified as I=1.25 (the two tanks mean that the zone has a redundant water supply for immediate post-earthquake fire service). If there is one tank and one pumping plant serving a pressure zone, and that pumping plant has a reliable source of power and a reliable supply of water and can pump the fire flows, then each of the pumping plant and water tank could be classified as I=1.25. Critical facilities (I=1.5) include non-redundant parts of the Otay, Alvarado and Miramar water treatment plants. Critical facilities (I=1.5) include pumping plants in pressure zones having no redundancy (either only one pumping plant serving a zone with no in-zone storage, or multiple pumping plants serving a zone with no in-zone storage and neither pumping plant has a reliable source of power). When assessing whether a facility has I=1.25 or I=1.5, a credible common cause failure mode that affects both the redundant structures should be considered; for example, if a single landslide were to fail two tanks, then the tanks are not redundant.

Table 8-1
Facility Importance and Performance Goals
(Reference CBC)

Facility Class	Description	Performance Goal
Standard I = 1.0 (Same as CBC Special, Standard or Miscellaneous categories)	Administrative centers, repair shops, service centers and similar support facilities	Provide substantial life safety protection for major earthquakes likely to affect the site. Facility may not be economically repairable in the event of such an event.
Important I = 1.25 (Same as CBC Essential, or Hazardous categories)	Structures and components of the transmission, distribution, treatment, and control systems with some level of redundancy or for which failure does not result in an unacceptable level of service.	Provide substantial life safety protection for major earthquakes likely to affect the site. Facility may experience significant damage but should be capable of restoration to service within a limited period of time.
Critical I = 1.5 (Other requirements same as CBC Essential, or Hazardous categories)	Structures and components of the transmission, distribution, treatment, and control systems with little or no redundancy and the failure of which results in an unacceptable level of service.	Provide substantial life safety protection for major earthquakes likely to affect the site and provide reasonable expectation of immediate, or essentially immediate post-earthquake operability.

8.1.5 Reference Codes and Standards

Regardless of design basis, all newly constructed City of San Diego Public Utilities Department facilities shall as a minimum comply with the applicable provisions of the following codes and standards, latest edition.

- Buildings, structures & equipment - California Building Code, as published by the International Code Council, 2016.
- Fire Suppression Systems - NFPA 13, as published by the National Fire Protection Association.
- Reinforced concrete water retention structures - ACI 350, as published by the American Concrete Institute.
- Welded Steel Water Tanks - ANSI/AWWA D100, as published by the American Water Works Association.
- Bolted Steel Water Tanks - ANSI/AWWA D103-, as published by the American Water Works Association.
- Prestressed Concrete Tanks - ANSI/AWWA D110, as published by the American Water

Works Association.

8.1.6 Symbols and Notation

Where used in Chapter 8, the symbols and notation below shall have the meaning indicated.

ACI	American Concrete Institute
ASCE	American Society of Civil Engineers
AWWA	American Water Works Association
I	Importance factor per **Table 8-1**
CBC	California Building Code
PGA	Peak ground acceleration - g
PGD	Permanent ground deformation
SDPUD	San Diego Public Utilities Department

8.2 Site Criteria

Information specifying potential geologic hazards in the City can be found in the San Diego Seismic Safety Study, Geologic Hazards and Faults Maps. Additional resources are available on-line from the California Geological Survey and the U.S. Geological Survey.

8.3 (NOT USED)

8.4 Underground Piping

8.4.1 Failure Mechanisms

Underground piping systems have been frequently damaged in past earthquakes. Failure of piping systems is a significant problem. It can result in loss of pressure, reduction in quality of potable water, draining of local reservoirs, significant infiltration in waste water systems, and for pressurized lines, substantial erosion damage to adjacent land and improvements. The primary causes of underground piping failures are:
Ground failures including liquefaction, lateral spreading, and landsliding. Large deformation of the ground from these effects imposes similar deformation on embedded piping. Failures at points of weakness including joints, tees, air valves, hydrant laterals and similar fittings as well as at connections to structures are common.

Fault ruptures. Underground piping crossing zones of fault rupture are subject to extensive damage. Piping crossing the rupture zone can be subjected to abrupt shears as well as longitudinal tension or compression.

Differential settlement of soils, particularly adjacent to firm soils or structures founded on deep foundations. Essentially, embedded pipe will move with the surrounding soil. If one section of pipe moves due to settlement while adjacent sections are prevented from displacement either due to placement in firm soil or attachment to settlement-resistant structures, damage will occur.

Rigid attachment to flexible structures. Underground piping frequently experiences damage at connections to tanks, buildings, basins, and similar facilities. This damage results from differential movement of the structure, in response to the ground motion, with respect to the ground. Differential movement can occur from sliding, rocking, or flexing of the structure. The pipe which is embedded in the ground will attempt to act as an anchor for the structure and can be severely damaged unless flexibility is provided in the connection.

Response to ground shaking. The shaking felt by observers and structures placed on the ground is a direct result of seismic waves that occur within the ground. Piping embedded in ground which is responding to an earthquake is subjected to shearing, compression, and tension forces corresponding with the waves experienced by the ground. These forces can occasionally lead to failure of weak, corroded or brittle piping components.

Unrestrained joints. Unrestrained piping joints, such as the bell and spigot joints and rubber gasketed joints, are a frequent source of failure. As movement occurs in the ground around the pipes, these joints are forced to move, and damage to seals is not uncommon. In areas where gross ground failure occurs, complete disassembly of these joints can occur.

8.4.2 General Design Guidelines

Selection of appropriate routing. The best way to minimize failure potential of underground piping is to avoid routes through areas expected to experience either gross soil failures or ground fault rupture. During planning/initial screening of possible alignments for a new pipeline or for the initial evaluation of the seismic vulnerability of an existing pipeline, the existence of potential hazards should be reviewed per **Section 8.2**. In addition, the planning and design for all new major pipeline projects should include a geologic/geotechnical reconnaissance of the proposed routing.

Selection of appropriate materials. New buried pipes used for transmission or distribution systems should be designed with the following considerations. Note: “good” soils are those locations not in liquefaction, landslide or surface faulting zones.

- For new small diameter (8” – 10” diameter) installations. In good soil areas, use single lap welded steel pipe; rubber gasketed or mechanical jointed ductile iron; rubber gasketed PVC pipes. For better performance in soils that may be prone to PGDs, use heavy wall butt welded (preferred) or single lap welded steel pipe; fusion bonded high density polyethylene pipe; slip jointed and restrained ductile iron pipe. Corrosion protection is needed for all metal pipe.

- For new large diameter (12" to 24" diameter) installations. In good soil areas, use single lap welded steel pipe; rubber gasketed or mechanical jointed ductile iron, rubber gasketed PVC pipes. For better performance in soils that may be prone to PGDs, use heavy wall butt welded (preferred) or single lap welded steel pipe; fusion bonded high density polyethylene pipe; slip jointed and restrained ductile iron pipe. Corrosion protection is needed for all metal pipe.

- For new transmission (30" diameter and larger) installations. In all soil areas, use single lap welded, butt welded, or double lap welded steel pipe as determined in design. Double lap joints (welds inside and outside) should be designed to be as strong and as the main body of the pipe while allowing up to 4% strain in the pipe. Steel bells shall be formed using an internal anvil or similar; significant cold rolling should be avoided. Heavy wall construction should be used in soils prone to PGDs. Corrosion protection is needed for all metal pipe. Reinforced concrete cylinder pipe may be used with special design only (bell ends should be stronger than the pipe; in soils prone to PGDs, girth joints must be welded inside and outside).

- For critical pipelines subject to surface faulting on active faults, and which serve areas without a reliable redundant source of water. These pipelines shall be designed in accordance with **Section 8.4.3**.

- For critical pipelines that traverse liquefaction or landslide zones, and which serve more than 10,000 people, without a reliable redundant source of water. These pipelines shall be designed to accommodate permanent ground deformations associated with that hazard zone; or the hazard may be mitigated with suitable ground stabilization techniques. Acceptable design strategies include pipe designs for no breakage; and / or designs to use rapidly deployable suitable diameter flex hose with suitable valves and manifold connections on either side of the hazard zone. The hazard zone shall be established in a rational manner. Valves and branches should not be located within these zones without suitable justification that these appurtenances will not adversely affect pipeline performance. Valves either side of the hazard zone should be designed to close without manual intervention, should pipe failure lead to a credible life safety risk due to erosion or inundation to nearby locations; any such non-manual valves should have a power source that is not dependent on power or natural gas supply from San Diego Gas and Electric. Large diameter pipes which are critical for delivery of fire flows should be designed to reasonably accommodate the hazard zone without failure.

- For critical pipes through landslide zones. Set the pipeline back far enough from the top of unstable slopes as to avoid being included in the probable zone of slippage. Provide measures to stabilize the slope. In some cases, it may be possible to position the pipeline below the potential landslide plane or zone of failure. If landsliding is confined to shallow depths, it may be possible to deepen the trench through the slide area to install the pipe below the zone of potential sliding. For critical pipelines where the zone of landsliding is relatively deep, tunneling beneath the slide should be considered. Pipes that must traverse a landslide can be designed to accommodate some landslide movement by using heavy walled butt welded steel pipes, or other designs that are approved by the engineer.

- Service connections in areas prone to PGDs should be designed to accommodate some flexibility between the service connection and the main pipe.

- Hydrant laterals in areas prone to PGDs should be designed to accommodate some flexibility between the hydrant lateral and the main pipe.

Alternative pipeline materials and pipeline joinery may be used if justified to be adequate for seismic loads by the engineer.

Pipeline types that are particularly susceptible to failure in soils with permanent ground deformations include (roughly from most vulnerable to less vulnerable): fiberglass pipe; cast iron pipe with cemented, lead or caulked joints; screwed fitting steel pipe; PVC or cast iron pipe with rubber gasketed joints; reinforced concrete with steel cylinder pipe with rubber gasketed joints; ductile iron or steel pipe with rubber gasketed joints. In addition, any metal pipeline with corrosion is susceptible to failure when exposed to PGDs.

New above ground pipes used for transmission or distribution systems (such as at river or stream crossings), should be designed with the following consideration:

- Above ground piping shall be designed for deadweight, operational, thermal and earthquake load conditions such that essential piping has a very high reliability of remaining functional during and after earthquakes. The three directions of earthquake loads shall be considered simultaneously in the design using a square root of the sum of the squares approach.

<u>Provision of flexibility at transitions</u>. Wherever underground pipe is connected to a structure (tank or building) or equipment (pump station) subject to credible permanent ground deformations or significant structural movements, or transitions from one subsoil condition to another, it is important to provide for flexibility in the design of the piping to accommodate credible differential ground and structure movements. Flexibility can be provided by:

- Providing oversized sleeves with flexible gaskets at pipe penetrations through building and structure walls.

- Providing flexible couplings in pipe adjacent to rigid connections to structures or equipment.

- Routing piping above grade in areas where extreme differential ground movements are expected, and providing expansion loops in above-grade piping (if feasible) to accommodate expected movements.

8.4.3 Fault Crossing Design Guidelines

The existing pipeline network that makes up the SDPUD water distribution system is exposed to failure due to potential fault offsets. In a few instances, the existing pipe network has been installed with valves either side of the fault zone, to "valve out" possible leakage from pipes that cross the fault.

New installations of pipelines that traverse active faults should be designed with the following special provisions.

- An assessment should be made of the area served by the new pipeline, as well as by existing pipelines. If the area served does not have a reliable source of water for fire fighting, available within 8 hours following a major earthquake and capable of lasting for at least 24 hours following a major earthquake, then a fault crossing design should be used for the new pipeline.

- Fault crossing designs are of three basic types: (a) avoid crossing the fault, if practical; (b) design the pipe to accommodate fault offset without failure of the pressure boundary; (c) provide suitable valves and manifolds and bypass pipe to allow rapid restoration of water service across the fault zone, should the pipe break at the fault. A combination of (b) and (c) may be suitable in some instances.

  Pipes that are designed per (b) shall be engineered following the principles for fault offset outlined in the American Lifeline Alliance Seismic Guidelines for Water Pipelines (latest edition). The pipe route should be configured, whenever practical, so as to cause net tension in the pipe given the fault offset.

- Pipes that are designed per (c) shall include suitable in-line valves either side of the fault zone, spaced far enough apart such as not to significantly increase the chance of failure of the pipe due to fault offset. The in-line valves may be manually or automatically actuated. Automatic actuation valves are required if the failure of the pipeline at the fault offset will credibly cause a life safety concern to nearby people, or cause enough erosion as to create a significant loss to nearby facilities. Automatic actuation should be based on instrumentation that senses whether the pipeline actually has broken, such as by sudden drops in pressure and increased flow, coupled with very high levels of peak ground acceleration (over 0.3g). Remote operation of any automatic actuation valve may be provided at the engineer's option. Any actuation system shall be capable of operating without reliance of San Diego Gas and Electric power, for at least one full close cycle.

- Pipes that are designed with design feature (c) but not (b) should include suitable sized bypass manifolds. The bypass manifolds should be sized to accommodate the minimum of 1,000 gpm, the minimum fire flow, or the average winter day demand for the area served by this pipeline.

Suitable above ground pipelines (flex hose or pipe) should be available to be installed within 8 hours following a major earthquake, in order to restore fire flows to the area.

- The type of design adopted for a new pipeline (a, b or c) should recognize all the seismic hazards for the area to be served by this pipeline. For example, a fault crossing design will not be effective if the pipe is also likely to fail due to landslide or liquefaction hazards. The area to be considered should be governed by the pressure zone hydraulics and geotechnical hazards of the pipe system serving the area.

- Small diameter distribution pipelines (10 inch diameter and less) may not be designed per options (a), (b) or (c) (i.e., no special fault crossing design) if breakage of the distribution pipeline due to fault offset does not materially impact the post-earthquake performance of the distribution system. If these cases, gate valves shall be included on the distribution pipe within 200 feet either side of the fault zone, and hydrants located just outside these gate valves.

- All new pipelines with nominal diameter of 20 inches and larger (or which serve a population of 10,000 or more people or which serve a critical facility) which cross an active fault shall include either design provisions (b) or (c).

- All new pipelines with nominal diameters of 36 inches and larger which cross an active fault shall include design provision (b) and optionally (c).

- All new pipelines with nominal diameters of 48 inches and larger which cross an active fault shall include design provisions (b) and (c).

- All new pipelines that traverse potentially active fault zones (such as the La Nacion fault zone) may, at the option of the engineer, adopt design options (b) or (c).

8.5 Underground Structures

Underground structures are to be designed in accordance to the latest adopted versions of the CBC, ASCE 7, and all other applicable standards.

8.6 Water Storage Structures

8.6.1 Flat Bottom Steel Tanks and Standpipes

A reference source on the seismic behavior of tanks is ASCE 7. A treatment of the influence of anchorage on computed overturning moments and buckling allowables is provided in AWWA D-100 and AWWA D-103.

Flat bottom steel tanks and standpipes shall be anchored and provided with fixed steel roofs. The tanks shall be designed in accordance with the latest edition of AWWA D-100 , AWWA D-103, and all applicable standards.

8.6.2 Prestressed Concrete Tanks

Prestressed concrete tanks shall be designed in accordance with the latest edition of AWWA D110 and all other applicable standards.

8.6.2.1 Base Connection

Base connections of prestressed concrete tanks shall be designed as defined in AWWA D110.

Steel reinforcement and anchor cables provided at the base of tanks shall be fully embedded on both sides of the base joints, to permit the development of the full yield strength of the steel.

8.6.2.2 Roof Connection

Wall to roof connections shall be either flexibly or rigidly tied, with positive mechanical anchorage in the form of dowels, tension cables, or other suitable devices. Unrestrained, free joints are not permitted.

8.6.2.3 Hydrodynamic Seismic Hoop Tensile Stress

Circumferential stresses shall be calculated in accordance with AWWA D110. Designs shall include provision for steel reinforcement to carry 100% of the circumferential tensile stresses due to seismic accelerations.

8.6.2.4 Cover

A minimum of 2 inches of cover shall be provided over prestressing strands for fire protection of tanks located in high fire hazard areas or any tank with appreciable fuel load located within 10 feet of the outside wall surface of the tank.

8.6.2.5 Backfill

The beneficial effects of backfill against the wall of a tank with respect to sliding resistance may be considered if the fill is engineered and a geotechnical report is provided which provides appropriate passive pressure values to be used. In order to consider the beneficial effects, the backfill must be provided around the entire perimeter of the tank. If backfill height varies, only beneficial effects of minimum height shall be used.

8.6.3 Water Retention Basins

Open roof, water retention basins shall be designed in accordance with the latest edition of ACI 350 and ACI 350.3.

Circular basins shall be designed for seismic forces calculated in accordance with **Section 8.6.2**.

8.6.4 Internal Structures

This section applies to all internal components (including mechanical equipment) and structures within reservoirs and water retention structures including roof support structures, piping, ladders, paddles, agitator shafts, and similar items.
In addition to other loads, resulting from self weight, operating forces, etc., internals shall be designed to resist a uniform seismic lateral force per unit height of internals as indicated in the latest edition of ACI 350.3.

8.6.4.1 Other Reservoir Systems

Redwood tanks shall not be used for new installations unless established that they are as reliable as comparable steel tanks.

Concrete tanks may be designed per ACI 350.

Roofs and valve works for open cut lined reservoirs shall be designed in accordance with this document.

8.7 Reservoir Outlet Towers

This section applies to terminal reservoirs and earth embedment dam reservoirs with outlet towers.

Free-standing reservoir towers in terminal reservoirs shall be designed to withstand seismic forces, using the latest edition of the CBC, ASCE 7, ACI 371R, and all other applicable ACI standards.

Outlet towers in terminal reservoirs shall be considered Critical structures because their failure may affect the structural integrity of the dams and potentially block inlet / outlet pipe.

The design of outlet towers and associated components are under California Division of Safety of Dams (DSOD) jurisdiction. The DSOD should be consulted regarding seismic evaluation / design criteria for the particular component under their jurisdiction.

8.8 Pumping Plants

Equipment, including pumps, switchgear, transformers, and similar items, as well as above ground piping shall be designed in accordance with **Section 8.9**.

Underground piping at pumping plants shall be designed in accordance with **Section 8.4**.

8.9 Equipment

8.9.1 General

Equipment components vulnerable to seismic hazards shall incorporate appropriate design measures to limit risks from these vulnerabilities should be implemented.

8.9.2 Vulnerabilities

Below, vulnerabilities are described which can reduce the reliability of the equipment.

8.9.2.1 Vertical Pump

- Shafts with unsupported length greater than 20 feet, must be evaluated for seismic loads.
- The impeller drive must be supported within the casing.
- Evaluate anchorage for seismic loads. Expansion anchors are not acceptable.
- Avoid seismic interactions of pump with other components.
- Assure that all equipment installed near vital pumps will not impact the pumps during seismic excitation and that such equipment are securely anchored.

8.9.2.2 Valves

- Cast iron valves should not be used. Actuator and yoke should be supported by the pipe and neither should be independently braced to the structure or supported by the structure unless the pipe is also braced immediately adjacent to the valve to a common structure.
- Sufficient slack and flexibility is provided to tubing, conduits, or piping which supplies air, fluid or power needed to operate the valve.
- Valves should not be near surrounding structures or components which could impact the valve during seismic excitation.

8.9.2.3 Motor Control Centers

- Must be floor mounted NEMA type enclosure.
- Anchorage must be evaluated for seismic loads. At least two anchor bolts should be used per MCC section.

- Anchorage of the MCC must attach to base structural members (not sheet metal).
- Avoid excessive eccentricities when mounting internal components.
- Do not mount heavy or vibration sensitive components directly to sheet metal. Use structural frame metal. Vibration sensitive components may require qualification by test or similarity, if that component is essential to operation.

8.9.2.4 Control Panels and Instrument Racks

- Anchorage must be evaluated for seismic loads.
- All door latches must be secured with locking devices.
- Wire harnesses or standoffs should be installed on cable bundles to preclude large deformation of bundles.

8.9.2.5 Battery Racks

- Battery cells should be lead-calcium, weighing 450 lbs. or less.
- Batteries should be supported on two-step or single tier racks which have x-bracing.
- Batteries should be restrained by side and end rails.
- Provide snug fitting crush-resistant spacers between cells.
- Racks must be anchored, and anchorage evaluated for seismic loads.

8.9.2.6 Above Ground Equipment Piping

- Provide sufficient flexibility at equipment connections and nozzles.
- Assure flexibility of pipe routed between buildings.
- Assure that pipe has sufficient space to displace during seismic excitation without impacting other components or structures.

8.9.2.7 Diesels

- Diesels should be anchored directly to the structural floor, or mounted on a skid which is directly anchored to the structural floor. Vibration isolators should not be used. Components (batteries, day tanks, mufflers, electric panels, etc.) should all be seismically designed.

8.9.2.8 Vibration Isolated Equipment

- Equipment mounted on vibration isolators are vulnerable to damage in earthquakes. Vibration isolators for equipment essential to functionality of the facility should not be used. “Snubbed” vibration isolators should only be used if the “snubbing” devices are approved by the engineer as meeting the strength and operational requirements described herein.

8.9.3 Equipment Anchorage

The following equipment shall be mounted in accordance with the CBC:

- Valves
- Engines
- Motors
- Generators
- Turbines
- Vertical Pumps (limited unsupported shaft length)
- Hydraulic and Pneumatic Operators (limited yoke length)
- Motor Operators (limited yoke length)
- Compressors
- Transformers with anchored internal coils

8.9.4 Functional Qualification

The following equipment can be considered as structurally rugged, and need be designed for the minimum anchorage forces and the other recommendations in this document. In addition, if post-earthquake operability of this equipment is critical, functional seismic qualification should be addressed by a knowledgeable engineer. Functional seismic qualification may be based on test or experience with similar equipment.

- Air handling equipment and fans (without vibration isolators)
- Low and Medium Voltage Switchgear (< 13.8 kV)
- Instrumentation Cabinets
- Distribution Panels
- Solid State Battery Chargers
- Motor Control Centers
- Instrument Racks
- Batteries in battery racks (must be in seismically designed battery racks)
- Floor mounted inverters up to 5 kVA
- Chillers

8.9.5 Above Ground Piping, Raceways, Conduits and HVAC Ducts

Earthquake restraints for above ground piping, raceway and conduit systems, and HVAC ducts as determined by the CBC code, are oriented to reducing life safety risk, by limiting the falling potential for these items. Post-earthquake functionality of these systems is not assured by following the CBC code, and in some cases, the CBC-mandated support systems may increase the potential for functional failures. Restraint systems other than that required by the CBC code may be used, if justified by the engineer. Issues to be considered in design of above ground piping, raceway, conduit and HVAC ducts are as follows:

- Plastic pipes shall be braced laterally at intervals not more than twice that recommended by the manufacturer for vertical support.
- Pipes (and raceways, conduit, ducts) that cross expansion joints between adjacent structures shall be provided with expansion fittings, multiple bends or other suitable provisions to ensure their capacity to sustain expected differential movements between the structures.
- Special care shall be taken to ensure small branch lines off pipe headers do not by virtue of their attachment to structures or equipment, act as the brace for the pipe header unless demonstrated by calculation to have suitable capacity for this service.
- At the option of the engineer, pipes that contain very hazardous materials (chlorine gas) shall be stress analyzed following provisions of the ASME code to ensure that stress levels in the pipes and attached components are within allowables.

8.10 Existing Facilities

All existing facilities shall be evaluated in accordance to the California Existing Building Code (CEBC), CBC, and ASCE 41 as modified by the San Diego Municipal Code (SDMC).

8.11 References

All latest adopted versions of codes and standards apply.

American Concrete Institute. "Building Code Requirements for Reinforced Concrete" ACI 318.

American Concrete Institute. "Environmental Engineering Concrete Structures" ACI 350.
American Concrete Institute. "Seismic Design of Liquid-Containing Concrete Structures" ACI 350.3.American Concrete Institute. "Guide for the Analysis, Design, and Construction of Elevated Concrete and Composite Steel-Concrete Water Storage Tanks" ACI 371R.

American Lifelines Alliance. "Seismic Guidelines for Water Pipelines".

American Society of Civil Engineers. "Minimum Design Loads for Building Structures" ASCE 7, Reston, Virginia.

American Society of Civil Engineers. "Seismic Evaluation and Retrofit of Existing Buildings" ASCE 41, Reston, Virginia.

American Water Works Association. "D-100 – Standard for Welded Steel Tanks for Water Storage" AWWA D-100, Denver, Colorado.

American Water Works Association. "D-103 – Factory Coated Bolted Tanks for Water Storage" AWWA D-103, Denver, Colorado.

American Water Works Association. "D-110 – Standard for Wire and Strand-Wound Circular Prestressed Concrete Tanks" AWWA D-110, Denver, Colorado.

City of San Diego. "The City of San Diego's Municipal Code" SDMC, San Diego, California.

International Conference of Building Officials. "California Code of Regulations Title 24, Part 2" California Building Code (CBC), Whittier, California.

International Conference of Building Officials. "California Code of Regulations Title 24, Part 10" California Existing Building Code (CEBC), Whittier, California.

National Fire Protection Association. "NFPA-13 Installation of Sprinkler Systems," NFPA-13. Quincy, Ma.

Chapter 9

SECURITY DESIGN CRITERIA

9.1 General

This chapter outline the design requirement of the security systems for water facilities. This Standard Security Specification shall be used in conjunction accordance with the most current approved edition of the Standard Drawings and the Standard Specifications for Public Works Construction (SSPWC or GREENBOOK) and WHITEBOOK, as adopted by the City.

9.2 Securing Electronic Equipment

All security system components, such as control panels, switches, etc., shall be installed in a secure, accessible location within a protected space. All on-site electronic security equipment shall be mounted in locations designated or approved by a Security & Emergency Planning Section. Any electronic equipment installed outside of a building shall be installed in an all-weather enclosure equipped with tamper proof latches, alarms, and/or card readers.

9.3 Wiring for Electronic Security

All wiring must be concealed and installed in an electrical conduit, unless otherwise specified. Any exposed conduit 1" or greater, conduit from hand holes to poles, or other above-grade equipment shall be threaded galvanized steel. If wiring conduits are installed inside a secured facility, wiring shall be protected using rigid or flexible conduits. Other suitable forms of protective covering may be considered if design requires explosive proofing.

All wiring and field connections shall be weather tight and secured the length of the conduit from the device to the enclosure along the walls or structures.

The grounding/bonding conductor shall be green PVC jacketed, stranded copper, soft conductor, unless otherwise noted. Follow Commercial Building Grounding and Bonding Requirements for Telecommunications, the most current version of the CEC, or per the manufacturer's recommendations.

9.4 Communications

Public Utilities Department (PUD) uses two primary methods of communication for access control information: (1) detection systems and (2) streaming video surveillance footage from the Department's facilities to the Security Operations Center. The operational requirements for each facility must be evaluated to determine a suitable communication path during the design phase.

SanNet (City's proprietary communication network) and SecNet (Security & Emergency Management's proprietary communication network) are both used depending on the site's conditions and availability. The operational requirements for each facility must be evaluated to determine which communication path is most suitable. PUD will conduct a Feasibility Study for the communication path for each site. Fiber or Microwave are the preferred methods of communication. The Security Network (SecNet) and the City's Network (SanNet) are the preferred destinations for the communication signal that will communicate back to the Security servers at the Chollas Security Operations Center (SOC)

9.4.1 Wireless Microwave Network (SecNet)

SecNet is a wireless microwave network that is designed to create a point-to-point link. When designing a microwave link, the required bandwidth and travel distance shall be considered. A high definition camera at its peak setting may require up to 7 MB/s. This bandwidth will determine the product type for each site. Transmissions carrying a larger amount of data over a longer distance may have to use a licensed link and may require a repeater. A licensed link may require additional licensing from the FCC.

9.5 Construction Specifications

This section identifies the minimum specification design, performance and control requirements for Public Utilities Facilities.

9.5.1 Exterior Lighting

Exterior lighting is expected to produce the least amount of glare over the surveillance area. To provide accurate color images in secured sensitive areas (i.e., entrances, exits), white-light LED shall be installed. For general lighting and anywhere light pollution may affect the operational efficiency or image quality of the CCTV system, LED lighting shall be installed. In secured sensitive areas where light pollution must be avoided (i.e., residential neighborhoods), infra-red (IR) illuminators shall be installed.

9.5.2 Perimeter Barriers

Perimeter barriers shall consist of fences, walls, gates, landscape, and other devices necessary to control or limit access to the facility. The perimeter barriers shall be uniform and shall protect the entire facility without interruption, unless otherwise specified. Security & Emergency Planning Section will assess the site and determine the need for additional secured perimeters within the facility through security vulnerability and risk assessments.

9.5.2.1 Fencing

Aesthetics, unit cost, effectiveness, and residential safety shall be considered to determine the ideal fence type. Acceptable fence types are wrought iron style and chain-link. Wrought iron style require a fence height minimum of 9 feet and a maximum of 10 feet. For chain-link fences, the fence height shall be a minimum of 8 feet and shall require a top guard (barbed wire/concertina coils), totaling the fence height to a maximum of 10 feet.

All accessible valves, vaults, water fixtures, and irrigation system fixtures are located inside the security fence. Specific fencing height and materials must be determined on a case-by-case basis. An intrusion alarm should be considered at the front gate as may be required by the City Project Manager. City Project Managers may require an intrusion alarm in the front gate. The security fence is placed, wherever possible, on or immediately adjacent to the property line.

1. *Wrought Iron Style Fencing System*

Architectural wrought iron style is an option for fencing with the top ends clipped/sheared to form a point or with cast points inserted into end of tubing. The vertical post shall be a minimum of 4-inch square tubing and 10 ga. and horizontal post shall be 2-inch and 11 ga. Additionally, the individual pickets at the top of the wrought iron style fence will be radiused out towards the threat a minimum of 12-inches, with 1-inch squared tubing and 12 ga. The finished height for wrought iron style shall be no less than 10 feet.

2. *Chain-Link Fence*

In high security areas, where the risk of cutting through standard chain-link is probable, No Cut No Climb fencing shall be installed with approval from a representative of the Security and Emergency Planning Section. Specification for no cut no climb shall be established by the DESIGN CONSULTANT and approved by Security and Emergency Planning on a case by case basis.

Standard chain-link fencing shall be galvanized steel with black PVC vinyl coating and a minimum of 9-gage wire mesh. The mesh openings shall be no greater than 2-inches per side and no less than 1-inch.

Chain-link fencing posts, rails, and braces shall have a galvanized coating. The top and bottom edge of the fence fabric shall be secured using tension wire or hog rings every 12-18 inches. Posts, rails, bracings, and tension wire of these components shall be installed on the secure side. The bottom edge of the fabric shall have a 2-inch gap or smaller from fabric to hard ground. Fabric shall be mounted to galvanized steel posts with additional bracing at corners, end posts, and gate openings. The horizontal bottom rails, tension wires, and concrete curbs, sills sheet piling, piping or other materials shall be installed such that the fence fabric is prevented from being lifted by hand more than 5-inches in height.

The preferred climbing deterrents are barbed wire with concertina (razor wire). The double barb wire shall be designed with "Y" style outrigger, double concertina will be coiled inside. Outriggers (support arms) shall be installed at 45-degree angles in a double arm design. These double arm outriggers shall consist of 18-inch arms, each having three strands of barbed wire at regular intervals along the top of the fence. Outriggers must be permanently affixed to vertical fence posts with threaded fasteners or by spot welding. All field welds shall have cold galvanizing spray applied to prevent corrosion. Fasteners used to affix outriggers to vertical posts shall be tamperproof by design, or by spot welding. Outriggers arms shall be coated to match adjacent posts and fabric.

Stainless steel concertina is a single coil, wire reinforced and each roll consists of 18 to 24-inch diameter coiled, 31 coil loops per roll, spaced 12 to 18 inches apart and with pairs of loops alternately clipped together. The concertina wiring extends at least 50 feet along the fence line without distortion and shall be secured at a minimum interval of 12 to 18 inches or per manufacturer's recommendations.

Barbed wire shall consist of two 12.5 ga. twisted line wires with 4 to 6 inches of barb spacing. The barb wire must be class 1 zinc-coated galvanized steel, aluminum coated steel, or PVC over zinc-coated steel as specified. All barbs must consist of four points with spacing of 5 inches or smaller.

9.5.2.2 Reinforced Concrete/Concrete Masonry Unit Walls

Reinforced Concrete or Concrete Masonry Unit Wall shall meet the minimum height of 8 ft excluding the top guard. Top guard shall be designed by the DESIGN CONSULTANT and shall be approved by a representative of the Security and Emergency Planning Section before being installed.

9.5.2.3 Gates

The security gates shall extend within 2 inches of the finished surface, roadway, or floor when closed and secured. Gate materials shall be the same as the adjacent fence. A powered locking system shall be installed and designed to provide an equal level of resistance when swing gates, sliding gates, and personnel gates are closed and secured. A magnetic lock (Mag-lock) shall be installed with at least 1200 lbs. of holding force.

1. *Personnel*

Gates used for personnel shall be either swing or full height turnstile. These gates shall have access control car readers installed on both the secure and unsecure sides.

The single swing gates shall match the fence fabric material, height and climbing deterrent of the adjacent fence. Gate hinges shall be pressed steel or malleable iron having a minimum zinc coating of 1.2 oz. per square-feet and allow the gate to open and close without binding. Hinges shall be designed to permit a gate swing of 180 degrees. A hydraulic gate closure shall be installed on the secure side of a gate.

The full-height turnstile gates require climbing deterrents matching the adjacent fence shall be installed between the top of the gate post and the turnstile when a gap is present.

2. *Vehicular*

For vehicular gates, height shall match the adjacent security fencing and when feasible, the gate opening shall be as wide as the roadway approaching the gate. Acceptable gate types are single wheel, rolling (V-groove) slide gates or single swing gates. The operational and space requirements for the gate must be evaluated to determine which gate type is most suitable.

Powered gate operators and photo eye sensors are required for all vehicular gates. Product type, horsepower, voltage and phases will be determined by anticipated traffic flow and access control procedures. For the avoidance of degradation over time, ground safety loops (gate trigger/metal detector) shall be installed and all points shall be completely sealed.

For single wheel supported (v-groove) sliding gates, the wheels shall be hardened steel and tack welded. The v-track for these gates shall be one galvanized steel piece with "no-weld" to avoid cracks and rust.

All single swinging vehicular gates shall be designed to swing inward toward secured area at either 90 or 180 degrees. The hinges of these gates shall be secured to the gate post and the gate frame by tack welding to prevent twisting or turning. Bolts and all other hardware associated with the hinges shall be welded or peened to prevent removal by hand tools.

9.5.2.4 Landscape

Landscape shall be installed as low shrubs, mid-size shrubs, trees, or cacti. Vegetation shall be installed with a minimum 3-foot separation maintained between the security fencing and fully matured landscaping.

Low shrubs are dense and spiny vegetation growing up to 3 feet in height. They shall be planted 2-3 feet apart, or as directed by landscape architect, forming a tightknit barrier. Mid-size shrubs are vegetation with thorns or spines growing from 6-10 feet within 5 to 10 years. Planting shall be 3 to 4 feet spacing or as directed by landscape architect and shall be an equivalent distance from walkways and any other high traffic locations.

Trees growing more than 15 feet or with a trunk size larger than 5 feet in circumference, shall not be planted in or around the perimeter unless the following is met: plant trees such that the edge of the canopy, at full maturity, is a minimum 3 feet from the perimeter fence line and top guards (barbed wire or concertina rolls). For existing facilities all tree limbs shall be trimmed and maintained so there is at least 3-foot clearance between the tree, fence line and top guards.

If aesthetics permit, cactus shall be considered a primary component of the planting palette around the perimeter fence line of any PUD facility.

9.6 Access Control System

Software House Ccure 9000 software running on a Ccure server is the PUD standard for an access control system. To maintain compatibility with PUD's existing standard systems, substitutions or equivalent products will not be accepted per SDMC 22.3007 and 22.3008. The access control system shall be a networked system, that can operate independently as a standalone system. Therefore, if the network connectivity is lost, the access control panels shall continue operating independently without degradation in the operation of the system.

Card readers and electric locking devices shall be installed at all designated entry doors to the protected space, including stairwell doors at points of public access. Elevators directly accessing protected spaces, shall have card access to control the movement of the elevator on a floor by floor basis. All doors equipped with a card reader or electric locking device shall have door contacts and request to exit (REX) motion sensor connected to the access control system. All readers are to be installed 46 inches above finished floor unless otherwise noted. The access control system shall be a networked system, but shall be capable of operating independently as a standalone system. If network connectivity is lost, the access control panels shall continue operating independently without degradation in the operation of the system.

9.6.1 System Interface Requirements

The access control panels, I-star, shall be connected to a dedicated 120 VAC power source through an external power supply. All access control panels shall be grounded to prevent electrostatic charges and other transient electrical surges from damaging the panel.

In the event of an AC power failure, the external power supplies shall send an alarm to report a "Power Failure" alert to the City's access control system server and the end user/operator. For the case of power outages, access control panels shall have replaceable batteries for panel memory backup enabling the panel to retain the downloaded database and configuration.

9.6.2 Card Reader

The software for card readers shall be Software House model (SWH-4100) or equal. The reader shall have a minimum life expectancy of 1,000,000 reads and shall be equipped with three visual indicators (LEDs) and an audible tone. All readers shall be capable of normal operation indoor, outdoors, and within a temperature range of 40°C and ± 75°C. For outdoor applications, an optional weather hood shall be installed. See Table 9-1 for a list of the color scheme standard for card readers.

Table 9-1
Color Scheme Standard for Card Readers

Red LED	Green LED	Yellow LED	Indication
ON	ON	ON	Online-Door Locked
Flashes	OFF	OFF	Invalid Card Read; Access not granted
OFF	Flashes	OFF	Valid Card Read; Access granted
OFF	OFF	Flashes	Offline or device issue
Flashing	Flashing	Flashing	Alarm: Door forced or held open

Removal of the existing coating and recoating may require that the site be classified as a lead paint removal project, depending on the lead content of the original paints used. If the site is classified as a lead paint removal site, the DESIGN CONSULTANT incorporates the procedure developed by the City Asbestos and Lead Management Program (ALMP) for removal of lead-based paints from the exterior and interior surfaces of the standpipe. The ALMP manages and directs all aspects of lead-based paint removal from the facility. The DESIGN CONSULTANT also provides for the removal of asbestos or other hazardous material from the site.

Final features of the site are decided on a case-by-case basis. Improvements largely depend on the anticipated future use of the land such as a park or parking area, or the site may be prepared for sale of the property. The DESIGN CONSULTANT coordinates the final site features with the City Project Manager.

9.7 Closed Circuit Television System

Milestone Xprotect Corporate is the PUD standard for Closed Circuit Television (CCTV) system, which runs on a centralized management server and may not be substituted. To maintain compatibility with PUD's existing standard systems, substitutions or equivalent products will not be accepted per SDMC 22.3007 and 22.3008. The CCTV system shall monitor entrances, restricted areas, critical asset areas alarm conditions, access points, parking lots, building perimeters, and interior areas. These CCTV systems shall be operated from a centralized workstation or the PUD Security Operations Center (SOC).

9.7.1 Cameras

All components of the CCTV system shall be compatible with the standard PUD CCTV system and integrated with all security subsystems (Access Control, two-way speaker system) to ensure a full operational system. Unless otherwise stated a device license and at least one year of care plus coverage should be purchased for all new installed cameras. The following camera manufacturers are acceptable: Samsung, Bosch, Canon, Axis, Pelco, Flir, or equal. Other manufacturers may be considered if they complete a proof of concept with approval of a representative of the Security and Emergency Planning Section.

The type of cameras to be installed are fixed, pan tilt zoom (PTZ), and multi-sensor multi-directional. Fixed cameras shall be the primary type to surveillance designated access control and monitoring points. PTZ cameras shall be used for site perimeter and exterior building areas to support the fixed cameras. The multi-sensor multi-directional cameras shall be used in large unobstructed areas and multi-entrance rooms.

All installed cameras shall adhere to the following minimum technical specifications:

- Include device license with one year of care plus coverage
- Include latest secured version of firmware/software
- Internet Protocol
- Resolution of 1920x1080 p
- 3.0 Megapixel
- Wide Dynamic Range
- Low Light capabilities
- Electronic Image Stabilization
- Open Network Video Interface Forum compliant
- Powered over Ethernet
- IP-66 weatherproof housing and IK-10 Vandal proof housing (applicable to outdoor cameras)

Cameras shall be installed on approved mounting surfaces structured for weight, wind load, and extreme weather conditions. External poles for cameras shall be constructed of metal with a concrete base, installed and grounded in accordance with the NEC, and weather resistant.

When mounting cameras, orient the camera so that equipment may swivel inward for maintenance. Camera conduits shall be a minimum of 8 feet above the highest climbing aide (steps, stem wall, caisson). Cameras shall not be installed behind, next to, or on any natural/manmade object that may restrict the field of view, cause signal loss, or cause camera malfunction.

9.7.2 Network Video Recorder (NVR)

The network video recorder (NVR) shall be installed on a Windows PC and shall have no storage restrictions (RAID, NAS, etc.). The NVR shall be capable of recording in the following formats: H.264, MPEG-4, and M-JPEG. NVR shall perform simultaneous recordings at a minimum frame rate of 30fps, 24 hours a day, for a minimum of 90 days.

The City of SAN DIEGO	DEVIATION FROM STANDARDS (DESIGN ONLY)	CITY ENGINEER
DRAWING NUMBER(S):	DSD PROJECT NUMBER:	WBS OR IO NUMBER(S):

PROJECT TITLE/DESCRIPTION:

PROJECT LOCATION(S):

PLACE RCE STAMP OF EOR HERE

ENGINEER OF RECORD: ______________________________
(EOR) (Print Name)

______________________ ____________ ____________
(Signature) (RCE NUMBER) (Date)

STANDARDS DEVIATING FROM (e.g. 2018 Greenbook Section; 2018 Standard Drawing SDG-133 Curb Ramps Type A and B):

LOCATIONS OF DEVIATION(S) (Street names/intersections or facility locations):

DESCRIPTION OF DEVIATION(S):

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REASON(S) FOR DEVIATION(S):

MITIGATION MEASURES FOR DEVIATION:

SEE ATTACHED SHEETS (e.g. D sheets, photos or sketches) PROVIDE SHEET NUMBERS WITH DESCRIPTIONS.:

REVIEWED BY:
DESIGN/PLAN CHECK ENGINEER:______________________________

(Print Name)

______________________________ ______________

(Signature) (Date)

APPROVED BY:
DEPUTY CITY ENGINEER (DCE): ______________________________

(Print Name)

______________________________ ______________

(Signature) (Date)