San Diego County Water Authority

Engineering Department

Design Manual
Volume Two

Facility Design Guide

ESD-160 *October 2007*

ESD 160 Design Manual

Volume Two: Facility Design Guide

REVISION LOG

Item (Table of Contents, Chapter, or Appendix)	Rev. No.	Date Entered	Initials
Chapter 2	001	9/21/2012	MEC

Instructions:

After revising your ESD as described in the revision transmittal, enter the item revised, date entered, and initial above.

SDCWA
San Diego County Water Authority
Engineering Department

ESD 160
Design Manual: Volume Two
Facility Design Guide

October 2007

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ESD 160 Design Manual: Volume Two (Facility Design Guide)

Introduction and use

The *ESD 160 Design Manual: Volume Two (Facility Design Guide)* documents the practices and standards that are used for design of projects at the San Diego County Water Authority.

Personnel involved in design of Water Authority projects shall adhere to the practices and procedures described in this document. Engineering management shall be responsible for enforcement of these practices in their respective design management of projects.

Revisions and maintenance

This manual is intended to be a living document that evolves to meet changing San Diego County Water Authority needs.

Engineering management continuously monitors the design activities for its various projects and will identify refinements to or additional practices and procedures.

The Engineering Department is responsible for maintaining this manual, for revising chapters as practices and procedures change, and for issuing manuals and revisions to appropriate personnel.

Users may suggest changes or additions to this document by submitting a Change Request Form to the Manager of the Administration and Controls Group. This form is available at the Water Authority server in the directory I:\0130.00\Resources\Forms&Templates. Comments will be reviewed, and if changes are instituted, the manual will be revised and revisions will be distributed to manual users.

Personnel entrusted with this manual are responsible for maintaining it in a current and update condition as revised chapters are published.

Validation

The San Diego County Water Authority *Engineering ESD 160 Design Manual: Volume Two (Facility Design Guide)* is hereby accepted and approved.

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Michael T. Stift, Director of Engineering
San Diego County Water Authority

Table of Contents

Chapter 1 Introduction

Overview

Purpose	This chapter presents an introduction to the purpose, use, and organization of the Facility Design Guide.
Topics	This chapter is composed of the following topics:

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1.1 Facility Design Guide is Part of the Design Manual

1.1.1
Facility Design Guide is the Second Volume of the Design Manual

1. The Facility Design Guide is the second volume of a two-volume Design Manual that consists of the following:
   1.1. VOLUME 1 – DESIGN CONTRACTOR GUIDE: Provides design management and administrative procedures, including requirements for design schedule and budget control, reporting, QA/QC program, deliverables at different levels of design, construction cost estimating, records management, and other topics. The Design Contractor Guide also describes the relationships between the Design Contractor and the Design Manager.
   1.2. VOLUME 2 – FACILITY DESIGN GUIDE: Provides design requirements for different types of facilities, including pipelines, pump stations, and flow control facilities.

1.1.2
Purpose of the Facility Design Guide

1. The Facility Design Guide provides general technical guidelines that shall be followed by Design Contractors selected by the Water Authority to prepare engineering reports, construction drawings, specifications, and other documents for construction of the facilities necessary to implement the CIP and/or to provide services during other project phases. The design of these facilities shall be based on:
   1.1. Applicable codes and standards.
   1.2. The project-specific scope of work.
   1.3. Criteria presented in the project Predesign or Planning Study Report
   1.4. The Water Authority Design Manual
   1.5. Documents and other standard manuals referenced in the Design Manual
2. The Facility Design Guide is intended to ensure uniformity of design concepts, formats, methodologies, procedures, construction materials, types of equipment, and quality of work products produced for the Water Authority.
3. The Design Contractor shall take full responsibility for the designs produced. This responsibility of the Design Contractor is in no way diluted or absolved by the Design Manual.

1.1.3 Design Manager

1. A Design Manager will be assigned to each project and will be the Design Contractor's point of contact with the Water Authority for the project.
2. The Design Manager will administer the Contract to ensure compliance with provisions of the Contract and the Design Manual.

1.1.4 Inconsistencies

1. Inconsistencies may exist between the Design Manual, Predesign Report, project scope of work, and other Water Authority documents. Resolution of such inconsistencies, if any, is discussed in the Design Contractor Guide, Chapter 1, Paragraph 1.4.

1.1.5 Reference to the Design Contractor Guide

1. Refer to the Design Contractor Guide for additional information and requirements.

1.1.6 Hyperlinks

1. The Facility Design Guide chapter tables of contents are hyperlinked. Other references are not hyperlinked.

1.2 Use of the Facility Design Guide

1.2.1
Use by Design Contractors

1. The Facility Design Guide identifies general design details and approaches to be used for design of Water Authority facilities. The Facility Design Guide is intended to promote uniformity in key design concepts and equipment types.
2. The Facility Design Guide does not limit the responsibility of the Design Contractor, but assists in providing professionally sound, efficient, uniform, and workable facilities, including pipelines, flow control facilities, pump stations, and other facilities. Not all aspects of design are addressed in the Facility Design Guide, and, in all cases, the Design Contractor must use good engineering judgment and practices.
3. The Design Contractor shall incorporate the design criteria presented in the Facility Design Guide into the overall facility design. Sometimes the criteria are given in ranges, in which case the final criteria shall be selected within the indicated range. In other cases, specific criteria have been given and shall be followed by the Design Contractor. However, the Design Contractor may request changes to the criteria presented in the Facility Design Guide to suit the specifics of the project. Refer to Section 1.2.2 below for more information.
4. If documents referenced in the Facility Design Guide have been updated since the original writing of the Facility Design Guide, the Design Contractor shall use the documents current at the time the design is initiated. Such document use shall be referenced in writing to the Design Manager.

1.2.2
Deviations from the Facility Design Guide

1. If the Design Contractor desires to deviate from the criteria presented in the Facility Design Guide, the Design Contractor shall propose such modifications, with justifications, to the Design Manager as described in Design Manual, Volume 1 - Design Contractor Guide.

1.3 Organization of the Facility Design Guide

1.3.1 Six Chapters in the Facility Design Guide

1. The Facility Design Guide is presented in six chapters as follows:

   1.1. Chapter 1 – Introduction

   Describes the purpose, use, and organization of the Facility Design Guide. It also describes how the Facility Design Guide coordinates with the Design Contractor Guide and other Water Authority manuals and documents.

   1.2. Chapter 2 – Transmission Pipelines

   Describes requirements for design of Water Authority transmission pipelines, including materials, methods of jointing, inline valves and flow meters, venting and draining, instrumentation and control and other appurtenances.

   1.3. Chapter 3 – Pump Stations

   Describes requirements for design of Water Authority pump stations, including pump types and selection, control valves, flow meters, buildings and other structures, instrumentation and control, and other appurtenances.

   1.4. Chapter 4 – Flow Control Facilities

   Describes requirements for Water Authority above-ground and below-ground flow control facilities, including flow meter types and requirements, control valve types and requirements, buildings, underground vaults, instrumentation and control, and other appurtenances.

   1.5. Chapter 5 – Seismic Design Criteria

   Describes seismic design criteria applicable to Water Authority pipelines, flow control facilities, pump stations, and other facilities.

   1.6. Chapter 6 – SCADA and Instrumentation & Control

   Describes SCADA and Instrumentation & Control requirements applicable to Water Authority pipelines, flow control facilities, pump stations, and other facilities.

1.3.2 Engineering Disciplines

1. Where appropriate, Chapters 2, 3, 4, 5 and 6 include related guidelines for the disciplines listed below. Other disciplines may be addressed as well.

   1.1. Civil

1.2. Structural

1.3. Architectural

1.4. Landscaping and irrigation

1.5. Electrical

1.6. Instrumentation and Control

1.7. SCADA (Supervisory Control and Data Acquisition)

1.8. Mechanical Equipment, piping and plumbing, and HVAC (Heating, Ventilating, and Air Conditioning)

1.9. Hydraulics

1.10. Corrosion

1.11. Miscellaneous

1.3.3 Chapter Layout

1. Each chapter of the Facility Design Guide is composed of sections as illustrated in Figure 1-1.

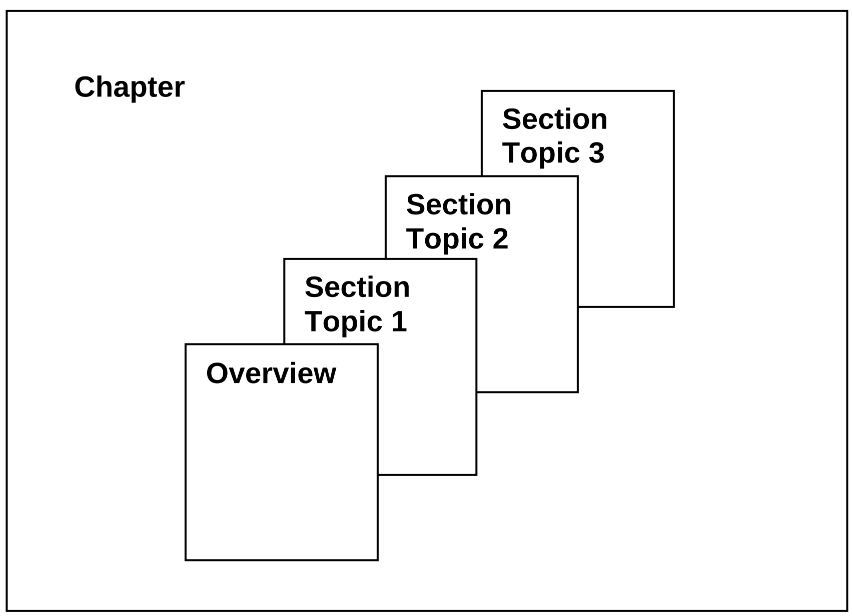

Figure 1-1: Chapter Layout

2. An overview is provided for each chapter, identifying the specific sections within that chapter. Each section in the chapters is a major chapter topic, and the blocks of information provided within each section are the chapter subtopics.

Chapter 2 Transmission Pipelines

Overview

Purpose

This chapter presents the Water Authority general requirements for design of pipelines and pipeline appurtenances.

Topics

This chapter is composed of the following topics:

2.1 Introduction

2.1.1 General

This chapter outlines the standards that shall be followed in the design and construction of Water Authority pipeline projects. These standards cover the following items:

- Pipe alignment (horizontal and vertical).
- Pipe materials.
- Linings and coatings.
- Pipe fittings (wyes, tees, etc.).
- Pipe jointing.
- Pipe special connections (e.g., connection to other pipes and structures).
- Thrust restraint.
- Special crossings (e.g., freeways, highways, railroads, etc.)
- Pipeline appurtenances including:
    - Isolation and control valves, valve actuators, and associated structures.
    - Air valve assemblies and associated structures.
    - Blowoff and pump well and associated structures.
- Pipe hydraulic design and transient flow analysis.
- Pipe installation and layout.
- Pipe trench (bedding, backfill, etc.).
- Trenchless pipe construction.
- Pipeline assessment.
- Pipeline instrumentation and control (I&C).

2.1.2 Standards and Guidelines

In several sections of this chapter, the Design Contractor is required to use and specify Water Authority Standard Documents including standard specification sections and standard drawings. In all cases, the Design Contractor shall verify the adequacy of these standard documents to the project specifics. The Design Contractor shall review and propose changes to the Water Authority documents, per project needs and shall follow the procedure outlined in Chapters 1 and 14 of the Design Contractor Guide (Design Manual – Volume One; ESD-160) in proposing and requesting changes.

It is to be noted that the Water Authority standards are usually higher than AWWA standards, which are considered by the Water Authority as minimum requirements. Whenever using an AWWA standard, the

Design Contractor shall confirm that no higher standard is required by the Water Authority Standard Specifications and/or Drawings.

A. Water Authority Standards and Guidelines

The main Water Authority standards and guidelines for use in pipeline design and construction include:

- General Conditions and Standard Specifications (hereinafter referred to as —GC&SS"). Refer to Attachment 2-1 for the cover page of the GC&SS.
- Standard Drawings & Standard Details (hereinafter referred to as SD&SD). Refer to Attachment 2-2 for the cover page of SD&SD.
- Cathodic Protection Guide Drawings. Refer to Attachment 2-3 for the cover page of the Cathodic Protection Guide Drawings.
- Electrical/Instrumentation Guide Drawings. Refer to Attachment 2-4 for the cover page of the Electrical/Instrumentation Guide Drawings.

B. National Standards and Guidelines

Several national standards and guidelines are available for use in pipeline design and construction including:

- Cal-OSHA (California Occupation Safety and Health Administration/Act) standards, as applicable.
- C200, AWWA Standard for Steel Water Pipe – 6 In. (150 mm) and Larger.
- C203, AWWA Standard for Coal-Tar Protective Coatings and Linings for Steel Water Pipelines – Enamel and Tape – Hot-Applied.
- C205, AWWA Standard for Cement-Mortar Protective Lining and Coating for Steel Water Pipe – 4 In. (100 mm) and Larger – Shop Applied.
- C206, AWWA Standard for Field Welding of Steel Water Pipe
- C207, AWWA Standard for Steel Pipe Flanges for Waterworks Service – Sizes 4 In. Through 144 In. (100 mm through 3,600 mm).
- C208, AWWA Standard for Dimensions for Fabricated Steel Water Pipe Fittings.
- C209, AWWA Standard for Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines.
- C214, AWWA Standard for Tape Coating Systems for the Exterior of Steel Water Pipelines.

- C215, AWWA Standard for Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines.
- C217, AWWA Standard for Cold-Applied Petrolatum Tape and Petroleum Wax Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Buried or Submerged Steel Water Pipelines.
- C219, AWWA Standard for Bolted, Sleeve-Type Couplings for Plain-End Pipe.
- C221, AWWA Standard for Fabricated Steel Mechanical Slip-Type Expansion Joints.
- C224, AWWA Standard for Two Layer Nylon-11 Based Polyamide Coating System for Interior and Exterior of Steel Water Pipe, Connections, Fittings, and Special Sections.
- C602, AWWA Standard for Cement-Mortar Lining of Water Pipelines In Place – 4 In. (100 mm) and Larger – In Place.
- C606, AWWA Standard for Grooved and Shouldered Joints.
- ASTM (American Society for Testing and Materials) standards, as applicable.
- AWWA M11, Steel Pipe—A Guide for Design and Installation.
- AWWA M27, External Corrosion—Introduction to Chemistry and Control.
- AWWA M29, Cleaning and Lining Water Mains.
- AWWA M44, Distribution Valves: Selection, Installation, Field Testing, and Maintenance.
- American Society of Civil Engineers (ASCE) Manual No. 89, *Pipeline Crossings.*
- ASCE Manual No. 46, Report on Pipeline Location.
- American Iron and Steel Institute (AISI) Steel Plate Engineering Data, Vol. 3, *Welded Steel Pipe.*

2.2 Pipeline Alignment

2.2.1 Horizontal Alignment

Preliminary pipeline horizontal alignment is generally developed during the project planning or predesign phase and is presented in the project Planning Study or Predesign Report. If a horizontal preliminary alignment is available, the Design Contractor shall review and recommend the necessary changes to accommodate the development of design. Such changes may be triggered by utility conflicts, constructability issues, environmental issues, permitting requirements, easement/right-of-way needs, etc. Refer to Chapters 5, 7, and 10 of the Design Contractor Guide for more information.

The pipeline horizontal alignment may need to be chosen to:

- Avoid vertical high points or to conform to other requirements of the hydraulic transient analysis. Refer to Section 2.7.4 for additional information.
- Avoid, if possible, running parallel to sewer or reclaimed water lines.

The Design Contractor shall submit the proposed horizontal alignment changes to the Design Manager for approval prior to their incorporation into the project design. If no horizontal alignment is available, the Design Contractor shall develop one for the project. The horizontal pipeline alignment shall be detailed and finalized during subsequent design phases of the project.

Drafting of pipeline horizontal alignment drawings shall be per the requirements stated in the Water Authority Drafting Manual (ESD-120; refer to Attachment 2-5 for the cover page of the Manual). Elements of the horizontal alignment shall be as indicated in Section 2.2 (Pipelines Plans and Profiles) of ESD-120 and include:

- Pipeline material and size.
- Pipeline lining and coating.
- Pipeline station on pipe centerline.
- Pipeline horizontal curve data.
- Pipeline appurtenances.
- Easement limits.

2.2.2 Vertical Alignment

The Design Contractor shall develop the pipeline vertical alignment (profile) that minimizes construction costs while still meeting the needs and design intent of the project. Abrupt vertical grade breaks resulting in upward thrust shall be avoided. Whenever practical, use a depth of one pipe diameter for large pipes and two pipe diameters for small pipes. Minimum cover for pipelines is discussed in Section 2.6 of this chapter.

Factors to be considered in vertical alignment design 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 and permitting requirements.
- Construction requirements.
- Maintenance requirements.

The Design Contractor shall submit the proposed vertical alignment to the Design Manager for approval prior to their incorporation into the project design. Vertical pipeline alignment shall be detailed and finalized during subsequent design phases of the project.

Drafting of pipeline vertical alignment drawings shall be per the requirements stated in the Water Authority Drafting Manual (ESD-120). Elements of the vertical alignment shall be as indicated in Section 2.2 (Pipelines Plans and Profiles) of ESD-120 and include:

- Stations and invert elevations at grade breaks with the pipeline stationing representing the centerline of the pipe (refer to Chapter 6 of the Design Contractor Guide for information on selecting the appropriate datum for the project).
- Pipeline shell thickness.
- Pipeline vertical curve data.
- Pipeline joint type.
- Lining and coating material and thickness.

2.2.3 Horizontal and Vertical Curves

It is usually advantageous to lay out a transmission pipeline on a curve instead of a series of straight chords. Curved alignment offers the potential advantages of better hydraulics, reduced right-of-way requirements, and a lower cost.

Curves for welded steel pipes are accomplished using the allowable pipe deflection. Refer to the ―Steel Pipe" section of the GC&SS (see Attachment 2-1) for more discussion and limitations on pipe deflection.

In some cases beveled pipe joint special sections are used to provide angular changes beyond the allowable deflection. Refer to the ―Steel

Pipe” section in the GC&SS (see Attachment 2-1) for more discussion and limitations on pipe beveling. Stresses resulting from beveling the end of a pipe in excess of the amount specified in the GC&SS shall be evaluated and included in the pipe shell and joint design.

In some cases fabricated bends are used to provide the desired angular change in the pipeline alignment. Refer to the —Steel Pipe” specification section in the GC&SS (see Attachment 2-1) for more discussion and limitations on fabricated bends. The radius of curvature (R) for the axis of fabricated bends shall be at least equal to 2.5 times the inside pipe diameter (D). Stresses (including stress intensification factors) at miters of fabricated bends shall be evaluated and included in the pipe shell design.

2.2.4 Utility Separations

Pipeline separation from sewer mains shall, as a bare minimum, adhere to State of California Department of Health Services (CA-DHS) criteria. The CA-DHS requires a 10-feet minimum separation (wall to wall) between parallel sewer mains and water-conveying pipelines for most installations. Refer to CA-DHS standards for details. Sewer mains crossing water pipelines shall be sleeved across the right-of-way of the pipeline. Reclaimed water mains shall be treated as sewer mains for separation purposes.

A minimum 4-foot separation from the edge of the proposed trench section is recommended between water-conveying pipelines and other utilities (e.g., storm drains, gas mains, etc.). Verify that the separation distance is sufficient to ensure the lateral soil support of the Water Authority Pipeline.

Special construction methods and materials are necessary whenever the minimum horizontal and vertical separations cannot be maintained. In selecting the special construction method and design, the Design Contractor shall consider design factors such as external forces, impacts of groundwater, soil strength characteristics, and electrolytic interaction between pipelines’ cathodic protection systems. Approval by CA-DHS is mandatory in cases where special construction methods and materials are required.

It is to be noted that no utilities are allowed to be located within the pipeline trench section. In most cases, this will result in clearance requirements considerably larger than the CA-DHS minimums.

2.2.5 Property Requirements

Land space requirements are usually determined during the project planning phase. During the project design phase, the Design Contractor shall precisely determine additional land space requirements, if needed, to safely install and maintain the pipeline.

Additional property requirements may be needed for deeper than usual pipelines, or pipelines located in canyons, ―open space" areas, and other areas with difficult accessibility. All property requirements shall be coordinated with the Water Authority Right of Way Section , as outlined in Chapter 7 of the Design Contractor Guide (Design Manual - Volume One; ESD-160).

Additional land space requirements may be needed to maintain the pipe appurtenances. The Design Contractor shall include provisions for access roads to all pipeline appurtenances (e.g. blowoffs, air valves, isolation valves, access manways, etc.). Access roads shall have a minium width of 14 feet with a two foot shoulder on each edge (overall 18 feet minimum). The materials used for access roads depend on the maximum slope and anticipated service conditions. The following table is provided as a guide.

Slope	Material	Notes
<15%	Aggregate base or native material	GC&SS, Section 02510
15-25%	Asphalt-concrete	3-inch minimum with base
>25%	Roughened Concrete	As approved by the Water Authority

The minimum inside radius of curvature for access roads shall be 50 feet. Include in the design of access roads appropriate drainage features to control stormwater and prevent the depositing of road base onto adjacent properties. For additional requirements, refer to Section 02510, Access Roads in the GC&SS (see Attachment 2-1).

2.3 Pipe Materials, Linings, and Coatings

2.3.1 Pipe Materials

An array of pipe materials is currently available in the market. The choice of a particular pipeline material is usually a function of project type and nature, cost (initial and maintenance), pressure requirements, owner requirements, operation and maintenance requirements, etc.

The Design Contractor shall use and specify the materials outlined in the specification sections in the GC&SS (see Attachment 2-1) in the design of pipelines. The Design Contractor shall follow the procedures outlined in Chapters 1 and 14 of the Design Contractor Guide in using and proposing changes to the GC&SS.

Pipeline material in use by the Water Authority varies according to the purpose of the pipe. The following are the materials used by the Water Authority.

A. Steel Pipe

Steel pipes and fittings are used by the Water Authority in all new transmission pipelines and sometimes used in blowoff discharge piping and other appurtenances. The Design Contractor shall use and reference in the Contract Documents the steel pipe specifications outlined in the GC&SS (see Attachment 2-1). Applicable specification sections to steel pipeline design in the GC&SS include:

- Steel Pipe.
- Installation of Pipe.
- Disinfection of Piping.
- Pressure Testing of Piping.
- Piping Schedule and General Piping Requirements.
- Pipe Hangers and Supports.

B. Ductile Iron (DI) Pipe

DI pipes and fittings may be used by the Water Authority in blowoff discharge piping. The Design Contractor shall use and reference in the Contract Documents the –Ductile Iron" specifications outlined in the GC&SS (see Attachment 2-1).

C. PVC Pipe

PVC pipes and fittings may be used by the Water Authority in blowoff discharge piping. The Design Contractor shall reference appropriate standards such as the Standard Specifications for Public Works Construction (Green Book) or regional standards such as the Water Agencies Standards (www.sdwas.com).

2.3.2
Pipe Linings and Coatings

A. Linings

Linings are materials applied to the pipe interior for corrosion protection. Lining materials and requirements for pipe lining are outlined in the GC&SS (see Attachment 2-1). Applicable specification sections to pipe lining in the GC&SS include:

- Steel Pipe.
- Ductile Iron Pipe.
- Plant-Applied Cement Mortar Lining.
- Fusion-Bonded Epoxy Lining and Coating.
- Field-Applied Cement Mortar Lining.
- Polyurethane Lining and Coating.

The Design Contractor may propose changes to the GC&SS (see Section 2.1 for more information on change procedure).

Large steel pipelines are normally cement-mortar lined. Large pipelines may be polyurethane or epoxy lined, if they are subjected to frequent wet/dry cycles, to avoid cracking of cement mortar lining. Small pipelines may be polyurethane or epoxy lined, if needed, to preserve hydraulic characteristics. Polyurethane and epoxy linings may also be used if velocity of water in the pipeline is greater than the maximum limit for cement-mortar lining.

Where pipes are cement mortar lined, hoop circumferential stresses in the pipe shell due to internal and external pressure and resultant strains in the cement mortar lining shall be limited to thresholds that will minimize the potential for cracking and/or delamination of the lining and ensure its design life under all operating scenarios

B. Coatings

Coatings are materials applied to the exterior of the pipe for corrosion protection. When selecting coating materials, the Design Contractor shall consider:

- Capability of the material to perform the desired function in a safe and economical manner.
- Material deterioration and its satisfactory operation over the design life of the pipeline.
- Capability of the selected material to withstand the aggressive environment to which it will be exposed.

Coating materials and requirements for pipe coating are outlined in the GC&SS (see Attachment 2-1). Applicable specification sections to pipe coating in the GC&SS include:

- Cement Mortar Coating.

- Coal-Tar Coating.
- Cold-Applied Plastic Tape Coating.
- Fusion-Bonded Epoxy Lining and Coating.
- Polyurethane Lining and Coating.
- Painting and Coating.

The Design Contractor may propose changes to the GC&SS (see Section 2.1 for information on change procedure).

Reinforced cement mortar coating for buried steel pipes shall be a minimum of one-inch thick on top of a cold-applied tape wrap. Coatings for steel surfaces exposed to the atmosphere shall be epoxy or polyurethane.

DI pipe and fittings shall be coated per requirements outlined in ―Dctile Iron" specification section in the GC&SS (See Attachment 2-1).

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2.4 Pipe Fittings, Jointing, and Special Connections

2.4.1 Pipe Fittings

Pipe fittings include all special pieces, such as wyes, elbows (5° up to 90°), tees, and reducers.

A. Steel Pipe Fittings

Refer to the –Steel Pipe” specification section in the GC&SS (see Attachment 2-1) for requirements of steel pipe fittings. Steel fittings shall comply with ANSI/AWWA C-208.

Fittings for welded steel pipe shall be designed in accordance with standard practices as stated in AWWA M11 (Steel Pipe – A Guide for Design and Installation) and other AWWA standards.

Welded steel pipe elbows shall have a maximum deflection of 15 degrees on miter ends. As such, elbows of 0 to 22.5 degrees shall be fabricated in two welded pieces; 22.5 to 45 degrees shall be fabricated in three welded pieces; 45 to 60 degrees shall be fabricated in four welded pieces; and 60 to 90 degrees shall be fabricated in five welded pieces. The evaluation of pipe stresses within the elbow shall include the hoop stress intensification factor resulting from the geometry of the elbow.

Some welded steel pipe fittings such as tees and wyes may require reinforcement using wrapper plates or crotch plates. The Design Contractor shall provide calculations, per AWWA M11 procedure, to determine the required increase in wall thickness or crotch plates in steel pipe fittings.

Wall thickness of steel pipe fittings shall conform to requirements outlined in AWWA M11 and other AWWA standards. Coating and lining shall be per Section 2.3.

B. Ductile Iron Fittings

Refer to the –Ductile Iron Pipe” specification section in the GC&SS (see Attachment 2-1) for requirements of DI pipe fittings.

2.4.2 Pipe Jointing / Coupling

Several methods are available for connecting pieces of pipe together. The choice of a particular jointing method is generally a function of pipe material size, pressure requirements, and thrust forces, among other factors.

The following are some of the most commonly used pipe jointing types with their restraining and misalignment characteristics:

1. **<u>Flanged Joints:</u>**

- Complete restraint against all movement.
- Limited tolerance for misalignment.

2. **Welded Joints:**

- Complete restraint against all movement.
- Tolerance for misalignment varies with welding as follows:
    - Butt weld - None except by trimming pipe ends.
    - Lap weld – Limited.
    - Butt strap – Limited.

3. **Restrained Flexible Sleeve Coupling Joints:**

- Restraint against axial movement with allowance for limited angular and translational movement.
- Good allowance for misalignment.

The following are specific requirements for different pipe materials used by the Water Authority. The Design Contractor shall refer to Water Authority Standard Specification Section 15122 (Pipe Couplings and Expansion Joints) for more information.

A. Steel Joints

Steel pipe jointing can be done with flanges, welds, or restrained flexible sleeve coupling depending on the longitudinal force, the type of adjoining end (another piece of pipe, fitting, valve, flowmeter, etc.), and the need to easily disassemble the joint. The Design Contractor shall refer to the —Steel Pipe” and —Installation of Pipe” specification sections in the GC&SS (see Attachment 2-1) for requirements of steel pipe joints.

Depending on the longitudinal stresses caused by forces due to thrust or due to Poisson’s effect and temperature, pipeline joints may be welded or flanged. The procedure for design of pipe joints to resist longitudinal forces is discussed in Section 2.7. The Design Contractor shall refer to Chapter 5, Seismic Design, for design guidelines of steel pipes and joints subjected to traveling waves and ground deformations as well as where the pipes cross active faults, liquefaction zones, or landslide hazards.

Flanged joints shall comply with the GC&SS (see Attachment 2-1). Flanges shall be selected in accordance with design pressure, test pressure, surge pressure, and the drilling pattern of the adjoining equipment (i.e., valves).

Welded joints may be lap welded, butt welded, or butt-strap welded. Field welding shall conform to the —Installation of Pipe” section in the GC&SS (see Attachment 2-1). The Design Contractor shall refer to the SD&SD for welding details of steel pipe joints (refer to Attachment 2-2).

Single and double welded lap, butt, and butt-strap joints are shown in the ―Welded Steel Pipe Details I, II, and III" drawings in the SD&SD.

The following are general requirements and allowable forces for each type of weld:

1. **Lap Welds**

Preparation of lap-welded joints (commonly referred to as bell and spigot joints) shall be in accordance with the GC&SS (see Attachment 2-1). Shaping the pipe bell with an expanding press or by moving the pipe axially over a die is acceptable. However, shaping the pipe bell using offset rollers which move around the pipe end shall not be permitted.

- **The stresses within the lapwelded joint shall be computed by the Design Contractor. If the stresses are greater than the allowable stresses, three options or a combination of these options shall be considered.** Increase the wall thickness.
- Use a double lap weld (one weld inside and one weld outside the pipe) instead of a single lap weld with a seal weld.
- Use a butt weld instead of a lap weld.

2. **Butt Welds**

Full penetration butt joint welds with appropriate inspection and nondestructive testing can resist stresses equal to stressesresisted by the pipe wall.

3. **Butt Strap Welds**

Butt strap joints may be necessary on closure sections or for connecting new to existing pipelines. Refer to ―Installation of Pipe" specification section in the GC&SS (see Attachment 2-1) for additional information. Closure joints, as recommended by AWWA M11 Chapter 8 (Pipe Joints), shall be included in the design of steel pipelines to minimize the effect of contraction due to temperature variation.

. The stresses within the butt-strap joint shall be computed by the Design Contractor. If the stresses are greater than the allowable stresses, consider increasing the wall thickness and/or using a wider butt-strap.

B. Ductile Iron Joints

DI pipe jointing can be done with flanges, mechanical joints, grooved or shouldered joints. The Design Contractor shall refer to the ―Ductile Iron Pipe" specification section in the GC&SS (see Attachment 2-1) for requirements of DI pipe joints.

2.4.3 Pipe Special Connections

A. Structure Penetrations

Design considerations taken because of pipe penetrations into structures (e.g., vaults, buildings, etc.) include:

- Structure special reinforcement.
- Pipe support.
- Sealing to prevent water from moving into or out of the structure.
- Eliminating steel reinforcement in structure walls coming in contact with the pipe which may result in a short to the cathodic protection system.

The Design contractor shall use and specify the following Water Authority documents in structure penetrations:

- ―Wall Pipes, Seep Rings, and Penetrations” specification section in the GC&SS (see Attachment 2-1).
- ―Structural Details I” drawing in the SD&SD (see Attachment 2-2).

In case of using structural walls to restrain the pipe, the Design Contractor shall size and use anchor rings per AWWA M11 requirements.

B. Connection to other Pipes

The Design Contractor shall provide the appropriate design suitable for connecting new pipelines to existing pipelines. Pipe condition , pipe size, pipe materials, cathodic protection isolation, and the maximum time allowable for making the pipe connection, are all factors that shall be considered when designing connections to existing pipelines.

A shutdown to Water Authority operations may be required for connections to existing pipes. Therefore, all connections to existing pipes shall be coordinated with the Water Authority Operations and Maintenance Department.

C. Dismantling Joints

These types of Joints are used for easy dismantle of the equipment fitted in the pipe. They are used before valves and other pieces of equipment. The Design Contractor shall refer to the ―Pipe Couplings and Expansion Joints” specification section in the GC&SS (see Attachment 2-1) for additional requirements on dismantling joints.

2.5 Pipeline Appurtenances

2.5.1 General

Pipeline appurtenances may include isolation valves, control valves, air valve assemblies, flowmeters, blowoff stations, outlets, and access structures. Attachment 2-6 provides a summary of general design criteria for pipeline appurtenances. The following sections outline additional requirements.

2.5.2 Valves

The location, size and type of valve shall be as outlined in the below requirements and as recommended by the Design Contractor. Valve specifications shall follow the —Valves” specification section in the GC&SS (see Attachment 2-1). The Design Contractor shall follow the procedures outlined in Chapters 1 and 14 of the Design Contractor Guide in using and proposing changes to the GC&SS. Unless otherwise specified, all valves shall be minimum ANSI Class 150.

A. Isolation and Control Valves

Isolation valves constitute the majority of inline valves in the Water Authority pipeline system. However, control (throttling) valves are sometimes used depending on the project requirements. Valves commonly used in Water Authority pipeline projects include:

- For isolation – Mainly metal or rubber seated, as applicable, butterfly valves, or ball valves. Plug valves may also be used.
- For flow modulation (throttling) – Mainly plug valves. The Design Contractor may recommend other types of valves (e.g., sleeve, cone, and plunger) depending on the application.

Plug valves have generally four patterns (short, venturi, full bore, and regular). The Design Contractor shall specify the pattern that is most appropriate for the project. Venturi patterns are preferred unless another pattern is deemed appropriate for the project.

If mainline valves are considered for the project, they shall be supported by a complete hydraulic-transient analysis documenting no negative impact (refer to Section 2.7.4 for more information). For safety during maintenance operations, the Design Contractor shall coordinate with the Water Authority Operations and Maintenance Department in determining means for isolating pipe sections to achieve double valving requirement. This may entail adding two valves at the same general location.

Valves shall be properly sized. The Design Contractor shall provide calculations demonstrating that the valve will not experience flashing or cavitation problems under all operating conditions. Refer to Attachment 2-6 for additional design requirements

The Design Contractor shall select the valve flow characteristics (quick opening, linear, equal percentage) that best match the control and the hydraulic-transient requirements (refer to Section 2.7.4 for more information). The selection shall be based on installed (i.e., actual operating conditions), and not inherent (i.e., lab controlled conditions), pressure conditions.

The majority of isolation valves are manually operated. A few isolation valves and control valves are operated with electric actuators coupled with hand-operated backup system. The Design Contractor shall refer to the “Electric Motor Actuators” specification section in the GC&SS (see Attachment 2-1) for requirements of electric actuators. Refer to Section 2.10 in this chapter for information on valve closing time requirements to avoid surge problems. Valves shall be chosen so as to have physical closing times that are at least as slow as the minimum time recommended in the hydraulic-transient analysis (refer to Section 2.7.4 for more information).

Isolation and control valves shall be connected to the main pipeline with flanges. For cathodic protection requirements, refer to Section 2.7.6. Isolation and control valves shall be equipped with a restrained flexible sleeve coupling (see Section 2.4.2), or dismantling joint (see Section 2.4.3) for proper installation and later maintenance.

Most inline valves are equipped with a valving system to allow for bypassing flow from one side of the valve to the other. This bypass valving system shall be equipped with manually-operated positive shutoff valves (e.g., plug, ball, etc.), thus allowing for the equalization of pressure on both sides of the valve before opening it. The Design Contractor shall investigate the need for a valve bypass system depending on pressures encountered at each valve in the project.

Isolation and control valves shall be equipped with air valves (see Section 2.5.2) on their down-slope sides. Valves shall also be equipped with blowoffs (refer to Section 2.5.3) on their upslope sides. This is to allow for proper drainage and later refilling of isolated sections of the pipeline.

Valves connected to a pipeline being tested shall not be subjected to test pressures greater than the manufacturer’s recommendations. The Design Contractor shall consider the testing and surge pressures, to which the pipe may be subjected to, in specifying the valve pressure class.

B. Air Valve Assemblies

Air valve assemblies shall be used to provide adequate ventilation during the filling and draining of pipelines, to permit the release 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. Wherever possible, the pipeline shall be designed such that air valves are not the sole means of protection against surge conditions (refer to Section 2.7.4 for more information). The Design Contractor shall refer to the ―Air-Release and Vacuum-Relief Valves" specification section in the GC&SS (see Attachment 2-1) for requirements of air valve assemblies.

The locations of air valves shall be generally determined by the vertical alignment (profile) of the pipeline system. In general, air valves shall be installed at high points and at long downsloping gradients. Sometimes, air valves shall also be installed on the low side of pipelines to allow for air intake and release from that portion of the line. Combination air and vacuum valves shall be placed downslope of a permanently closed valve separating two different pressure areas. Whenever practical, air valves shall be located with pipeline access manways (refer to Section 2.5.3).

Air valve assemblies shall be installed within appurtenant right-of-way or street type structures along the pipeline alignment. The Design Contractor shall refer to the following drawings in the SD&SD (see Attachment 2-2) for standard structure assemblies and details for air valve assemblies located with pipeline access manways:

- Manway & Air Release Valve (Right-of-Way Type).
- Manway & Air Release Valve (Street Type).
- Manway Air Vacuum & Air Release Valve (Right-of-Way Type).
- Manway Air Vacuum & Air Release Valve (Street Type).
- Vault Details I.
- Vault Details II.

The following air/vacuum relief valve configurations shall be used to alleviate the above mentioned adverse conditions:

- Air release valve (AR).
- Air vacuum valve (AV).
- Multiple valves (AV and AR).
- Combination type air release/air vacuum (AR/AV).

Air vacuum valves shall be capable of venting large quantities of air while the piping is being filled and allow a sufficient amount of 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.

A typical AR/AV type assembly consists of parallel combination air release/air vacuum valves, isolation valves, and a slow closing check valves. AR/AV valves are attached to a 30" manway outlet on the main transmission pipeline via a reducing companion flange and an isolation valve. All AR/AV valves shall be connected to the 30” manway with a flanged steel connection that is welded to the main pipe. The isolation valve is provided to allow easy removal for maintenance.

The Design Contractor shall provide the necessary calculations for sizing air valve assemblies. Air and vacuum valves shall be sized for the air evacuation rate associated with maximum water discharge rates from influencing blowoffs 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 specification shall state the design pressure range for each air valve assembly. The Design Contractor shall also refer to Attachment 2-6 for additional design requirements of air-valve assemblies.

2.5.3 Other Appurtenances

A. Flowmeters

The Water Authority utilizes a variety of flowmeters on its pipelines. When required by the project, the following types of flowmeters may be used:

- Venturi meters. Mainly used in flow control facilities/service connections.
- Ultrasonic meters (Transit time – Spool piece type). Mainly used on transmission pipelines.
- Magnetic meters. Not currently in use by the Water Authority. Prior approval is required to use this type of flowmeters.

The Design Contractor shall refer to Chapter 4 of this Guide for extensive discussion on flowmeters. All flowmeters on pipelines shall be accessible and housed within a vault structure.

The Design Contractor shall include in the design drawings and specifications the requirements for electrical isolation of the flowmeter from buried pipe using insulated flanges, dielectric unions, independent electrical grounds, and electrical DC-AC decouplers.

B. Blowoffs

Blowoffs shall be located at low points (i.e., at grade changes) along the vertical alignment of pipelines, at critical flushing points, and at in-line valves. Access location to the blowoff shall be within five feet of the low point or special arrangements shall be made to facilitate pumping water left in the pipeline below the drain-pipe invert level. The size of the blowoff depends on:

- Size of the pipeline.
- Reach of the pipeline to be drained.
- Number of blowoffs within the pipeline reach.
- Distance between blowoffs.

Blowoffs shall be sized and located to drain their influential reach of a pipeline in approximately 8 hours. If it takes longer than 8 hours to drain, the blowoff shall be upsized, or additional blowoffs shall be added to the pipeline. Refer to Attachment 2-6 for additional blowoff design criteria. The Design Contractor shall use and specify the following standard details in the SD&SD (see Attachment 2-2) for blowoffs:

- Blowoff Plan & Sections (Right-of-Way Type).
- Blowoff Plan & Sections (Street Type).
- Energy Dissipator and River Crossing Details.

The receiving system downstream of the blowoff (e.g., storm drain) shall be evaluated as to its suitability (size, etc.) to accept the maximum flow from all affecting blowoffs. The Design Contractor shall be cognizant that certain mitigating conditions, mandated by the CA-RWQCB (Regional Water Quality Control Board), apply to the discharge of treated potable water into storm drains and natural drainage courses, and shall consider those conditions (e.g., erosion potential, dechlorination requirement) when evaluating the downstream receiving system.

The blowoff discharge point shall be located out of traveled way and be housed in an approved structure/enclosure. Blowoff stations may include:

- Pumping chamber to permit further withdrawal of water below the normal blowoff surface elevation.
- Energy dissipaters at the discharge point to control erosion of the flow receiving system.
- Stilling basin to facilitate dechlorination of treated water.

The Design Contractor shall refer to the ―Energy Dissipater and River Crossing Details” in the SD&SD (see Attachment 2-2) for more information on blowoff energy dissipaters at discharge points.

C. Pump Wells

In case blowoffs can not be accommodated, the Design Contractor shall use pump wells to facilitate drainage of pipelines. The Design Contractor shall use and specify the following standard details in the SD&SD (see Attachment 2-2) for pump wells:

- Pump Well Plan & Sections (Right-of-Way Type).
- Pump Well Plan & Sections (Street Type).

D. Outlets

An outlet is simply a branch off the pipeline, or a specified diameter tee to allow for future pipeline connections without taking the pipeline out of service. Outlets for future connections shall have an isolation valve followed by a short spool pipe and a blind flange or a dished head piece. Usually the isolation valve is housed within a vault structure. See Attachment 2-6 for additional design criteria.

Outlets may require reinforcement using using collars, wrapper plates or crotch plates.. The Design Contractor shall provide calculations, per AWWA M11 procedure, to determine the required increase in wall thickness or crotch plates in steel pipe outlets.

Thrust restraining shall be considered at all outlets. Refer to Section 2.7.5 for more information.

E. Cutoff Walls

In unpaved areas with steep terrain, pipeline backfill is protected from erosion by cutoff walls. An example is shown in the San Diego Regional Standard Drawings (See Attachment 2-7 for the cover page). The spacing of cutoff walls is a function of pipe slope. The Design Contractor shall specify concrete cut-off walls on slopes exceeding 30 percent (16.7 degrees). Refer to —Installation of Pipe” specification section in the GC&SS (see Attachment 2-1) for additional requirements for cutoff walls.

The Design Contractor shall:

- Include in the design drawings and specifications the requirements for electrical isolation of the pipeline from any rebar or other metallic objects in the cutoff walls.
- Add notes that refer to a testing procedure in the cathodic protection specifications to verify electrical isolation during the construction phase of the project.

F. Access Manways

Pipeline access manways shall:

- Have a minimum inside diameter of 30 inches.
- Be combined with air valve assemblies (refer to Section

2.5.2).

- Be combined with blowoffs (refer to Section 2.5.3).
- Be included at all major outlets.

Access-manway spacing depends on the topography along the pipeline alignment. Access manways may be of the buried type if installed for access during construction. See Attachment 2-6 for additional criteria used in the design of access manways.

The Design Contractor shall use and reference the following Water Authority documents for additional design criteria and details of access manways:

- The —Steel Pipe” specification section in the GC&SS (see Attachment 2-1).
- The SD&SD (see Attachment 2-2) drawings including the street and right-of-way types manways, and vault structural details.

2.6 Pipe Trench

2.6.1 General

The Design Contractor shall use the ―Installation of Pipe” and ―Earthwork” specification sections in the GC&SS (see Attachment 2-1) in designing and specifying construction requirements for pipe trenches. In addition, the Design Contractor shall refer to the ―Trench Section and Pipe Stulling Details” drawing in the SD&SD (see Attachment 2-2) for additional requirements.

The Design Contractor shall review the Water Authority GC&SS (see Attachment 2-1), the SD&SD (see Attachment 2-2), and Manuals and shall amend them as necessary to meet specific project requirements for pipe handling, bedding, backfill, and surface restoration. Any deviation from Water Authority standards shall be initiated per requirements of Chapters 1 and 14 of the Design Contractor Guide.

2.6.2 Pipe Trench Width

The Design Contractor shall determine the appropriate trench width by considering the pipe size, depth of cover, type of soil material to be removed, the space required to install the pipe and operate construction equipment, OSHA requirements, etc. The trench shall be as wide as necessary for proper installation of the pipe and backfilling, and shall provide adequate room to meet safety requirements for workers.

For rectangular trenches and embankment conditions, the width of the trench affects the dead load calculations used in pipeline thickness determination. The Design Contractor shall ensure that the pipe wall design is adequate to meet loading requirements for the actual trench configuration. Refer to Section 2.7.2 for the determination of pipe wall thickness on the basis of external loading.

2.6.3 Pipe Trench Depth

Pipe trench depth consists of the pipe bedding zone, pipe zone, trench zone, and pavement zone. Refer to the ―Trench Section and Pipe Stulling Details” drawing in the SD&SD (see Attachment 2-2) for additional information.

A. Pipe Bedding and Backfill (Pipe Zone)

The minimum depth of bedding material beneath the pipe invert shall be based on the expected unevenness of the trench bottom and the diameter of the pipe. Typically six (6) inches is adequate; however, the Design Contractor shall design the appropriate thickness to be used according to the trench conditions. When unstable soils are encountered and over-excavation is required, foundation stabilization material shall be specified for use at the base of the trench.

Above the pipe bedding is the pipe zone, which is considered to include the full width of the excavated trench from the bottom of the pipe to a point at least 12 inches above the top outside surface of the barrel of the pipe. Particular attention shall be given to the pipe zone to ensure that firm support is provided to prevent any pipe lateral movement during final backfill of the pipe zone. Using controlled low strength materials in this area can mitigate this concern. Hand tamping with approved tamping bars, supplemented by compacting with mechanical tamping equipment, is allowed.

The Design Contractor shall review the trench backfill provisions in the Water Authority Standard Specifications and Drawings, and modify the provisions, if necessary, to meet the requirements of the project

B. Trench Zone

Trench zone is the zone just above the pipe zone up to the bottom of ground-surface restoration layers. To optimize reduction from HS-20 surface loads, the minimum depth of cover over the top of a pipeline is recommended to be five (5) feet. In no case shall cover depth be less than three (3) feet for pipe diameters 24” through 96”, and four (4) feet for pipe diameter larger than 96”. In all cases, the design shall be accompanied by a complete load and safety calculations.

C. Ground-Surface Restoration (Pavement Zone)

Surface restoration shall be according to the requirements of the agency with jurisdiction over the project area.

2.6.4 Construction Issues

The method and equipment used to excavate a trench are typically left to the Construction Contractor as means and methods. However, the project specification shall include provisions for corrective measures to be used by the Construction Contractor if allowable trench widths are exceeded, except when safety requirements dictate a wider trench.

An adequate shoring safety system shall be designed by the Construction Contractor for trenches exceeding five (5) feet in depth or trenches in unstable soil of any depth. The safety system shall meet the requirements of applicable local and state construction safety orders and federal requirements. Contract Documents shall require that the Construction 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.

Water Authority pipeline projects may be constructed next to or adjacent to existing Water Authority pipelines. In case of working in the vicinity of existing Water Authority pipelines, the Design Contractor shall refer to and specify requirements outlined in the Engineering Guidelines for Review of Proposed Right of Way Encroachments (ESD-170; see Attachment 2-8).

2.7 Pipeline Design

2.7.1 General

The design of pipelines and their appurtenances shall be the responsibility of the Design Contractor. Specials (e.g., outlets, bulkheads) may be designed by the pipe manufacturer. The Design Contractor shall be cognizant to the manufacturing practices of the pipe manufacturer and accommodate for such practices in the design. The following sections describe the different pipeline design parameters and considerations.

2.7.2 Pipe Wall Thickness

The design procedures used in determining pipeline wall thickness shall consider the following parameters and loading conditions:

- Pipe material.
- Maximum allowable deflection.
- Minimum wall thickness.
- External loads.
- Internal loads.
- Construction conditions.
- Longitudinal thrust forces caused by valves or changes in alignment.
- Longitudinal stresses resulting from changes in temperature.
- Combined stresses, defined as the cumulative axial/normal and bending stresses along the same axis. Seismic loads and deformations.
- Longitudinal stresses due to Poisson's effect.
- Equivalent stresses determined in accordance with Hencky-Von Mises' theory for combination or orthogonal principal stresses.

The selected pipe wall thickness shall be the greatest of the thicknesses computed for the parameters/loading conditions listed above.

2.7.2.1 Minimum Wall Thickness

The minimum wall thickness shall be the greatest of the following:

- Provides a maximum diameter/thickness ratio (D/t) of 200 or a minimum wall thickness of 3/8-inch for pipes 42-inch in diameter and larger, whichever is greater.
- For handling and internal loading, wall thickness shall be calculated by the Design Contractor based on AWWA

standards. An adequate factor of safety shall be included.

2.7.2.2 Design for External Loads

The common external loads on a pipeline include dead loads (the earth load and any improvements constructed above the pipe), live loads (caused by construction traffic and/or vehicular traffic traveling above the pipe), and hydrostatic and uplift pressures (from surrounding groundwater). Discussion on each of these sources of loads and loading scenarios are outlined below.

A. Dead Loads

Dead loads attributable to the weight of the backfill shall be the weight of the prism of soil with a width equal to the outside diameter of the pipe and a height equal to the depth of fill over the pipe, in accordance with AWWA M11 using the compacted and saturated soil weight determined in the geotechnical investigation.

B. Live Loads

Live loads caused by standard highway loadings (HS-20) or railroad loadings (E-80) shall be computed in accordance with applicable AWWA standards (refer to AWWA M11). Live loads from heavy construction vehicles shall be analyzed. Construction loads will affect the pipeline when it has less than minimal cover (refer to Section 2.6.3.B for cover requirements).

C. Groundwater Pressures

The Design Contractor shall consider the hydrostatic pressures from surrounding groundwater in the pipeline wall thickness design. The Design Contractor shall also calculate the uplift forces from surrounding groundwater and account for it in pipe design to make sure that pipe upward movement will not occur when the pipeline is completely empty. Maximum groundwater levels under all weather conditions and seasons shall be used in the calculations.

D. Loading Scenarios

Two conditions for external loads shall be considered:

- Live load plus dead load with full depth of cover. In calculating the dead load, the additional weight from coatings and linings shall be included.
- Live load plus dead load with minimal cover. The minimal cover used in the calculation shall be coordinated with the specification. The specification shall state the amount of cover required prior to operating heavy equipment above the pipe. The live loads shall represent the heaviest equipment expected for use in working above the pipe.

2.7.2.3
Design for Internal Loads (Design Pressure)

Internal pipeline loads include pressures resulting from normal operation, field testing, and during surge conditions. The Design Contractor shall design the pipeline wall thickness taking into consideration all internal load conditions to which the pipe may be subjected. The following is a brief description of each of these loading conditions:

A. Operating Pressure

Operating pressure is typically determined from the hydraulic gradeline for the pipeline under maximum static hydraulic conditions. This is usually determined by considering the effect of the discharge shutoff head of a nearby pump station, the overflow elevation of a regulating reservoir, and/or a vent spill elevation, whichever is greater. Pressure calculations reflect the difference in elevation between the hydraulic gradeline and the centerline of the pipe. The Design Contractor shall refer to AWWA M11 for more information on calculating operating pressure.

B. Field Test Pressure

Field hydrostatic-pressure test is normally conducted on pipelines to check for leaking joints. The Design Contractor shall consider the field testing pressures in pipeline wall thickness design. The hydrostatic test pressure shall not be less than the maximum anticipated surge pressure, the pump shutoff pressure (where applicable), and 1.25 times the operating pressure provided that it does not damage the cement mortar lining of pipes. The hydrostatic test pressure shall not produce a hoop stress in the pipe wall exceeding that recommended by AWWA M11. The Design Contractor shall refer to the ~~"S~~teel Pipe" and ~~"P~~ressure Testing of Piping" specification sections in the GC&SS (see Attachment 2-1) for more information on field test pressure.

C. Surge Pressure

The Design Contractor shall investigate the surge pressures and design the pipeline wall thickness accordingly, if feasible, otherwise another surge control measure shall be adopted. Surge pressures could be positive or negative (vacuum pressures). Refer to Chapter 9 of the Design Contractor Guide for more information on determination of surge pressures. The Design Contractor shall compute the allowable internal vacuum pressure, resulting from a hydraulic-transient condition, using the formulas described in AWWA standards for buried pipelines. For non-buried pipelines (e.g., above-grade crossings or pipelines in casings without control density fill or similar situations), use the applicable AWWA standards in calculating surge pressures.

D. Vacuum Pressure

The minimum design vacuum pressure for all pipes shall be equal to full vacuum (-14.7 psi), unless otherwise dictated by transient analysis or other design criteria.

2.7.2.4 Design for Thrust Forces

Longitudinal thrust forces caused by closed valves or change in pipeline alignment shall be calculated by using the methods described in AWWA standards. Closed valves create a force that may cause tension or compression in the pipe wall, depending on the location of the resisting forces. Bends in the alignment create forces as outlined in AWWA standards. Longitudinal thrust forces shall be accounted for when designing the pipe wall thickness.

2.7.2.5 Design for Longitudinal Force Due to Change in Temperature

When pipe joints are welded, the temperature of the steel is higher than when the pipe is in service and conveying water. The specification shall state the maximum allowable temperature of the steel when the closure joints are welded. The force due to a drop in temperature, between the time the joints are welded (maximum temperature) and the pipe is placed in service (minimum temperature considered 50°F), always creates tension in a buried pipe wall that shall be accounted for in the design.

2.7.2.6 Design for Longitudinal Stresses

The maximum magnitude of the longitudinal stress due to Poisson’s effect induced by internal forces (Section 2.7.2.3) is given by the formula:

$$\text{Longitudinal Stress} = (\text{Hoop Stress}) \times \text{Poisson's Ratio}$$

For steel, Poisson's ratio is assumed to be 0.303. Hoop stress is generally limited to 16,500 psi under static operating pressures. The longitudinal stress due to thrust (Stress A) shall be evaluated independently from the sum of longitudinal stresses due to Poisson’s effect and temperature (Stress B). Resultant calculations of axial/normal, combined and equivalent stresses in pipe barrels and joints shall then be based on the higher of the two longitudinal stresses (A) and (B).

2.7.2.7 Design for Seismic Loads and Deformations

The Design Contractor shall calculate the appropriate pipe wall thickness due to seismic loads, traveling waves and ground deformations. Refer to Chapter 5, Seismic Design, for design guidelines of buried pipes under earthquake loading conditions.

2.7.3 Pipe Size

Pipelines shall be sized to adequately accommodate the water flow rate specified in the project planning study or predesign report. In many situations, the project will be going through several phases with each having a different flow discharge. As such, the Design Contractor shall use extreme caution when determining the correct flow discharge, for the ultimate project phase, in sizing the pipeline.

Pipe size is determined by performing the proper hydraulic analysis. Typically, steel pipelines for Water Authority projects are designed using the Manning equation. Other formulas for pipe size calculations (e.g., Hazen Williams equation) are listed in AWWA M11. In cases where the Manning equation is not used, the Design Contractor shall provide the Manning roughness coefficient “n” corresponding to the roughness/friction coefficient used in the selected equation.

Calculations presented by the Design Contractor shall include losses induced by valves and pipe fittings on the pipeline. For transmission lines, typical pipeline minimum velocity is 2 fps and maximum velocity is 10 fps. Higher velocities up to 12 fps are allowed only on a short-term basis (i.e., during emergency conditions, or normal conditions of very low frequency and duration). The Design Contractor shall investigate frequency and durations where the pipeline may be subjected to high velocities and report results of the investigation to the Design Manager.

2.7.4 Transient Analysis

A transient analysis is normally performed during the project planning stage. This transient analysis is considered preliminary because certain assumptions shall be made to perform the transient analysis. As the project design progresses, some of those preliminary assumptions may require modification and the transient analysis shall be updated.

The Design Contractor shall:

- Review the transient analysis information done during the project planning or predesign stage.
- Update the transient analysis for consistency with the updated design conditions.
- Refer to Chapter 9 of the Design Contractor Guide for additional requirements used in performing transient analysis and surge control.

2.7.5 Thrust Restraint

Thrust forces generated at changes in pipeline size or direction due to bends, tees, reducers, and dead-ends (bulkheads, caps, plugs, closed valves, etc.) shall be restrained to maintain the function of the pipeline. The means used in restraining thrust forces are a function of:

- Pipe-joint type (welded joints, flanged joints, etc.).
- Magnitude of the force.
- Location of the pipeline (buried or above ground).
- Soil conditions.

The ultimate goal of thrust restraining is preventing the pipe joints from movement due to thrust forces. Several methods can be used to restrain pipe joints, including welding and bolting.

2.7.5.1 Restraining Fittings, Valves, and Reducers

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.

The requirements for fittings described in the previous paragraph 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 Contractor shall also recognize that the unbalanced thrust force can be transmitted upstream or downstream. In this case, the pipe joint system and restraining system shall be designed to transmit the force in either direction.

When anchor rings are embedded in the wall of a structure, they shall be 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 shall not be considered to carry compressive forces.

2.7.5.2 Thrust Forces Calculation

The Design Contractor shall calculate the thrust forces likely to be generated at each pipe change in direction or size. Dead ends, including closed valves, shall be considered a change in pipe direction.

Thrust forces shall be calculated per AWWA standards. Transient pressures caused by surge conditions (refer to Chapter 9 of the Design Contractor Guide for more information) shall be considered in conjunction with hydrostatic and operating pressures (refer to Section 2.7.2.3).

2.7.5.3 Thrust Restraining Systems

There are two main thrust restraining systems. Those that use pipe welding or coupling to restrain the pipe (restrained joints) and those that require an outside-of-the-pipe system (e.g., thrust blocks or soil forces) to restrain the pipe (unrestrained joints). Thrust blocks shall not be used for Water Authority transmission pipelines because of the high pressures and large pipe diameters, thus requiring large thrust blocks.

The Design Contractor shall design the complete thrust restraining system. A performance specification that requires the pipe manufacturer or Construction Contractor to submit a thrust restraint design for review is not acceptable.

2.7.5.4
Restrained Pipe Joints

A. Welded Joints

Welded joints directly transmit axial and shear forces as well as bending moments to adjacent pipe sections through the joint welds. . Thus, the Design Contractor shall include the stresses produced by such loads in the design of pipe joints and their welds. The Water Authority uses fully restrained welded steel pipe. Consequently, no outside-of-the-pipe restraining system is required.

Allowable stresses within pipe joints and welds shall not exceed the stresses allowed for pipe barrels/shells under all operating scenarios.

B. Flexible Sleeve Couplings

In order to allow for differential settlement, pipelines and other pipe elements (e.g., valves) contained within a structure (e.g., vault), may be connected with flexible (sleeve) couplings to allow for some movement. These couplings transmit only minor tension and shear forces across pipe joints. As such, a restraining harness is required for full axial thrust force. The harness shall 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 shall be required:

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

2.7.6
Cathodic Protection

The Design Contractor shall use and specify the following documents in design of the pipeline cathodic protection system:

- Water Authority Cathodic Protection Guide Drawings. Attachment 2-3 shows the front cover of the Guide Drawings.
- —Galvanic Anode Cathodic Protection” and —Impressed Current Cathodic Protection” specification sections in the GC&SS (see Attachment 2-1).

- Water Authority SD&SD (see Attachment 2-2).
- AWWA M11.
- Other AWWA standards.

The Design Contractor may propose changes to the Water Authority documents listed above per the procedure referenced in Section 2.1.

The Water Authority uses two distinct types of cathodic protection systems to prevent pipeline corrosion. These are the Galvanic Anode Cathodic Protection (GACP) and the Impressed Current Cathodic Protection (ICCP) systems.

The Design Contractor shall include a section in the Basis of Design Report (BODR) outlining the factors used in selecting the most appropriate cathodic protection system. Refer to Chapter 4 of the Design Contractor Guide for more information on the BODR. The following factors shall be considered when selecting the most appropriate type of cathodic protection system:

- Geotechnical conditions.
- Constructability.
- If the new pipeline will be connected to an existing CP system, consider the interaction of the new CP system with the existing one.
- The greater potential of ICCP vs. GACP for creating stray current interference on other pipelines in the vicinity of the project.
- The additional maintenance requirements of ICCP vs. GACP
- Existing availability and cost to supply electrical power for ICCP systems.
- Life cycle costs which consider costs of construction, operating, monitoring, and maintenance.
- The safety and security of the exposed cathodic protection equipment.
- The requirements of governing agencies and permitting requirements.

All design calculations for cathodic protection shall be prepared by a Corrosion Engineer, herein defined as a Professional Engineer registered in the State of California, with certification or licensing that includes education and experience in cathodic protection of buried or submerged metal structures, or a person accredited or certified by NACE International at the level of Corrosion Specialist or Cathodic Protection Specialist (i.e. NACE International CP Level 4).

A. All Cathodic Protection Designs

The Design Contractor shall perform the following and include in the BODR:

- Obtain basic soil corrosivity data (pH, chlorides, sulfates, electrical resistivity in as-received and saturated conditions) for soil at pipeline depths at a minimum of one soil test per 1,000 feet of pipe.
- Consider protection from vandalism in the selection of protective enclosures for all cathodic protection equipment.
- Provide analysis of how adequate and durable electrical continuity will be provided across buried pipe joints which are not welded. Examples include bonding across Carnegie joints, flexible couplings, and valves. Provide a list of critical inspection items that details where and when to perform electrical continuity tests during the construction phase of the project.
- Provide a plan of how adequate and durable electrical isolation of buried pipe will be achieved during the construction of the project. Provide a list of critical inspection items that details where and when to verify electrical isolation during the construction phase.
- Provide descriptions for any required inspection test procedures not included in the Water Authority documents. Include specific and repeatable go/no go test criteria.
- For impressed current cathodic protection designs, obtain geotechnical data such as deep borings or seismic refraction surveys to determine the depth to bedrock at the proposed anode holes. Borings or seismic tests are typically conducted to the proposed depth of the anode holes which generally exceeds the depth of the pipeline. Typical ICCP anode holes are drilled to depths between 50 and 200 feet.

B. Galvanic Anode Cathodic Protection Designs

The Design Contractor shall perform the following and include with the Contract Documents submittals at all design levels (refer to Chapter 4 of the Design Contractor Guide for design levels):

- Calculate the amount of cathodic protection current required in units of DC Amps.
- Calculate the quantity, weight, shape factor and alloy type of galvanic anodes required to continually generate the design current for a minimum anode replacement cycle of 25 years.
- Determine the optimum locations, depth, and spacing for installation of the galvanic anodes based on the geotechnical report, soil chemistry, and pipeline configuration. Galvanic anodes are typically installed vertically in holes drilled to a

depth of 15 feet with the wires trenched to a cathodic protection junction box in a normal depth trench. Where hard rock exists an option is to install the galvanic anodes horizontally in a deep trench offset from and parallel to the pipeline which is filled with a slurried mixture of 75% powdered gypsum, 20% powdered bentonite, and 5% sodium sulfate. The minimum anode trench depth typically varies between the depth of the pipeline's springline and invert.

C. Impressed Current Cathodic Protection Designs

The Design Contractor shall perform the following and include with the Contract Documents submittals:

- Calculate the amount of cathodic protection current required in units of DC Amps.
- Calculate the quantity, size, and type of impressed current anodes required to continually discharge the design current for a minimum anode replacement cycle of 25 years.
- Calculate electrical resistance to ground of the anode holes and the pipeline. If the pipeline exists, measure the electrical resistance to ground of the pipeline. Calculate CP system circuit resistance and size the rectifier with a minimum 50% reserve for voltage and current ratings.

D. Cathodic Protection Test Stations

The Design Contractor shall include in the design Cathodic Test Stations (CTS) to enable periodic cathodic protection system monitoring. Provide CTS at the following locations:

- Pipe Crossing CTS - Provide four-wire CTS at all locations where Water Authority cathodically protected pipelines cross other cathodically protected pipelines to enable testing the electrical interaction between the two pipelines. Provide a pair of test wires welded to each pipeline.
- Casing Isolation CTS - Provide Casing Isolation CTS at all locations where Water Authority cathodically protected pipelines run inside steel casings or steel reinforced tunnels to enable testing the integrity of electrical isolation between the pipeline and casing. Provide a pair of test wires welded to the pipeline and to the casing or tunnel.
- Insulated Flange CTS - Provide Insulated Flange CTS for all insulated flanges. Where insulated flanges are located inside vaults, mount the test boxes on the exterior walls of these structures to enable cathodic protection monitoring without entering the structure. Where multiple insulating flanges are connected in electrical parallel configurations, only one Insulated Flange CTS is required for each group. Provide a pair of test wires welded to the pipe on each side of the

insulated flange, total 4 wires required. For buried insulated flanges only, provide an additional pair of pipe test wires attached to the pipe a distance of 250 feet away (plus or minus 20-feet to the nearest pipe joint) from the insulated flange, total six wires required. Provide the additional pair of pipe test wires on the side of the insulated flange which will be cathodically protected. Use unique wire sizes or wire colors to distinguish the different pipe attachment locations.

- Provide Pipeline Current Style test stations for all pipeline projects over 5,000 feet long at intervals not to exceed one per 5,000 feet.
- Galvanic Anode Junction Boxes - Provide Anode Junction Boxes for all galvanic anode installations. Do not direct connect anodes to the pipelines. Provide an individual shunt for each anode wire to enable monitoring of individual anodes.
- All pipelines to be monitored with CTS shall have a minimum of two test wires welded to it.
- Wherever possible, mount CTS boxes to the exterior walls of vaults and other structures as opposed to free standing CTS boxes.
- Where flush mounted CTS are specified for a pipeline in a paved street, install the CTS boxes in areas away from traffic hazards, such as in medians or behind curbs.
- Where flush mounted CTS are specified provide a minimum of 24-inches of slack in all test wires to enable them to be removed from the box during periodic CP system testing.

E. Insulated Flanges

New pipelines shall be electrically isolated from electrical grounding systems and other underground structures (i.e., pump stations discharge piping, flow control facilities piping, etc.). Pipeline appurtenances such as valves need not be electrically isolated from the pipeline cathodic protection system, unless the valve has an electric operator.

Insulated flanges are generally used for the following purposes:

- Provide electrical isolation between the buried portion of pipelines and electrically grounded equipment inside vaults and pump stations.
- Provide electrical isolation between two pipelines of different materials or two different cathodic protection zones.
- Provide electrical isolation between the section of a buried pipeline and a pipeline section that is not isolated from concrete encased rebar (e.g. concrete encasements at road

crossings, or pump stations without insulated flanges inside or outside of the facility.

- Provide electrical isolation at locations where there is a change of ownership.

Buried insulated flanges involve significantly greater risks and complications as follows:

- Lack of ability to repair dielectric sleeves and washers for flange bolts should a lack of electrical isolation occur.
- Leaking flanges may require a pipeline shutdown to replace the gasket.
- More difficult working conditions than inside vaults.

Consequently, for buried insulated flanges, the following recommendations shall be followed whenever practical:

- Assemble the insulated flanges on two short sections of pipe under factory conditions such as at the pipe manufacturing plant.
- Perform electrical isolation testing of all flange bolts and from flange to flange at the pipe manufacturing plant. Note that the Water Authority cathodic protection specifications require that all flange bolts be individually tested for a minimum resistance as well as testing for a minimum flange to flange electrical resistance.
- Perform a hydro test of the completed assembly after all flange bolts have been fully torqued and it has passed the electrical isolation tests.

For insulated flanges, refer to the following documents for pipe flange and valve flange requirements:

- —Steel Pipe” specification section in the GC&SS (see Attachment 2-1).
- —Insulating Joint & Fabrication Details” in the SD&SD (see Attachment 2-2).

In lieu of buried insulated flanges, monolithic insulators (ISOJoints) may be used.

2.7.7 Pipeline Supports

The Design Contractor shall use and specify the following Water Authority documents in the design of pipeline supports:

- —Pipe Hangers and Supports” specification section in the GC&SS (see Attachment 2-1).
- —Pipe Supports and Concrete Pedestal Details” drawing in the

SD&SD (see Attachment 2-2).

The Design Contractor shall check bending, shear, and local buckling at supports. The Design Contractor shall also check the AWWA M11 for additional requirements for pipelines supported by pipeline supports.

The Design Contractor shall include in the design drawings and specifications the requirements for electrical isolation of the pipeline from any support brackets, rebar, or other metallic objects on the pipeline support. Add notes that refer to a testing procedure in the cathodic protection specifications to verify electrical isolation during the construction phase.

2.7.8 Pipeline Encasement

Road crossing, excess fill, reduction of pipeline cover, etc., are all reasons for potential concrete encasement of pipelines. The Design Contractor shall refer to the following documents for specific requirements and design guidelines for pipeline concrete encasement:

- —Installation of Pipe” specification section in the GC&SS (see Attachment 2-1).
- —Reinforced Concrete Pipe Encasement & Structure Base Details” drawing in the SD&SD (see Attachment 2-2).

The Design Contractor shall include in the design drawings and specifications the requirements for electrical isolation of the pipeline from any rebar or other metallic objects in the encasement. Add notes that refer to a testing procedure in the cathodic protection specifications to verify electrical isolation during the construction phase of the project.

2.8 Special Crossings

2.8.1 General

Special pipeline crossings include pipe crossing of other major pipelines, highways, major roads, railroads, etc. Two types of crossings are presented in this section; Permanent crossings for pipeline installations; and Temporary crossings during construction operations.

2.8.2 Permanent Crossings

In addition to the requirements stated below, the Design Contractor shall refer to the following for additional requirements on permanent crossings:

- The —Pipeline Crossing Details” drawing in the SD&SD (see Attachment 2-2).
- The ASCE —Pipeline Crossings” (Manuals and Reports on Engineering Practice No. 89).

A. Agency Coordination and Permits

The Design Contractor shall coordinate with agencies, as applicable to the project, to determine any requirements to be included in the Contract Documents for design and construction at special crossings. Refer to Chapters 5 and 10 of the Design Contractor Guide for more information on Agency Coordination.

Agencies to contact in cases of crossing of railroads, highways, and major roads include:

- Railroads: MTS/SANDAG (Metropolitan Transit System/San Diego Association of Governments), North County Transit District (NCTD)
- State Highways: Caltrans.
- Major Roads: Agency of Jurisdiction Utility Companies.

A Caltrans Encroachment Permit may be required to install pipelines on a major crossing. The Design Contractor shall conform to the requirements of the latest edition of the —Caltrans Manual of Encroachment Permits”.

B. Design Considerations

The Design Contractor shall provide both plan and profile views of all major crossings in the civil drawing section of the contract drawings. Unless otherwise approved, the Design contractor shall provide an access manway structure/assembly in cases where the pipeline is tunneled or cannot be easily excavated. Examples include interstate freeway crossings, major drainage way crossings, railroad crossings, and major roadway crossings. In addition, crossings under county or state highways may require a steel casing.

The Design Contractor shall consider the following in the design of pipelines with major crossing:

- Provide manway access adequate for equipment operation, inspection, maintenance, and repair of the pipeline and appurtenances.
- Provide pressure class and wall thicknesses in excess of that required for the design pressure (refer to Section 2.7.2) to provide additional pipe strength and sacrificial wall material (i.e., use a higher safety factor).
- Install shutoff valves on pipelines within reasonable distances of each end of the crossing.
- Design to accommodate free draining conditions and avoid trapping pockets of liquid or air in the pipeline
- Design the pipeline for all imposed loads. Maximum thermal expansion and contraction shall be calculated and accommodated.
- 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 between soil masses with differing compaction, loading, and settlement characteristics.
- All pipeline sections shall be made electrically continuous to facilitate future installation of cathodic protection for the pipeline.
- For pipeline crossings, perform an analysis of potentially harmful interactions between the two pipeline's cathodic protection systems. Mitigate against stray current interactions using a combination of pipeline separation distance at the crossings, pipe coatings, dielectric shields, and cathodic protection bond boxes.

2.8.3 Temporary Crossings

Temporary pipeline crossings may be required when live loads resulting from equipment passing over existing pipelines exceed the design loads of these pipelines. The Design Contractor shall refer to and specify requirements outlined in the Engineering Guidelines for Review of Proposed Right of Way Encroachments (ESD-170; see Attachment 2-8) in cases of working in the vicinity of existing Water Authority pipelines.

2.9 Trenchless Construction

2.9.1 General

In some cases it may be more appropriate to resort to trenchless pipeline construction than using the conventional cut-and-cover. Environmental impact, and other indirect costs due to noise, dust, loss of business, traffic delays, etc. are some of the major factors for selecting trenchless pipeline construction. Other factors may include problems with settlement, deep shoring, and difficult utility relocation or support.

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

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

The major trenchless construction methods include:

- Pipe Jacking - Can be used for large pipelines, however; a sleeve may be required to maintain cement-mortar coating. This method is not recommended for Water Authority projects.
- Horizontal Boring including the following methods, however; a sleeve may be required to maintain cement-mortar coating:
    - Microtunneling: Is particularly advantageous for difficult ground conditions.
    - Slurry Rotary Drilling: Is limited to 48 inch maximum pipe size.
    - Compaction/Pipe Ramming: Is limited to 52 inch maximum pipe size.
    - Directional Drilling: Is used for waterways crossings
    - Percussive Drilling: Is effective in drilling through hard rock. Is limited to 44 inch pipe size. Limitations include the environmental impact during initial startup due to dust from cuttings blown out by the compressor.
- Tunneling - The major advantages of tunneling over pipe jacking include:

- Tunneling of curved alignments can be accomplished.
- Excavation is feasible in hard rock.
- Length of tunnel is not limited by the thrust of the pipe jacking rams.

The selection of a particular method is a factor of subsurface ground conditions, surface features as waterways and highways, pipe size, pipe coating material, and the limitations/advantages inherent in each method. As each project is site-specific, consequently, the Design Contractor shall become familiar with possible trenchless construction methods and shall refer to the most appropriate. However, the Design Contractor shall not provide direction as to the means and methods, but performance requirements and limitations as required for the project.

2.9.2 Tunneling

As with pipe jacking and horizontal boring, the means and methods of advancement and the initial support are the Construction Contractor's responsibility. The Design Contractor shall be responsible for producing performance requirements and limitations applicable for each project. The Design Contractor shall use and specify the following specification sections in the GC&SS (see Attachment 2-1):

- Tunnel Instrumentation and Monitoring.
- Tunneling.
- Portal Area Development.
- Concrete Backfill and Grouting for Tunnels.
- Tunnel Support Systems.

A. Instrumentation and Monitoring Plan

The Design Contractor shall produce the tunnel instrumentation and monitoring plan. The plan shall include:

- Drawing(s) showing the tunnel layout and the location of all instruments used to monitor settlement of ground and structures in close vicinity of the tunnel.
- Monitoring requirements, schedule and frequency of taking measurements.
- Limits of ground movement and structure movement.
- Action to be taken in case measurement exceeded the settlement limit.
- Specifications of monitoring instruments.

The tunnel instrumentation and monitoring plan shall be submitted to the Design Manager for review at the Mid-Point design level (refer to Chapter 4 of the Design Contractor Guide for more information on design submittals levels).

B. Tunnel Excavation and Support Methods

Tunneling excavation and initial ground support methods are broadly classified according to ground conditions, whether hard rock, soft/weak rock, or soils. The methods can be further subdivided under mechanized or conventional excavation. Mechanical excavations may be performed by tunnel boring machines (TBM), shields, or mechanical excavators. Conventional excavations may be by drill-and-blast construction or by hand construction, pneumatic 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. TBMs have the advantage of causing less disturbance to humans compared with drill-and-blast excavations when advancing through hard rock.

Initial ground support depends on ground conditions. The following are some general requirements:

- In hard rock, common support types are no support, patterned or random rock bolts and wire mesh, or mine straps as required by rock 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.
- In soil, similar initial support systems as for soft or weak rock are used; however, rock bolting methods and sparse support are generally not acceptable.

The standard tunnel design practice is not to specify tunnel support methods. The Design Contractor shall 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).

C. Pipe Installation

After tunnel excavation is completed, 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 Contractor shall investigate any cost savings or other benefits to be derived using this corridor for other utilities (e.g., fiber optic control cables). In very special circumstances, a utility corridor with access may be required.

The gap between the pipe and the tunnel is backfilled with cementitious materials such as grout or cellular concrete, according to requirements of the ―Concrete Backfill and Grouting for Tunnels" specification section in the GC&SS (see Attachment 2-1). As such, cement mortar coating may not be required for pipes installed in tunnels. Other types of coatings may still be required for corrosion protection.

2.9.3
Tunnel Portal

Size of tunnel portal depends on the size and length of the pipe being installed, and on space requirements for the installation equipment. With directional drilling, a jacking pit is not necessarily required. With any other trenchless method, however, a small staging area is required adjacent to the work area and is typically a minimum of 5,000 square feet.

The Design Contractor shall provide the geotechnical criteria that will enable the Construction Contractor to design the shoring and foundation for their equipment. Also, the Design Contractor shall consider the Construction Contractor's staging requirements and need for jacking and receiving pits when planning special crossings.

2.10 Instrumentation and Control

2.10.1 General

Detailed Instrumentation and Control requirements are outlined in Chapter 6 of this Guide. In this chapter, general instrumentation and control requirements for pipelines are outlined. The Design Contractor shall follow the requirements outlined in this section and Chapter 6 of this Guide, and shall refer to the following Water Authority documents for additional requirements:

- The GC&SS (see Attachment 2-1).
- The Electrical/Instrumentation Guide Drawings (see Attachment 2-4 for the cover page).
- The Water Authority PLC Implementation Standards (see Attachment 2-9 for the cover page).

2.10.2 Valves and Other Equipment

A. Isolation and Control Valves

The Design Contractor shall determine the closing and opening times of electrically-actuated valves that will not induce surge in the flow carrying pipeline or other facilities. Minimum closing and opening times specified in the GC&SS (see Attachment 2-1) shall be observed. The valve gearing shall be specified so that the close/open time identified by the Design Contractor shall not be exceeded. Adjustment of opening and closing times of valves with an electronic means rather than mechanical means shall not be allowed.

The Design Contractor shall refer to the —Valves” and —Electric Motor Actuators” specification sections in the GC&SS (see Attachment 2-1) for additional requirements. The Design Contractor shall also refer to the PLC Implementation Standards (see Attachment 2-9) for valve control requirements.

Electric actuators operating isolation or control valves, at a minimum, shall be equipped with:

- Open and close limit switches to protect the valve gearing.
- Torque switch sensing mechanical overload in either open or close direction. The torque switch shall be interlocked with the valve operator to stop the valve movement in case of high torque.
- Local open/close push buttons for isolation valves.
- Local open/close/stop push buttons for control valves.
- Lights indicating open/close/travel positions.
- Position feedback for control valves.

- Generally Water Authority valves are configured to fail in place in case of a power loss. If the project requires a fail-to-close configuration, an emergency closing feature to close the valve at a controlled rate shall be provided. If the project requires a fail-to-open, an emergency opening feature to open the valve at a controlled rate shall be provided.

In some cases, the valve electric actuator is connected to the Water Authority SCADA system. In this case, the Design Contractor shall include in the design fiber optic cabling along the pipeline to carry the signals. The Design Contractor shall refer to the ―Fiber Optic Details” drawings in the SD&SD (see Attachment 2-2) for details.

For valves connected to the SCADA system, the electric actuator shall be equipped with a Local/off/remote selector switch to indicate control location.

B. Flowmeters

Flowmeters on pipelines are generally connected to the Water Authority SCADA system. Thus, the Design Contractor shall include in the design fiber optic cabling along the pipeline to carry the signals. The Design Contractor shall refer to the ―Fiber Optic Details” drawings in the SD&SD (see Attachment 2-2) for details.

The Design Contractor shall refer to Section 4.6.2 in Chapter 4 (Flow Control Facilities) for additional requirements for flowmeters.

Attachment 2-1: Cover Page of the Water Authority General Conditions and Standard Specifications

General Conditions and Standard Specifications

2005 Edition

John A. Economides
Director of Engineering

San Diego County Water Authority

Attachment 2-2: Cover Page of the Water Authority Standard Drawings & Standard Details

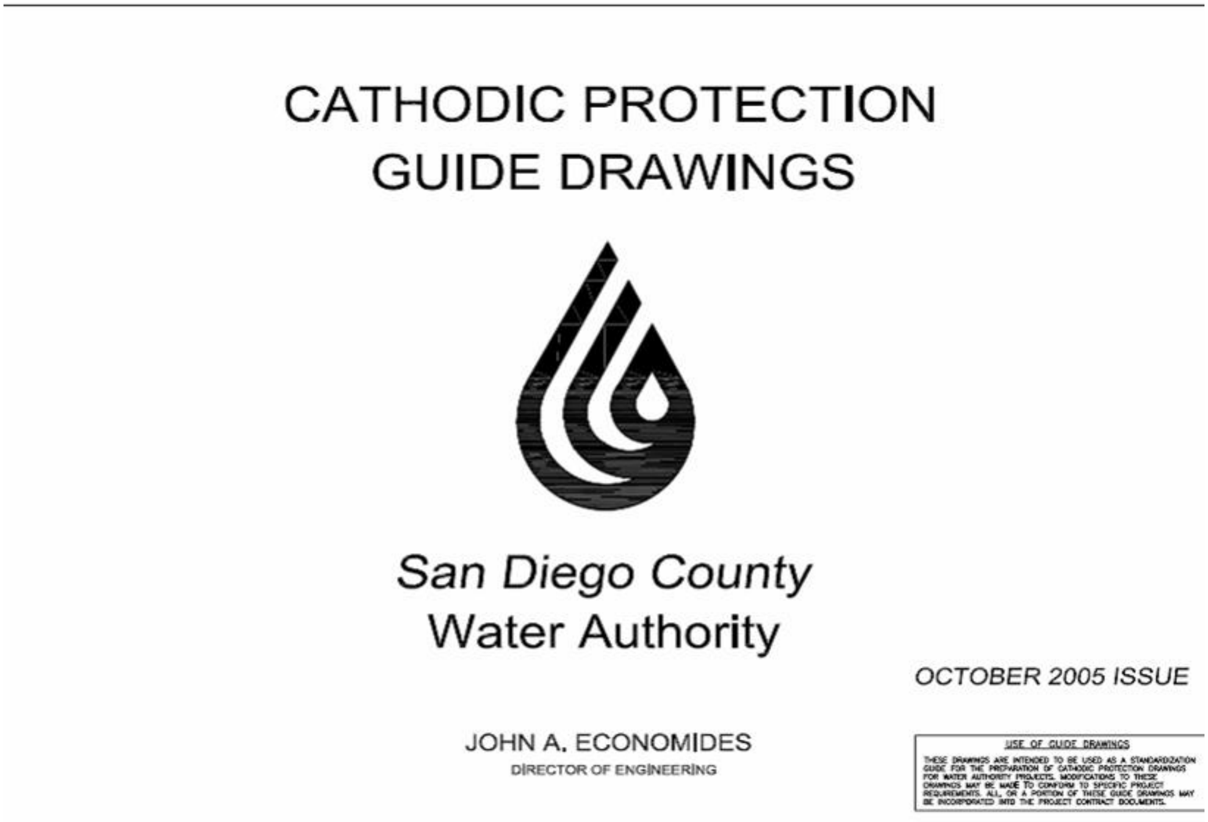
STANDARD DRAWINGS & STANDARD DETAILS

San Diego County
Water Authority

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

OCTOBER 2003 ISSUE

Attachment 2-3: Cover Page of the Water Authority Cathodic Protection Guide Drawings



CATHODIC PROTECTION
GUIDE DRAWINGS

San Diego County
Water Authority

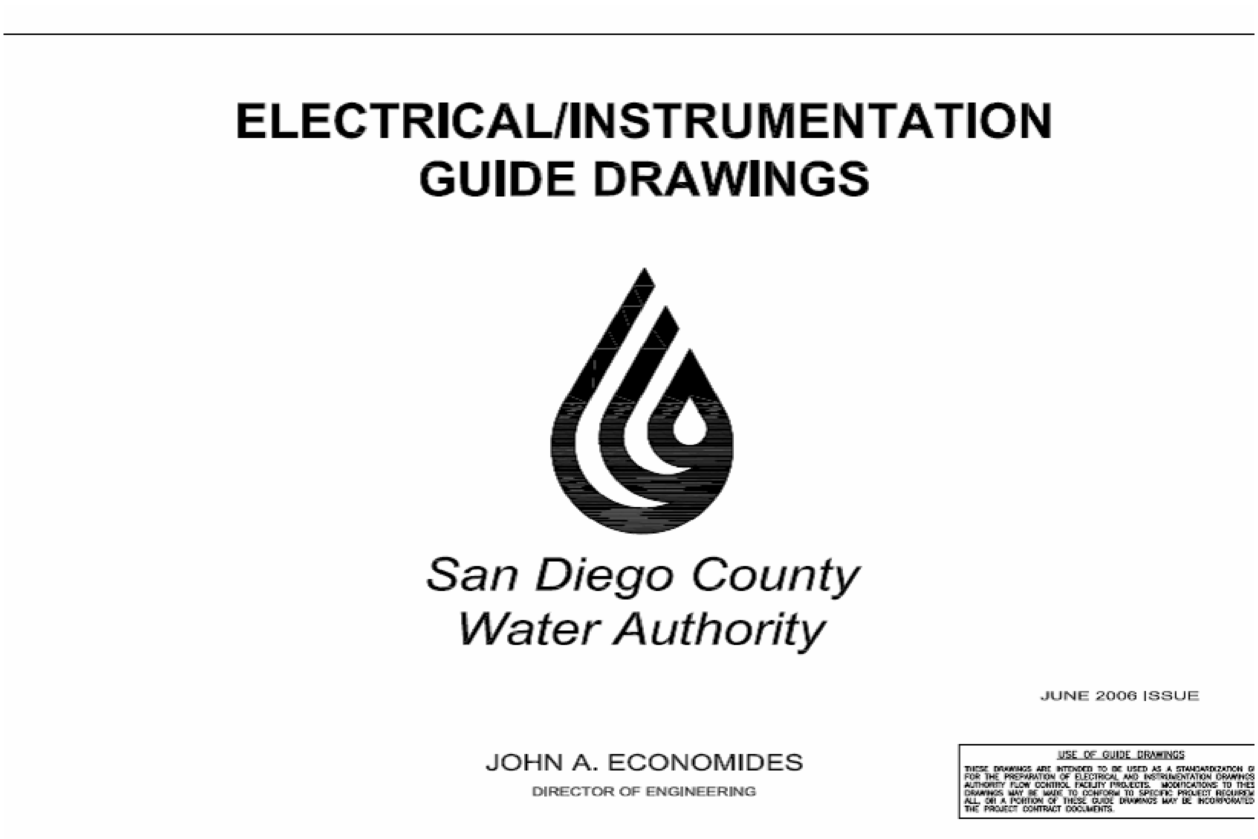
OCTOBER 2005 ISSUE

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

USE OF GUIDE DRAWINGS

THESE DRAWINGS ARE INTENDED TO BE USED AS A STANDARDIZATION GUIDE FOR THE PREPARATION OF CATHODIC PROTECTION DRAWINGS FOR WATER AUTHORITY PROJECTS. MODIFICATIONS TO THESE DRAWINGS MAY BE MADE TO CONFORM TO SPECIFIC PROJECT REQUIREMENTS. ALL, OR A PORTION OF THESE GUIDE DRAWINGS MAY BE INCORPORATED INTO THE PROJECT CONTRACT DOCUMENTS.

Attachment 2-4: Cover Page of the Water Authority Electrical/Instrumentation Guide Drawings



ELECTRICAL/INSTRUMENTATION GUIDE DRAWINGS

San Diego County
Water Authority

JUNE 2006 ISSUE

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

USE OF GUIDE DRAWINGS

THESE DRAWINGS ARE INTENDED TO BE USED AS A STANDARDIZATION G
FOR THE PREPARATION OF ELECTRICAL AND INSTRUMENTATION DRAWINGS
AUTHORITY FLOW CONTROL FACILITY PROJECTS. MODIFICATIONS TO THES
DRAWINGS MAY BE MADE TO CONFORM TO SPECIFIC PROJECT REQUIREM
ALL, OR A PORTION OF THESE GUIDE DRAWINGS MAY BE INCORPORATED
THE PROJECT CONTRACT DOCUMENTS.

Attachment 2-5: Cover Page of the Water Authority Drafting Manual

SDCWA
San Diego County Water Authority
Engineering Department

Drafting Manual

ESD-120 ***March 2004***

Attachment 2-6: General Design Criteria for Pipeline Appurtenances

Description	Criteria
A. Isolation and Control Valves	
1. Size	Size the valve for the application using valve sizing formulas
2. Location	As included in the scope of work and/or recommended by the Design Contractor
3. Design Considerations	Provide a bypass piping system with valving, if required
4. Actuation	Manual actuator - Per specifications
	Electric actuator - Provide suitable electric actuator per the application and specification. Valve actuator gears to be sized to close the valve within the acceptable surge closure time
5. Enclosure	Provide valve vaults for all types of valves
6. Pressure Class	The valve pressure class shall match the pressure class of the connected pipe
B. Air Valve Assemblies	
1. Types	Air release valves
	Vacuum valves
	Combination air/vac valves (most common type of valve)
2. Location	Place combination air/vac valves at all high points
	Place combination air/vac valves at grade breaks on steep slopes
	Place air release or combination air/vac valves on long downward sloping sections
3. Size	Size air valves as noted in paragraph 2.5.1 and per manufacturer's recommendations
4. Number	Depends on valve capacity. For high capacity, consider using multiple smaller (less expensive valves) rather than a single very expensive large valve.
	Valves considered for transient suppression effects shall be fully redundant
5. Enclosure	Per Standard Drawings
6. Pressure class	Pressure class of the valve shall match the pressure class of the adjacent pipe.
7. Design Consideration	Each air valve shall have a separate isolation valve to allow removal under pressure conditions

Attachment 2-6: General Design Criteria for Pipeline Appurtenances (Cont.)

Description	Criteria
C. Blowoffs	
1. Types	Major blowoff - Located at key drainage discharge points that will be used for initial blowoff
	Minor blowoffs - Located at low spots to drain off small residual amounts of water following initial blowoff
2. Location	At all low points where grade changes
	At appropriate drainage crossings
	Upslope of inline valves, if any
3. Size	Major blowoffs - Size to drain the pipeline in 8 hours. Use 8-inch minimum blowoff size
	Minor blowoffs - Use 4-inch minimum blowoff size
4. Design Consideration	If blowoff water is discharged into open ditches or other waterways, an energy dissipation system shall be included with the discharge pipe. Design dissipation systems to effectively integrate with roads, roadside ditches or waterways, as applicable.
5. Enclosure	Per the SD&SD
6. Pressure Class	Pressure class for all piping, valves, and fittings shall match the adjacent pipe
7. Pipe connection	Per the SD&SD
D. Outlets (Other than Manway Access)	
1. Types	Tee with isolation valve and blind flange or pressure (dished) head.
2. Location	As required by the Project
3. Size	Size to accommodate the desired flowrate
E. Access Manways	
1. Types	Manway with access (includes manway and access housing)
2. Location	Place manway with access at all crossing locations that are difficult to access from the surface (i.e., in casing or concrete encasement)
	Do not place access manways over steeply sloping sections of pipe where an entering worker would not have safe footing
	Combined with all air valves and blowoffs
3. Size	Per the SD&SD
4. Pressure Class	The manway pipe and fitting pressure class shall match the pressure class of the adjacent pipe

Attachment 2-7: Cover Page of San Diego Regional Standard Drawings

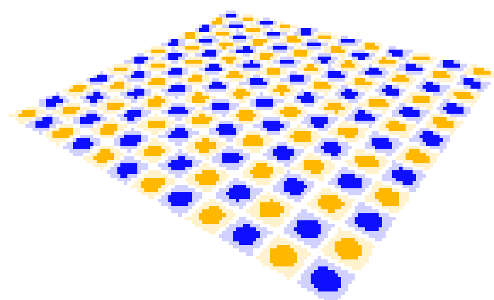
STANDARD DRAWINGS FOR AGENCIES IN THE SAN DIEGO REGION

Recommended by the Regional Standards Committee
Maintained and Published by the County of San Diego
Department of Public Works
April 2006
www.regional-stds.com

Attachment 2-8: Cover Page of the Water Authority Engineering Guidelines for Review of Proposed Right-of-Way Encroachments

San Diego County Water Authority

Engineering Department



Engineering Guidelines for Review of Proposed Right of Way Encroachments

ESD-170 ***September 2006***

Attachment 2-9: Cover page of the Water Authority PLC Implementation Standards

San Diego County
Water Authority

SDCWA

PLC IMPLEMENTATION STANDARDS

Version 2
(Released 03-14-05)

TMV Systems Engineering, Inc.

Chapter 3 Pump Stations

Overview

Purpose

This chapter presents the Water Authority general requirements for design of pump stations.

Topics

This chapter is composed of the following topics:

3.1 Introduction

3.1.1 General

This chapter outlines the guidelines and criteria that shall be followed in the design and construction of Water Authority pump-station projects. These guidelines and criteria are provided to ensure a consistent and thorough design process for each facility. The following items are covered in this chapter:

- Pump types and selection criteria.
- Pump station layout and piping configuration.
- Pump station design including:
  - Pump station hydraulics.
  - System head and pump characteristic curves.
  - Cavitation.
  - Surge control.
- Pump station appurtenances including:
  - Pump station valves.
  - Pump station flow meters.
- Pump speed control.
- Pump motors.
- Instrumentation and control.
- Factory and field testing.
- Electrical design criteria.
- Architectural design criteria.
- Structural design criteria.

3.1.2 Standards, Guidelines, and Codes

In this Guide, the Design Contractor is required to use and specify in contract documents specific Water Authority standards, equipment, materials, etc. In all cases, the Design Contractor shall verify the adequacy of all referenced standards, guidelines, materials, etc. to the project specifics. The Design Contractor shall review and modify the Water Authority documents, as required, to suit the project specifics. The Design Contractor shall follow the procedure outlined in Chapters 1 and 14 of the Design Contractor Guide (Design Manual – Volume One; ESD-160) in proposing and requesting changes to Water Authority Documents.

A. Water Authority Standards and Guidelines

In addition to this Guide, the other Water Authority Standards and Guidelines for use in pump station design and construction include:

- General Conditions and Standard Specifications (hereinafter referred to as “GC&SS”). Refer to Attachment 3-1 for the cover page of the GC&SS.
- Standard Drawings & Standard Details (hereinafter referred to as SD&SD). Refer to Attachment 3-2 for the cover page of SD&SD.
- Cathodic Protection Guide Drawings. Refer to Attachment 3-3 for the cover page of the Cathodic Protection Guide Drawings.
- Electrical/Instrumentation Guide Drawings. Refer to Attachment 3-4 for the cover page of the Electrical/Instrumentation Guide Drawings.

B. National Standards and Codes

Several national standards and codes are available for use in pump station design and construction including:

- ABMA - American Bearing Manufacturers Association.
- ACI - American Concrete Institute.
- AGMA - American Gear Manufacturers Association.
- ANSI - American National Standards Institute.
- ASHRAE - 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 (as outlined in Section 2.1.2 of Chapter 2, Transmission Pipelines).
- FS - Federal Specifications.
- HI - Hydraulic Institute Standards.
- IEEE - Institute of Electrical and Electronics Engineers.
- ISA - Instrumentation Standards and Automation Society.
- 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.
- UBC - Uniform Building Code.
- UFC - Uniform Fire Code.
- UL - Underwriters Laboratory, Inc.

- UMC - Uniform Mechanical Code.
- UPC - Uniform Plumbing Code.
- Cal/OSHA Title 8 – Occupational Safety and Health Administration.

The Design Contractor shall observe all applicable codes and other requirements adopted by local permitting agencies. In case of conflict between the requirements of this Guide and any code adopted by a local permitting agency, the code requirements shall prevail.

3.1.3 Submittals

The following is a list of Design Contractor's required submittals in this chapter:

- Pump Selection report – Due 30 days prior to submittal of the preliminary design package - Refer to Section 3.2.2 for more information.
- Hydraulic transient calculations – Due before initiating the detailed design - Refer to Section 3.4.5 for more information.
- Space and Function Requirement report –Due before issuing the Preliminary Design Package - Refer to Section 3.14.4 for more information.
- Noise compliance summary report – Due at the Preliminary Design - Refer to Attachment 3-7 and Section 3.9 for more information.

3.2 Pump Types and Selection of Pump Units

3.2.1 Pump Types

Pumps used by the Water Authority in water transmission applications are exclusively radial flow pumps (either horizontal split case pumps or vertical turbine pumps). Depending on the application, other types of pumps such as axial flow pumps, mixed flow pumps, positive displacement pumps, etc. may also be used. However, their application in water transmission is rather limited.

This section focuses on horizontal split case type pumps and vertical turbine type pumps. In case of using other types of pumps, the Design Contractor can easily extrapolate the requirements outlined below:

A. Horizontal Split Case Pumps

For horizontal split case pumps used in pump stations, the Design Contractor shall include the following features of pump construction in the project Contract Documents:

1. Type:	Horizontal split case.
2. Casing:	Close grained cast iron or cast steel tested to 150% of maximum head.
3. Impeller:	Enclosed single suction, bronze or stainless steel, hand finished, and dynamically balanced and keyed to shaft.
4. Wearing Rings:	Renewable, type 316 stainless steel.
5. Shaft:	Type 316 stainless steel, machined and ground, designed for maximum deflection.
6. Shaft Sleeve:	Type 316 stainless steel.
7. Shaft Coupling:	Heavy-duty flexible with OSHA safety guard.
8. Bearing:	Heavy-duty grease lubricated ball type, and double row thrust bearings - minimum L-10 bearing life, or renewable bearing in oil bath or pressurized oil system with cooling.
9. Seals:	Mechanical with flushing water. Cooling/flushing water must remain pressurized so it can be reclaimed.
10. Base:	Heavy cast-iron or steel base, with integral rim or pan and drain.

B. Vertical Turbine Pumps

For vertical turbine pumps used in pump stations, the Design Contractor shall include the following features of pump construction in the project Contract Documents:

1. Type:	Vertical canned turbine.
2. 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.
3. Bowls:	Cast iron with amine cured epoxy coated water passages
4. Impellers:	Cast bronze, enclosed single-suction type, balanced to operate within acceptable field of vibration limits.
5. Shaft:	Line shaft, type 316 stainless steel.
6. Shaft Couplings:	Type 304 stainless steel.
7. Wear Rings:	Bronze.
8. Seals:	Mechanical with flushing water. Cooling/flushing water must remain pressurized so it can be reclaimed.
9. Bearings:	Heavy-duty, grease lubricated, bronze - minimum L-10 bearing life.
10. Motor Coupling:	Shall allow for adjustment of the pump impeller at the upper end of the motor.
11. Discharge Head:	Steel.

The vertical turbine pump discharge head, sole plate, column, and cans shall be provided by the pump manufacturer as a package. Multiple manufacturers shall not be allowed.

3.2.2 Selection of Pump Units

The Design Contractor shall refer to the project planning study or predesign report for information on the preliminary selection of pump type (e.g., horizontal split case or vertical turbine pump). If the pump type information is lacking from the predesign report, the Design Contractor shall select the pump type that is most suitable for the project. The Design Contractor shall prepare a Pump Selection report outlining a comparative evaluation study between horizontal split case and vertical turbine pumps, as it pertains to the project. The analysis shall include:

- Technical selection criteria such as flow and head requirements.
- Functionality considerations.
- Cost considerations with various configurations.
- Operability and constructability issues.
- General arrangement drawings (see Attachments 3-5 and 3-6 for examples of horizontal split case and vertical turbine pump-station configurations).
- Recommendation on pump type and configuration including the desired number of stages (single stage or multiple stage pumps).
- Pumping source (e.g., open water body such as lakes, wetwell, etc.).
- Pump motor power requirements.
- Net positive suction head available (refer to section 3.4.3 for more information).

The Design Contractor shall submit the Pump Selection report at least 30 days prior to submittal of the Preliminary Design package (refer to Chapter 4, Design Development, of the Design Contractor Guide (Design Manual – Volume One; ESD-160) for more information). Based on the analysis presented in the Pump Selection report, the Design Manager will direct the Design Contractor as to which pump type and configuration to use before proceeding with design of the pump station.

3.3 Pump Station Siting and Layout

3.3.1
Siting Criteria

Siting of pump stations is usually done during the planning phase of a project. If not already determined, the Design Contractor shall consider the following parameters when siting pump stations:

- At a location that minimizes suction and discharge piping length.
- At a location that minimizes suction and discharge heads.
- At a location that is accessible to existing WA communication network facilities.
- Located within the public right-of-way or on an easement granted to the WA.
- Not on a location that is environmentally sensitive or banned from construction.
- Not located in vehicular corridors or curbside parking areas.
- Not located on steep slope areas or other areas that would present a challenge to construction efforts and to operation and maintenance.

3.3.2
General Arrangement

The Design Contractor shall refer to the project predesign or planning report for any requirements for pump arrangement and/or pump spacing. Should the predesign report have no requirements, the Design Contractor shall provide typical pumping equipment layout for pump stations (refer to Attachments 3-5 and 3-6 of this chapter for examples of horizontal split case and vertical turbine pumps general arrangement layouts). Any changes to the pump arrangement in the predesign report that the Design Contractor considers appropriate shall be coordinated with the Design Manager.

In general, the pumping equipment layout shall provide convenient access for Operations and Maintenance (O&M) personnel, equipment installation, adjustment of component parts, maintenance and equipment removal utilizing conventional general- purpose tools. Unless a stricter requirement is mandated by OSHA or NEC, a minimum of 3.5-foot clearance around equipment shall be provided for O&M access.

Pump Station equipment shall be arranged to provide adequate clearances on at least three sides. The Design Contractor shall allow for a minimum of 3.5-foot clearance between pump piping/appurtenances and all pump station walls, stairways, ladders, etc. Placing conduits, piping panels, etc. in any designated clear spaces shall be prohibited. Vertical floor to overhead obstructions shall be a minimum of 7.5 feet. Vertical clearance floor to equipment shall be a minimum of two feet. Where equipment manufacturers recommend a minimum clearance for maintenance, the Design Contractor shall provide an additional one (1) foot. All clearances shall be actual, to the most outstanding dimension (e.g., edge of flange), not nominal. In all cases, the Design Contractor shall adhere to OSHA and NEC requirements if stricter than what stated above.

3.3.3 Pump Inlet Piping Configuration

A. Horizontal Pumps

For horizontal split case pump configuration, the Design Contractor shall use Attachment 3-5 as a guide in configuring the inlet manifold and suction piping to each pump. Attachment 3-5 illustrates acceptable inlet configurations for two pumping systems; one in a pump room located below grade level and the other in a pump room located at grade level. The Design Contractor may suggest deviation to the piping configuration shown in Attachment 3-5.

B. Vertical Turbine Pumps

For vertical turbine pump configuration, the Design Contractor shall use Attachment 3-6 as a guide in configuring the inlet manifold and suction piping to each pump. Attachment 3-6 illustrates acceptable inlet configurations for two pumping systems; one located inside a building and the other located outdoors on a concrete slab (i.e., without a building). The Design Contractor may suggest deviations to the piping configurations shown in Attachment 3-6.

C. Bypass Line to Discharge

A bypass from the suction supply manifold to the discharge manifold may be required to protect against suction surge pressures or to supply low pressure flow in case of pump(s) failure. The bypass line shall be of the same size as the pump station suction supply manifold. The Design Contractor shall make provision for the installation of:

- A control valve (see Section 3.5.1 for more information on control valves) with a check feature that will close the valve in the event of power failure, thereby eliminating the need for a separate check valve. Alternatively, an isolation valve (see Section 3.5.1 for more information on control valves) and a check valve can be used.
- An air/vacuum valve (see Section 3.5.1 for more information on air valve assemblies) on the bypass line located in a valve vault or aboveground.

3.3.4 Pump Discharge Piping Configuration

A. Horizontal Pumps

For horizontal split case pump configuration, the Design Contractor shall use Attachment 3-5 as a guide in configuring the discharge manifold and discharge piping from each pump. Attachment 3-5 illustrates acceptable discharge configurations for two pumping systems; one located in a covered trench and the other one buried outside the pump station. The Design Contractor may suggest deviations to the piping configuration shown in Attachment 3-5.

B. Vertical Turbine Pumps

For vertical turbine pump configuration, the Design Contractor shall use Attachment 3-6 as a guide in configuring the discharge manifold and discharge piping from each pump. Attachment 3-6 illustrates acceptable pump-discharge configurations for two pumping systems; one for pumps located inside a building and the other for pumps located outdoors on a slab (i.e., without a building). The plan for the pumps inside a building is indicating a below-grade discharge header. However, above-grade discharge header configurations are also acceptable. The Design Contractor may suggest deviations to the piping configurations shown in Attachment 3-6.

C. Discharge Piping Assembly

The Design Contractor shall design exposed discharge piping using spool sections, tie-rod restrained coupling adapters or restrained flexible sleeve couplings (not with studs). Discharge piping shall be fitted and connected so that no lengths of pipe are too long to be removed by the hoisting system inside the pump station building. Provide unions for easy removal of all small piping appurtenances.

D. Bypass Line to Suction

The Design Contractor shall install a bypass line to relieve the discharge manifold to the suction manifold in a pump operation overpressure condition. This line can also be used to re-circulate pump test flows when required. The bypass line shall include:

- A flow meter to determine the amount of water being re-circulated. The meter shall be housed in a valve vault.
- A pressure relief valve (see Section 3.5.1 for more information on pressure relief valves). The valve shall be housed in a vault with the flow meter, or aboveground.
- A vacuum relief valve (see Section 3.5.1 for more information on vacuum relief valves) downstream of the pressure relief valve.

3.3.5 Pipe Couplings and Restraints

A. Pipe Joints and Couplings

The type of pipe joints or couplings and the care of their installation are important considerations that the Design Contractor shall specify. Welded joints, butt straps, flanges, and restrained flexible sleeve couplings are commonly used with steel pipes. Refer to Section 2.4 of Chapter 2 (Transmission Pipelines) for more information on pipe couplings.

On exposed piping installation, the Design Contractor shall avoid rigid connections in flanged piping between the pump and fixed discharge manifold piping, and shall specify flexible couplings. Restrained flexible sleeve couplings provide ease of assembly/disassembly of piping, minor adjustment in assembled piping, pump vibration isolation and strain relief at flanged fittings.

B. Pipe Restraints

On exposed piping installations, the Design Contractor shall provide thrust braces at pipe change in direction (e.g., at elbows) and at other locations, as required, to resist seismic forces, operational pressure, and surge pressures.

The Design Contractor shall design all piping joints and thrust restraints to withstand maximum anticipated pressure, whether operational, testing, or surge. Pipes penetrating walls (e.g., valve vaults or underground pump station walls) shall be equipped with intermediate flanges for thrust restraint (anchor ring). Refer to “Wall Pipes, Seep Rings, and Penetrations” specification section in the GC&SS (refer to Attachment 3-1) for more information.

Flanged coupling adapters and flexible sleeve couplings shall be provided with a suitable harness for longitudinal restraint. For bolted flanges, the Design Contractor shall ensure that flanges of different materials and pressure classes are compatible.

In all cases, the Design Contractor shall design pipe restraint while meeting the tolerances recommended by the pump manufacturer.

3.4 Pump Station Design

3.4.1 Pump Station Design Considerations

The pump station predesign report may contain preliminary information on system hydraulics, design capacity, system head curves, available net positive suction head (NPSH), pump operating curves, piping configuration, hydraulic calculations, transient analysis and surge control, instrumentation and control, and other pertinent information to the design of the pump station. The Design Contractor shall review the predesign report information and update the provided information to reflect the actual design parameters. The Design Contractor shall also provide any missing information from the predesign report that is deemed necessary for the pump station design.

The following are some of the pump station design parameters that the Design Contractor shall consider:

A. Flow Velocities

The Design Contractor shall size suction and discharge piping so that:

- The maximum suction velocity is 5 fps. Higher velocities are only allowed on a short-term basis (e.g., emergency conditions).
- The maximum discharge velocity is 10 fps. Higher velocities, up to a maximum of 12 fps, are only allowed on a short-term basis (e.g., emergency conditions).
- The minimum recommended discharge piping velocity is 3 fps.
- For vertical turbine pumps, the maximum barrel velocity is 3 fps.

The Design Contractor shall provide calculations of flow velocities for minimum, prevailing, and maximum flow conditions.

B. Piping Materials

Refer to Chapter 2 (Transmission Pipelines) for acceptable pipe materials, linings and coatings, etc. Suction and discharge piping shall be welded steel lined and coated. All linings and coatings shall be factory-applied. No handholes or field-applied linings are acceptable. Welded pipe subassemblies shall be designed by the pipe fabricator. Pipe subassemblies shall be connected with flanges or restrained flexible sleeve couplings.

The Design Contractor shall include in the Contract Documents a schedule of piping materials for all exposed and buried piping over 2 inches in diameter within the property limits of the pump station. The schedule shall include at least the following information:

Item No.	Diameter	Description	Units	Quantity	Remarks

Small piping, fitting, and appurtenances 2 inches and less in diameter connected to the pump suction and discharge piping shall use PVC bushings and stainless steel pipe. Galvanized steel pipe shall not acceptable.

C. Bolts and Fasteners for Piping

The Design Contractor shall specify all bolts and pipe fasteners per specification section "Piping Schedule and General Piping Arrangement" of the GC&SS (refer to Attachment 3-1). For buried flexible sleeve couplings, bolts and pipe fasteners are type 316 stainless steel. All buried fasteners shall be coated with polyamide cured epoxy and the coupling shall be wrapped with petrolatum/wax tape.

D. Dissimilar Metal and Isolation Connections

Insulating PVC bushings and dielectric flange gaskets shall be placed at pipe connections between dissimilar metals. The Design Contractor shall indicate any other electrical isolation fittings required to isolate pump station piping from sections of buried cathodically-protected piping. The Design Contractor shall refer to Section 2.7.6 of Chapter 2 of this guide for more information on cathodic protection.

E. Fittings for Differential Settlement

Flexible sleeve couplings, mechanical joints, or other flexible type fittings with restraining devices shall be provided where both inlet and discharge piping connect to a pump station or valve vault wall to allow for differential settlement. The fittings or couplings shall have a fusion bonded epoxy coating on both the inside and outside surfaces.

F. Vibration

Causes of pump vibration include:

- Poor suction conditions.
- Poor alignment.
- Air entrainment.
- Radial thrust.
- Pump operation at conditions outside the manufacturer's limits.

- Pump not installed properly.
- Pump base too small.

To minimize vibration and resonance, the Design Contractor shall:

- Properly design suction and discharge piping to prevent cavitation or excessive vibration.
- Select a pump that operates within a stable range on pump characteristic curves to prevent cavitation.
- Specify a mounting pedestal, floor or inertia block, of sufficient mass, typically three times greater than the mass of the pumps.
- Require, in the Contract Documents, level installation of the pump base and anchor bolts, and dynamically balanced pumps.
- Specify vibration amplitude that is less than the limits set by the Hydraulic Institute standards.
- Specify a unit responsibility and a single manufacturer for all pump components.
- Calculate the radial thrust and confirm it is within acceptable limits.
- Specify the pump and drive motor to be properly aligned prior to initial operation. Specify the alignment be verified and adjusted, if necessary, if the vibration condition persists.

G. Pump Base Plate Installation

The Design Contractor shall 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 and to the concrete equipment base for horizontal pumps. Specify type 316 stainless steel anchor bolts, nuts and washers for securing the pump base.

H. Pumps

All pumps within the pump station shall be of the same type and size. Variation in pump sizes may be allowed with proper justification from the Design Contractor and approval from the Design Manager. However, variation in pump type shall not be allowed under any circumstances.

Unless otherwise specified in the project predesign or basis of design report, pump stations shall be designed with one standby pumping unit having a capacity equal to the largest pumping unit in the station.

I. Expandability of the Pump Station

If the pump station is planned for expansion in the future, the Design Contractor shall ensure that adequate space is provided to accommodate the installation of all future pumps and equipment. The suction and discharge piping manifold shall be sized and arranged to accommodate future flows without having to take the pump station out of service, for extended periods of time, when expansion is required.

If it appears impractical or uneconomical to construct the pump station building to house future equipment, then the Design Contractor shall prepare a comparative study that addresses alternative means of providing the desired capacity to meet future requirements. The study shall contain comparison of cost, operability, and constructability issues between the proposed alternatives. Based on this study, the Water Authority will select an alternative to be pursued further with complete design.

3.4.2 Pump Characteristic and System Head Curves

The Design Contractor shall prepare a series of graphs for all possible cases (one graph for each case) of single and multiple running pump(s). Each graph shall address the following flow conditions:

- Minimum operating conditions (minimum flow).
- Maximum operating conditions (maximum flow).
- Prevailing operating conditions - use 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.

Each graph shall show and indicate the following:

- The system head curve(s) (operating condition) showing variation of total dynamic head (TDH) with flow. Provide a family of system head curves for a variety of operating conditions, including the minimum and maximum static lift head, minimum and maximum pipe roughness coefficient, minimum and maximum flow conditions, the prevailing (or most common) operating condition(s), etc.
- The number of pumps running.
- The selected pump(s)/impeller characteristic curve(s). This family of curves shall show the variation of pump discharge with head for different diameter impellers. The curves shall be as published by the pump manufacturer and shall not be extrapolated.
- If a pump speed control method is used (see section 3.6), provide the pump(s) operating curves at various speeds.
- Other pump(s) curves showing efficiency, Required Net Positive Suction Head (NPSHR), brake horse power (BHP), etc.

The Design Contractor shall carefully analyze the series of graphs developed for different operating conditions and number of pumps running and shall confirm the following for the selected pump(s)/impeller:

- The pump(s) characteristic curve is not “flat” - where a small change in total dynamic head (TDH) results in a large change in pump flow.
- The operating point on the system curve, for prevailing operating conditions, is near the maximum efficiency point (optimally just to the right of this point) of the pump characteristic curve. The maximum efficiency point is also known as the best efficiency point (BEP; minimum value of radial thrust).
- The pump(s) can still operate (i.e., pump shutoff head or runout conditions have not been reached), even with compromised efficiency, for both minimum and maximum operating conditions.
- The pump/impeller combination is located near the center of the pump operating curve (This is to facilitate modifying the pump with a different impeller to change pumping performance). Impeller modification may be required based on information determined during the pump station startup testing when the pump is discharging into the system. The maximum impeller size shall not be selected for a pump housing unless no other alternative is possible.

If any of the above criteria are not met, the Design Contractor shall select a different pump and repeat the testing procedure.

3.4.3 Net Positive Suction Head (NPSH)

The Design Contractor shall calculate the Net Positive Suction Head Available (NPSHA) for the following cases:

- Maximum flow and maximum temperature operating conditions.
- Minimum flow and maximum temperature operating conditions.

On the pump suction side (water supply source), the minimum operating suction hydraulic-grade-line elevation shall be used in the calculation of the NPSHA. A reasonable factor of safety (not less than 5 ft.) shall be applied to reduce the calculated NPSHA.

The Design Contractor shall compare the reduced NPSHA (following applying the factor of safety) with the Net Positive Suction Head Required (NPSHR) of the selected pump(s) at both minimum and maximum flow and speed conditions. To avoid cavitation, the NPSHR shall be less than the NPSHA at both maximum and minimum flow conditions. The Design Contractor shall select another pump if these conditions are not met.

This test shall be done for the cases of single and multiple running pumps.

3.4.4
Specific Speeds

Pump specific speed is a very useful tool for examining and comparing pump parameters. Specific speed is often used to determine which type of pump impeller to use. Applications that demand relatively high flow rates and low heads tend toward axial type of pumps with high specific speed impellers. In situations where the primary task is to pressurize water to higher elevations, selected pumps are usually radial flow pumps with low specific speed impellers.

The pump specific speed (N_S) is calculated as follows:

$$N_S = (\text{Speed; rpm}) * (\text{Flow; gpm})^{1/2} / (\text{TDH; ft})^{3/4}$$

In general:

N_S = 500 to 5000 for radial flow pump.

N_S = 5000 to 10000 for mixed flow pump.

N_S = 10000 to 15000 for axial flow pump.

In addition to the pump specific speed (N_S), the Design Contractor shall also calculate the suction specific speed (S_R) using the pump NPSHR (see Section 3.4.3) as follows:

$$S_R = (\text{Speed; rpm}) * (\text{Flow; gpm})^{1/2} / (\text{NPSHR; ft})^{3/4}$$

The Design Contractor shall also calculate the available specific speed (S_A) using the NPSHA (see Section 3.4.3) as follows:

$$S_A = (\text{Speed; rpm}) * (\text{Flow; gpm})^{1/2} / (\text{NPSHA; ft})^{3/4}$$

To avoid cavitation problems, the available specific speed shall be greater than the suction specific speed and shall be less than 8,500.

3.4.5
Pump Transient Analysis and Surge Control

A. Transient Analysis

The Design Contractor shall evaluate the pump station to determine the potential for hydraulic transients. The Design Contractor shall perform transient analysis and design a surge control system in accordance with requirements outlined in Chapter 9 (Surge and Transient Hydraulic Analysis) of the Design Contractor Guide (Design Manual – Volume One; ESD-160).

B. Surge Control

Surge protection shall normally be required at all pump stations. Before initiating the detailed design of pump stations, the hydraulic transient calculations prepared by the Design Contractor shall be submitted together with a description of any potential for hydraulic transients and a list of steps the Design Contractor recommends for further action or mitigation of the hydraulic transients.

Surge control measures for pump stations are limited to the following (refer to Chapter 9 of the Design Contractor Guide - Design Manual – Volume One (ESD-160) for limitations):

- Pipeline alignment revisions to eliminate potential column separation zones.
- Shaft-mounted flywheels to increase the rotating movement of inertia. It should be noted, however, that flywheels cause pump vibration and misalignment, and increase bearing wear to the pumping unit.
- Globe-type pump control valves on inlet or discharge pipelines. Pump control valves shall have an emergency shutdown power check feature for surge protection when power fails. These valves effect controlled closure, before flow reversal, when flow stops as a result of power failure. Both the valve body and flanges shall be rated to withstand the shutoff head of the pump or maximum surge pressure, whichever is greater.
- Surge tanks (hydropneumatic) on discharge pipelines – Generally used for small pump stations. The Design Contractor shall:
    - Size the tanks to reduce incremental surge pressure to a maximum of 33% of the discharge pipeline design pressure. The surge tank shall be designed, fabricated, and tested in accordance with the ASME Code for Unfired Pressure Vessels. If a surge protection tank is deemed necessary, it shall include all controls and appurtenances supplied by a single vendor as unit responsibility.
    - Provide an initial design and size calculation. The surge tank vendor will verify the design and sizing 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.
    - Size the surge tank air compressor at least twice the calculated capacity. Duplex (or dual) air compressors shall be provided. Sight glasses, piping, tubing, fittings, gauges, instrumentation, and other vulnerable

surge tank system components shall be protected to prevent damage resulting in surge tank failure.

- Surge control pipeline and a reservoir for large-size pump stations.
- Installation of a surge anticipator valve that senses a loss of power and/or pressure surge wave and opens on a set time delay or high pressure. Provide piping and valves to allow for pressure relief from the pump discharge side to the suction side.
- Installation of piping and other components of sufficient strength to withstand, both positive and negative, transient and surge pressures.

3.5 Pump Station Appurtenances

3.5.1 Valves and Actuators

A. General

The Design Contractor shall show on the design drawings all valves that are normally used by Operations and Maintenance personnel to isolate equipment or sections of piping, or that are used for normal operation or control procedures. Other small valves, which are part of packaged equipment or instrument systems required by codes or indicated in equipment specifications, do not have to be shown unless deemed important. All valves shall be numbered, and a schedule for all numbered valves shall be prepared by the Design Contractor. The valve schedule shall be shown on the drawings and shall include the valve number, pressure rating, type of valve, type of actuator, and sheet number of the drawing where the valve is shown. All valves shall be properly sized and selected to eliminate any possibility of flashing or cavitation. The Design Contractor shall refer to Section 2.5 in Chapter 2 (Transmission Pipelines) of this Guide and the following specification sections in the GC&SS (refer to Attachment 3-1) for additional requirements:

- Valves.
- Air Release and Vacuum Relief Valves.
- Electric Motor Actuators.

B. Isolation Valves

Isolation valves shall be installed on each pump’s inlet line and discharge line, and the pump station bypass and surge protection lines. This is to allow for removal and maintenance of pumps and other accessory equipment. Discharge isolation valves shall be installed a minimum of three pipe diameters downstream of pump control valves. Isolation valves shall be sited within the pump station building and/or site and shall not be directly buried.

C. Control Valves

Pump control valves are mainly provided to control flow during pump startup and shutdown operations. This is accomplished by controlling the opening and closing times of the valves to allow for gradual release and cessation of flow, respectively. Control valves may also be used on the pump bypass to discharge line (refer to Section 3.3.3 for more information). Control valves shall be equipped with a check feature that will close the valve in the event of power failure, thereby eliminating the need for a separate check valve.

Control valves shall be electrically or hydraulically actuated. Valve opening and closing times shall be regulated by a positive mechanical means and shall not be dependent on electronic means. Control valves shall be provided even if the pump is equipped with a variable frequency drive (VFD) or other speed control device.

During pump startup, each pump starts against a closed valve. The control valve shall open slowly to avoid introducing surges to the piping system. If the valve open time is very slow, to the extent that a pump may be subject to shutoff conditions, the Design Contractor shall then consider installing a bypass line to suction (see Section 3.3.4 for more information).

When the pump receives a stop signal, the pump shall continue operating until the control valve slowly moves to the fully closed position. This procedure is used to avoid introducing harmful surges into the piping system.

During power failure, the power check feature in the valve effects controlled closure of the valve.

The pump control valve shall allow for manual operation in the event of a pump speed-control equipment (e.g., VFD) failure. At this time, it becomes a regulating valve that controls the discharge flow (throttling) while the pumps are operating at constant speed. The pump control valve may also be used to prevent a pump runout condition.

Hydraulic losses when the valve is in the fully open position are considered a factor in selecting appropriate valves for a specific pump station. Control valves shall be identical in pump stations where all pumps are of the same size, and of the same type and manufacturer when pumps are of different sizes.

D. Air/Vacuum Relief Valves

Air valve assemblies (air release, air vacuum relief or combination air/vacuum relief) shall be provided at critical locations in the pump 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 filling of the piping, and to prevent piping collapse because of vacuum conditions caused by rapid drainage of the piping. Refer to Section 2.5.2 of Chapter 2 of this Guide for more information on air/vacuum relief valves. All valve relief ports shall be piped to the drains.

Air valve assemblies shall be 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.

The Design Contractor shall provide and specify:

- A 2-inch diameter air bleed (gauge cock) on each pump suction line.

- A gauge cock before each pump control valve and an air release valve after the pump control valve, on each pump discharge line.

E. Drain Valves (Blowoffs)

The Design Contractor shall provide a fitting on the suction and discharge side of each pump to drain pumps and check for residual pressure during maintenance prior to opening the drain. These fittings shall be welded to the main pipe and flanged for connecting an isolation valve. Flanges can be equipped with insulating kits if electrical isolation is desired. The Design Contractor shall adequately size the drains to handle the expected flows and drain the piping within a reasonable amount of time. Sumps and drains receiving the water drained from pipes shall also be adequately sized to handle the expected flows.

F. Other Valves

Such as isolation valves for instrumentation shall be ¼ turn ball valves. Insulating and reducing bushings shall be used, as applicable per instrument manufacturer recommendation, on the discharge side of the ¼ turn valve for proper instrumentation piping and for electrical isolation.

3.5.2 Flow Meters

To measure the entire pump station flowrate, a flowmeter on the discharge manifold shall be included. The manufacturer's recommendations for minimum unobstructed distance upstream and downstream of the flowmeter shall be followed. Flowmeters acceptable to the Water Authority include venturi meters and spool-type transit-time ultrasonic meters. Full magnetic meters may be used with prior approval from the Water Authority. For additional information on flow meters, refer to Section 4.3 of Chapter 4 of this Guide.

3.5.3 Pressure Gauges

Pressure gauge assemblies (pressure/vacuum) shall be installed on the suction and discharge sides of each pump (refer to Attachments 3-5 and 3-6 for location). In addition, pressure gauge assemblies shall also be installed on the pump station suction and discharge manifolds. Pressure gauge assemblies shall be mounted off the piping on a separate stainless steel stand to isolate the gauges from pump vibration. They shall be connected to the piping with the following fittings:

- Stainless steel nipple.
- Isolation ball valve with electrical isolation fitting.
- Flexible tubing off the piping to the gauge stand.

- Stainless steel instrument valve manifold.
- Air release cock.
- Diaphragm seal to prevent corrosion on the gauge(s) - fill the diaphragm seal and gauge with glycerin and provide a fitting for refilling.

To protect gauges from hydraulic shock pressure surges and pulsations, provide a stainless steel gauge snubber or a pulsation dampener. Gauges shall have a built-in safety plug for blowout protection in an overpressure condition.

The Design Contractor shall refer to the “Pressure Gauges” and “Field Mounted Instruments” specification sections in the GC&SS (refer to Attachment 3-1) for additional requirements on pressure gauges. For instrumentation and control requirements refer to Section 3.7 of this chapter.

3.6 Pump Motors and Speed Control

3.6.1 Pump Motors

Pump motors shall be of the squirrel cage induction type. The Design Contractor shall specify pump motors with the following characteristics:

- Meet NEMA MG-1 and MG-2 standards.
- High efficiency.
- Minimum efficiency shall be 93% at the specified operating points.
- Maximum rotational speed shall be 1800 rpm.
- Rated for 10 starts per hour.
- Nameplate horsepower shall exceed the maximum required by the pump at all points on the pump operating curve for the largest size impeller.
- For best efficiency, avoid oversizing motors since efficiency and power factor drop in motors running below load rating.
- A 1.15 service factor at ambient temperature plus 50°C.
- The temperature rise rating shall not exceed NEMA Class “B” temperature limits, as measured by the resistance method, when the motor is continuously operating at full load of 1.15 service factor in a maximum ambient temperature of 40°C.
- An Underwriter’s Laboratory (UL) or Factory Mutual (FM) rating.
- Totally enclosed fan cooled (TEFC).
- For vertical turbine pumps, motors shall have a hollow shaft for ease of adjustment.
- The Construction Contractor shall submit a detail showing how to adjust the pump impeller using the upper end of the motor.
- Cast iron frame.
- Copper windings - aluminum windings are not acceptable.
- NEMA Class “F” insulation with epoxy coating.
- 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.
- An over-temperature safety switch installed in the motor windings. Usually this is accomplished by redundant RTDs (Resistance Temperature Detectors) in each phase of the motor that are wired back to a protective relay (refer to Section 3.11.3) for more information.

- A heater element installed to reduce condensation. The motor heater element shall be strip type that automatically disconnects when the motor starts.
- Equipped with an anti-reverse rotation ratchet. Also install a lockout limit to prevent motor start if the pump control valve is not closed.
- For small motors not running on medium voltage, use solid state soft starters to reduce high power demand during startup. For motors running on medium voltage, use variable frequency drives (see Section 3.6.2) or reduced-voltage motor starters.

3.6.2 Pump Speed Control

A. General

In situations where the required discharge flow rate from the pump station is variable, a pump speed control method shall be required to vary the flow.

Several methods are currently available in the market that can be used to control the speed, and thus the discharge flow, of pumps. These methods include, among others, motor clutch control, Variable Magnetic Drives (VMDs), and Variable Frequency Drives (VFDs). In recent years the VFD method has been refined, has gained considerable advantages over other methods, and now has the largest share in the market. However, variable magnetic drives are beginning to emerge as a new technology that may prove better than VFDs.

The Design Contractor shall prepare a comparative study between VFDs and VMDs with recommendation as to which speed control method to select for the project. The comparative study shall include components such as cost, operation and maintenance, reliability, space requirements, power and efficiency considerations, etc.

B. Variable Frequency Drives (VFDs)

VFDs are electronic devices that control the speed of the motor by controlling the frequency of the voltage supplied to the motor. The VFD converts three-phase 60 hertz AC voltage to AC voltage at a desired frequency. Controlling the frequency controls the motor speed since the speed of an induction AC motor is proportional to the frequency of the voltage applied.

When multiple pumping units are provided, it is sometimes advantageous to equip a select group of pumps with VFDs and have the others run at constant speed. This is usually done to increase the overall efficiency of the pump station, and to minimize capital and maintenance costs. Each project is unique and the Design Contractor shall look into the project specific requirements to determine the need for and number of VFD units for the pump station.

For each VFD unit, the Design Contractor shall allow for and specify the following:

- A bypass connection to allow for pump operation at full speed without the VFD. The Design Contractor shall refer to Section 6.4 of Chapter 6 of this Guide for pump/VFD control options.
- Acceleration and deceleration ramping capabilities to smoothly transition flow when starting and stopping pumps.
- Continuous operation capability.
- Harmonics controller. An 18-pulse converter, PWM (Pulse Width Modulation), or equivalent, may be used. Harmonics filters are not desirable.
- The Construction Contractor to perform a Harmonics study following installation of the VFDs.

C. Variable Magnetic Drives (VMDs)

VMDs consist of a precision rotor assembly containing high-energy permanent magnets (mounted on the load shaft), and a copper conductor assembly connected to the motor shaft. Relative motion between the magnets and the copper creates a magnetic field that transmits torque through the air gap between the components. In effect, the magnetic "pull" between the magnets on the load side of the drive and the copper on the motor side creates the coupling force.

Varying the width of the air gap changes the coupling force, so the amount of torque transmitted between the motor and load can be continuously adjusted. This allows precise and efficient speed control for optimum performance, including "cushioned starts."

3.7 Instrumentation and Control

3.7.1
General

In this chapter, general Instrumentation and Control requirements for pump stations are outlined. Detailed Instrumentation and Control requirements are covered in Chapter 6 (SCADA, and Instrumentation & Control). The Design Contractor shall follow the requirements outlined in this section and Chapter 6 of this Guide, and use and specify the following Water Authority documents:

- The following specification sections in the GC&SS (refer to Attachment 3-1):
  - Electrical Controls and Miscellaneous Electrical Equipment.
  - General Instrumentation System Requirements.
  - Field-Mounted Instruments.
- Electrical/Instrumentation Guide Drawings (refer to Attachment 3-4).

3.7.2
Equipment and Instruments

Instrumentation and control at pump stations shall be provided to measure, control, and monitor the pumping operation including auxiliary equipment. The pump station shall be equipped with modules enabling communication with the Water Authority master data acquisition, processing and management center in the Escondido office (Escondido Control Center).

3.7.3
Vibration Monitoring

To monitor vibration and resonance, the Design Contractor shall specify in the Contract Documents the following:

- A vibration monitoring system (Entek XM-120 or equal). Redundant sensors shall be placed to monitor all three planes of movement X, Y, and Z on the inboard and outboard of both the pump and the motor.
- All cables and software with licensing for PC based setup, calibration and data logging.

3.7.4
Pump Station Surge Control

The Design Contractor shall provide the means to avoid surges on pump start/stop operation. Pressure surges caused by the transition from one-pump to two-pump operation, two to three, etc., shall also be avoided. The means to achieve surge control may consist of pump discharge control valves, hydropneumatic surge tanks, pressure relief valves, surge relief pipelines, reservoirs, other means, or a combination of them (refer to Section 3.4.5 for more information and additional requirements).

A. Control Valves

Control valves shall be provided with valve open and closed limit switches so that the control system verifies that the valve is in the proper position before starting or stopping the corresponding pump. All electrically operated valves shall also provide a valve position signal from an optical or other non-potentiometer signal source.

During normal starting and stopping of the pumps, each pump shall start against a closed valve. The valve shall open slowly to control upsurge. During the pump stopping sequence, the control system shall initiate 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 close. Closure time shall be determined by the Design Contractor to control surges in the pipeline.

All opening and closing times of control valves shall be independently adjustable, with times initially set as recommended in the final surge analysis. All control valves shall be equipped with (refer to Section 2.11.2 of Chapter 2 for additional requirements):

- Open limit switch - 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, unless the valve is used for flow throttling.
- Close limit switch - to protect the valve gearing and allow the start of pump.
- Torque switch -to protect the valve gearing and generate an alarm condition.
- Position indication for control, monitoring, and to generate alarm conditions.
- A power loss detector and an emergency closing feature to close the valve at the controlled rate in the event of motor power loss.
- Control status switch to indicate local or remote control conditions.

B. Surge Tanks

Surge tanks shall have a complete control and alarm system, as follows:

- The alarms shall include high and low water level, high and low pressure switch alarms, air compressor failure, etc.
- Alarm conditions shall start/stop pumps and add/vent air as

required to re-establish the required tank level and pressure conditions.

- Surge tanks shall be equipped with level probes, add/vent air pressure solenoids and pressure switches to maintain water level near the center of the tank.

C. Bypass Line to Discharge

Bypass line to discharge is covered in Section 3.3.2. The Design Contractor shall provide for installation of a pressure gauge and an air/vacuum valve on the bypass line located in a valve vault or above ground.

D. Bypass Line to Suction

Bypass line to suction is covered in Section 3.3.3. The pressure relief valve shall be equipped with the following:

- Close limit switch to indicate when the valve is closed, and to provide an alarm condition if the valve is slightly open thus allowing unintentional release of water to the suction side.
- Open limit switch to indicate when the valve is fully open.

3.7.5 Pressure Gauges

The Design contractor shall provide each pump with the following:

- A compound pressure gauge (combination vacuum and pressure) on the suction pipe. This is to keep the operator informed of pressure conditions on the pump suction side.
- A pressure switch on the pump station suction header. In the event of low suction pressure, the control system shall shut down the pumps sequentially. The pumps shall not start again until the operator acknowledges the alarm condition.
- A pressure gauge on the discharge pipe. Typical locations for these gauges are shown in Attachments 3-5 and 3-6 for horizontal and vertical turbine pumps, respectively.
- Differential pressure transducers shall have digital displays.

3.7.6 Pump Control Panel

For large pump stations running on medium voltage, each pump shall have a pump-control panel with a PLC that controls the pump, the VFD, and the Control Valve. The pump-control PLC will gather information from the instrumentation, receive speed setpoints from the Master PLC and will communicate with the Master PLC via ControlNet. The pump-control PLC shall have a color touch screen HMI for local control of the pump. In addition to the pump-control PLC, the pump-control panel shall also house the protective relays (refer to Section 3.11.3 for more information) that communicate to their respective PLC on ControlNet, Modbus, or DeviceNet.

Small pump stations may have a single pump control panel for all pumps.

3.7.7
Pump Station Telemetry and Alarms

Pump station data transmission to the Water Authority Operations Center shall be effected as described in Chapter 6 of this Guide.

At a minimum, the telemetry data transmitted shall include (Refer to the Water Authority PLC Implementation Standards for additional requirements):

- Pump(s) running status (on/off).
- Pump motor(s) high temperature.
- Bearing temperature.
- Vibration monitoring system parameters.
- Electric power metering parameters.
- Pump(s) circuit breaker/motor starter failure.
- Pump motor winding temperature.
- Pump motor overload alarm.
- Pump bearing temperature.
- Pump Control status (local/remote).
- Control power failure.
- Main power phase unbalance/failure.
- Pump(s) control valve failure.
- Pump(s) control valve status (open/close).
- Low suction pressure.
- Discharge flow rate.
- Discharge pressure.
- Pump room flooding as sensed by a float level switch in a sump.
- Intrusion alarm and door/hatch status for each entryway.
- Generator run status and failure.
- Ventilator fan failure, etc.
- Pump station ambient temperature.

The control system shall be designed so that simultaneous pump starts during normal operation or following a power outage scenario are not allowed. The Design Contractor shall allow for an operator-selected, initially set to 15-seconds, time interval between pump starts.

The control logic shall be configured to avoid excessive pump cycling. The start/stop cycles per hour shall be within the motor manufacturer's specifications.

When the pump reaches a speed that is higher than a predetermined speed (usually 90% of the pump maximum speed), the control system shall not allow for an additional increase in speed. This is to avoid disproportionate increase in electric power consumption. In some cases when the pump is running at close to its maximum speed, it may be advantageous to disengage the VFD and run the pump at constant speed. This will increase the overall system efficiency.

Similarly, when the pump is running at a predetermined low speed and pressure requirements dictate further reduction in pump speed, the control system shall turn off the pump to avoid running the pump at very low efficiency and the corresponding substantial electric power losses.

The VFD for each pump shall be 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.

To reduce cost, the Design Contractor may propose a control system that uses a combination of variable-speed pumps and constant-speed pumps. However, this proposal shall be supported by the appropriate technical and cost information and shall be approved by the Design Manager.

3.8 Corrosion Control

3.8.1 General

The Design Contractor shall design and specify in the Contract Documents the appropriate corrosion control requirements for the project components that are subject to corrosion. The Design Contractor shall refer to Chapter 2 of this Guide for information on cathodic protection for pipelines. The Design Contractor shall also refer to the Water Authority Cathodic Protection Guide Drawings (refer to Attachment 3-3) and the following specification sections in the GC&SS (refer to Attachment 3-1) for additional requirements:

- Crystalline Waterproofing.
- Plant-Applied Cement Mortar Lining.
- Cement Mortar Coating.
- Coal Tar Coating.
- Cold Applied Plastic Tape Coating.
- Fusion Bonded Epoxy Lining and Coating.
- Field Applied Cement Mortar Lining.
- Polyurethane Lining and Coating.
- Painting and Coating.
- Galvanic Anode Cathodic Protection.
- Impressed Current Cathodic Protection.

3.8.2 Protective Coatings and Linings

The term “coatings” refers to materials applied to the external surfaces of various structures (whether buried, submerged, or exposed) for protection against corrosion. The term “linings” describes materials applied to the internal surfaces of pipes, tanks and equipment for corrosion prevention.

The Design Contractor shall select appropriate coatings and linings for the various elements of the pump station, taking into account the service environment, ability of the coatings and linings to resist aging and maintain adhesion to the structure’s surface, ability to be applied with minimal defects, ability to withstand normal handling and storage, reparability, cost, and availability.

Steel surfaces immersed in water (surge tank internals, for example) require cathodic protection and shall have appropriate linings and coatings that, in addition to general requirements, are resistant to cathodic disbondment.

Normally, cathodic protection at pump stations is applied to surge tank internals (impressed current type) and some items immersed in water, such as valves, etc. (galvanic anode type).

More detailed information on coating and linings for pipelines, including generic types of coatings and linings, their application, and relevant standards is found in Chapter 2 of this Guide.

3.8.3 Electrical Isolation from Buried Pipe

Buried pipelines connected to pump stations are almost always protected from corrosion by cathodic protection systems. Cathodically protected pipe must be electrically isolated from the pump station's pumps, other equipment and appurtenances (e.g., valves, flowmeters, etc.), and the reinforcing steel in the walls and floors of the pump station structure.

There are two distinct design approaches of achieving electrical isolation between buried cathodically protected pipelines and pump stations.

A. Internal Electrical Isolation Approach

This design approach uses insulated flanges installed inside the pump station building on all pipe sections penetrating walls and floors.

The pros and cons of using the internal electrical isolation approach are listed below:

- With wall and floor penetrations, several insulated flanges are usually required, which increases the overall costs.
- Inspection is fairly easy.
- If problems occur with insulated flanges inside a pump station they can be easily repaired. Typically repair can occur without shutting down the pipeline.

B. External Electrical Isolation Approach

This approach uses buried insulated flanges or buried monolithic insulated joints (MIJ). An MIJ is essentially a heavy duty pipe special that acts like a large dielectric union with the important exception that it is welded inline with butt straps and can not be disassembled. Reasonable care must be taken when welding MIJs in pipelines so that the heat from welding does not melt the internal seals. For this reason, a minimum pipe length is required on each side of the MIJ. The lead time for MIJs is at least three (3) months.

The pros and cons of using the external electrical isolation approach are listed below:

- The buried pipe will only be protected from corrosion up to the point of electrical isolation. The pipe sections from the buried dielectric flange or MIJ must be concrete encased back to the pump station walls or floors. The pipe to be concrete encased can be installed with only the shop primer (i.e., no coating is required).

- Inspection of the electrical isolation at the buried insulated flanges can not be easily done.
- Compared to the cost of the internal isolation approach, some cost savings may be achieved because of using fewer insulating flanges. The cost savings of fewer insulated flanges has to be weighed against the additional cost of concrete encasement plus the cost savings of deleting the pipe tape coating for the concrete encased sections.
- There is no requirement for electrical isolation between the pipe and rebar at the wall and floor penetrations.

3.9 Noise Control

3.9.1 General

The noise design guidelines outlined in Attachment 3-7 define the minimum technical requirements to control noise from individual pieces of equipment or units within the pump station, at the facility boundary, and in the community. The noise-control guidelines shall be used by the Design Contractor for the design, material and equipment selection, construction, startup O&M considerations. Any deviations from the requirements of the noise-control guidelines shall be justified and requested in writing by the Design Contractor. Design Manager approval of all such deviations shall be required.

The Design Contractor shall also design a system in compliance with the permitting requirements and environmental considerations. Refer to Chapter 10, Environmental Compliance and Permit Support, of the Design Contractor Guide (Design Manual – Volume One; ESD-160) for more information.

3.9.2 Design Phase

Noise control for the design phase is covered in Attachment 3-7 in Paragraph 4.

A. Background Noise Levels

The Design Contractor shall conduct an ambient noise (background noise) survey during project design so that existing noise levels within the planned facility boundaries, at facility boundary lines and, where appropriate, in the community can be considered and incorporated into the design of the facility. The ambient noise survey procedures are discussed in Attachment 3-7 (paragraph 3.6) and shall be conducted in accordance with the methods described in Paragraphs 4.3 and 4.4 of Attachment 3-7.

B. General Facility Design

The Design Contractor shall prepare pump station designs that result in operating facilities that comply with all local, state and federal noise regulations. Facility noise predictions shall be developed during the engineering design phase to predict the pump station noise levels at locations frequented by O&M personnel, facility boundary line noise levels, and (where appropriate) community noise levels. The sound pressure levels of completed facilities during their operation shall be guaranteed by the Design Contractor to be within permissible limits of the noise-control 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 shall be identified by the Design Contractor and brought to the attention of the Design Manager.

3.9.3 Maintenance Considerations

The Design Contractor shall consider maintenance and safety issues while preparing the design and specifying noise control measures and devices. Maintenance and safety issues are discussed in Paragraph 3.5 of Attachment 3-7.

3.10 Testing and Facility Acceptance

3.10.1 General

The Design Contractor shall specify in the Contract Documents the requirements outlined below for testing, startup, and commissioning of the pump station facility. The Design Contractor shall refer to Chapters 19, Construction Phase, and 20, Startup and Commissioning, Closeout and Warranty, of the Design Contractor Guide (Design Manual – Volume One; ESD-160) for additional requirements.

3.10.2 Factory Acceptance Testing (FAT)

FAT greatly reduces the difficulty of debugging during field testing. The difficulty and expense of fixing anything onsite is much greater than at the factory. Also, the schedule pressure to get a system in operation intensifies after the equipment has been delivered, often resulting in poor startup practices.

The Design Contractor shall prepare a preliminary FAT plan, covering requirements and logistics, to be finalized by the Construction Contractor. The Design Contractor shall prepare specifications that require the Construction Contractor to test all major equipment at the factory prior to shipment to the project location. The Design Contractor shall also indicate that the FAT will be witnessed by the Water Authority.

A. Factory Testing Report - Pump Motors

The Construction Contractor shall have the pump motor manufacturer/supplier submit certified factory test information for the supplied pump motors. The information shall include motor heat run and efficiency test curves.

B. Factory Testing Report - Pump Units

Pumps shall be tested and certified at the pump manufacturer facilities. The Construction Contractor shall demonstrate and record the actual pump performance. The test shall be conducted per the Hydraulic Institute Society test requirements and shall include:

- Certified pump test curves recording the actual performance of each pump.
- Head/flow data (TDH/GPM).
- Pump shutoff head.
- Motor electric current draw at startup and up to 15 seconds.
- Motor RPM.
- Overall efficiency.

C. Factory Testing Report – VFD Units

If VFDs are required for pump speed control, the factory pump test shall also include the VFD units along with their control system and PLCs. Pump operation shall be demonstrated at 100 rpm increments in operating speed from full speed to the minimum allowable speed to verify VFD operation and pump performance.

3.10.3 Site Acceptance Testing (SAT)

A. Operational Test Procedures

The project specification prepared by the Design Contractor shall specify requirements for site acceptance testing (SAT). These requirements shall include a schedule of operational tests, to be witnessed by the Construction Manager, that demonstrate the proper operation of all equipment at the pump station. The Design Contractor shall coordinate SAT requirements and schedule of operational tests with the Operations and Maintenance Department of the Water Authority.

The Construction Contractor shall be required to demonstrate the proper operation of all mechanical equipment, electrical controls, emergency power operations, and warning displays. Simulated failure conditions shall be initiated, as required, to demonstrate the warning procedures.

Refer to Chapter 6, Instrumentation and Control, of this Guide for testing requirement of the entire facility including all equipment and the control system.

B. Installed Equipment Certification

The Design Contractor shall prepare 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 (e.g., pumps, motors, VFDs) certifying that the equipment has been properly installed, lubricated, accurately aligned, and is free from undue stresses imposed by connecting piping or anchor bolts.

The certifications from the Construction Contractor (and/or its equipment suppliers and subcontractors) shall certify that major equipment was installed, tested, and is operating according to manufacturer's recommendations. Certifications shall be provided for the following major equipment and appurtenances:

- Pumps and motors.
- VFD units.
- Emergency generator units including fuel tanks.
- Transformers.
- Isolation valves.

- Control valves.
- Check valves.
- Flow meters.
- Motor control centers.
- Pump control panels.
- Telemetry panels.
- Breakers and protective relays.
- Automatic transfer switches.
- Pressure gauges and switches.
- Other equipment, instruments, and appurtenances as required.

C. Electrical Testing Report

Prior to startup and testing of the facility, an initial electrical testing of all equipment shall be performed. This initial testing may require the Construction Contractor to activate circuits, shutdown circuits, run equipment, make electrical measurements, replace blown fuses, and install temporary jumpers. The Construction Contractor shall prepare an Electrical Testing report certifying and documenting successful electrical testing and demonstrating the following:

- Correct operation of the utility interface protective devices.
- Correct operation of all switchgear and MCC protective devices.
- Relays are functional and calibrated to manufacturer's tolerances.
- Correct operation of current transformers per ANSI/IEEE standards, including EDT (Eddy Current Testing), turns ratio and gas testing.
- Correct power transfer with no short circuit issues.

D. Facility Testing

All testing requirements outlined in Section 3.10.2, Factory Acceptance Testing, shall be repeated for the project site testing. In addition, the following shall also be tested:

- Discharge control valves.
- Water to wire efficiency.

Data collected during project site testing shall include:

- Pressure in the suction and discharge piping.
- Power, voltage, and current input to VFDs.
- Opening and closing times of valves.
- Motor power output, voltage, and current.

- Pump discharge flowrate.
- Electrical system testing including automatic transfer switches (ATS).
- Instrumentation and control system (refer to Section 6.6 in Chapter 6 for more information).
- Generator system.

E. Startup and Commissioning Report

The Construction Contractor shall prepare a Startup and Commissioning report that includes:

- Accepted start-up procedure submittal.
- Record of all training being completed.
- List of accepted O&M manuals.
- Accepted notice to begin start-up.
- Accepted list of all factory representatives and other key personnel that will be on-site with contact information.
- Completed wire lists and connection details.
- Completed NIST (National Institute of Standards and Technology) traceable calibrations of all instrumentation.
- Completed as-builts.
- Summaries of recorded data from all equipment.
- List of all instruments used in the testing.
- Revised settings of various equipment and instrumentation.
- Revised performance data of equipment as obtained during the startup testing.
- Failures and corrective actions.

F. Vibration Testing and Analysis Report

The Construction Contractor shall be required to submit a vibration test plan for review and approval, and to provide a Vibration Test and Analysis report for the installed pumping and piping, and emergency generation equipment. The vibration testing and the analysis report shall be performed by a State of California Registered Professional Mechanical Engineer experienced in this type of work. The report shall document the measured vibration levels at critical locations on the equipment across the range of operating and pump speed conditions.

3.11 Electrical Design and Emergency Power Generator

3.11.1 Electrical Design Work

A. Drawings, Specifications, and Calculations

The Design Contractor shall refer to Chapter 4 of the Design Contractor Guide (Design Manual – Volume One; ESD-160) for more information on drawings, specifications, and calculations. The Design Contractor shall also refer to the GC&SS (refer to Attachment 3-1) including the following specification sections:

- General Electrical Requirements.
- Raceways and fittings.
- Wires and Cables.
- Wiring Devices.
- Cabinets and Consoles.
- Safety Socket Can.
- Grounding.
- General Purpose Dry-Type Transformers.
- Panelboards.
- Lighting Systems.
- Uninterruptible Power Supply.
- Electrical Controls and Miscellaneous Electrical Equipment.

The Design Contractor shall prepare the technical specification sections and the electrical drawings necessary to assemble and construct a complete electrical package. The Design Contractor shall also prepare electrical calculations for load determination and shall use extreme caution when calculating the load demand. San Diego Gas and Electric Company (SDG&E), the electric utility company in San Diego County, shall be approached officially for allocation of electrical power demand for the pump station. The Design Contractor shall coordinate power-supply for the project with SDG&E. Any errors in calculating demands or items not accounted for may lead to severe project delays while re-approaching SDG&E for power demand alterations.

B. Codes and Standards

The pump station electrical system shall comply with the requirements of NEC, ANSI, UL, NEMA, and IEEE, as applicable.

3.11.2 Electrical Service and Distribution

Distribution (utilization) voltages are 69 kV, 12 kV, 4.16 kV, 480 V, and 240/120 V unless other voltages are specified for special cases. Incoming service voltage to the pump station shall be coordinated with SDG&E.

The Design Contractor shall design the pump 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 shall incorporate redundant power sources.

Vital components serving the same function shall be divided as equally as possible between at least two MCCs.

Outdoor installations shall be in weatherproof enclosures.

During pump startup, the voltage drop at the motor terminals shall not exceed 15%. Feeder and branch circuit conductors shall be 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:

- Motors:
  - Smaller than 3/4 hp, 115 volts, single-phase, 60 Hz.
  - 3/4 hp and larger (up to 300 hp), 460 volts, 3-phase, 60 Hz.
- Miscellaneous non-motor loads of 0.5 kW and less shall be single-phase rated at 115 volts, 60 Hz.
- Non-motor loads larger than 0.5 kW shall be rated at 460 volts, 3-phase, 60 Hz, unless this voltage rating is not available for the equipment selected.
- Lighting:
  - Outdoors: General area lighting; Energy-saving fluorescent, 115 volts, single-phase. Specific area lighting; Motion-activated fluorescent.
  - Indoors: Fluorescent, 115 volts, single-phase.
- General-purpose receptacles shall be rated 20 amps, 120 volts, single-phase.
- Special purpose receptacles may be 120 volts, or 480 volts (3-phase as required).
- All air conditioning control power circuits shall be 120 volts, single-phase.
- An uninterruptible power supply (UPS) shall be provided for all main control panels, PLCs (Programmable Logic

Controllers), and all other process controllers as required for the specified instrumentation and controls. All UPS power supplies shall be 120 Volts, single-phase, 60 Hz received from the power panel circuit.

- All instrumentation and instrument-panel power shall be 24 Volts DC supplied directly from the UPS. Provide separate fuses for each field device.
- Switchgear DC control shall be equipped with batteries and primary and backup chargers to maintain functionality of the protective relays.

3.11.3 Electrical Equipment

The Design Contractor shall size electrical equipment and rate materials according to the NEC code requirements. Electrical equipment panels shall be provided with cooling fans or other means to dissipate heat.

A. Medium Voltage Motor Controllers

Medium voltage controllers shall be modular design, vacuum contactor type. All medium voltage starters shall be furnished with protective relays. All protective relays shall communicate to their respective PLC on ControlNet, Modbus, or DeviceNet. All protective relays with PTs (Potential Transformer), CTs (Current Transformer) and/or RTDs (Resistance Temperature Detector) shall have three CTs and three PTs as well as redundant RTDs. Indoor enclosures for motor controllers shall be NEMA 12 rated and below grade enclosures shall be NEMA 4 rated.

B. 600-Volt Motor Control Centers

MCCs shall have the following requirements:

- Low voltage motor control center (MCC) assemblies shall conform to the UL and ANSI standards for NEMA Class 2, Type B wiring.
- All breaker handle mechanisms shall have padlocking devices on the “OFF” position.
- All indicator lights mounted on the MCC shall be LED push-to-test type.
- All combination magnetic starters shall have MCPs (Motor Circuit Protectors) and time delay mechanisms to prevent the unit from dropping out during momentary utility voltage dips.
- A continuous-bus ground shall be provided.

C. Variable Frequency Drives

VFDs, where required, shall be provided with the pump and motor to provide unit responsibility for a system that performs over the required head and flow ranges. The VFDs shall be used to drive induction motors, and shall be equipped with a harmonic controller. Refer to Section 3.6.2 for more information.

D. Switchgear

Switchgears shall conform to:

- UL and ANSI standards, and comply with the service requirements of SDG&E.
- For outdoor applications, the switchgear shall be weatherproof NEMA 4, non-walk-in type.
- Busbars shall be copper, fully insulated and silver-plated at joints. A full-length ground bus shall be provided.

E. Grounding

All feeders shall have an equipment grounding conductor in the same raceway. Equipment grounding conductors shall be sized in accordance with NEC requirements.

3.11.4 Emergency Power

A. Emergency Plug-in Connection

In stations without an alternative backup power source (i.e., second service or a dedicated onsite emergency power plant), the Design Contractor shall allow for installation of a manual transfer switch and an emergency plug-in power connection, or an outdoor cabinet (with appropriate NEMA rating) with lugs for connection, to the pump station for use with a portable generator.

The pump station shall 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.

The transfer switch shall have the same current amperage interrupt rating (AIC) as the line power main breaker.

The following warning sign shall be posted on the manual transfer switch panel:

"DO NOT TRANSFER POWER UNDER LOAD"

B. Emergency Power Generator

Diesel engine generator units may be required as an emergency power source. These units are usually factory-packaged by the manufacturer and delivered pre-assembled to the pump station site. Unless otherwise noted in the project predesign report or not feasible, the emergency diesel generator shall have sufficient capacity to start and operate all online pumps, plus pump station auxiliary loads, such as instruments and controls, lighting, air compressors, ventilation units, fuel pumps, and the like. Unless otherwise required, the emergency diesel generator shall not be required to operate spare or standby pumps. The Design Contractor shall specify a two-year standard service contract for the emergency diesel generator to be provided by the Construction Contractor.

The Design Contractor shall specify that:

- The construction Contractor shall confirm emergency generator set meets all current APCD requirements.
- All permitting and inspection is part of the Construction Contractor's work.
- The fuel tank and the automatic transfer switch (ATS) shall be located external to the engine generator unit.

The preferred fuel tank installation is either a frame-mounted fuel tank under the emergency generator unit that is surrounded by an outer containment tank, or an aboveground tank installed in a block-wall enclosure incorporating a confinement tank. The aboveground tank shall be used where possible. All diesel storage tanks shall have a desiccant dry-air breather on vents to prevent water condensation in the tank. Unless otherwise noted in the project predesign report or not feasible, fuel tanks shall be sized to sustain a minimum of 24 hours of continuous pump station operation at full capacity. All containment tanks shall be monitored for a rupture/leak in the primary tank.

The pump station shall have an interlock-protected emergency power ATS to automatically start the generator in the event of loss of main power (i.e., power loss of a phase, reverse power, or low voltage brownout). The ATS shall be mounted in sight of the generator control panel or remote status annunciator panel for ease of operation. The ATS shall be provided with communication provisions for remote annunciation and control via the local telemetry system.

3.11.5 Lighting and Receptacles

A. Lighting

Refer to paragraph 3.12.2 of this chapter for lighting voltages. The State of California Energy Conservation Standards shall apply, where applicable.

Lighting levels shall be as follows:

Area	Illumination Level
Electrical Equipment Rooms	40 foot-candles
Exterior Lighting	0.1-1 foot-candle
Pumping Area (dry well)	30 foot-candles
Mechanical Equipment Rooms	30 foot-candles

Lighting shall be switch operated. For loads exceeding the switch capacity, use a lighting contactor. Provide switches at all doors. The pathway to the main lighting switch shall be lighted with non-switched lighting fixtures.

Exterior lighting, around unattended pump stations, shall be provided with motion-activated switching with manual on/off control. For outdoor lighting, the Design Contractor shall select luminaries that produce the least glare over the surrounding area. Exterior fixtures shall be vandal-resistant.

Emergency egress lighting in all interior areas of the pump station shall be accomplished with units having emergency battery backup packs illuminating the egress path to the outdoors. At least 90-minute battery backup capacity shall be provided.

B. Receptacles

20 amp, NEMA 20-R, 120-volt grounding convenience receptacles for GFI plugs shall be provided throughout the pump 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 shall be provided so that the receptacle can be reached by a 50 foot long cord.

All receptacles in outdoor areas shall be in weatherproof enclosures and be protected by GFI circuit breakers.

3.12 Pump Station Support Systems

3.12.1 Ventilation

The Design Contractor shall design the ventilation system to cool the facility using outside air as a cooling medium. In case outside air is not adequate to provide sufficient cooling for the facility, the Design Contractor shall propose other alternatives (e.g., heat exchangers using inlet water). The Design Contractor shall discuss and obtain approval from the Design Manager and the Water Authority Operations and Maintenance Department on the proposed cooling system.

The Design Contractor shall calculate 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 shall be based on the latest edition of ASHRAE HVAC Applications; Chapter: Ventilation of the Industrial Environment; Paragraph: Ventilation Airflow for Temperature Control. 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
- Δt = temperature rise of the air, °F

The Design Contractor shall 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 Contractor shall use six (6) air changes 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 Design Contractor shall design the ventilation system for noise levels as described in Section 3.9 of this chapter. This noise limit shall include the sum of fan intake, fan discharge, motor, and casing rotation noise. The maximum fan noise load at one meter distance shall be 85 dBA. Ventilation systems shall specify the use of low noise fans.

Provide replaceable dust filter elements on inlet wall louvers or supply air fans. Inlet ventilation dust filters shall be installed to minimize entry of dust into the station. Filters shall be located at access doors in the ducting, fan heads, and at convenient locations for maintenance access.

The dust filter shall be of the replaceable media on rolls with automatic sensors that send an alarm signal when the roll is running low and when it is consumed.

Inlet wall louvers shall be weatherproof and shall be 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 shall be provided.

As a special pump station requirement, exhaust louvers may have motor-operated grates that open when the ventilation system is in operation.

Pump station ventilation systems operate by thermostatic control with manual on/off override.

Underground pump station areas in coastal and other high-humidity areas shall be equipped with a wall-mounted dehumidification system.

3.12.2
Overhead Hoist

The Design Contractor shall design an overhead hoist system for the installation, disassembly, maintenance, and removal of piping, motors, pumps, valves, flow meters, and other major components in the pump station. Design of all hoists shall be in accordance with the Hoist Manufacturer's Institute.

Hoisting systems include:

- Traveling bridge cranes of the top running type consisting of electric drives, end truck, trolley hoist, and controls. The controls for this type of hoisting shall be both tethered and wireless.
- Monorails or jib crane systems with manual hoists.

On large pump stations, hoisting system may be designed to handle only small equipment. The Design Contractor shall provide roof access hatches or operable, vandal resistant, skylights for removal of pumps and motors using truck-mounted mobile cranes. The Design Contractor shall install a high access door at the end of the crane rail to allow for positioning a truck-mounted crane inside the pump station for the removal of equipment. On some pump stations, embedded eyebolts may be provided to assist in equipment removal.

3.12.3
Pump Room Drainage System

The drainage system shall consist of a floor drain, hub drain, cast iron drain pipe, holding sump and sump pumps. The drainage system shall be designed to handle drainage from the pump seals, power check valves, air release valves, blowoffs and other drains placed on the piping, and housekeeping. Floor drains shall be located and floor slopes designed so that equipment pads do not interfere with drainage. The drainage system shall be discharged to the municipal sewer system. The Design Contractor shall consult 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 shall be 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 shall be covered with aluminum grating.

Sump pumps shall be duplex-type submersible pumps complete with lifting chain, discharge valve, check valve, and piping, starter, level controls, and automatic alternator.

High water level alarms shall be connected to the main pump station control panel. For underground installations, the high water level or flood alarm shall be separate from the sump pump controls and mounted on the wall approximately one foot from the floor level.

3.13 Pump Station Site Work

3.13.1 Site Constraints

The Design Contractor shall review the project predesign report for site constraints that may affect the design appearance, character, materials selection, earthwork, and location on the pump station site. Views of the facility from areas surrounding the project site shall be analyzed, and alternatives discussed to harmonize the appearance of the facility with its visual context. Regardless of the visual circumstances, the pump station operating floor shall be in all cases located above the 100-year flood elevation.

Pump station sites may not be located on easements, and shall be entirely located on Water Authority owned land with secured and fenced parking area around the pump station that is adequate for staging a major overhaul of the facility.

The impact of the project on existing drainage patterns shall be investigated. The Design Contractor shall develop mitigation strategies if necessary.

3.13.2 Site Utilities

The Design Contractor shall identify and coordinate with appropriate local utility agencies representatives as described in Chapter 5, Records Research, Utility Coordination, and Field Investigations, of the Design Contractor Guide (Design Manual – Volume One; ESD-160). The Design Contractor shall also refer to the predesign report for any available information on utilities that might be impacted by each project.

The Design Contractor shall design the water service with a reduced pressure backflow protection device installed after the water meter. The site water piping system shall include a minimum 3/4-inch water riser and hose bib placed inside the pump station building for cleaning the building and adjacent site. The design shall include parking posts placed around the reduced pressure backflow prevention device to protect it from damage due to traffic.

3.13.3 Access and Parking

A vehicle access road at the pump station site shall allow the positioning of a crane truck of the size required for removal of the largest pump station equipment through roof hatches when appropriate. All vehicle access roads to pump stations shall be asphalt paved with a minimum width of 24 feet, and shall conform to the local fire codes.

Avoid locating truck access roads and parking over inlet discharge piping penetrations into the pump station walls to avoid pipe shear loadings at these locations. The site shall include sufficient parking space for two 3-ton maintenance trucks.

3.13.4 Landscaping

All pump stations shall be landscaped in a manner that meets community standards and conforms to the “Revegetation” specification section in the GC&SS (refer to Attachment 3-1). The landscape design shall 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 shall be developed by a member of the Design Contractor team who is a licensed landscape architect.

Irrigation systems and plant material shall not be installed outside the facility fence unless it is absolutely necessary to screen objectionable views of the facility from the community or to prevent the erosion of manufactured slopes.

Landscaping selected by the Design Contractor shall be drought tolerant. Landscaped features on the pump station site shall be low maintenance and low irrigation (xeriscaping) types.

Landscaped areas shall be provided with an automatic irrigation system. A reduced pressure backflow prevention assembly shall be 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 shall be mounted in the door of the controller cabinet inside the pump station. Reclaimed water shall be used for irrigation, if available.

Fence perimeter shall be kept clean of any vegetation. For security purposes, keep trees that could be used for "jumping" the perimeter fence to ten (10) feet away from the fence.

3.13.5 Security

The pump station site shall be completely enclosed by a 6- to 8-foot high fence. The fence shall be chain-link or architectural wrought iron type to meet community architecture requirements. The fence may have webbing to reduce station visibility, if required by a community architecture review. A 6-foot high masonry brick wall around the station may also be constructed where appropriate to match existing architecture. Refer to the “Fencing” specification section in the GC&SS (refer to Attachment 3-1) for additional requirements.

All pump station appurtenances located outside the pump room, such as isolation valves, valve vaults, domestic water fixtures, and irrigation system fixtures shall be located inside the site security fencing. If possible, the security fence shall be located on or immediately adjacent to the property line.

All gates and doors shall be provided with locks keyed to conform to the Water Authority's master key system. The main gate shall have an electronic access control system with cardkey access. Gates, doors, windows, skylights, and other openings to the pump station shall be equipped with intrusion switches (refer to Chapter 6, SCADA, and Instrumentation and Control, for more information). Intrusion events shall be monitored both locally and remotely.

The Design Contractor shall make provisions, such as conduit installation, to enable installation of power and control conductors for a video camera-based security system with strategically located cameras. Consult with the Water Authority security representative for location of cameras.

The Design Contractor shall refer to the following specification sections in the GC&SS (refer to Attachment 3-1):

- Access Roads.
- Fencing.
- Access Control and Intrusion Alarm System.

The Design Contractor shall also use the following guidelines, developed by ASCE/AWWA/WEF:

- Interim Voluntary Security Guidance for Water Utilities. Refer to Attachment 3-8 for the cover page of this guidance. The Design Contractor shall refer to the following sections in this guidance and provide a list, for the Design Manager approval, of all applicable security elements that could be included in the design:
    - Applicable paragraphs of section 4 (Design Considerations for Developing Physical Security at New Facilities and Retrofits).
- Guidelines for the Physical Security of Water Utilities. Refer to Attachment 3-9 for the cover page of these guidelines. The Design Contractor shall refer to the following sections in these guidelines and provide a list, for the Design Manager approval, of all applicable security elements that could be included in the design:
    - Table 3.1 (Security Measures for Wells and Pumping Stations);
    - Table 7.1 (Security Measures for Water System Support Facilities); and
    - Appendix A (Physical Security Elements).

3.14 Architectural Treatment

3.14.1 General

This section provides a general basis for the approach to architectural design of pump stations. Although the guidelines described in this section apply to pump stations, the general concepts could be applied to other Water Authority facilities that incorporate pump stations and other related buildings/structures (e.g., combined reservoir/pump station facilities).

3.14.2 Design Performance Guidelines

The Design Contractor shall 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. The Design Contractor shall:

- 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.
- Discover and document the degree and type of human interaction anticipated to occur within and around the planned facility, including Water Authority personnel and access to the facility in the form of visits by non-Water Authority personnel. The building design 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.
- Determine locations and sizes of structures and other functional systems that may already exist at the project site, as well as the availability and types of utility services that may be required. Develop strategies to successfully integrate the design of the new facility into this context.
- Investigate existing zoning constraints, applicable building codes, and anticipated public and governmental review procedures necessary during the course of the design.

- 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.
- Review and incorporate mitigation measures included in environmental documents for the project.
- Use the minimum criteria for noise control described in Section 3-9 of this chapter. Additional, or stricter criteria may be established in the environmental approval process. The Design Contractor shall use the most conservative criteria established.
- Analyze views of the facility from areas surrounding the project site and develop alternatives to harmonize the appearance of the facility with its visual context. The Design Contractor shall ensure that viewsheds are optimized while hydraulic elevations and storm drainage provisions are preserved.
- Analyze facility and related structures for safety. Minimize confined space areas, as possible.

3.14.3 Design Appearance Guidelines

The architectural design shall 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:

- **Height of Structures** - The facilities shall be kept as low in profile as is functionally possible. Where appropriate, the design shall 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 shall be considered in achieving this balance.
- **Electrical and Pump Rooms** - It is preferable to separate the electrical equipment room from the pump room. The electrical room is either located in a separate building or separate from the pump room by a divider wall fitted with a fixed viewing window. For pump stations with both an electrical room and pump room in the same building, the electrical room shall be elevated at least 4 inches to provide positive drainage in the event of a pipe failure and flooding. The electrical room shall have a window in the wall between the pump room and the electrical room for safety and to enable viewing of pump operation.

- **Rest Room** – All pump stations shall be equipped with a uni-sex bathroom. Positive drainage to a nearby sewage drain or an on-site leachate facility shall be accommodated.
- **Reflective Finishes** - Visible and highly reflective materials and surface finishes shall be avoided on the exterior of the facility.
- **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 shall be achieved through the use of integral coloration and, in the case of concrete, pigmented admixtures, rather than applied coloration such as paint.
- **Roofs** - The design of roof systems shall be carefully developed to harmonize with the visual context of the facility. Where flat roofs are appropriate, they shall be predominately hidden by parapet walls. Where pitched roofs are desired, consideration shall be given to selecting pitch, materials, and coloration to harmonize with surroundings. Highly reflective roof surfaces shall not be visible from adjacent property. Mansard and jogging roof lines shall 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 hatches for ease of equipment removal using a mobile crane.
- **Windows** - Where windows are appropriate to the design, they shall 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 shall be chosen for their consistency with the palette of materials and colors selected for the facility.
- **Insets, Grills, Trim and Accents** - Insets, grills, trim material, and accents shall be employed judiciously and only where necessary or appropriate for compatibility with adjacent structures. Insets, grills, trim, and accents shall be consistent with the color palette chosen for the facility and shall avoid bold, strong, or reflective colors.
- **Doors and Frames** - Door and frame colors shall be compatible with the wall surface in which they are located.
- **Lighting** - Lighting shall satisfy functional and security needs while not creating light pollution in the form of point sources of direct glare visible from a distance. Lighting shall be

sensitive to the privacy of adjacent land uses. Fixtures shall 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 that light immediate areas are encouraged. Natural lighting of the interior of the building in the form of skylights and clerestory windows is also encouraged.

- **Equipment and Service Areas** - All mechanical and electrical equipment shall be screened from public view.
- **Materials** - 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 emergence from the basic structural system, and their appropriateness in accommodating the deployment of mechanical and electrical systems within the facility. Materials used in the construction of the facility shall conform in composition and application to all applicable regulations, including those concerning volatile organic content, lead, mercury, CFCs, and asbestos. Materials used for the roofing system and the building perimeter envelope shall be established for optimum durability over the full range of climatic variations typical to the region.

The above parameters form the basis of directions to the Design Contractor about the appearance of the building. The Design Contractor shall develop 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.

3.14.4 Space and Function Requirement Report

The Design Contractor shall prepare a Space and Function Requirement report (SFR) at the early stages of Design, before issuing the Preliminary Design Package (see Chapter 4, Design Development, of the Design Contractor Guide (Design Manual – Volume One; ESD-160) for more information). The SFR report shall document the space and function of the facility as guided by the requirements in Sections 3.14.2 and 3.14.3 above. The report shall thoroughly document gross area and volume requirements, as well as a schematic of the basic functional relationships within the facility. It shall also completely describe the parameters of appearance, function, size, and layout. The Design Contractor shall submit the SFR report to the Design Manager for review and approval. Following the SFR report approval, the Design Contractor shall proceed with detailed design of the facility where functional relationships and area and volume requirements are further developed.

3.15 Structural Guidelines

3.15.1 Standards and Codes

In addition to the requirements stated in Chapter 5, Seismic Design Criteria, the most recent version of the following standards, codes, reports and design aids shall be used for the structural design of pump stations:

- California Building Code (CBC) by the International Conference of Building Officials, 2001 edition.
- Building Code Requirements for Minimum Design Loads in Building and Other Structures, per the CBC.
- Title 24, Part 2, California Building Code.
- Uniform Building Code (UBC) of the International Conference of Building Officials.
- Building Code Requirements for Reinforced Concrete, ACI (American Concrete Institute) 318, and commentary ACI 318R, as contained in UBC.
- Environmental Engineering Concrete Structures (ACI 350 R).
- Concrete Manual by the U. S. Bureau of Reclamation.
- Concrete Reinforcing Steel Institute (CRSI) Handbook.
- Rectangular Concrete Tanks, by Portland Cement Association (PCA).
- Water resources technical publication, Engineering Monograph No. 27, Moments and Reactions for Rectangular Plates by the U. S. Department of Interior Bureau of Reclamation.
- 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).
- Structural Welding Code Steel, ANSI/AWS-D1.1.
- Specification for the Design of Cold Formed Steel Structural Members, by American Iron and Steel Institute (AISI).
- Specifications for Masonry Structures, ACI 530.
- Reinforced Masonry, Engineering Handbook by Amrhein
- Timber Construction manual, by the American Institute of Timber Construction (AITC).
- National Design Specifications for Stress-grade Lumber and its Fastenings, by National Forest Products Association.

- Recommended Lateral Force Requirements and commentary by the Seismology Committee of the Structural Engineers Association of California, commonly known as Blue Book, (SEAOC Blue Book).
- Formulas for Stress and Strain, by Roark and Young.
- Standard of the Occupational Safety and Health Administration (OSHA).
- State of California Construction Safety Orders (Cal-OSHA).

The Design Contractor shall also refer to the following specification sections in the GC&SS:

- General Concrete Construction.
- Structural Steel, Aluminum and Miscellaneous Metalwork.

3.15.2
Design Loads and Loading Combinations

The following criteria define the minimum design loads to be used in the design of pump station structures. All design loads shall conform to the requirements of the UBC and all applicable requirements of other documents referenced in Section 3.15.1 of this chapter. Seismic loads shall be in accordance with the seismic loads described in Chapter 5, Seismic Design Criteria.

Dead loads, live loads, wind loads, hydrostatic and hydrodynamic loads, lateral loads, seismic loads, impact and vibration loads and miscellaneous loads are described below.

3.15.3
Design Loads

A. Dead Loads

Dead loads, which are defined as the weight of all permanent construction, including equipment and piping permanently connected to the pump station, shall be determined using the following unit weights:

Material	Dead Load
Concrete	150 pcf
Steel	490 pcf
Aluminum	169 pcf
Fiberglass	100 to 115 pcf
Wood	40 pcf
Masonry, concrete block, solid	
grouted 8 inches wide	75 psf (lightweight)
	84 psf (normal weight)
12 inches wide	118 psf (lightweight)
	133 psf (normal weight)

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

- All equipment (including all internal and refractory lining) and piping permanently attached to and considered part of the structure, including future equipment and piping.
- Fireproofing used on structural steel, equipment, etc.
- Structural steel platform framing and floor plates (use an estimate of 20 psf). Heavy beams or girders, such as those required to carry other than platform live loads, are considered separately.
- Piping 12 inches in diameter and smaller are treated as uniformly distributed loads. A typical minimum value of 20 psf is used.
- Piping larger than 12 inches in diameter is treated as a concentrated load.

B. Live Loads

Live loads shall be determined as follows:

- Roof Loads: in accordance with the ASCE 7/ANSI A58.1, UBC, or local code, whichever is more stringent.
- Stairs, Platforms, and Walkways: 100 psf or local code, whichever is more stringent.
- Minimum concentrated load on ladders and stairs is in accordance with the requirements of ANSI-A58.1, OSHA, Cal-OSHA or local code, whichever is more stringent.
- 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 of equipment in determining the actual design live load and concentrated loads. Minimum loads for some specific areas are:
    - Pump Room or Generator Floor 150 psf
    - Auxiliary Equipment and Control Rooms 250 psf
    - Equipment Rooms 200 psf
- Mechanical areas are designed for a minimum 100 psf of live load. Additional consideration shall be given for the type, size, and weight of specific equipment and the maintenance of equipment in determining the actual design live load and concentrated loads. Minimum loads for some specific areas are:
    - Equipment Floors 300 psf
    - Shaft, Duct or Vent Floors 100 psf

- Lifting eyebolts capable of lifting concentrated equipment loads shall be incorporated into the design as live loads.
- Floor loading shall be compared with actual equipment load derived from vendor drawings. The more stringent uniform load will be used.

C. Wind Loads

Wind loads shall be in accordance with the CBC or the requirements of the local code, whichever is more stringent. The design shall be governed by the maximum wind or maximum seismic loads, whichever is greater.

D. Lateral Loads

All pump station structures shall be designed for the applicable pressures, as follows:

- For all yielding structural components, lateral soil loads shall be determined by using active soil pressure conditions as recommended in the geotechnical report.
- For all non-yielding structural components, lateral soil loads shall be determined by using at-rest soil pressure conditions as recommended in the geotechnical report.
- A minimum surcharge pressure equal to an additional 2 feet of soil shall be used for all structures adjacent to the traffic loading conditions.
- Hydrostatic pressure imposed by the fluid contained is considered in the design. The unit weight of water is 62.4 pcf.
- Hydrostatic pressure imposed by groundwater conditions, in addition to lateral soil pressure, shall be considered in the design. Lateral pressure distribution shall be as recommended in the geotechnical report.
- Seismic soil pressure shall be determined in accordance with the seismic loads described in Chapter 5 of this Guide.

E. Seismic Loads

Seismic loads shall conform to or exceed the requirements provided in Chapter 5, Seismic Design Criteria.

Basic guidelines for determining the design ground acceleration and seismic forces include:

- Seismic lateral loads due to soil and water shall be determined in accordance with the recommendations in the geotechnical report.
- All seismic forces shall be determined using this Guide and load factors given in ACI 318 and ACI 350R.

- When selecting ground motions for seismic design of pump station structures, consider the requirements for uninterrupted operation after a major earthquake.

F. Impact and Vibration Loads

If applicable, impact and vibration loads are considered in the design as follows:

- Craneways shall be designed to resist a horizontal transverse force equal to 20% of lifted load plus the weight of the trolley, applied at the top of the rails and distributed with due regard for lateral stiffness of the structure supporting the rails. Craneways shall also resist a horizontal longitudinal force equal to 10% of the maximum wheel loads of the crane applied at the top of each rail.
- For structures carrying live loads that include impact loads, the assumed live loads shall be increased in accordance with the current edition of American Institute of Steel Construction, Specification of the Design, Fabrication, and Erection of Structural Steel for Buildings, AISC Publication No. S-326.
- All forces produced by the equipment or machinery having a tendency to vibrate shall be considered in the design of supporting structures. The magnitude of force shall be obtained from the equipment supplier for use in the design.
- Impact forces due to process operation such as surging fluid shall be properly calculated and considered in the design.

G. Miscellaneous Loads

If applicable, miscellaneous loads shall be considered in the design as follows:

- Miscellaneous loads of a special nature, such as thrust from expansion joints and special appurtenances.
- Surcharge loads, such as due to adjacent structures and vehicular loads.
- Loads imposed by piping including thrust blocks pipe bends and thermal effects on piping.
- Thermal loads.
- Operating pressure forces, forces due to surging fluids and test forces and loads.
- Construction loads and conditions.

3.15.4 Loading Combinations

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

- Static soil pressure (active or at rest) plus hydrostatic loading plus hydrodynamic loading plus seismic forces due to dead loads.
- Static soil pressure (active or at rest) plus seismic soil pressure plus seismic forces due to dead loads plus permanent surcharge.
- Suspended slabs, walls, and roofs: Dead loads plus seismic dead loads or wind load, whichever is greater, plus percent of live load as required by the CBC.
- Load cases indicated in the CBC.

3.15.5 Allowable Stresses

All allowable stresses listed in the following paragraphs may be increased by 33% for seismic loading for evaluations performed using working stress methods as indicated in the CBC.

A. Reinforced Concrete Structures

Allowable stresses for concrete structures shall be in accordance with ACI 318/ACI 350R.

B. Steel and Aluminum Structures

Unless modified for various major facilities, the allowable stress steel members and connectors shall be in accordance with the requirements of the allowable stress design method of the AISC specification.

Allowable stress for aluminum members shall be in accordance with the requirements of the specifications of the Aluminum Association.

C. Masonry Structures

Allowable stresses for masonry structures shall be in accordance with the requirements of the ACI 530 and UBC.

D. Timber Structures

Allowable stresses for timber structures shall be in accordance with the requirements of the National Design Specifications for Stress-Grade Lumber and its Fasteners, Timber Construction Manual by AITC and UBC.

3.15.6 Structural Design Requirements

A. Reinforced Concrete Structures

Reinforced concrete structures shall be designed using the strength design method or the working stress method pursuant to the following requirements:

- The structural design of reinforced concrete environmental engineering structures and support facility structures shall be in accordance with the general requirements of ACI 318 and ACI 350R.
- Reinforced concrete pump station structures shall be designed for strength and serviceability. The strength design method and the working stress design method (an alternative design method) are acceptable methods of reinforced concrete design.
- The structural engineer shall establish the design criteria for each structure within the limitations of the ACI and the UBC.
- Strength Design Method - Use the following guidelines in applying the strength design method:
  - All concrete support facility structures such as administration, operation, and process buildings that are not considered environmental engineering structures (i.e., not hydraulic structures) shall be designed by the strength design method in accordance with ACI 318.
  - All environmental engineering structures (hydraulic structures) are not recommended for design by the strength design method in accordance with ACI 318. However, if the Design Contractor used the strength design method, the load factors of ACI 318 shall be modified in accordance with the ACI 350R. The load factor modifications shall be in accordance with Section 2.6.5 of ACI 350R.
  - Serviceability requirements for both support facility structures and environmental engineering structures shall be in accordance with the provisions of the ACI 318 and Section 2.6.6 of the ACI 350R.
- Working Stress Design (Alternative Design Method) - The alternative design method shall be in accordance with the ACI 318, Appendix A, and the exceptions given in Section 2.6.7 of the ACI 350R.
- Minimum Material Strength - Minimum strengths for concrete and reinforcing steel shall be:
  - Concrete: 28 day compressive stress of 4,000 psi.
  - Reinforcing Steel: Yield strength of 60,000 psi per ASTM A615.

- Joints - The Expansion, contraction and construction joints shall be provided in accordance with ACI 350R to allow flexibility and to adequately tolerate differential movements, as well as temperature and shrinkage stress. All types of joints in environmental engineering structures shall be provided with waterstops and sealant where water tightness is required. All joint detailing, type and location criteria shall be in accordance with Section 2.8 of ACI 350R. The locations of all joints shall be shown on the drawings.
- Expansion Joints - In general, expansion joints shall be provided at abrupt changes in the structural configuration.
- Contraction Joints - Contraction joints are a type of movement joint used to dissipate shrinkage stresses. If used, contraction joint spacing shall be at intervals not to exceed 24 feet, unless additional reinforcement is provided in accordance with Figure 2.5 of the ACI 350R. For environmental engineering structures in high seismic zones, partial contraction joints, where 50% of the reinforcement passes through the joint, shall be used.
- Construction Joints - Construction joints are located so as to least impair the strength of the structure, to provide logical separation between segments of the structure, and to facilitate construction. All reinforcement shall be continued across or through the joint unless designed as a contraction or expansion joint.
- Lifting Devices - Lifting devices shall be provided as required. Lifting devices shall have galvanized coating to reduce corrosion and shall be mechanically connected to rebar where reinforced concrete construction is used.

B. Steel Structures

Steel structures shall be designed in accordance with the requirements of AISC specifications and the following additional requirements:

- Seismic Design - Shall be in accordance with paragraph 3.16.2 of this chapter and Chapter 5, Seismic Design Criteria.
- Minimum Material Strength - Shall be as follows:
    - All structural steel shapes shall be ASTM A992.
    - All steel plates and bars shall be ASTM A36.
    - Structural steel pipe shall be ASTM A501 or ASTM A53, Type E or S, Grade B.
    - Structural tubing shall be ASTM A500, Grade B.
    - Composite construction may be used for floor support. Beams and concrete-filled composite metal deck Composite design shall be in accordance with the

requirements of the AISC, Manual of Steel Construction.

- Composite steel deck shall be in accordance with the requirements of AISI specifications.
- Open web, longspan and deep longspan steel joists can be used for roof support; camber and other requirements shall comply with the specifications of SJI (Steel Joist Institute).
- Crane supports shall be designed for a maximum deflection of 1/450 times the span or as required by the equipment manufacturer, whichever is more restrictive.
- All aluminum shapes, plates, bars and pipes shall meet the minimum requirements of ASTM 6061-T6 alloy.
- All stainless steel shapes, plates, bars, pipes, anchor bolts and fasteners shall meet the requirements of ASTM A167 and ASTM 276, Type 316.

- Joints - Structural joints or connections shall be bolted or welded and shall be designed in accordance with the requirements of AISC Specifications and the following additional requirements:
  - Connection bolts shall be ASTM A307, A325 or A490. When high strength bolts are used, Type N connections shall be used for regular framing design. When structural members are subjected to vibration, cyclic or fatigue loading SC connections shall be used.
  - Connections shall be designed for all tributary forces and the minimum force shall be 6 kips.
  - All welding shall be in accordance with the requirements of ANSI/AWS D1.1 code. All butt and bevel welds shall be complete penetration. E70XX electrodes shall be used.
  - Shop connections shall be either welded or bolted. Use field bolt connections when possible.
  - All aluminum and stainless steel connections shall be made with type 316 stainless steel fasteners meeting the requirements of ASTM A167 and ASTM A276.

C. Masonry Structures

Masonry structures shall be designed in accordance with the requirements of Specifications for Masonry Structures, ACI 530/ASCE 6, CBC, and the following additional requirements:

- Seismic Design - Shall be in accordance with paragraph 3.16.2 of this chapter and Chapter 5 Seismic Design Criteria.
- Minimum Material Strength - Shall be as follows:
  - Concrete Blocks: 28 days compressive strength of 1,500 psi meeting the minimum requirements of ASTM C 90, grade N, Type I.
  - Mortar for Unit Masonry: Meeting the minimum requirements of ASTM C270, type M or S, or the requirements of CBC.
  - Reinforcing Steel: Yield strength of 60,000 psi per ASTM A615.
  - Cold-Drawn Steel Wire: ASTM A82.
  - Mortar and Grout for Reinforced Masonry: Meeting the minimum requirements of ASTM C476 or the requirements of the UBC.
- Joints - Expansion and control joints shall be provided in accordance with the requirements of ACI 530/ASCE 6, UBC, and the Engineering Handbook Reinforced Masonry by Amrhein.

D. Timber Structures

Timber structures shall be designed in accordance with the requirements of the National Design Specification for Stress-Grade Lumber and its Fastenings, CBC, and the following additional requirements:

- Seismic Design - Shall be in accordance with paragraph 3.16.2 of this chapter and Chapter 5, Seismic Design Criteria.
- Minimum Material Strength - Shall be as follows:
  - Beams and Stringers: Douglas Fir-Larch South (surface dry or green used at 19% maximum moisture content).
  - Plywood: Douglas Fir Plywood, Structural Type I.
  - Allowable Stresses: Refer to paragraph 6.3.D of this chapter.
- Joints - Structural joints or connections shall be of the bolted type and shall be designed in accordance with the requirements of the National Design Specifications for Stress-Grade Lumber and its fasteners and the CBC.

3.15.7 Detailing

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

- 2001 edition of CBC.

- The provisions in Chapter 21 of the latest edition of ACI 318.
- The provisions in the latest edition of ACI 350R.
- Detailing of different structural elements to ensure that ductility and other requirements are in accordance with the requirements of the SEAOC Blue Book.
- Chapter 5, Seismic Design Criteria including Special Detailing Requirements.

3.15.8 Major Element Design Requirements

These procedures define general guidelines for the Design Contractor when designing major elements of pump station structures.

A. Concrete Slab

The following structural concepts shall be considered when designing reinforced concrete slab:

- A one-way or two-way slab system with beams.
- When the slab system is rigidly connected to the walls, a frame analysis shall be performed in which the relative rigidity and stiffness of the different elements shall be considered.
- Control, construction and contraction joints shall be provided in the slab structure system in accordance with the ACI 350R. Roof joints shall be aligned with wall joints.
- On large exposed slabs used in pump station structures requiring expansion joints, ductile moment resisting frames shall be provided to resist seismic forces. The maximum recommended spacing for expansion joints shall be 120 feet.

B. Concrete Walls

The following structural concepts shall be considered in designing concrete walls:

- Cantilever walls, which are considered yielding walls, with active soil pressure.
- Walls restrained at the top, which are considered non-yielding walls, with at rest soil pressures.
- For long structures, where walls are designed as cantilever, consider restraint at end walls or cross walls.
- Contraction, construction and expansion joints shall be provided in walls in accordance with ACI 350R. All wall joints shall line up with slab joints. The maximum recommended spacing of expansion joints shall be 120 feet. All joints shall be provided with waterstops.
- Reinforced concrete walls over 10 feet high in contact with water shall have a minimum thickness of 12 inches. The

minimum wall thickness of any reinforced concrete structure shall be 8 inches.

C. Concrete Foundation

Unless groundwater or other geotechnical requirements dictate a mat foundation, the foundation shall consist of a spread-footing cast monolithically with the floor slabs. Floor slabs shall be designed concrete slab on grade with a minimum 6-inch thickness. The floor slab shall be provided with contraction, construction and expansion joints detailed and spaced to allow movement at these joints and to adequately tolerate differential settlement, temperature and shrinkage stresses.

Where a mat foundation is required, it shall be designed as a slab on an elastic foundation or by any other accepted rational method.

All foundations and floor slabs shall be provided with contraction, construction, contraction and expansion joints in accordance with the recommendation of the ACI 350R. All joints shall be provided with waterstops.

D. Equipment Footing

Equipment support shall be designed for the maximum load under operating or testing conditions. Only 50% of floor live load shall be combined with the test loading in the design. Test and seismic loading need not be combined.

The most unfavorable effects from wind and seismic loads shall be considered in the design. Wind and seismic loads shall be assumed not to be acting on the equipment simultaneously. The factor of safety against wind and seismic overturning and sliding shall not be less than 1.5. Piping connected to the equipment shall not be used as a means to resist the wind or seismic loading.

Movement and shear acting on equipment support caused by removing any components from the equipment shall be considered in support design.

E. Support for Rotating and Reciprocating Equipment

The effect of impact, vibration, and torque from the equipment shall be considered in accordance with the requirements of Section 2.9, ACI 350R. In the absence of equipment data required for the support structure vibration design, preliminary support shall be sized by $W_1 / W_2 = 3$ (minimum)

Where: W_2 = weight of equipment

W_1 = weight of supporting structure, or

= in horizontal direction, weight of entire diaphragm, or

= in vertical direction, weight of an area equal to the shadow area + 2t (where t = thickness of supporting slab), or

= weight of pedestal

Final support design shall be in accordance with the requirements of Section 2.9, ACI 350R.

Support shall be isolated from the surrounding slab to minimize the effect of vibration on adjacent structure whenever possible.

Equipment shall be anchored to the support using anchor bolts. Bolts shall be designed for vibration, impact, torque, seismic and wind loading. Only type 316 stainless steel bolts shall be used to anchor equipment. Minimum bolt size shall be 3/4-inch. Expansion anchors shall not be used to anchor equipment. The requirements of Chapter 5, Seismic Design Criteria (equipment anchorage) shall also apply.

Raw water pump stations shall provide for inlet screening and the problems associated with the existence of mussels as appropriate. The pump station design shall incorporate these operational and feature guideline requirements into the project Contract Documents.

Attachment 3-1: Cover Page of the Water Authority General Conditions and Standard Specifications

General Conditions and Standard Specifications

2005 Edition

John A. Economides
Director of Engineering

San Diego County Water Authority

Attachment 3-2: Cover Page of the Water Authority Standard Drawings & Standard Details

STANDARD DRAWINGS & STANDARD DETAILS

San Diego County
Water Authority

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

OCTOBER 2003 ISSUE

Attachment 3-3: Cover Page of the Water Authority Cathodic Protection Guide Drawings

CATHODIC PROTECTION
GUIDE DRAWINGS

San Diego County
Water Authority

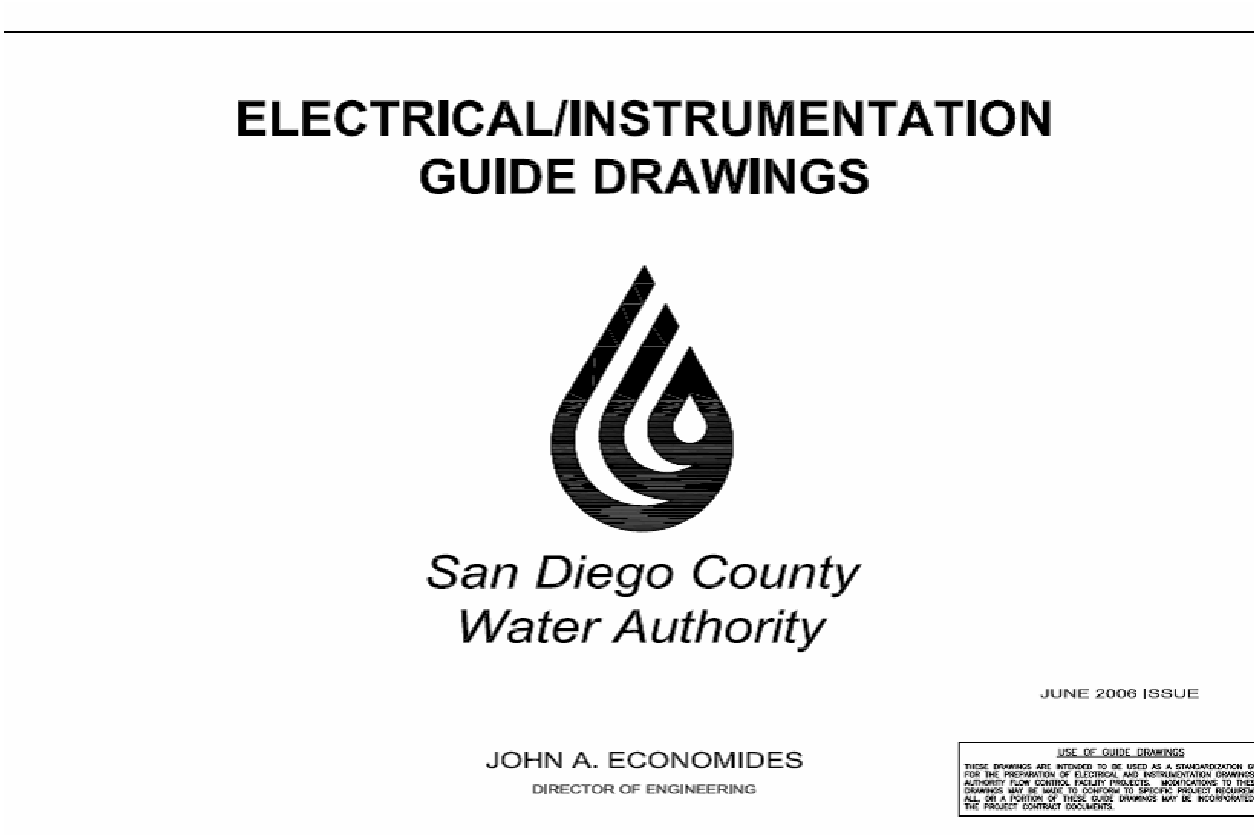
OCTOBER 2005 ISSUE

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

USE OF GUIDE DRAWINGS

THESE DRAWINGS ARE INTENDED TO BE USED AS A STANDARDIZATION GUIDE FOR THE PREPARATION OF CATHODIC PROTECTION DRAWINGS FOR WATER AUTHORITY PROJECTS. MODIFICATIONS TO THESE DRAWINGS MAY BE MADE TO CONFORM TO SPECIFIC PROJECT REQUIREMENTS. ALL, OR A PORTION OF THESE GUIDE DRAWINGS MAY BE INCORPORATED INTO THE PROJECT CONTRACT DOCUMENTS.

Attachment 3-4: Cover Page of the Water Authority Electrical/Instrumentation Guide Drawings



ELECTRICAL/INSTRUMENTATION
GUIDE DRAWINGS

San Diego County
Water Authority

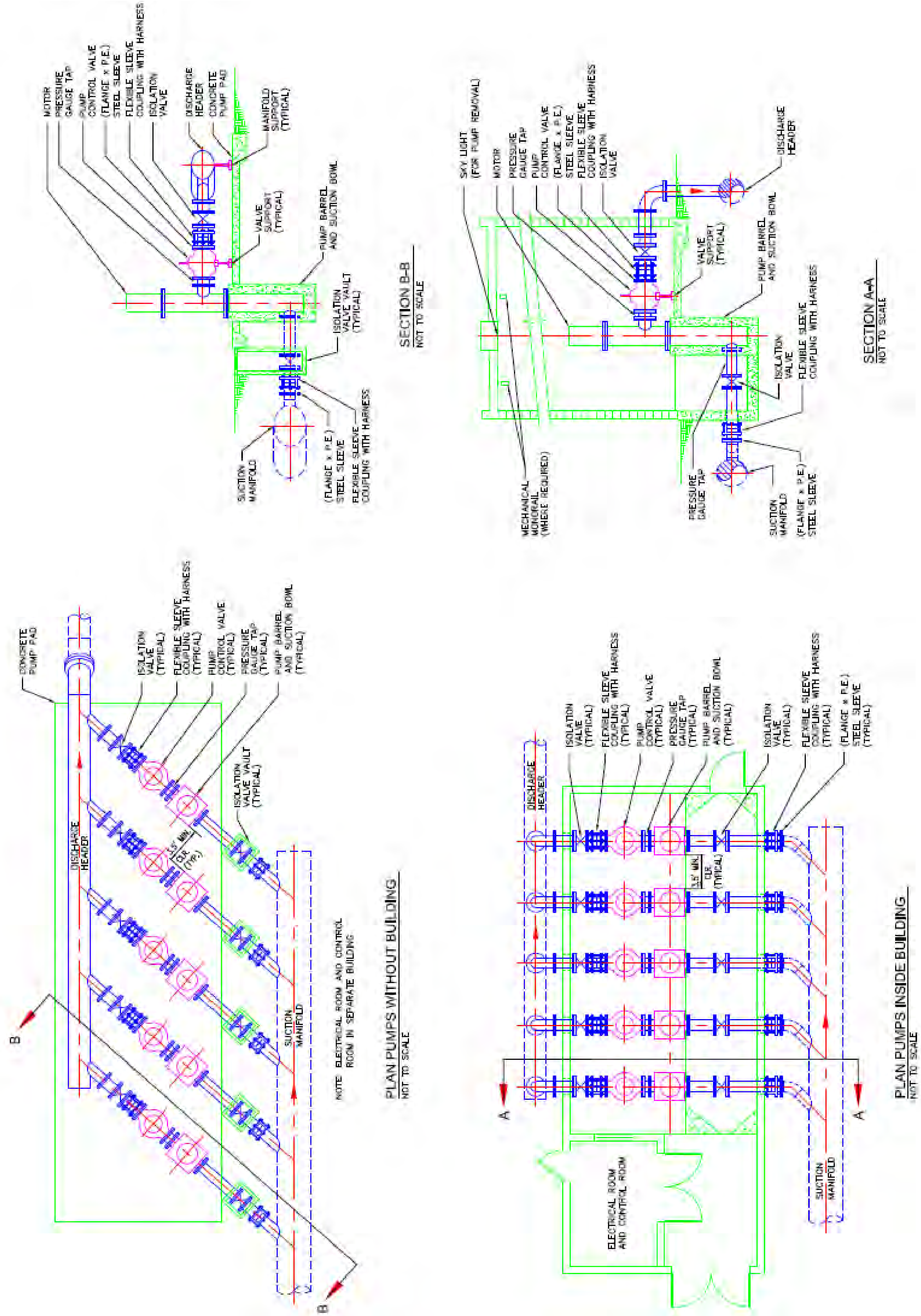
JUNE 2006 ISSUE

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

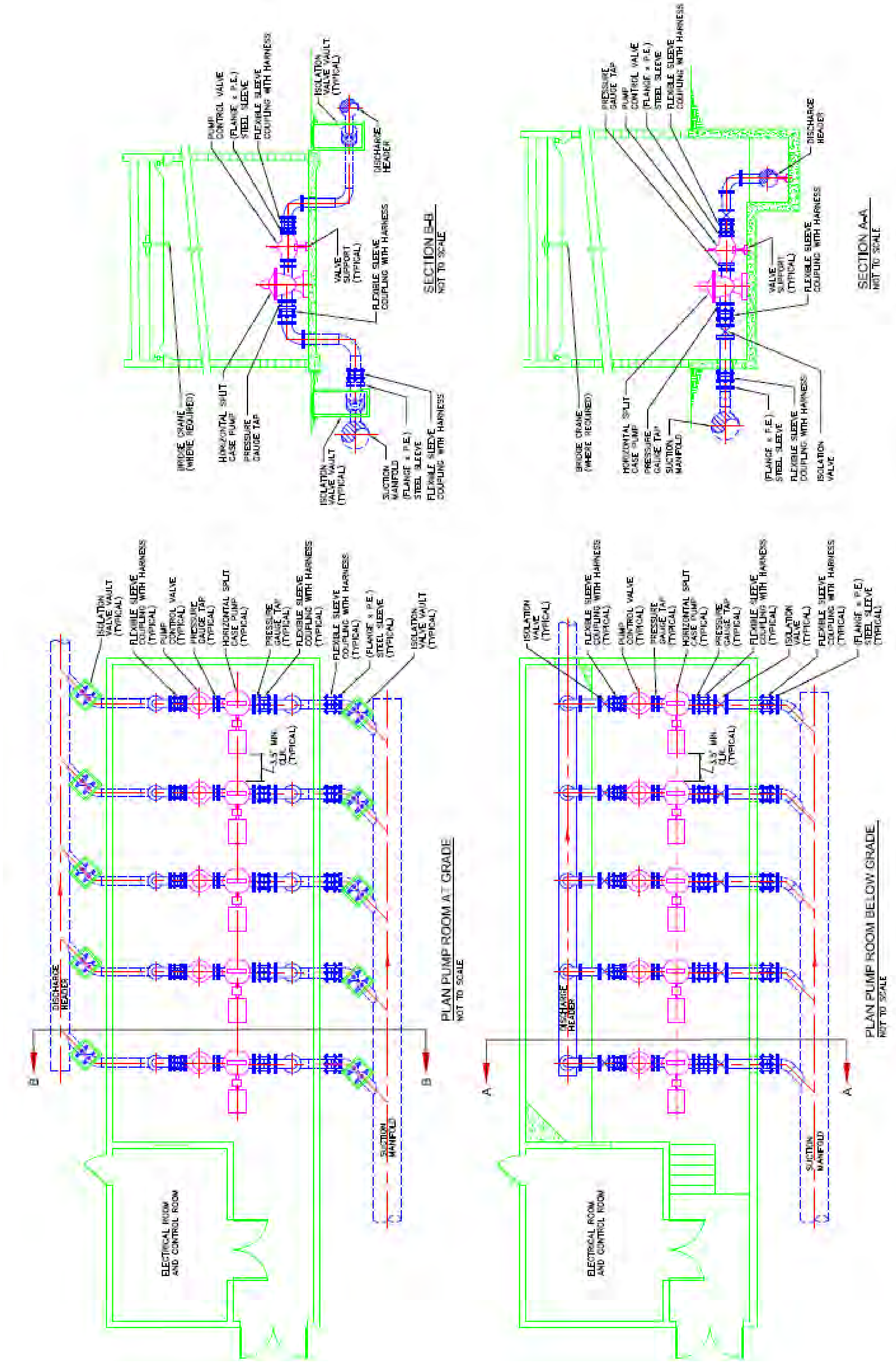
USE OF GUIDE DRAWINGS

THESE DRAWINGS ARE INTENDED TO BE USED AS A STANDARDIZATION G
FOR THE PREPARATION OF ELECTRICAL AND INSTRUMENTATION DRAWINGS
AUTHORITY FLOW CONTROL FACILITY PROJECTS. MODIFICATIONS TO THES
DRAWINGS MAY BE MADE TO CONFORM TO SPECIFIC PROJECT REQUIREM
ALL, OR A PORTION OF THESE GUIDE DRAWINGS MAY BE INCORPORATED
THE PROJECT CONTRACT DOCUMENTS.

Attachment 3-5: Typical Equipment Arrangement for Horizontal Split Case Pumps



Attachment 3-6: Typical Equipment Arrangement for Vertical Turbine Pumps



Attachment 3-7: Noise Control Guidelines

1.0 SCOPE

These noise-control guidelines define the minimum technical requirements that shall be used for design, material and equipment selection, construction, and startup to control noise from individual pieces of equipment, at the facility boundary and in the community. Any deviations from the requirements of these noise-control guidelines shall be justified and requested in writing by the Design Contractor. Written approval from the Design Manager shall be obtained.

The Design contractor shall adhere to the requirements outlined below. All work indicated below shall be performed by a member of the Design Contractor team who is a qualified and certified acoustical consultant, and who shall be approved by the Design Manager.

2.0 CODES AND STANDARDS

2.1 Noise Regulations

The following noise regulations are used (the Design Contractor shall also adhere to noise regulations from other local agencies having jurisdiction over the project location):

- California Administrative Code, Title 8, Group 15, Article 105, “Control of Noise Exposure”.
- County of San Diego Code of Regulatory Ordinances, Chapter 4, Sections 36.401-36.443, “Noise Abatement and Control”.
- The most recent version of the Cal-OSHA.
- Agency of Jurisdiction requirements.

2.2 Noise Standards

The following noise standards are used:

- ANSI (American National Standards Institute); S1.4, Specification for Sound Level Meters.
- ANSI; S1.11, Specification for Octave Band and Fractional-Octave Band Analog and Digital Filters.
- ANSI; S1.13, Measurement of Sound Pressure Levels in Air.
- ANSI; S1.25, Specification for Personal Noise Dosimeters.
- ANSI; S1.40, Specifications for Acoustical Calibrators.

Attachment 3-7: Noise Control Guidelines (Continued)

3.0 DESIGN PHASE

3.1 Noise Modeling

The following shall be followed:

- The Design Contractor shall provide calculations to predict the composite facility generated noise. For large facilities (> 10 pieces of equipment), a facility noise computer model shall be used.
- Plan and elevation coordinates for noise sources and sensitive receptors shall be used in the noise model.
- Measure the noise level 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).
- Both the overall noise level (dBA) and levels at frequencies of 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz shall be determined for each piece of noisy equipment. Noise limit shall not exceed 85 dBA (Time Weighted Average for 8-hour exposure), as imposed by Cal-OSHA.
- Calculate the combined noise levels of pieces of equipment, if located near each other. The combined sound pressures are additive.
- Model distance versus noise attenuation between facility noise sources and community receiver locations. Attenuations as atmospheric absorption, noise barrier attenuation shall be consistent with published acoustical data. The model shall be calibrated to accurately account for noise levels at noise sources, facility property lines, and at community-sensitive receptor locations.
- Noise levels are used when addressing the following considerations:
    - The technical and economic feasibility of selecting low noise equipment.
    - Any requirement for additional noise abatement measures.
    - Locations that cannot be designed with adequate noise controls and therefore shall be designated as high noise areas requiring the use of personal hearing protection and/or noise shelters.
    - Influence of noise controls on facility operation and maintenance.

3.2 Facility Area Noise Limits and Treatment

The Design Contractor shall design interior work spaces (non-industrial areas) so that the noise does not exceed the limits shown below in Table 1. Architectural acoustic treatments to interior walls, floors, and ceilings, and special window treatments shall be considered. In addition, appropriate isolation of internal building noise and vibration sources shall be considered.

Attachment 3-7: Noise Control Guidelines (Continued)

3.3 In-Facility Occupational Noise Exposure Planning

The Design Contractor, in consultation with the Water Authority Operations and Maintenance Department, shall estimate O&M personnel work locations, and normal and worst-case work durations.

Facility employee TWA (Time Weighted Average) noise exposures shall be predicted by the Design Contractor for the following conditions:

- Facility design with standard equipment.
- Facility design with quiet equipment.

The Design Contractor shall compare the predicted number and submit the findings to the Project Manager for review and comment.

3.4 Boundary Line and Community Noise Planning

Sound levels at or beyond facility boundaries shall conform to the noise limits shown below on Table 2. The Design Contractor shall adopt the most recent codes of the County of San Diego and Cities/Agencies having jurisdiction over the project location.

For design noise control, the following prioritized options may be used:

- Locate noisy equipment in more remote areas of the facility.
- Select equipment that conforms to the noise limits.
- Select equipment that can be externally treated with acoustical enclosures, silencers, lagging, etc.

Provide noise attenuation treatments or controls, in addition to those furnished by equipment suppliers.

Submit, at the Preliminary Design Level (refer to Chapter 4, Design Development, of the Design Contractor Guide (Design Manual – Volume One; ESD-160) for more information), a noise compliance summary report that includes equipment type, manufacturer, operating characteristics, location and predicted noise levels The report shall be updated as necessary. Calculations used to predict sound levels at the facility boundary and in the community shall be included in the report.

An equipment noise data sheet (see Attachment 3-3-1) shall be provided to potential equipment suppliers. The data sheet provides space for the bidder to list their specified distance-equipment noise levels and associated noise control costs for:

- Standard equipment package.
- Optional quiet-design version of equipment.
- Equipment with add-on noise controls (acoustical enclosures, upgraded silencers, etc.).

Attachment 3-7: Noise Control Guidelines (Continued)

3.5 Maintenance Issues

Ease of maintenance shall be considered by the Design Contractor in locating noise control systems and acoustically treated equipment within the facilities.

Ease of removal and reinstallation of noise control systems shall be given a high priority 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 shall be considered by the Design Contractor to avoid operational difficulties and equipment temperature problems where noise control systems are used.

Robust noise control systems, with long life expectancies, shall be investigated to reduce untimely replacement costs.

3.6 Ambient Baseline Noise Survey

The Design Contractor shall conduct an ambient baseline noise survey during project design so that existing noise levels within the facility, at facility boundary lines and, within the community can be incorporated into the design. The ambient noise survey shall be conducted in accordance with the methods referenced in Sections 4.3 and 4.4 of these noise-control guidelines. The Design Contractor shall obtain approval from the Design Manager on locations of ambient noise measurements. Sound measurement instrumentation shall conform to the ANSI S1.4, S1.11 and S1.13 standards.

4.0 POST-CONSTRUCTION OPERATIONAL COMPLIANCE CONFIRMATION

The Design Contractor shall follow and specify the following:

4.1 Compliance Confirmation

An operating facility noise survey, consisting of in-facility noise measurements, facility boundary line noise measurements and, where appropriate, community location noise measurements, shall be conducted following facility startup.

4.2 Noise Survey after Facility Startup

During the operating facility noise survey, the facility equipment shall be in normal operation mode with the highest practical load condition up to a full rated load.

The survey shall be conducted by the Design Contractor, preferably the same person(s) who conducted the Ambient Noise Survey during the Design Phase.

If a particular piece of equipment does not meet its guaranteed noise specification limit, as submitted on its noise data sheet, appropriate corrective actions or noise mitigation measures shall be taken at the supplier’s expense.

Attachment 3-7: Noise Control Guidelines (Continued)

4.3 In-Facility Noise Surveys

Sound readings shall be taken 1 meter 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.

Working areas above, below, or adjacent to equipment normally occupied or frequented by personnel, such as platforms, shall also be measured.

Sound readings shall be taken in control rooms and offices at normal work stations. All sound pressure level readings shall include the overall sound level in dBA and the sound pressure levels at frequencies of 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. Sound measurement instrumentation shall conform to the ANSI S1.4, S1.11 and S1.13 standards.

4.4 Facility Boundary Line Survey

The survey measures the overall sound level (dBA) and at the frequencies mentioned in Section 4.3 at locations used in the Design Phase noise survey. Include any new locations that may have become important since

4.5 Community Noise Survey

If residences are within 150 meters (500 feet) of any facility boundary line, readings similar to those required under Sections 4.3 and 4.4 shall be taken at nearby representative residential locations.

4.6 Reporting Noise Survey Results

The Design Contractor shall prepare and submit an Operational Facility Noise report summarizing the following:

- In-facility results including the non-industrial area and industrial equipment noise survey results and the employee noise exposure results.
- Facility boundary line noise survey results.
- Community locations noise survey results.
- Any noncompliance with the requirements of these noise-control guidelines shall be highlighted along with recommended measures to achieve full compliance.

Attachment 3-7: Noise Control Guidelines (Continued)

Table 1

Noise Level Limits for Facility Work Areas

Non-Industrial Facility Work Area[1]	L_{eq} (15 min) Sound Level, dBA
Warehouses	65
Control Rooms	60
Open Offices	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.

L_{eq} - The equivalent continuous sound level or energy average sound level over a set period of time

Attachment 3-7: Noise Control Guidelines (Continued)

Table 2
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	50	45
2.	Residential density equal to or greater than 11 dwellings	55	50
3.	Commercial	60	55
4.	Industrial	75	75
5.	All Residential Zones near Construction (Note 1 does not apply)	75	no construction 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.

Attachment 3-7-1: Equipment Noise Data Sheet

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

	A	B-1	B-2	B-3	C-1	C-2	C-3	
OCTAVE BAND	Equipment Noise Level Allotment	Maximum RMS Sound Pressure Level (Lp) in dB re: 20 μPa at __1___ meter(s)			Maximum Sound Power Level (Lw) in dB re: 1 picowatt (10^{-12} watt)			
CENTER FREQ [Hz]	Maximum RMS Lp at__1_meter(s)	Standard Equipment	With Special Design	Added Acoustic Treatment	Standard Equipment	With Special Design	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:	EQUIPMENT NOISE DATA SHEET	SHEET 1	OF 2	JOB NUMBER	
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			REV

Attachment 3-7-1: Equipment Noise Data Sheet (Continued)

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									

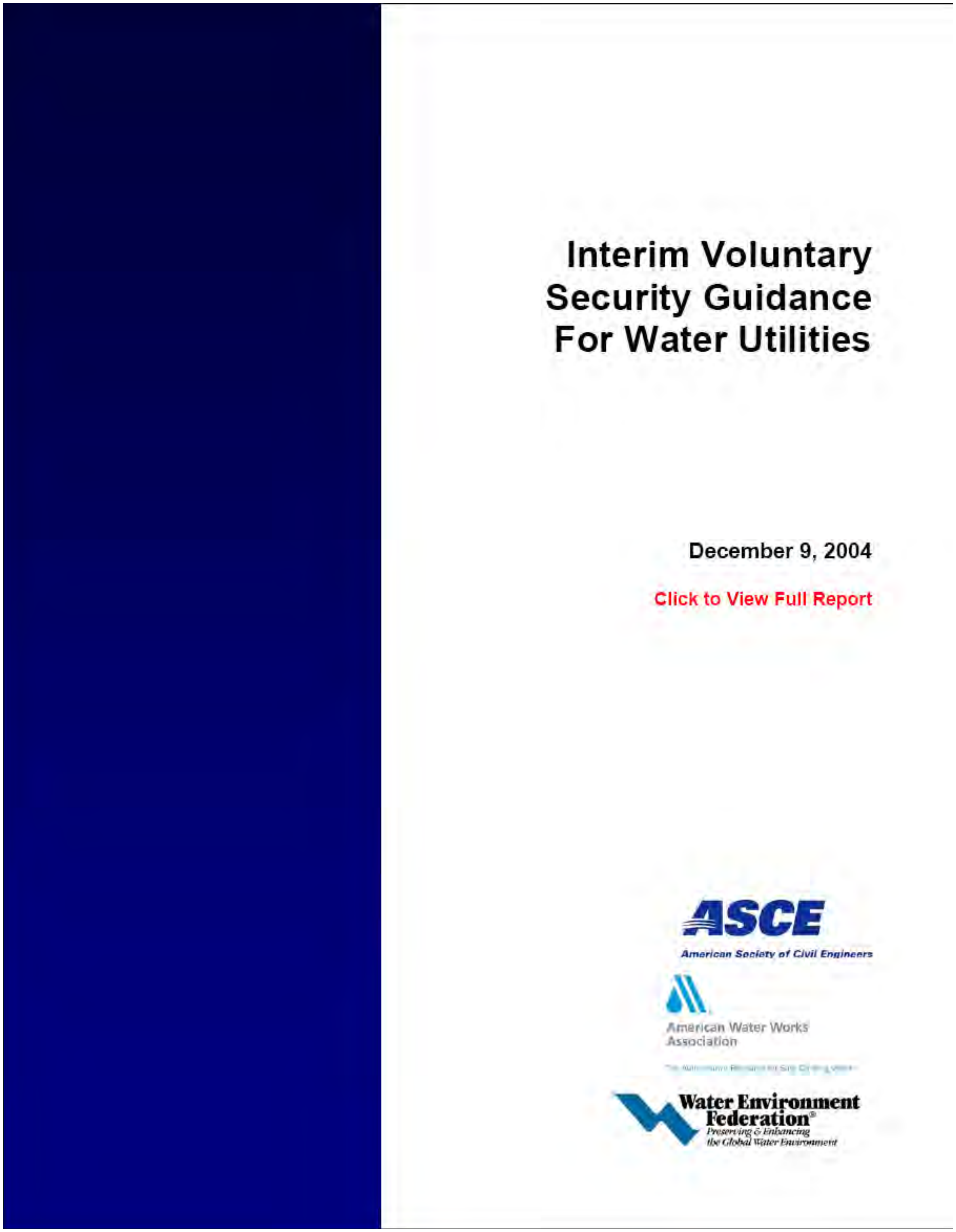
* Maximum octave band sound pressure level (Lp) for all locations.

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)

Attachment 3-8: Cover Page of the ASCE/AWWA/WEF Interim Security Guidance for Water Utilities



Interim Voluntary
Security Guidance
For Water Utilities

December 9, 2004

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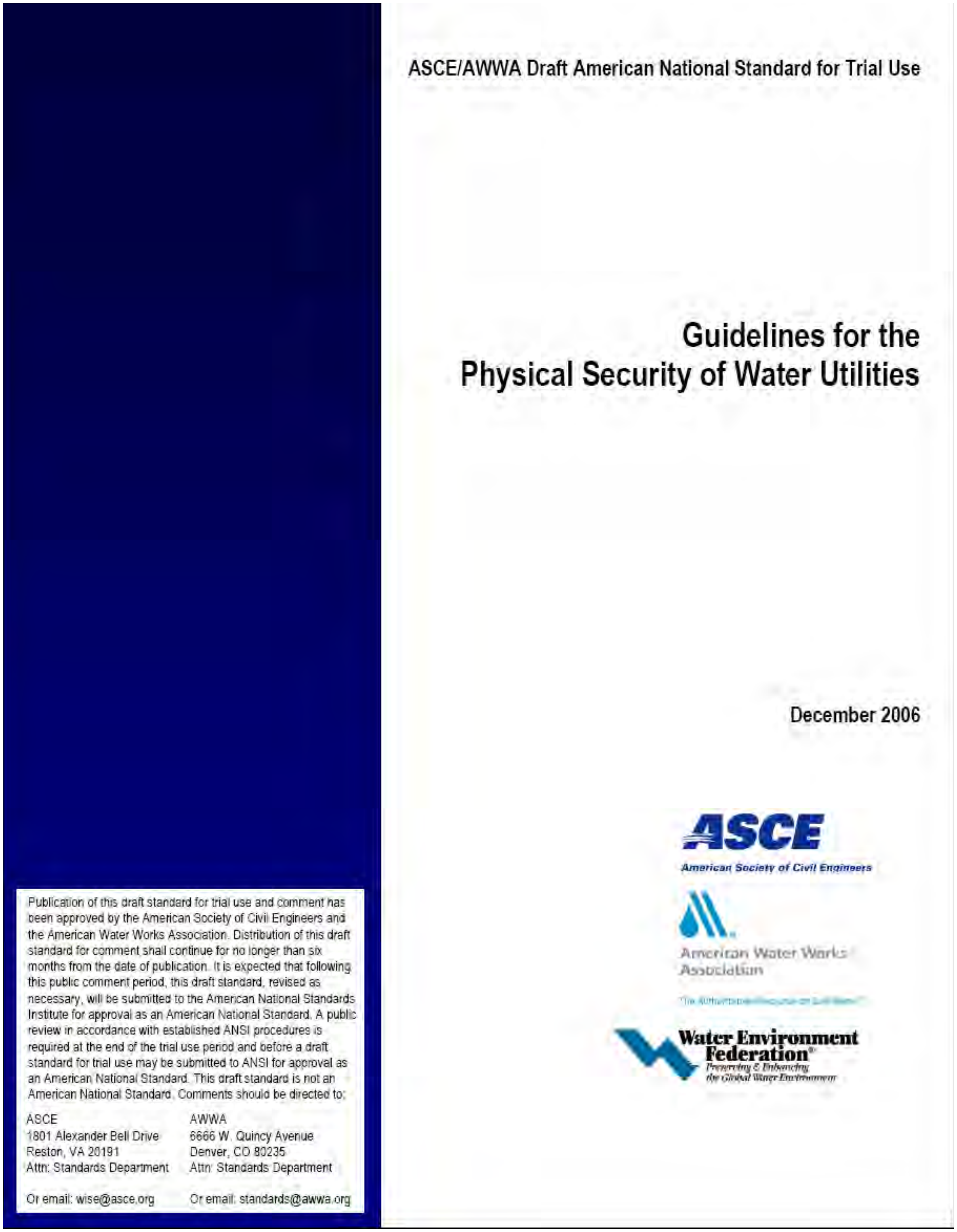
the Global Water Environment

Attachment 3-9: Cover Page of the ASCE/AWWA/WEF Guidelines for Physical Security of Water Utilities



ASCE/AWWA Draft American National Standard for Trial Use

Guidelines for the Physical Security of Water Utilities

December 2006

ASCE
American Society of Civil Engineers

American Water Works Association

Water Environment Federation®
Preserving & Enhancing the Global Water Environment

Publication of this draft standard for trial use and comment has been approved by the American Society of Civil Engineers and the American Water Works Association. Distribution of this draft standard for comment shall continue for no longer than six months from the date of publication. It is expected that following this public comment period, this draft standard, revised as necessary, will be submitted to the American National Standards Institute for approval as an American National Standard. A public review in accordance with established ANSI procedures is required at the end of the trial use period and before a draft standard for trial use may be submitted to ANSI for approval as an American National Standard. This draft standard is not an American National Standard. Comments should be directed to:

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Chapter 4 Flow Control Facilities

Overview

Purpose

This chapter presents the Water Authority general requirements for design of flow control facilities.

Topics

This chapter is composed of the following topics:

4.1 Introduction

4.1.1 General

This chapter defines and outlines the guidelines and criteria that shall be followed in the design and construction of Flow Control Facilities (FCFs) and supporting buildings and structures. FCFs are connected to Water Authority untreated or treated water delivery pipelines. In some cases, FCFs are located outside the Water Authority's delivery system and connected to a member agency's water-delivery system where the Water Authority owns water rights. FCFs serve the following functions:

- Provide a means of delivering water from the Water Authority delivery system to member agencies based on agreements between the Water Authority and the member agencies. .
- Provide a means of controlling and measuring water-flow delivery to member agencies. In some cases, FCFs may also include the pressure reducing function. This is accomplished by adding the proper components (e.g., pressure reducing valves) to the FCF.

In addition to requirements outlined in this chapter, requirements outlined in Chapter 2 (Transmission Pipelines) for piping, flowmeters, valves, cathodic protection, etc. are also applicable to FCFs. The Design Contractor shall use and specify, as applicable, the standards and guidelines outlined in Section 2.1.2 of Chapter 2 (Transmission Pipelines) in the design of FCFs.

Some requirements from Chapter 3 (Pump Stations) and Chapter 6 (SCADA, and Instrumentation and Control) are also applicable to this chapter. These requirements are referenced in this chapter, as applicable.

4.2 Location of Flow Control Facilities

4.2.1 Siting Criteria

FCF siting is usually done during the planning phase of a project. If not already determined, the Design Contractor shall consider the following parameters when siting FCFs:

- Preferably near the Water Authority delivery pipeline to minimize inlet pipeline length.
- Near the member agency water system to minimize outlet pipeline length.
- Mutually agreed upon location by the Water Authority and the member agency.
- At a location that is accessible to existing Water Authority communication network facilities.
- Located within the public right-of-way or on an easement granted to the Water Authority.
- Not on a location that is environmentally sensitive or banned from construction.
- Preference to an at-grade versus below-grade building or structure.
- Not located on steep slope areas or other areas that would present a challenge to construction efforts and to operation and maintenance.
- Not located in vehicular corridors or curbside parking areas.
- For below grade FCFs, access hatches are preferably located away from normal pedestrian paths as sidewalks.

4.3 Configuration and Design Criteria

4.3.1 Configuration and Equipment

Generally, a FCF would include a turnout valve vault connected to the main delivery pipeline, an inlet pipeline to the FCF structure, interior flow control pipe train (or service connection), and an outlet pipeline delivering the required flow to member agency. FCFs will usually house a single pipe train that delivers water to a member agency; however multiple pipe trains (from a common inlet header) may be combined within a single structure. Each pipe train shall be configured to include the required piping and equipment (valves, flowmeter, etc.) to provide the design flows to the member agency. The following are some of the major components for FCFs and appurtenant facilities:

A. Turnout Connection

A turnout connection shall be provided at the delivery point on the delivery pipeline to facilitate isolation of the FCF. The turnout connection is comprised of outlet piping connected to the delivery pipe and an isolation valve housed within a vault structure. The turnout connection is usually located adjacent to the delivery pipe and is separate from the FCF structure. In some cases, when the FCF structure is located immediately off the delivery pipe, a separate turnout structure may not be needed, however an isolation valve would still be required. The need and location of a turnout connection would generally be included in the project pre-design report.

B. Inlet and Outlet Piping

The FCF inlet pipeline is the portion of piping that continues from the turnout connection, or from the main delivery pipeline if no turnout connection is provided, and extends to the FCF structure. Branching of the inlet pipeline would be required if multiple pipe trains are considered. In such case, all inlet pipe branches shall enter the FCF structure at relatively the same elevation and parallel to each other.

Outlet pipelines shall be designed to connect the FCF structure to the member agency's distribution system pipeline. Usually, the member agency would take ownership of the outlet pipeline either a few feet outside the FCF structure, at a property or easement line, or at another point that is agreed upon between the Water Authority and the member agency.

C. Pipe Trains (Service Connections)

The interior delivery pipe(s) to a FCF are identified by the member agency that it serves (e.g., Otay 14, San Diego 5). The pipe train shall include an upstream isolation valve, a flow meter, a control valve, and a downstream isolation valve. The pipe train shall be supported above the floor of the structure with pipe supports in accordance with the

Water Authority standards. The height of the pipe train shall be per the requirements outlined in Section 4.4.

FCFs may be configured to accommodate single or multiple pipe trains. The number of pipe trains, or service connections, inside a FCF is generally a function of:

- Maximum flow to be regulated and metered.
- Range of flow to be regulated and metered.
- Space constraints.
- Redundancy requirements.
- Type of service (i.e., whether treated water or untreated water service). In some cases, both treated and untreated water service connections are housed within a single FCF building. However, in this case, separate pipe train(s) is used for each type of service.
- Some FCF buildings may have separate pipe trains serving different agencies.

D. Flowmeters

Each pipe train within a FCF shall be equipped with a flowmeter to accurately measure the flow of water from the delivery system to the member agency. The acceptable flowmeter type used for revenue metering at Water Authority FCFs is a venturi meter. However, depending on meter size, site and space constraints, and bi-directional flow requirements, magnetic flowmeters may be more applicable. As compared to venturi meters, magnetic flowmeters have shorter laying length, and shorter upstream and downstream straight pipe requirements. Water Authority approval is necessary before using magnetic flowmeters.

The Design Contractor shall coordinate with the Water Authority Operations and Maintenance Department the selection of the flowmeter for the project. The selection of a flowmeter type is usually a function of:

- Project specific requirements.
- Required measuring accuracy.
- Acceptable head losses.
- Space requirement.
- Flow range.
- Flow Reynolds Number.
- Flow direction (uni- vs. bi-directional).
- Initial and maintenance costs.
- Maintenance and field-calibration ease.

Some of the flowmeter physical requirements include:

- Flanged connections to the FCF piping.
- Body material for Venturi meters shall be cast iron.

E. Flow Control Valves

The primary function of flow control valves is to regulate the flow through the FCF. Each pipe train shall be equipped with a flow control valve located downstream of the flowmeter inside the FCF housing structure. The distance between the flowmeter and the flow control valve shall be per the flowmeter manufacturer's recommendation. Control valves shall be connected to other piping via a flanged connection.

Flow control valves shall be of the plug type (venturi pattern). The Design Contractor may propose other types of control valves to suit the project requirements; however, acceptance by the Water Authority is mandatory.

Flow control valves shall be electrically actuated according to the Water Authority standards. Refer to Section 2.5.2 of Chapter 2 (Transmission Pipelines) for more information.

F. Isolation Valves

The primary function of isolation valves in FCFs is to locally isolate the entire facility or a particular pipe train to enable the performance of maintenance and repair operations. Isolation valves shall be installed on each pipe train, with one valve upstream of the flowmeter and another downstream of the flow control valve. Distance between the flowmeter and the upstream isolation valve shall be per the flowmeter manufacturer's recommendation.

Isolation valves are usually:

- Ball or metal-seated butterfly type with flanged connections to other piping.
- Equipped with manual operators. Electric operators may be used for large valves that are difficult to operate manually.
- Located within the FCF building or structure.

G. Other Appurtenances

Each pipe train shall be equipped with the following:

- Air release/air vacuum valves to allow air entrance/escape during draining and filling cycles of the FCF piping. Air release/air vacuum valves are usually installed upstream of the FCF inlet isolation valve and downstream of the outlet isolation valve. Refer to Section 2.5.2 in Chapter 2 (Transmission Pipelines) for more information on air release/ air vacuum valves. Additional air vent piping (or gooseneck) may be required between the control valve and either upstream or downstream isolation valves to allow for draining sections of the pipe train.

- Pressure transmitter/gauge assemblies installed upstream of the FCF inlet isolation valve and downstream of the outlet isolation valve. Pipe connections for the process piping for these assemblies may be combined with the air release/air vacuum valve connection at the top of pipe or may have a separate connection at piping springline at the same location. Refer to the following Water Authority documents for more information:
    - o "Pressure Gauge" specification section in the Water Authority General Conditions and Standard Specifications (GC&SS). Refer to Attachment 4-1 for the cover page of the GC&SS.
    - o "Instrumentation Details" drawing in the Electrical/Instrumentation Guide Drawings (refer to Attachment 4-2 for the cover page).
- Minimum 2-inch drains on the pipe train to facilitate draining facility piping, or inlet and outlet piping as required.
- A sampling station, installed only on treated water FCFs, for taking water samples for laboratory analysis. Sample station piping connection shall be installed per the "Treated Water Sample Station Connection and Cabinet Assembly Details" drawing in the Water Authority Standard Details and Standard Drawings (refer to Attachment 4-3 for the cover page).
- Mechanical couplings (usually sleeve flexible couplings) shall be installed on FCF piping to facilitate valve or meter removal when future repairs are required. Though the number of couplings required should be minimal, their placement shall be such that it benefits the removal and installation of the major components. The Design Contractor shall determine which coupling types are suitable based on the pipe train configuration. All couplings shall be restrained.
- Connections of pipe trains with piping outside the FCF building shall be accommodated with welded joints or butt-strap connections.

4.3.2 Design Criteria

A. Pipe Material, Coating and Lining, and Cathodic Protection

Inlet and outlet piping that is exterior to the FCF and pipe trains inside the FCF shall be welded steel pipe with lining and coating designed per requirements outlined in Section 2.3 of Chapter 2 (Transmission Pipelines).

The turnout connection piping shall be cathodically isolated from the main delivery pipeline and the outlet piping heading to the FCF. Insulating flange kits shall be installed on the outlet flange from the delivery pipeline and just downstream of the turnout valve. The FCF piping shall be cathodically isolated from the inlet and outlet piping. Insulating flange kits shall be installed on the upstream side of the inlet isolation valve, and on the downstream side of the outlet isolation valve. Refer to Section 2.7.6 of Chapter 2 (Transmission Pipelines) for more information on cathodic protection.

The buried FCF outlet piping shall be electrically isolated from the member agency piping at the point of transfer in ownership of the pipeline. This is usually accomplished using insulated flanges or monolithic insulators (ISOJoints). The buried outlet piping shall have an independent cathodic protection system.

B. Pipe Size and Thickness

All inlet and outlet piping shall be designed per requirements outlined in Section 2.7 of Chapter 2 (Transmission Pipelines).

Pipe trains within the FCF shall be optimized to handle the prevailing flow rate; however, they shall be able to handle both the minimum and maximum flow demands. The range of flow is usually requested by the member agency. The Design Contractor shall ensure that the design velocities are not below 3 fps and do not exceed 8 fps while accommodating the minimum and maximum flow demands. Brief and infrequent pipe exposure to higher velocities, up to 12 fps, is permissible. Refer to Section 2.7.3 of Chapter 2 (Transmission Pipelines) for additional requirements.

Piping internal to the FCF shall be designed to withstand the highest of the pressures listed below (refer to Chapter 9 (Surge and Transient Hydraulic Analysis) of the Design Contractor Guide (ESD-160; Volume One), and Section 2.7 of Chapter 2 (Transmission Pipelines) of this Guide for more information):

- Upstream static pressure.
- Surge pressure due to pump shutoff, valve closure, etc., unless a surge control mechanism is in place.

C. Flowmeters

Since flow measurements are used for revenue billing, accuracy of flow-metering systems within FCFs is of utmost importance to both the Water Authority and member agencies. The upstream and downstream piping systems to the flowmeter shall be carefully designed to maximize flowmeter accuracy. In addition, flow transmitters shall be carefully selected and specified to maintain high accuracy in flow measurements.

Venturi flowmeters sizing involves determining the meter beta ratio (constriction diameter to pipe diameter ratio) as a function of prevailing, maximum, and minimum flow rates. Sizing is usually done according to the manufacturer's recommendations. Differential pressure transmitters shall be installed with venturi flowmeters to measure the pressure differential across the meter and accordingly determine the flow rate. The following are some general design guidelines for venturi flowmeters:

- At maximum flow conditions and to maintain the flowmeter reading accuracy, the differential pressure for venturi flowmeters shall be between 250 and 300 inches of water.
- At minimum flow conditions, the differential pressure shall not be below 2.5 inches of water.
- Minimum to maximum flow ratio shall not exceed 1:10.
- Reynolds number shall be a minimum of 75,000.
- Accuracy of the meter shall be ±0.5% with a discharge coefficient of 0.99.

If another type of flowmeter (other than venture) is used, the Design contractor shall confirm with the meter manufacturer the accuracy at both minimum and maximum flow conditions.

D. Flow Control Valves

The Design Contractor shall size control valves based on upstream pressures and required downstream pressures. The Design Contractor shall provide the proper calculations that demonstrate that the control valve will not experience cavitation or flashing conditions.

4.4 Housing Structure and Site Work

4.4.1 General

FCF pipe train(s), equipment and appurtenances shall be housed within a structure or building. Several options are available for the FCF housing structure including:

- Housing Structure Type - At grade or below grade.
- Material of Construction - Cast-in-place concrete, pre-fabricated concrete structure, concrete block w/wood or steel structure roof, pre-fabricated steel structure, etc.
- Construction Method: Site-built or packaged unit.

The selection of the housing structure depends on a multitude of site-specific parameters covering technical, environmental, cost, and operations and maintenance considerations. Probably the most important distinction between options for FCF housing structure is whether it is at grade or below grade. Though the Water Authority prefers at-grade structures for most FCFs, below-grade structures may provide greater benefits due to certain site conditions. Some of the main differences between at- and below-grade FCFs include:

- For at-grade structures, the advantages over below-grade structures include:
    - Easier and safer accessibility to equipment and appurtenances.
    - Confined space entry permit not required.
    - No requirement for sump pump.
    - Less chance for flooding.
    - Easier to ventilate.
- For below-grade structures, the advantages over above-grade structures include:
    - Fewer or no architectural concerns.
    - No major inlet/outlet pipe modifications to elevate pipes to FCF building elevation.

Another important consideration in selecting the housing structure for FCFs is whether the facility will be site-built or a packaged unit.

The Design Contractor shall refer to the project predesign report for the recommended housing structure for the FCF. If the predesign report does not have the proper information, the Design Contractor shall prepare a comparative study between the different options with recommendation of the best option.

4.4.2 Design Considerations

The following are some design considerations that are applicable to all types of FCFs:

- The minimum inside vertical clearance (floor to ceiling) shall be seven feet.
- Safe access, to both sides of the pipe train, to appurtenant equipment that requires regular maintenance (e.g., valve operators, air valves) shall be maintained.
- Isolation and control valves shall be elevated and supported by appropriate means with unobstructed clearance of at least two feet above the finished floor elevation.
- The size of the housing structure shall:
    - Accommodate all the FCF piping, equipment, appurtenances, electrical and control panels, access stairs, ventilation system, etc.
    - Allow for a minimum 3.5-feet clearance from all sides to allow for maintenance and hoisting of equipment and piping.
- Security requirements outlined in Section 3.13.5 of Chapter 3 (Pump Stations) shall also be followed for FCFs.
- Intrusion alarm shall be installed at doors and other FCF access openings, as required.
- Personnel access openings to the FCF building or structure shall be via an access-control card reader and electric lock system.
- Indoor enclosures shall be NEMA 12 rated. Below-grade enclosures shall be NEMA 4 rated.
- Architectural design considerations shall follow, as applicable, the requirements outlined in Section 3.14 of Chapter 3 (Pump Stations) of this Guide.
- Structural design considerations shall follow, as applicable, the requirements outlined in Section 3.15 of Chapter 3 (Pump Stations) of this Guide.
- All FCF sites shall be fenced following the requirements outlined in Section 3.13.5 of Chapter 3 (Pump Stations).
- Safe access into a paved driveway and parking area is required.
- Landscape design considerations shall follow the requirements outlined in Section 3.13.4 of Chapter 3 (Pump Stations) of this Guide.

The following are specific design considerations for below-grade housing structures:

- Design to avoid permit confined-space entry requirement.

- Personnel and equipment access hatches shall be provided and shall satisfy the following requirements (refer to the "Structural Steel, Aluminum and Miscellaneous Metal Work" specification section in the GC&SS (see Attachment 4-1) for information on access hatches):
  - Hinged and spring-assisted to accommodate a one-person operation.
  - Have hold open stay bars and safety railings when doors are in the open position.
  - Designed to withstand continuous H-20 traffic loadings.
  - Panels shall not be longer than 8 feet in any direction.
  - Sized to accommodate the hoisting of piping and equipment.
  - Equipment access hatches to be equipped with a locking mechanism (padlock or integral keyed lock).
  - Main access hatch for personnel to be equipped with an electric locking device compatible with the access control system.
  - Equipped with drain channels to prevent rainwater or surface runoff water from entering the FCF structure. Drain water shall be piped to a location away from the structure and not the FCF sump. Refer to the following drawings in the Water Authority Standard Details and Standard Drawings (see Attachment 4-3) for additional information:
    - "Manway Air Vacuum & Air Release Valve (Right-of-Way Type)".
    - "Blowoff Plan & Sections (Right-of-Way Type)".
  - Equipped with intrusion alarm.
- An active ventilation system (e.g., supply fan) shall be provided. The ventilation system shall start automatically when an access hatch is opened. A/C units are not preferred.
- All below-grade FCFs shall be provided with a sump. Actual sump dimensions shall be per the sump pump manufacturer's recommendation with a minimum 1.5-foot x 1.5-feet wide and 1.5-feet deep. The sump shall be located at one of the floor corners. The finished floor shall be sloped towards the sump from all directions. A permanent submersible sump pump, with integral level controls and discharge piping directing sump water away from the FCF structure, shall be installed in the sump. The sump shall be

accessible for portable pumping operations to collect and dispose of unwanted water.

- Equipped with a flood alarm system separate from the sump pump system.
- All structure wall or floor penetrations shall be equipped with water-tight seals.

The following are specific design considerations for above-grade housing structures:

- In case the pipe-train size is larger than 12”, roof hatches shall be provided for equipment access.
- Personnel and roll-up doors shall be provided.
- Adequate ventilation shall be provided. If natural ventilation is not sufficient, active ventilation means (e.g., a supply fan) shall be used; however, A/C units are not preferred.

4.5 Electrical Design

4.5.1 General

The Design Contractor shall refer to Section 3.11.1 of Chapter 3 for requirements to be used in the design of the FCF electrical system. The Design Contractor shall coordinate the power supply to the FCF with the local utility company (San Diego Gas & Electric; SDG&E).

4.5.2 Electrical Service and Distribution

Utilization voltage ratings are as follows:

- Motors:
    - Smaller than 3/4 hp, 115 volts, single-phase, 60 Hz.
    - 3/4 hp and larger, 460 volts, 3-phase, 60 Hz.
- Miscellaneous non-motor loads of 0.5 kW and less shall be single-phase rated at 115 volts, 60 Hz.
- Lighting:
    - Outdoors: General area lighting; Energy-saving fluorescent, 115 volts, single-phase. Specific area lighting; Motion-activated fluorescent.
    - Indoors: Fluorescent, 115 volts, single-phase.
- General-purpose receptacles shall be rated 20 amps, 120 volts, single-phase.
- Special purpose receptacles may be 120 volts, or 480 volts (3-phase as required).
- Special purpose DC control circuits are 24 volts.
- An uninterruptible power supply (UPS) shall be provided for all main control panels, PLCs (Programmable Logic Controllers), and all other process controllers as required for the specified instrumentation and controls. All UPS power supplies shall be 120 Volts, single-phase, 60 Hz received from the power panel circuit.
- All instrumentation and instrument-panel power shall be 24 Volts DC supplied directly from the UPS. Provide separate fuses for each field device.
- All feeders shall have an equipment grounding conductor in the same raceway. Equipment grounding conductors shall be sized in accordance with NEC requirements.

4.5.3 Lighting

Lighting shall be switch operated. For loads exceeding the switch capacity, use a lighting contactor. Provide switches at all doors. For fenced FCFs, exterior lighting to the FCF structure shall be provided with motion-activated switching with manual on/off control. For outdoor lighting, the Design Contractor shall select luminaries that produce the least glare over the surrounding area. Exterior fixtures shall be vandal-resistant.

4.6 Instrumentation and Control

4.6.1 General

This section covers some general instrumentation and control requirements for FCFs. However, the Design Contractor shall refer to Chapter 6 (SCADA, and Instrumentation and Control) of this Guide for detailed instrumentation and control requirements. The Design Contractor shall also use the following Water Authority documents for additional information and requirements:

- GC&SS (refer to Attachment 4-1).
- Electrical/Instrumentation Guide Drawings (refer to Attachment 4-2).
- PLC Implementation Standards (refer to Attachment 4-4 for the cover page).

Instrumentation and control for FCFs is provided to measure, control, and monitor water flow. The FCF shall be equipped with devices enabling communication with the Water Authority SCADA system (master data acquisition, processing and management center known as the Escondido Control Center).

4.6.2 Instruments, devices, and Equipment

Several types of instruments, devices, and equipment are used in FCFs including the following:

A. Isolation and Flow Control Valves

The Design Contractor shall follow Section 2.10 of Chapter 2 (Transmission Pipelines) for the instrumentation and control requirements for isolation and flow control.

Rapid increase or decrease in flow shall be entirely avoided in order not to induce a flow control problem. Therefore, the Design Contractor shall:

- Determine the control valve opening and closing times that will not induce rapid flow changes.
- Specify valve gearing that shall meet the required opening and closing times.

B. Flowmeters

Transmitters or controllers for flowmeters shall be capable of totalizing flow within a specified period of time. The Design Contractor shall refer to the PLC Implementation Standards (refer to Attachment 4-4) for totalizer control functions.

Differential pressure transmitters used with venturi flowmeters shall be equipped with a square-root extraction function to enable transforming the measured differential pressure to flow rate.

In case of more than one pipe train serving the same agency, the Design Contractor shall configure the control system so that when the desired flowrate set point is dialed in (see Chapter 6 for more information), the control system shall select the appropriate pipe train that can accommodate the desired flow and provide the highest metering accuracy.

C. Sump Pumps

Permanent sump pumps shall be configured to:

- Automatically start based on a high-level float switch installed inside the sump at a level recommended by the pump manufacturer.
- Automatically stop based on a low-level float switch installed inside the sump at a level recommended by the pump manufacturer.

Sump pumps shall have a fully functional local control panel to enable starting, stopping, and monitoring the pump while in operation. Alarm conditions and pump running status (On/Off) shall also be sent to the facility PLC.

D. Flood Alarm Float Switch

A separate flood alarm switch shall be installed on one of the FCF walls and hardwired to the facility PLC. The purpose of this level switch is to generate an alarm indicating flood conditions at the FCF. Refer to the Electrical/Instrumentation Guide Drawings (see Attachment 4-2) for installation details of the flood alarm float switch.

4.6.3 Member Agency Interface Cabinet

Normally the panels and cabinets, which are located within FCFs include the control panel, communications cabinet, access control cabinet, and where required, the video equipment cabinet. These panels and cabinets are covered in Chapter 6 (SCADA, and Instrumentation and Control). Also, located at FCFs is the Member Agency Interface Cabinet (MAIC), and because of its uniqueness to FCFs, its requirements are covered in this chapter

The MAIC shall be located outside the FCF housing structure and mounted on the FCF wall or other supporting structure. This setting facilitates access to the cabinet by the member agency. Multiple MAICs may be required if more then one member agency has a service connection within the FCF building.

The following delineates the responsibilities and provision of components between the Water Authority and the member agency for the MAIC:

- Water Authority
  - Install the MAIC with suitable NEMA rating. The cabinet shall be adequately sized to house terminal blocks, other necessary devices, and the member agency communication devices, as required.
  - Route upstream and downstream pressure, and flow signals from the FCF control panel to the MAIC. Pressure and flow are the important signals that member agencies usually monitor.
  - Install service power receptacle (separate circuit) within the MAIC for member agency use.
- Member Agency
  - Install all communication devices necessary for communication with their SCADA system.
  - Install any conductors downstream of the MAIC.

The Design Contractor shall be responsible for designing and specifying the Water Authority MAIC components.

Attachment 4-1: Cover Page of the Water Authority General Conditions and Standard Specifications

General Conditions and Standard Specifications

2005 Edition

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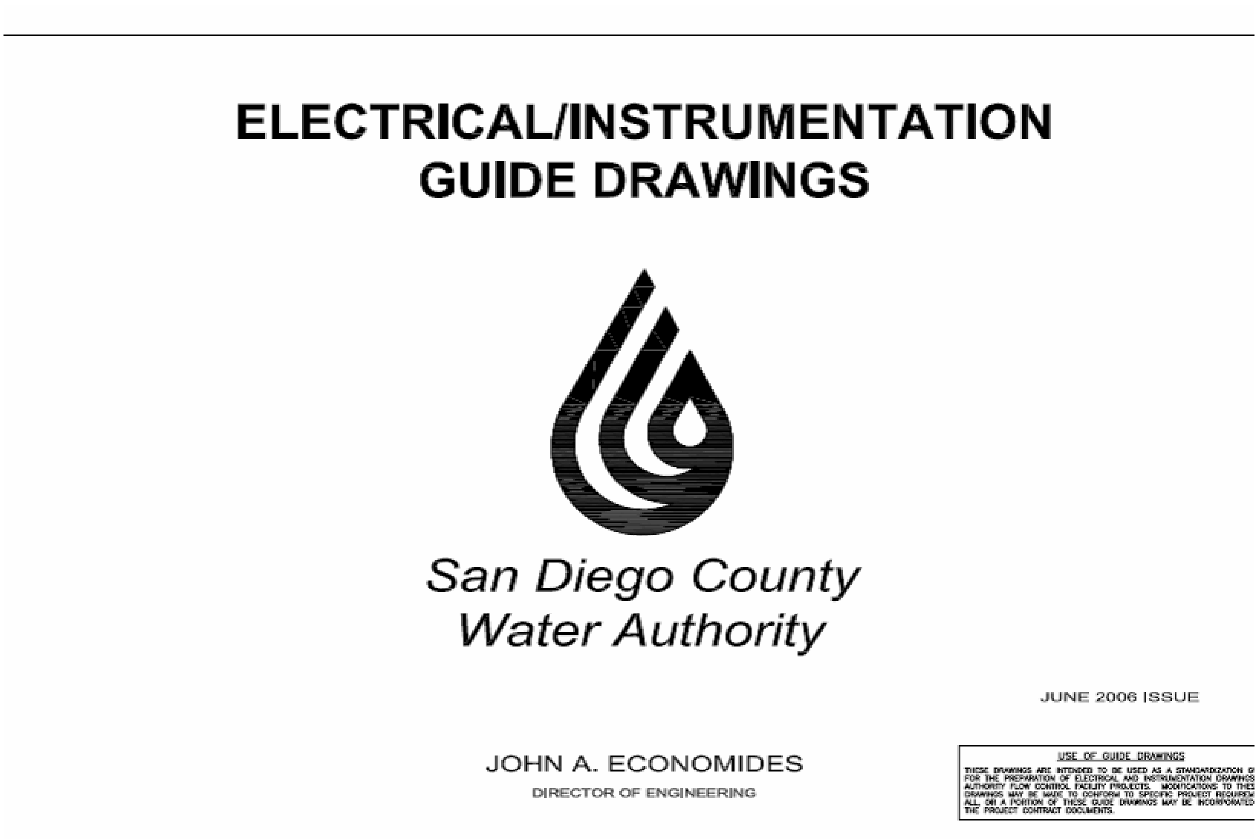
Director of Engineering

San Diego County Water Authority

Attachment 4-2: Cover Page of the Water Authority Electrical/Instrumentation Guide Drawings



ELECTRICAL/INSTRUMENTATION
GUIDE DRAWINGS

San Diego County
Water Authority

JUNE 2006 ISSUE

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

USE OF GUIDE DRAWINGS

THESE DRAWINGS ARE INTENDED TO BE USED AS A STANDARDIZATION G
FOR THE PREPARATION OF ELECTRICAL AND INSTRUMENTATION DRAWINGS
AUTHORITY FLOW CONTROL FACILITY PROJECTS. MODIFICATIONS TO THES
DRAWINGS MAY BE MADE TO CONFORM TO SPECIFIC PROJECT REQUIREM
ALL OR A PORTION OF THESE GUIDE DRAWINGS MAY BE INCORPORATED
THE PROJECT CONTRACT DOCUMENTS.

Attachment 4-3: Cover Page of the Water Authority Standard Drawings and Standard Details

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STANDARD DRAWINGS
& STANDARD DETAILS

San Diego County
Water Authority

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

OCTOBER 2003 ISSUE

Attachment 4-4: Cover Page of the Water Authority PLC Implementation Standards

San Diego County
Water Authority

SDCWA

PLC IMPLEMENTATION STANDARDS

Version 2
(Released 03-14-05)

TMV Systems Engineering, Inc.

Chapter 5 Seismic Design Criteria

Overview

Purpose

This chapter presents the Water Authority general guidelines and requirements for seismic design of pipelines, pump stations, flow control facilities, buildings, and other facilities.

Topics

This chapter is composed of the following topics:

List of Tables:

List of Figures:

List of Attachments:

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5.1 Introduction

5.1.1 General

The water systems owned and operated by the San Diego County Water Authority (Water Authority) are vital lifelines for the communities located within San Diego County and must be designed for a high degree of reliability. The Water Authority, and many of its capital facilities, is located within an area of California that is at risk of experiencing major earthquakes. Loss of Water Authority facilities following such an earthquake could result in a general hazard to the public health and disruption of water supply needed for the economic well being of the community. Disruption of water deliveries could also impact the availability of water for fire fighting purposes provided by other water agencies.

5.1.2 Purpose, Intent, and Reference

The purpose of Chapter 5 is to set forth a consistent and economical set of criteria for the seismic resistive design of Water Authority facilities in order to provide an appropriate level of reliability. It is intended that Chapter 5 be used as a reference by all persons performing design of Water Authority facilities, including Water Authority engineering staff, design contractors, suppliers, and design-build contractors.

Where applicable, design of Water Authority facilities shall be in general conformance to standards specified herein. Designers are cautioned these standards must be applied in conjunction with basic principles of engineering mechanics and application of sound engineering judgment in order to provide appropriate designs.

Chapter 5 is intended for both new designs and retrofit of existing facilities. For design of new facilities, it is the intent to apply, as a minimum, the referenced building codes and industry standards to the full extent. For evaluation and modification to existing facilities, alternative criteria may be prescribed with justification as the detailed project objectives are developed and approved by the Water Authority.

5.1.2.1 Codes and Standards

Nothing in Chapter 5 shall be construed to allow design of new facilities to a level less than required by the applicable building codes and industry standards, or to absolve the Design Contractor of its responsibility as engineer of record.

The Water Authority, as a California state agency, is not legally bound to comply with regulations and codes promulgated by local agencies, such as the County of San Diego and/or cities located within the service area. However, for other reasons the Water Authority may choose to comply with such local codes and regulations.

Finally, the Water Authority is legally bound to comply with applicable permits, codes, and regulations issued by state and federal agencies, such as the California Department of Transportation (CalTrans) or the U.S. Bureau of Reclamation.

5.1.2.2 Terminology

The use of the term “shall” in Chapter 5 is not to be interpreted such as to prevent use of alternative, technically justified procedures or methodologies. Such alternative procedures that result in meeting compliance with the intent of Chapter 5 with respect to performance and reliability may be used subject to a case-by-case approval by the Water Authority.

The term “major earthquake” in Chapter 5 is defined as an earthquake of Moment Magnitude M7.1 or larger on the Rose Canyon – Silver Strand fault, M7.4 or larger on the Elsinore Fault, or M7.9 or larger on the San Andreas fault.

Refer to Attachment 5-1, Symbols and Notations, for additional terminology definitions.

5.1.3 Applicability

The following sections define the applicability of Chapter 5.

5.1.3.1 Facilities Included

Chapter 5 is applicable to the design, repair, alteration, and rehabilitation of the following types of permanent facilities:

- Buildings and building-like structures, including pump stations, hydropower generating stations, flow control facilities, process buildings, control centers, office buildings, warehouses, service centers, and their equipment, systems and contents.
- Water retention structures, including reservoirs, clearwells, sediment-ation basins, and filter beds, and their internal elements, such as columns, pipeline vents and risers, division walls, etc.
- Reservoir roof structures.
- Tunnels.
- Small buried structures, including valve boxes, concrete vaults, flow control facilities, pressure control facilities, and pump stations.
- Underground piping for transmission pipelines.
- Atmospheric storage tanks.

5.1.3.2 Facilities Excluded

Chapter 5 does not apply to the design of the following types of facilities:

- Dams and associated components under California Department of Water Resources, Division of Safety of Dams (DSOD), or the Federal Energy Regulatory Commission (FERC) jurisdiction. The DSOD or FERC shall be consulted regarding seismic evaluation and design criteria for the particular component under their jurisdiction.
- Outlet towers in reservoirs.
- Instrumentation and control equipment, including associated facilities such as vaults, lines, conduits, cabinets, and so forth.
- Power plants sized 50 megawatts and larger. Such power plants are covered by regulations of the Federal Energy Regulatory Commission (FERC).
- Any temporary facilities as determined by the Water Authority.

5.1.4 Level of Service Goal

The basic level of service goal for the Water Authority system shall be to deliver at least the minimum water flows as defined in the Water Authority's Emergency Storage Project (ESP) to each member agency within seven days after a major earthquake.

5.1.5 Seismic Performance Class

The Water Authority will assign a Seismic Performance Class (SPC) to each new facility and component. The selection of the SPC shall be to satisfy Sections 5.1.2, 5.1.3, 5.1.4 and 5.1.6 of Chapter 5. An entire project may be assigned one SPC, or components of a project may be assigned their own SPCs, as required to meet overall performance goals. The SPC shall be clearly indicated in project-specific design documentation. For pipelines, see Table 5-2 for the correlation between SPC and Pipe Function Class (PFC).

5.1.6 Facility Importance and Performance Goals

Building codes define the minimum requirements for seismic resistant design. While minimum seismic design has proven to be effective to protect life safety, facilities of greater importance must be designed to meet more stringent criteria to protect public safety, as well as improving post-earthquake functionality/operability. These seismic design criteria have addressed this issue by assigning an SPC based on performance goals, and by requiring more stringent requirements for facilities that are critical for attaining the post-earthquake water delivery goals. In defining the performance goals and assigning facilities and components into the SPC, the following factors have been and should be considered:

- The intended function of the facility and/or components;
- Available redundancy in the event of facility failure;
- The level of service the Water Authority could provide in the event of facility or component failure;
- The difficulty of recovering from failure; and
- The impact of failure, such as inundation of surrounding areas.

The performance goals and the corresponding SPC for non-pipeline facilities are listed in Table 5-1. The seismic importance and the corresponding PFC for pipeline facilities are listed in Table 5-2.

5.1.6.1
Use of Table 5-1

In using Table 5-1, a common cause/failure mode is a situation where multiple failures are likely to be produced by a single cause. For example, an earthquake-induced landslide under a pump station can be assumed to cause a common cause failure to all pumps within the pump station. However, earthquake-induced ground shaking is not likely to cause all the pumps within a pump station to fail.

The "I = 1.25" and "I = 1.50" values in Table 5-1 do not apply to the design or evaluation of transmission pipelines. For transmission pipelines, I is always equal to 1.0. In no case should the combined value of [Peak Ground Acceleration (PGA) * I] used for design need to exceed 0.9g.

Portions of the water system do not need to be seismically upgraded that if they do not pose credible life safety threat as a whole and meet the performance goals in Section 5.1.4. When these portions of the water system are modified for purposes other than seismic, the new or modified portions should be designed in accordance with seismic criteria for new facilities per Chapter 5.

Where the detailed requirements of this chapter or referenced standards and codes require the application of an I-Factor, it shall be determined in accordance with the Table 5-1.

Table 5-1: Seismic Performance Goals and Seismic Performance Class (SPC)

PERFORMANCE GOAL	SPC AND CODE "I" VALUE*	POTENTIAL EXAMPLES
Provide life safety protection for major earthquakes likely to affect the site. Facility may not be economically repairable in the event of such an event.	Standard, I, I = 1.0	Administrative centers, repair shops, service centers and similar support facilities. Repair shops needed for post-earthquake repairs may need to be in a higher SPC.
Provide life safety protection for earthquakes likely to affect the site. Facility may experience damage but should be capable of restoration to service within 30 days.	Important, 2, I = 1.25	Structures and components of the storage, distribution, treatment and control systems with some level of redundancy or for which failure does not result in an unacceptable service level.
Provide life safety protection for earthquakes likely to affect the site. In addition, provide reasonable expectation of post-earthquake operability. Facility should be capable of restoration to a level of service consistent with adopted post-earthquake Level of Service goals within 24 hours.	Critical, 3, I = 1.5	• Structures and components of the storage, distribution, treatment and control systems with no redundancy or with redundancy having common-cause failure modes, and the failure of which results in an unacceptable service level. • Facilities having no redundancy or redundancy with common-cause failure modes, are classified as Critical. Attention must also be given to hydraulic flow limitations when assessing redundancy. • Facilities needed for emergency response, such as emergency operations centers and emergency repair/response centers.

*I = Importance Factor (or I-Factor) as defined by IBC

Table 5-2: Seismic Performance Class (SPC) and Pipe Function Class

SPC	PFC	SEISMIC IMPORTANCE	DESCRIPTION
	1	Very Low to None	Pipelines that represent very low hazard to human life in the event of failure. Not needed for post earthquake system performance, response, or recovery. Widespread damage resulting in long restoration times (weeks or longer) will not materially harm the economic well being of the community.
1	2	Ordinary, Normal	Normal and ordinary pipeline use, common pipelines in most water systems. All pipes not identified as PFC 1, 3, or 4. Includes Essential pipelines that have two or more redundant pipelines that are reliable for a 475-year earthquake.
2	3	Critical	Critical pipelines serving large numbers of member agencies and present significant economic impact to the community or a substantial hazard to human life and property in the event of failure. Includes Essential pipelines which have one redundant pipeline that is reliable for a 975-year earthquake.
3	4	Essential	Essential pipelines required for post earthquake response and recovery and intended to remain functional and operational during and following a design earthquake. No redundant pipelines available to provide service post earthquake.

5.1.7 Reference Codes and Standards

Regardless of design basis, all newly constructed Water Authority facilities shall as a minimum comply with the applicable provisions of the codes and standards and guidelines, latest edition, listed below.

- Buildings, structures & equipment – ICC, International Building Code, the International Code Council, Falls Church, Virginia.
- Fire Suppression Systems – NFPA l3, 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.
- Transmission Pipelines – Seismic Guidelines for Water Pipe-lines, American Lifelines Alliance

5.1.8 Additional References

Refer to Appendix A, Supplemental Seismic Design Criteria for Water Facilities, of the Facility Design Guide for supplemental information for seismic design of water capital facilities. Appendix A is presented for information only and any use of information contained therein does not absolve the Design Contractor of its responsibility for the design as engineer of record.

5.2 Site Criteria

5.2.1 Seismic Hazards

Water Authority facilities are located in an area where the level of seismicity ranges from one of the highest in California in its northern service area to one of the more moderate in the southern area. The hazards associated with such potential seismic activity include:

- Fault rupture at site traversed by active faults.
- Ground motions generated by earthquakes occurring on nearby or distant faults.
- Instability of slopes at or near the site.
- Liquefaction, in saturated cohesionless soil strata underlying the site of a facility, that may lead to loss of bearing for shallow foundations, lateral support of deep foundations, settlements, lateral spreads and/or lateral flows, and buoyancy effects.
- Loss of strength in cohesive soil strata underlying a facility that may lead to comparable consequences.

Some of these hazards need to be identified and evaluated on an area or system-wide basis and some require site-specific investigations.

5.2.2 Geologic Studies

Regional and site geologic studies may be required. These hazard evaluations shall include identification of faults and other geologic features that may affect project facilities.

5.2.3 Seismologic Studies

Seismologic studies may be needed to assess the seismicity of the region and to establish earthquake events that will be used in the analysis, evaluation, and design of the project facilities. These studies should cover historic seismicity, including recurrence relationships for the region and for each source identified in the geologic studies. The information gathered should be sufficient to conduct both a deterministic and probabilistic evaluation of earthquake ground motions for a generic site condition, e.g., a rock outcrop.

5.2.4 Geotechnical Studies

A California-licensed geotechnical engineer shall determine if previous investigations and field work performed for the site are sufficient. If not, a field investigation or laboratory testing program, or both, may be required. The extent of geotechnical studies should be detailed for facilities that are classified per Table 5-2 as SPC 2 or 3, or PFC 3 or 4.

5.2.5 Ground Shaking

The parameters required to characterize the seismic loads for engineering analysis or design of a structure will depend on the method used to analyze the structure.

In general, scenario ground motions should be used when evaluating the performance of the water system as a whole, while either deterministic or probabilistic motions should be used for design of a specific facility at a specific location. By "scenario ground motion", it is meant the selection of a specific earthquake rupture at a specific location.

5.2.5.1 Deterministic Methods

Deterministic estimates of ground motions for a given earthquake are made by defining the magnitude of the earthquake scenario, determining the source-to-site distance, and applying attenuation relationships available in the seismic literature.

5.2.5.2 Probabilistic Methods

Probabilistic analysis is used to estimate earthquake ground motions associated with a selected probability level, e.g., a probability of exceedance over the life of the structure. Such analysis is commonly referred to as probabilistic seismic hazard analysis (PSHA).

5.2.5.3 Design Ground Motions

The prescribed design ground motions requirements are minimum requirements. Additional requirements may apply.

For the assessment of seismic geohazards and the design of system facilities other than buildings, tanks, and equipment anchorage, ground motions shall be determined by probabilistic procedures.

Design ground motions with 10% probabilities of exceedance in 50 years (475-year approximate return period) shall be used for facilities in SPCs 1, 2 and 3. In lieu of using the 475-year earthquake motions directly, the design ground motions may be taken as 2/3 of the 2,475-year (2% in 50 years) motions, at the discretion of the Design Manager; but in no case less than the 475-year motion. The design ground motion need not exceed a deterministic limit taken as the 84^{th}-percentile level spectrum for the scenario earthquakes listed in Section 5.2.4.2.

Design spectra for facilities in SPC 3 shall be obtained from a site-specific study.

Design motions (generally ground velocities) for pipelines shall be taken as the 475-year, 975-year or 2,475-year motions for PFC 2, 3 or 4, respectively, as adjusted to reflect rock, firm soil, or soft soil conditions along the alignment of the pipeline.

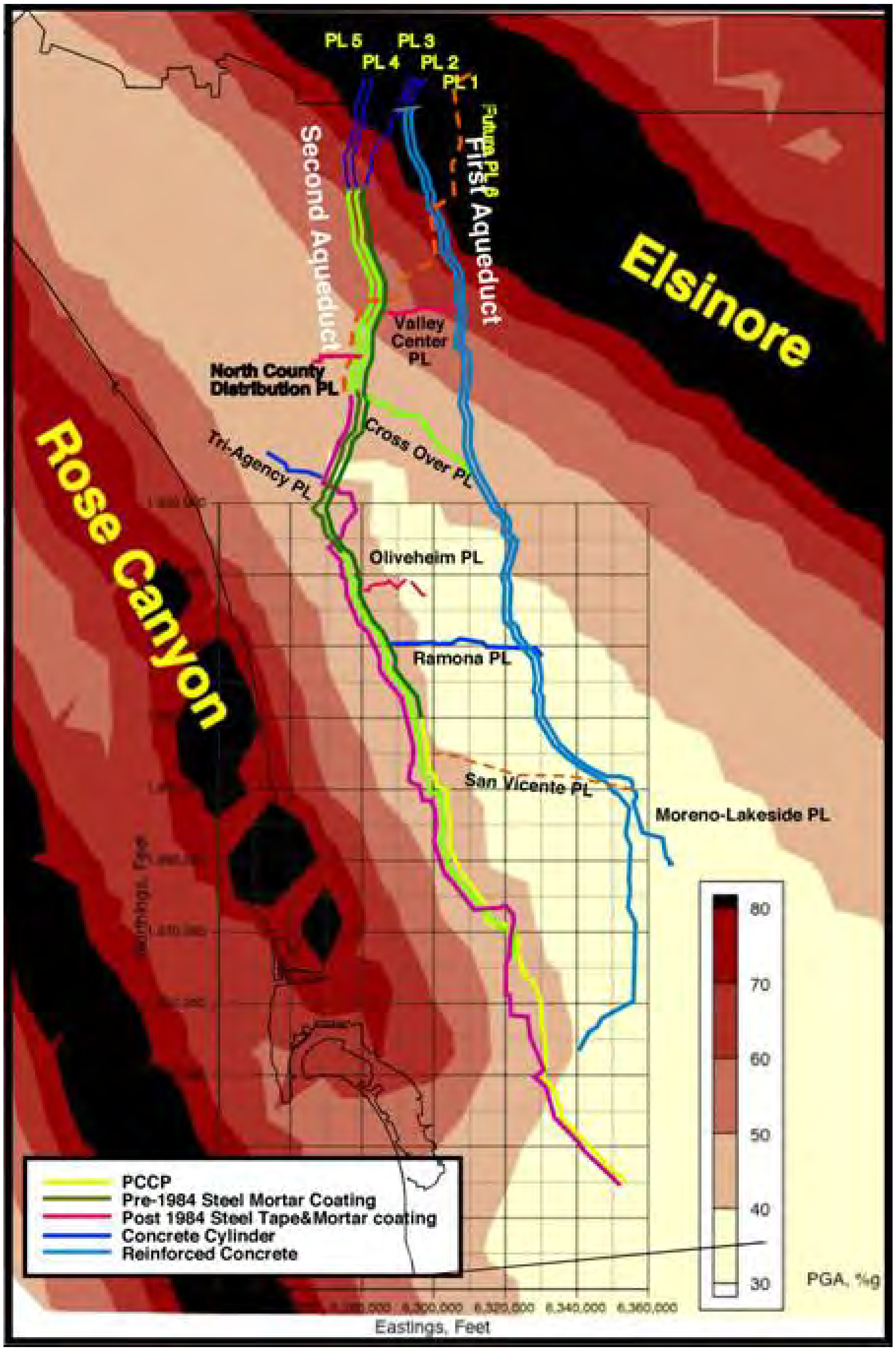


Figure 5-1: 2,475-Year Horizontal PGA (Rock Level)

5.2.5.4 Selection of Fault Displacement Parameters

When a facility must be placed across a primary active fault, it shall be designed with the recognition that surface faulting or folding may occur.

5.2.5.5 Liquefaction

The potential for liquefaction of a site shall be considered in the design of Water Authority facilities. This phenomenon can be highly damaging to aboveground, as well as underground structures and utilities, and shall be taken into account in the design of Water Authority facilities. Liquefaction occurs where loose, saturated, granular soils (silts, sands, and gravels) lose a substantial amount of strength when subjected to intense ground shaking.

Comprehensive soil liquefaction susceptibility mapping has not been completed throughout the San Diego County area. Therefore, liquefaction potential at a facility site shall be addressed on a project-specific basis by a California-licensed geotechnical engineer.

5.2.6 Lateral Spreads and Slope Movements

The potential for lateral spreads and slope movements shall be considered in design of Water Authority facilities.

Lateral spreads and slumping are ground-failure phenomena that can occur on sloping ground. If the site has a significant slope, or is adjacent to an open cut, e.g., depressed stream or road bed, liquefaction and soil failure can cause the flow of materials down slope or towards the cut.

5.2.7 Landslides

The potential for damaging landslides at a site shall be considered in the design of Water Authority projects. The potential for landslides at hillside sites, or sites adjacent to steep slopes, bluffs, and/or cuts, should be addressed by a California-licensed geotechnical engineer or California-licensed engineering geologist.

Landslides occur when the combination of gravitational and ground shaking-induced inertial forces temporarily exceeds the strength of the earth materials in the slope. Landslides are often triggered by strong ground shaking, particularly in areas close to the causative fault.

5.2.8 Settlements

Differential settlement of soils shall be considered in the design of Water Authority facilities. Such damaging settlements can occur as a result of liquefaction or other modes of seismic ground shaking.

5.2.9 Wave Propagation Hazards

For long linear systems, such as Water Authority pipelines, the effects of traveling waves and ground deformation shall be considered in the design and evaluation of such facilities.

5.2.10 Seismic Soil Pressure on Structures and Retaining Walls

In the design of structures and retaining walls associated with Water Authority facilities, appropriate static and seismic soil pressure increments shall be considered.

5.3 Buildings and Building-Like Structures

5.3.1
Applicability

A building is defined as any enclosed or partially enclosed above grade structure that provides for shelter of persons or equipment, and that is occasionally occupied. A building-like structure is any unenclosed above grade structure that has one of the lateral-force-resisting systems defined in ASCE 7-05.

5.3.2
Design Basis of New Buildings

The design of all elements of buildings, including structural elements of the lateral-force-resisting system, structural elements not part of the lateral-force-resisting system, and non-structural elements shall as a minimum comply with all applicable sections of the IBC, except as modified herein.

5.3.2.1
Classification of Buildings

Seismic Use Groups for new buildings are defined in the IBC. A Seismic Use Group of 1, 2, and 3 shall be assigned to facilities with SPC 1, 2, and 3, respectively.

5.3.2.2
Importance Factors

Importance factors for SPC 1, 2, and 3 are equal to 1.0, 1.25, and 1.5, respectively. The Importance Factor (I) for non-structural elements shall be 1.5 for facilities with SPC 2 and 3, and 1.0 for Class 1 facilities.

5.3.3
Detailing

Detailing requirements shall be as defined in the IBC.

5.3.4
Foundations

Soil-foundation interaction effects for massive structures shall be considered in the evaluation of foundations. A California-licensed geotechnical engineer shall provide information regarding liquefaction and other geotechnical hazards and appropriate mitigation measures as discussed in Section 5.2.

5.3.5
Inspection Criteria

All buildings, building components, and equipment necessary for the post-earthquake function of the facility shall be inspected per IBC requirements during construction to assure that the construction meets the intent of the design. Inspection of the completed facility shall also be performed to assure that possible seismic interactions between nearby components will not affect functionality of the facility.

5.4 Underground and Aboveground Piping

5.4.1 Piping Classifications

Table 5-3 provides a description of the characteristics of pipelines associated with each Seismic Performance Class (SPC). Also shown in Table 5-3 is the equivalence between SPC and Pipe Function Class (PFC), as provided in the Seismic Guidelines for Water Pipelines prepared under the auspices of the American Lifelines Alliance.

Table 5-3: Equivalence of Pipe Function Class and Seismic Performance Class

Seismic Performance Class (SPC)	Pipe Function Class (PFC)	Pipeline Description
	1	Pipelines that represent very low hazard to human life in the event of failure. Not needed for post earthquake system performance, response, or recovery. Widespread damage resulting in long restoration times (weeks or longer) will not materially harm the economic well being of the community.
1	2	Normal and ordinary pipeline use, common pipelines in most water distribution systems. Most WA pipelines do not fall under this class.
2	3	Critical pipelines and appurtenances serving large numbers of member agencies, with significant economic impact to the community or a substantial hazard to human life and property in the event of failure. All WA aqueduct pipelines with parallel pipelines fall under this class.
3	4	Essential pipelines required for post-earthquake response and recovery and intended to remain functional and operational during and following a design earthquake. WA aqueduct pipelines without any redundant pipelines fall under this class.

5.4.2 General Design Guidelines

The following guidelines shall be used in the design of Water Authority pipelines.

5.4.2.1 Selection of Pipe Classifications

- All Water Authority pipelines are SPC-classified pipelines, either SPC 1, 2, or 3.
- SPC 1 pipelines are normal and ordinary distribution pipelines, generally but not exclusively 6 to 10 inches in diameter. The purpose of such pipelines is for local distribution of water to

housing tracts and commercial users. Water Authority aqueducts are not SPC 1 or PFC 2 pipelines.

- SPC 2 pipelines are critical pipelines serving a large number of member agencies that present significant economic impact to the community or a substantial hazard to human life and property in the event of failure. Some Water Authority Aqueduct non-aqueduct pipelines, such as blowoff and flow control facility inlet pipelines, may be classified as SPC 2 (PFC 3) pipelines.
- SPC 3 pipelines are essential pipelines that are required for post-earthquake response and recovery and intended to remain functional and operational during and following a design earthquake. All Water Authority aqueduct pipelines are classified as SPC 3 pipelines. Other types of Water Authority pipelines may be classified as SPC 3 as well.

5.4.2.2 Selection of Ground Shaking

For buried pipelines, the effect of ground shaking shall be evaluated by specifying the Peak Ground Velocity (PGV) along the length of the pipeline. The PGV shall be set at the 475-year motion for SPC 1 pipelines, 975-year motion for SPC 2 pipelines, and the 2,475-year motion for SPC 3 pipelines.

5.4.2.3 Selection of 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 locations of landslides hazards should be based on site-specific information. In addition, the planning and design for all new major pipeline projects should include a geologic/geotechnical reconnaissance of the proposed routing.

5.4.2.4 Bypass Pipelines

Bypass pipeline systems can be used to accommodate large PGDs, such as fault offset, as long as the time and resources involved to deploy such systems are considered satisfactory by the Water Authority.

5.4.2.5 High Seismic Hazard Areas

Any distribution or transmission pipeline of SPC 1, 2, or 3 that traverses a zone of high to very high liquefaction potential, to site-specific landslide potential, or fault offset at active seismic faults, should be designed to accommodate the ground deformation.

5.4.3 Transmission Pipelines

All Water Authority transmission pipelines are classified as SPC 3 and shall be designed accordingly.

5.4.4 Other Water Authority Pipelines

Small diameter, non-transmission pipelines at Water Authority facilities that are not exposed to PGDs or differential movements at soil-to-structure interfaces may be classified SPC 2 or 1 and may be designed for seismic loading using suitable methods.

5.4.5 Aboveground Piping, Conduit, Cable Trays, and HVAC Duct

Newly installed piping, conduit, cable trays, and HVAC ducts shall as a minimum be provided with braces that satisfy SMACNA (Sheet Metal and Air Conditioning Contractors National Association) requirements for Seismic Hazard Level A (the highest hazard level).

5.4.6 Piping Passing Through or Below Bodies of Water

Piping passing through bodies of water, e.g., reservoirs, creeks, rivers, bays, etc., shall be evaluated for internal and external hydrodynamic effects and the effects of saturated soils with regard to interaction with piping systems.

Pipes that cross below bodies of water shall also be checked for scour forces, as well as all other loads described elsewhere in Chapter 5.

5.5 Soil Retaining Structures

5.5.1 General

Soil retaining structures, such as retaining walls and U-walls, shall be designed for appropriate static and seismic soil pressure depending on the restraining conditions of the wall. Where applicable, the effects of hydrodynamic loads shall be considered in the design.

5.5.2 Yielding Walls

For yielding walls, active soil pressure may be used for design.

5.5.3 Gravity Retaining Walls

For gravity retaining walls, methods described in the seismic engineering literature may be used to determine the seismic soil pressures.

5.5.4 Non-Yielding Walls

For non-yielding walls, at-rest soil pressure shall be considered for static loading. Seismic soil pressure may be obtained from methods used in ASCE 4-98.

5.6 Underground Structures

5.6.1 Tunnels

Resistance of bored and cut-and-cover tunnels to seismic forces shall be determined.

- Seismic response of tunnels shall be determined and considered in the design.
- Detailing shall conform to IBC requirements.
- If possible, align tunnels so they do not cross known active faults. When a tunnel must be placed across a primary active fault, it shall be designed with the recognition that surface faulting or folding may occur.
- Existing tunnels shall be investigated using procedures of 5.6.1.1 and shall include assessment of impacts due to fault crossings.

5.6.2 Vaults

Underground vaults for valves, flow control facilities, and similar structures shall be designed as outlined below.

- At sites with firm soils, a California-licensed geotechnical engineer shall determine seismic forces to be considered in the design. Past earthquakes have not caused extensive damage to building walls below grade. In some cases, however, it may be advisable to verify the adequacy of retaining walls to resist increased pressure due to seismic loading. In addition to designing walls of the structures for the increased pressures indicated above, the structure as a whole shall be designed to resist sliding as a result of such pressures.
- At sites with soft and/or liquefiable soils, a California-licensed geotechnical engineer shall determine seismic forces for soft and/or liquefiable soil sites, including liquefiable soil pressures, to be considered in the design.
- Detailing shall conform to IBC requirements.

5.7 Water Retention Structures

5.7.1
Steel Tanks

Steel tanks shall be designed in accordance with the latest edition of AWWA D100. Steel tanks shall be anchored and provided with fixed steel roofs.

5.7.2
Prestressed Concrete Tanks

Prestressed concrete tanks shall be designed in accordance with the latest edition of AWWA D110.

5.7.3
Water Retention Basins

Water retention basins shall be designed as described below.

- Open roofed basins shall be designed in accordance with the latest edition of ACI 350.
- Circular basins shall be designed for seismic forces calculated in accordance with Section 5.7.2.
- Rectangular basins and foundations shall designed by combining earthquake forces aligned with each principal axis of the basin.
- Division walls shall be designed as end walls of individual basins.
- Liners shall be designed to not leak excessively or in a manner as to be unrepairable within 30 days after a major earthquake.
- Embankments not otherwise covered by DSOD shall be designed to withstand a 475-year earthquake (increased by I = 1.25 or I = 1.5) with at least 3 inches of freeboard available.

5.7.4
Internal Components

Seismic design of 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 shall be designed according to applicable standards and codes.

5.7.5
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.

5.8 Pump Stations

5.8.1 Enclosure Structures

Enclosure structures for pump stations, including buildings, building-like structures, and vaults, shall be designed in accordance with Section 5.3 or 5.6.2. This includes structures that fully or partially enclose any mechanical or electrical components that are needed to operate the pump station.

5.8.2 Equipment

Pump station equipment, including pumps, switchgear, transformers, and similar items, as well as above ground piping, shall be designed in accordance with Section 5.9.

5.8.3 Underground Piping

Underground piping at pump stations shall be designed in accordance with Section 5.4.

5.9 Equipment

5.9.1 General

Some equipment components are inherently rugged and maintain structural integrity and functionality during and after earthquakes. For these components, little special seismic design needs to be paid to these elements.

On the other hand, some equipment components are vulnerable to seismic hazards and appropriate design measures to limit risks from these vulnerabilities shall be implemented where practical.

5.9.2 Equipment Functional Classification s

Equipment can be classified according to its structural and functional ruggedness.

5.9.2.1 Structurally and Functionally Rugged Equipment

The following equipment can be considered as structurally and functionally rugged, and need be designed only for the minimum anchorage forces and the other recommendations in Chapter 5:

- Valves
- Engines
- Motors
- Generators
- Turbines
- Horizontal pumps
- Vertical pumps (limited unsupported shaft length)
- Hydraulic and pneumatic operators (limited yoke length)
- Motor operators (limited yoke length)
- Compressors
- Transformers with anchored internal coils

5.9.2.2 Structurally Rugged Equipment

The following equipment can be considered as structurally rugged, and need be designed for the minimum anchorage forces and the other recommendations in Chapter 5. 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

5.9.3 Horizontal Pumps

Horizontal pump installations shall be designed as outlined below:

- Evaluate anchorage for seismic loads. Expansion anchors are not acceptable.
- Engine (or motor) and pump must be connected by a rigid base or skid.
- Sufficient slack and flexibility must be provided in cooling, fuel, and electrical lines.
- Avoid attaching heavy valves to pipe near pumps.
- Avoid seismic interactions of pumps with other components.
- Assure all equipment installed near vital pumps will not impact the pumps during seismic excitation and the pumps are securely anchored.

5.9.4 Vertical Pumps

Vertical pump installations shall be designed as outlined below:

- 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 all equipment installed near vital pumps will not impact the pumps during seismic excitation and the pumps are securely anchored.

5.9.5
Valves

Valve installations shall be designed as outlined below:

- Cast iron valves shall not be used.
- Actuator and yoke should be supported by the pipe. 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 shall be provided for tubing, conduits, or piping that supplies air, fluids, or power needed to operate the valve.
- Valves should not be near surrounding structures or components that could impact the valve during seismic excitation.

5.9.6
Motor Control Centers

Motor Control Centers (MCCs) shall be installed in floor-mounted, NEMA-rated enclosures. Other seismic requirements include:

- Anchorage shall be evaluated for seismic loads. At least two anchor bolts shall 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.

5.9.7
Control Panels and Instrument Racks

Control panel and instrument rack installations shall be designed as outlined below:

- Anchorage shall be evaluated for seismic loads.
- All door latches must be secured with locking devices.
- Wire harnesses or standoffs shall be installed on cable bundles to preclude large deformation of bundles.

5.9.8
Battery Racks

Battery rack installations shall be designed as outlined below:

- Battery cells should be lead-calcium and weigh 450 pounds or less.
- Batteries shall be supported on two-step or single tier racks that have X-bracing.
- Batteries shall be restrained by side and end rails.
- Provide snug fitting crush-resistant spacers between cells.
- Racks must be anchored and anchorage shall be evaluated for seismic loads.

5.9.9
Above Ground Equipment Piping

Design of above ground equipment piping installations shall include the following seismic considerations:

- 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.

5.9.10
Vibration Isolated Equipment

In general, equipment, including diesel engines, should be rigidly mounted to supporting foundations and structures, without the aid of vibration isolation devices. Exceptions are situations in which vibrations transmitted from the equipment would be troubling to building occupants or other equipment within the building. Equipment mounted on vibration isolators is vulnerable to damage in earthquakes. Use of vibration isolators for equipment essential to functionality of a facility should be avoided.

If it is determined that vibration isolators must be used, isolators shall include seismic restraints (or snubbers) to prevent excessive movement in a seismic event. Designs of vibration isolators, including seismic restraints, shall be in accordance with IBC requirements. The supplier of vibration isolators shall submit certified calculations, sealed by a California-registered civil, structural, or mechanical engineer, indicating the adequacy of the hardware and attachment anchorage to meet its criteria. ASCE Manual of Practice 96 contains examples of suitable installations.

5.9.11 Equipment Anchorage

Equipment anchorage is an important consideration in the design to assure functionality. A majority of equipment failures due to seismic loads can be traced to anchorage failure.

5.9.11.1 Expansion Anchors

Wedge-type (or torque-controlled) expansion anchors have been widely tested and has reasonably consistent capacity when properly installed in sound concrete. Other expansion anchor seismic factors include:

- Other types of non-expanding anchors, such as lead cinch anchors, plastic inserts, and lag screw shield, are not as reliable and should not be used.
- Expansion anchors should not be used for vibrating equipment as they may rattle loose and provide no tensile capacity.
- Proper bolt embedment length should be assured. Inadequate embedment may result from use of shims or high grout pads.
- Bolt spacing of ten bolt diameters is required to gain full capacity. Comparable spacing is required between bolts and free concrete edges.
- The exposed heads of all expansion anchors shall be stamped with a letter that indicates its full length and the lettering system shall be shown on the drawings.

5.9.11.2 Epoxy Anchor Bolts

Epoxy anchorage systems may be used for retrofits or new construction in areas with limited edge distances or limited embedment depths, or in other areas, subject to the environmental limitations on epoxy systems. Inadequate embedment may result from use of shims or high grout pads. Seismic considerations include:

- Epoxy anchors should not be used for vibrating equipment.
- Bolt spacing and edge distance requirements are the same as for expansion anchors.
- The exposed heads of all epoxy anchors shall be stamped with a letter that indicates to its full length and the lettering system shall be shown on the drawings.

5.9.11.3 Cast-In-Place Anchors

Seismic factors that shall be considered in the design of cast-in-place equipment anchors include:

- Properly installed, deeply-embedded, cast-in-place, headed studs and J-bolts are desirable since the failure mode is ductile (steel governs).

- Properly installed, undercut anchors with long embedment lengths behave essentially like cast-in-place bolts and are similarly desirable.
- Care should be taken to extend anchors through grout to provide required embedment in the concrete below.
- Bolt spacing and edge distance requirements are the same as for expansion anchors.

5.9.11.4 Welded Anchors

Well designed and detailed welded connections to embedded plates or structural steel provide high capacity anchorage.

5.9.12 Anchorage Forces

The minimum design forces for anchorage and bracing of equipment shall meet IBC requirements. Amplification of ground motions within a building to establish in-structure response spectra may be developed using rational methods, such as those described in ASCE 4-86. A minimum factor of safety of four should be used for expansion anchors used for equipment anchorage.

5.9.13 Electrical Distribution and Transmission Equipment

All new high voltage equipment shall be designed for earthquakes in accordance with IEEE 693. High voltage equipment includes all equipment at substations rated at 34.5 kV or higher.

Transmission towers shall be designed for earthquake, wind, ice, and conductor mechanical loads in accordance with latest IEEE 693, ASCE 7 and all applicable NESC/NES standards.

5.9.14 Existing Facilities

The Design Manager shall determine if a seismic evaluation is required for an existing facility. Any of the following actions may trigger a requirement for a seismic evaluation of an entire facility, including site soil stability, equipment, structures, piping, etc., as follows:

- Facility upgrade that increases nominal operating capacity by 20% or more.
- Facility upgrade in which 30% or more of the major pieces of operating equipment are replaced, such that the expected design life of the facility is extended.
- Facility repair, as for example from fire or other damage, that has a construction cost in excess of 30% of the replacement cost of the facility.

- Addition of floor space in excess of 20% of existing space.
- Addition of a partial or full story.
- Change in occupancy or structure utilization.
- Change in live load or equipment load by more than 20%.
- Additions or alterations that introduce structural irregularities that substantially adversely affect the seismic capacity of the original structure.

5.9.14.1 Existing Facility Upgrade Requirement

If a trigger to re-assess a facility occurs, and that reassessment shows the facility does not meet the basic life safety goal, then some type of upgrade of that facility is warranted.

If the basic life safety goal is met, then the facility is not required to be seismically upgraded or retrofitted as long as the basic Level of Service goal described in Section 5.1.4 is satisfied.

5.9.14.2 Existing Facility Retrofit Requirement

Facilities found to have unacceptable seismic adequacy should be brought into compliance with the requirements of Chapter 5 for new construction to the extent practical.

Attachment 5-1: Symbols and Notations

Where used in Chapter 5, symbols and notation shall have the meanings indicated below.

SYMBOL OR NOTATION	MEANING
D	required freeboard for tanks - ft
ft	feet
f_p	seismic force on component - lbs/ft
f_w	hydrodynamic force on submerged component - lbs/ft
g	acceleration due to gravity = 32.2 ft/sec^2
gpm	gallons per minute
lbs	pounds
kips	kilo-pounds
k_h	horizontal seismic coefficient in the soil (Equation 5-1)
km	Kilometer
m	meter
psf	pounds per square foot
r	radial distance from center of tank to submerged object – ft
s_u	Undrained shear strength of soil, psf
t	time - seconds
u	Fluid particle velocity - ft/sec
$\|u\|$	Absolute value of fluid particle velocity - ft/sec
$\hat{u}$	Fluid particle acceleration - ft/sec2
$\ddot{u}_v$	Vertical peak ground acceleration – g
w_p	Unit weight of component - lbs/ft
w_w	Unit weight of water displaced by component - lbs/ft
A	Area of cross section of a component - in^2
AF	Acre Feet (about 325,853.4 gallons)
C_d	Drag coefficient, taken as 1.0 for circular sections and 1.6 for open sections such as structural shapes
C_w	Numerical coefficient used in the calculation of first mode impulsive period of tank
D	Diameter of tank – ft
D_c	Diameter of circle that circumscribes perimeter of submerged object at level under consideration - ft
G	Specific gravity of fluid (equals 1.0 for water)
H	Total height of the fluid in the tank – ft
H_f	Height of base of tank above base of foundation - ft
H_{rw}	Height of the wall that is retaining the soil
H_t	Total height of tank shell- ft
I	I-Factor per Table 5-1
IBC	International Building Code
M	Flexural moment at a section of an element - ft-lb; or Moment Magnitude
M_f	Total overturning moment of tank and foundation - ft-lb
MGD	Million Gallons per Day

SYMBOL OR NOTATION	MEANING
N_c	Convective hoop force in shell of tank - lbs/in
N_i	Impulsive hoop force in shell of tank - lbs/in
PGA	Peak ground acceleration - g
PGD	Permanent ground deformation
R	Response modification factor per IBC (2006 edition), except as otherwise specified herein
R_w	Response modification factor per AWWA D-100 (1996 edition) Table 25, except as otherwise specified herein
S	Site coefficient for soil characteristics given in Table 16-J of the 1994 UBC
WA	San Diego County Water Authority
S_a	Spectral acceleration of an elastic structure with known natural period of vibration and damping - expressed in fractions of the acceleration due to gravity - g
S_{ai}	Spectral acceleration of tank shell and contents in impulsive mode, g, (can be taken as peak spectral acceleration from spectrum) for a 2% damped spectrum
S_{ac}	Spectral acceleration of tank shell and contents in convective (sloshing) mode, g, for a 0.5% damped spectrum
T	Natural period of vibration of a structure - sec
T_i	Impulsive period of water in tank - sec
T_w	Sloshing period of water in tank per AWWA D-100 Section 13.3.3.1 - sec
V	Seismic shear force at the base of a structure - lbs
V_f	Total shear associated with tank and foundation - lbs
W_1	Weight of effective mass of tank contents that moves unison with tank shell per AWWA D-100 Sec. 13.3.3.2 - lbs
W_2	Weight of effective mass of tank contents that moves in first sloshing mode, per AWWA D~100, Section 13.3.3.2 – lbs
W_f	Weight of foundation - lbs
W_r	Total weight of tank roof plus permanent loads, if any - lbs
W_s	Weight of tank shell - lbs
X_1	Height from the bottom of tank shell to the centroid of lateral seismic force applied to W_1 per AWWA D-100 Section 13.3.3.2 – ft
X_2	Height from the bottom of tank shell to the centroid of lateral seismic force applied to W_2 per AWWA D-100 section 13.3.3.2 - ft
X_s	Height from bottom of tank shell to center of gravity of the shell - ft
Y	Distance of object in reservoir below the undisturbed fluid surface (value of Y is negative if object is above surface) - ft
Y_i	Distance of object in reservoir above the undisturbed fluid surface – ft
Z	Seismic zone coefficient = 0.4g, representative of the effective horizontal peak ground acceleration produced by an earthquake - g
γ	Unit weight of fluid - lbs/ft^3

SYMBOL OR NOTATION	MEANING
γ_s	Unit saturated weight of soil backfill - lbs/ft^3
Δp	Incremental dynamic earth pressure due to seismic shaking on embedded structures
Ω	System overstrength factor (ASCE 7-05, Table 12.2-1)

Chapter 6 SCADA and Instrumentation & Control

Overview

Purpose

This chapter presents the Water Authority general requirements for SCADA, and instrumentation and control systems.

Topics

This chapter is composed of the following topics:

6.1 Introduction

6.1.1 General

This chapter provides the Design Contractor with an overview of the existing Water Authority Supervisory Control and Data Acquisition (SCADA) system, and of design concepts, formats, and methodologies to be applied in the design of Water Authority Instrumentation and Control (I&C) systems. In addition to this chapter, the Design Contractor shall also refer to and follow the requirements, as applicable, outlined in Section 2.10 of Chapter 2 for Transmission Pipelines, Section 3.7 of Chapter 3 for Pump Stations, and Section 4.6 of Chapter 4 for Flow Control Facilities.

This chapter outlines the standards and procedures that shall be followed in the design, construction, and/or installation of SCADA and I&C systems in Water Authority projects. These standards cover requirements for the following items:

- SCADA-system components.
- Control-system components.
- I&C devices.
- Design documents.
- Testing and acceptance.
- Training.

The Design Contractor shall be responsible for:

- Preparing the project I&C documents (drawings and specifications).
- Preparing the project I&C support documents such as process control narratives.
- Conducting the required programming of the project Programmable Logic Controllers (PLCs).
- Coordinating with the Water Authority Human Machine Interface (HMI) developer and programmer.

6.1.2 Standards, Guidelines, and Codes

In this Guide, the Design Contractor is required to use and specify in contract documents specific Water Authority standards, equipment, materials, etc. In all cases, the Design Contractor shall verify the adequacy of all referenced standards, guidelines, materials, etc. to the project specifics. The Design Contractor shall review and modify the Water Authority documents, as required, to suit the project specifics. The Design Contractor shall follow the procedure outlined in Chapters 1 and 14 of the Design Contractor Guide (Design Manual – Volume One;

ESD-160) in proposing and requesting changes to Water Authority Documents.

A. Water Authority Standards and Guidelines

In addition to this Guide, the other Water Authority Standards and Guidelines for use in SCADA and I&C systems design and construction include:

- General Conditions and Standard Specifications (hereinafter referred to as "GC&SS"). Refer to Attachment 6-1 for the cover page of the GC&SS.
- Standard Drawings & Standard Details (hereinafter referred to as SD&SD). Refer to Attachment 6-2 for the cover page of SD&SD.
- Electrical/Instrumentation Guide Drawings (hereinafter referred to as EI- GD). Refer to Attachment 6-3 for the cover page of the Electrical/Instrumentation Guide Drawings.
- PLC Implementation Standard. Refer to Attachment 6-4 for the cover page of the PLC Implementation Standard.

B. National Standards and Codes

Numerous industry-wide codes and standards are used in I&C systems design and construction including:

- IEEE 100 - Dictionary of Electrical and Electronic Terms.
- IEEE 802.3 - Ethernet Standards.
- IEEE 802.11 - Wireless Communication Standards.
- IEEE 802.16 - Broadband Wireless Communication Standards.
- IEC 61131 – Programmable Controller Languages.
- ANSI/IEEE C37.90.1 - Transient Specification (Standard for Surge Withstand Capability).
- ISA S5.1 - Instrumentation Symbols and Identification.
- ISA S5.3 - Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems.
- ISA S5.4 - Instrument Loop Diagrams.
- ISA RP7.3 - Quality Standard for Instrument Air.
- ISA S18.1 - Annunciator Sequences and Specifications.
- ISA S20 - Specification Forms for Process Measurement and Control Instruments, Primary Element and Control Valves.
- ISA S51.1 - Process Instrumentation Terminology.
- ISO 11898 - Controller Area Network.
- NEMA 250 - Enclosures for Electrical Equipment.

- NEMA ICS - Enclosures for Industrial Control and Systems.
- NFPA 70 - National Electrical Code (NEC).
- NFPA 72 - National Fire Alarm Code.
- NIST – National Institute of Standards and Technology.

6.2 SCADA System

6.2.1 Existing System

SCADA systems include control and monitoring hardware and software, instrumentation, equipment and devices, communication networks, and other periphery control elements. The existing Water Authority SCADA system is comprised of the following components:

- A PC-based system for control, monitoring, and archiving that runs on a number of software programs including Wonderware Industrial Application Server, Wonderware Intouch, Wonderware ActiveFactory, and others.
- Computer servers for network administration and storage of historical records.
- Routers and switches for communication and data transmission.
- MDS (Microwave Data Systems) for wireless communication with remote facilities.
- Leased telephone circuits, including T-1 WAN (Wide Area Network) links, for communication with remote facilities.
- An Ethernet-based communication network.
- A single-mode fiber optic cable system.

The central control room of the existing SCADA system is currently located at the Water Authority Escondido office and is known as the Escondido Control Center (ECC). Refer to the EI-GD (see Attachment 6-3) for more information on communication links between new facilities and the ECC. See Attachment 6-1 for the cover page of the Electrical/Instrumentation Guide Drawings. A study is underway to determine the feasibility of moving the ECC to a new location. The ECC will continue to operate until a planned new control center is completed.

6.2.2 Connection of New Facilities

As the Water Authority expands its services through implementation of new projects, additional Programmable Logic Controllers (PLCs) will have to be installed to interface with the existing SCADA system. Refer to Section 6.3.2 for more information on PLCs. Ethernet is the standard network connecting the ECC with remote facilities. ControlNet is used as the communication protocol between the ECC and the PLCs located at Water Authority facilities.

Depending on project location, surrounding topography, and nearby existing Water Authority communication facilities, one of the following options may be used to tie new facilities into the Water Authority

SCADA system. The options are listed according to the preferred mode of communication:

- The new facility is located nearby the Water Authority fiber optic communication network. In this case, connect the new facility to the nearest fiber optic pullbox. Refer to the "Fiber Optic Communication Link Control System Block Diagram" drawing in the EI-GD (see Attachment 6-3) for more information.
- The new facility is located nearby a Water Authority's wireless microwave repeater. In this case, connect the new facility to the nearby microwave repeater using fiber optic cables. Refer to the "Fiber Optic Communication Link Control System Block Diagram" drawing in the EI-GD (see Attachment 6-3) for more information.
- The new facility is not located nearby the Water Authority's fiber optic network nor nearby a wireless microwave repeater. However, it has a clear path to one of the Water Authority's wireless microwave repeaters or to a Water Authority facility communicating with the SCADA system. In this case, connect the new facility to the nearest microwave repeater, or to the facility communicating with the SCADA system, via wireless microwave radio communication with spread spectrum 5.8 GHz MDS (Microwave Data System). Radio communication via 900 MHz MDS may be allowed if no video transmission is required. Refer to the "Microwave Radio Communication Link Control System Block Diagram" drawing in the EI-GD (see Attachment 6-3) for more information. When using wireless communication, distance limitations of the carrying signals should be considered.
- The new facility is not located nearby the Water Authority's fiber optic network or a wireless microwave repeater, and does not have a direct path (i.e., the signal is blocked by buildings or by natural terrain) to one of the Water Authority's wireless microwave repeaters nor to a facility communicating with the SCADA system. In this case, connect the new facility to the SCADA system via a leased telephone line. Refer to the "Telco Frame Relay Communication Link Control System Block Diagram" drawing in the EI-GD (see Attachment 6-3) for more information.

All wireless-transmitted data shall be secured and carried over the Water Authority's Aqueduct Control System (ACS) network, which is a private network with designated Ethernet IP addresses. The network IP address for each project is assigned by the Water Authority Operations and Maintenance (O&M) Department.

No transmission shall be allowed over the internet. All wireless communication shall be designed and effected using the IEEE 802.11 and IEEE 802.16 standards. Algorithms such as WEP (Wired Equivalent Privacy) that are known to be prone to eavesdropping or unauthorized access shall not be used.

Data transmission between new facilities and the ECC shall be for the following types of data and priority shall be in the order indicated:

- I&C signals for control and monitoring.
- Site access control system (see Section 6.3.7 for additional information).
- Video surveillance (see Section 6.3.7 for additional information).
- Other types of data, as required.

In addition to the above requirements, some major or critical facilities may require voice communication, via telephone lines, to accommodate communication to the ECC, other facilities, and field personnel.

6.3 Instrumentation & Control System Requirements

6.3.1 General

The I&C system requirements and selected components for a new facility are a function of the type of facility (e.g., pump station, flow control facility), and the size of the facility. The I&C system may vary from a single control panel with a PLC that controls and monitors facility equipment and instruments, to a complete control room equipped with computer workstations, PLC cabinets, and linking devices. Either type of facility would have a communications cabinet housing equipment with the capability to communicate with the ECC via an established communications network.

The Design Contractor shall advise the Water Authority on the most appropriate I&C system configuration for the new facility. The Design Contractor shall fully coordinate the I&C system design with the Water Authority O&M Department. Within 45 calendar days from Notice to Proceed (NTP), the Design Contractor shall deliver a presentation to O&M staff covering the control philosophy for the new project, including expected level of automation and the proposed control system configuration for the new facility.

6.3.2 Programmable Logic Controllers (PLCs)

A. General

Water Authority facilities are equipped with Allen Bradley PLCs for control, monitoring, and data communication. PLCs shall have the following minimum requirements:

- Equipped with redundant power supply.
- Based on failure assessment, may be equipped with redundant processors.
- Equipped with ports enabling interfacing with the facility communications cabinet (see Section 6.3.5).
- Equipped with interface devices to communicate with all facility networks.

PLCs shall be designed to accommodate all known immediate loads. The PLC power supply, number of input/output (I/O) points, wiring terminals, and other components shall have a minimum of 25% active spare capacity. Memory size shall have a minimum of 50% spare capacity. Important facilities shall be provided with redundant PLCs. The Design Contractor shall advice the Water Authority whether redundant PLCs are needed.

The Design Contractor shall refer to the following documents for more information on PLCs:

- “Programmable Logic Controller” specification section in the GC&SS (refer to Attachment 6-1).
- PLC Implementation Standard (refer to Attachment 6-4).

There are three PLC configurations that the WA generally use based on the needs of the facility:

- CompactLogix PLC for small facilities (e.g., a standard flow control facility; FCF).
- ControLogix PLC deployed in a redundant configuration for large facilities (e.g., pump station).
- Single ControlLogix PLC for facilities which are more complicated than an FCF but less complicated than a pump station.

The type of PLC used is a function of the number of I/Os, memory needs, and consequence of failure.

B. Programming

To simplify deployment, and to provide redundancy for safety reasons, facility PLCs shall be capable of executing programs autonomously without involving the host computers of the SCADA system. The Design Contractor shall be responsible for programming facility PLCs. The control logic programmed into the PLC shall conform to the operating descriptions (process control narratives), and P&ID drawings developed by the Design Contractor (refer to section 6.5 for more information).

The Design Contractor shall use the “IEC 61131” functional block or ladder programming language for creating programs to run on PLCs. The Design Contractor shall use the following documents while performing programming for the PLCs:

- “Programming Software for Programmable Logic Controllers”) specification section in the GC&SS (refer to Attachment 6-1).
- PLC Implementation Standard (refer to Attachment 6-4).

In programming the PLCs, the Design Contractor shall abide by the requirements stipulated in the above-mentioned documents including providing the required software and conducting the necessary training.

C. Safety Features

PLCs shall have the logic to execute the necessary actions when physical override switches on the PLC cabinet toggled “ON” during maintenance operations. This is done to ensure operator safety by avoiding automatic control of equipment and processes while maintenance functions are underway, i.e., system operators at the ECC shall not have control capability of the facility when maintenance functions are being carried out.

6.3.3
Control Panel

The control panel, where the PLC usually resides, shall have an on-line 120 VAC uninterruptible power supply (UPS) unit with battery backup, sized to power the PLC modules and other devices within the panel for a minimum of 2 hours after a power failure. All facility field instrument and control wiring that is routed to the control panel will terminate at the control panel terminal block prior to connecting to the PLC or other control panel device. Refer to the following Water Authority documents for additional requirements on control panels:

- The EI-GD (refer to Attachment 6-3) including the following drawings:
  - Control Panel Terminal Block Rail Assembly Drawings.
  - Control Panel & PLC Wiring Diagrams.
  - Control Panel Elevations and Miscellaneous Details.
- The GC&SS (refer to Attachment 6-1) including the following specification sections:
  - Uninterruptible Power Supply.
  - Cabinets and Consoles
- The PLC Implementation Standard (refer to Attachment 6-4) including the following section:
  - PLC Drawing Formats.

The Design Contractor shall size control panels to effectively house all components, devices, and peripherals needed for immediate and future service requirements. The Design Contractor shall determine the need for future growth, and plan additional space in the control panel accordingly. A minimum 25% spare capacity applies to future growth capacity. All control panels designed to accommodate future expansion shall have blank plates to cover cutouts. Wireways in the control panel shall be designed to have no greater than 50% fill, in any portion, when fully wired.

6.3.4
Human Machine Interface

PLCs shall have an HMI (operator interface) for local process monitoring and control. The HMI may vary from a small monitor attached to the control panel (Panel View) to a fully equipped control room with consoles, computers (workstations), printers, display monitors, and other equipment.

The HMI will display process graphics especially configured for the facility and an alarm window showing the most recent alarms including an alarm summary page. The HMI displays will be designed and configured by the Water Authority. However, the Design Contractor shall specify all required equipment (computers, etc.) and power and control communication devices required for proper implementation of the HMI system.

The Design Contractor shall specify other types of HMIs, such as interface panels mounted on pieces of equipment, as required. Training on the use of these interface panels shall be provided by the Construction Contractor.

6.3.5 Communications Cabinet

In addition to control panels (see Section 6.3.3), new facilities shall be equipped with communications cabinets. The main purpose of the communications cabinet is to house the communications devices that interface signals transmitted and received between the ECC and the facility PLC, card access control cabinet, and surveillance equipment (see Section 6.3.8). Several essential communication devices are included in the communications cabinet including:

- Routers for communication with microwave radio transceiver, leased telephone line modems, or fiber optic switch transceiver, as applicable.
- Fiber optic cable termination cabinet, if used.
- Radios for wireless communication, if used.
- UPS power supply.
- A 10 Mbps RJ-45 Ethernet port through which a laptop computer can gain access and interface with the control system.

The Design Contractor shall refer to the EI-GD (see Attachment 6-3), and to the “Cabinets and Consoles” specification section in the GC&SS (see Attachment 6-1) for the different types of communications cabinets and other related requirements.

6.3.6 Device-Level Network

For more complicated facilities, the Water Authority has started to shift from the traditional analog (4-20 mA) type of control for field equipment and devices to a digital-type system. The Water Authority adopted Foundation-Fieldbus as the device-level network of choice for some projects. Other types of field buses (e.g., DeviceNet) may be proposed by the Design Contractor. Depending on the nature of the project and the complexity and number of instruments and devices, a decision is made by the Water Authority whether to use the traditional 4-20 mA for control and monitoring or to switch to a digital-type system or combination of digital and analog systems.

If the type of device-level control is not already stated in the project predesign report, the Design contractor shall hold a meeting at the inception of the project with the O&M Department to discuss control options (digital fieldbus vs. traditional 4-20 mA) for the device-level network.

Specific to the digital-type fieldbus network, the Design Contractor shall:

- Specify field equipment and devices that are certified compatible with the selected digital fieldbus network.
- Specify in the contract documents that equipment manufacturers shall provide track records of similar installations.
- Specify the necessary digital fieldbus network components.
- Prepare the block diagram for the digital fieldbus network showing the network components and configuration.
- Prepare initial wiring diagrams for the digital fieldbus network to be finalized by the Construction Contractor.
- Specify the necessary communication modules / linking devices between the PLCs and the digital fieldbus network.

The Design Contractor shall also specify in the contract cocuments the following requirements to be carried by the Construction Contractor:

- Provide licenses to all software used in setting up the network or individual instruments. Requirements shall be similar to those stipulated in “Field-Mounted Instruments” specification section in the GC&SS (see Attachment 6-1).
- Provide a copy of the DD (Device Description) and the EDS (Electronic Data Sheet) files used in the setup of the device-level network.
- Provide the necessary training to O&M staff. See Section 6.5.4 below for training requirements.
- Furnish the Water Authority with the latest version of each of the following tools (single station license)
    - Conformance Test Kit (verifies communication behavior of a device).
    - Interoperability Test Kit (verifies functionality of a device).

6.3.7 Field Instrumentation

All field instruments shall be of the latest proven industrial quality design and manufacturing. Each instrument shall have a history of successful use in its specified application. If the failure of any single field instrument could jeopardize the continuous operation of the process, redundant instruments shall be provided for a fault-tolerant configuration. The Design Contractor shall use and specify the "Field-Mounted Instruments" specification section in the GC&SS (see Attachment 6-1).

If a digital fieldbus device-level network is used, then instruments shall be certified compatible to the selected fieldbus (refer to Section 6.3.5 for additional requirements). If a digital fieldbus network is not used, then instruments shall be of an intelligent version capable of communicating with the latest version of HART (Highway Addressable Remote Transducer) protocol (currently HART 375). Refer to the "Field-Mounted Instruments" specification section in the GC&SS (see Attachment 6-1) for more information on HART communication requirements for instruments.

It is to be noted that the "Field-Mounted Instruments" specification section does not cover all instruments. The Design Contractor shall develop specifications for all other types of instruments needed for the project with requirements similar to those outlined in the "Field-Mounted Instruments" specification section, including requirements for spare parts, training, warranty, etc.

6.3.8
Security

The Design Contractor shall use the following guidelines, developed by ASCE/AWWA/WEF, in the design of the control system:

- Interim Voluntary Security Guidance for Water Utilities. Refer to Attachment 6-5 for the cover page of this guidance. The Design Contractor shall refer to the following sections in this guidance and provide a list, for the Design Manager's approval, of all applicable security elements that could be included in the design:
    - Applicable paragraphs of the "Cyber Security Management, Operations, and Design Considerations" section.
- Guidelines for the Physical Security of Water Utilities. Refer to Attachment 6-6 for the cover page of these guidelines. Depending on the type of facility, the Design Contractor shall refer to the project-pertinent sections in these guidelines and provide a list, for the Design Manager's approval, of all applicable I&C security elements that could be included in the design. Applicable sections include:
    - Table - Security Measures for Raw Water Facilities.
    - Table - Security Measures for Wells and Pumping Stations.
    - Table - Security Measures for Distribution Systems.

  - o Table - Security Measures for Water System Support Facilities.
  - o Appendix A - Physical Security Elements.

The following are other elements of the security system that the Design Contractor shall consider:

A. Access Control System

The facility access-control system is mainly comprised of a programmable card-swipe terminal with keypad that is installed at the facility entrance. It is designed to grant, monitor, and log access of operator entrance to and exit from the facility and prevent unauthorized entrance. The card-swipe terminal shall be hardwired to what is known as the cardkey access control panel (CACP).

The card reader shall be located on the inside face of the facility wall, adjacent to the entry doorway, and shall be capable of reading an access card key through the wall. A Water Authority logo shall be painted on the exterior side of the wall (opposite the card reader) identifying where personnel are to place their access card keys to be read by the sensor, and thereby unlocking the door to access the facility.

Signal from the card reader is sent to the CACP whereby access is either granted or denied based on pre-programmed parameters. The CACP communication wiring shall be routed to the facility communications cabinet and connected to the communication service router. Access control signals are transmitted over separate network channels from the SCADA data, and are accessible through the security access system workstation located at the ECC.

For more information on cardkey access system, refer to:

- The "Access Control and Intrusion Alarm System" specification section in the GC&SS (see Attachment 6-1).
- The following drawings in the EI-GD (see Attachment 6-3):
  - o Process and Instrumentation Diagram.
  - o Fiber Optic Communication Link Control System Block Diagram.
  - o Microwave Radio Communication Link Control System Block Diagram.
  - o Telco Frame Relay Communication Link Control System Block Diagram.

B. Intrusion Switches

Intrusion switches are installed at possible entrance points (e.g., doors, access hatches) within the facility. Intrusion switches are hardwired to the facility PLC whereby their signal is sent, with the other I&C signals, to the ECC. For more information on intrusion switches, refer to the "Access Control and Intrusion Alarm System" specification section in the GC&SS (see Attachment 6-1), and to the EI-GD (see Attachment 6-3).

C. Video Surveillance

In some projects, video cameras or other surveillance equipment may be required. A separate security specialist shall design the site-specific surveillance configuration, specify surveillance cameras, processing equipment, wiring types, enclosures, and associated equipment.

The Design Contractor shall coordinate with the Water Authority security representative to determine need, number, and location of video cameras and associated equipment. The Design Contractor shall also obtain information from the security representative on power and control requirements for video cameras and processing equipment. Appropriate conduits/conductors for power and signal wiring shall be included in the design to accommodate for proper functioning of video cameras and signal transfer and communication with the main security management system located at the ECC.

Surveillance equipment communication wiring shall be routed to the facility communications cabinet and connected to the communication service router. Surveillance signals are transmitted to the ECC over separate network channels from SCADA data. Refer to the communication link control system block diagrams in the EI-GD (see Attachment 6-3) for more information.

6.4 Equipment Control

6.4.1 Control Templates

The Design Contractor shall consult the PLC Implementation Standards document (see Attachment 6-3) for specific equipment/device control requirements. The PLC Implementation Standards document contains the following standard control templates:

- Analog Input: Scales analog inputs into engineering units and uses the scaled value to generate alarms.
- Analog Output: Scales analog outputs from engineering units to raw units.
- Diagnostics: Provides status monitoring functions for the PLC.
- Setpoint Control (PID control): Maintains an operator entered setpoint (for flow, pressure, etc.) by comparing the setpoint with the process variable (PV) value, and adjusting the output value (controlled variable; CV) through manipulation of the Final Control Element (FCE).
- Discrete Signal Override: Forces a discrete signal to a particular state.
- Equipment Runtime: Accumulates equipment run times based on the equipment “ON” signal.
- Totalizer: Totalizes an analog value based on the analog signal.
- Flow Control Facility: Monitors the general conditions of the FCF and provides signals of abnormal conditions.
- Service Connection (subcomponent of a Flow Control Facility): Controls and monitors a service connection.
- Motor Control – Single Speed: Controls and monitors single speed motors.
- Motor Control – Variable Speed: Controls and monitors variable speed motors.
- Valve Control – Single Ended: Describes the control functions for an open/close valve.
- Valve Control – Double Ended: Describes the control functions for an open/close/stop valve.
- Valve Control – Modulating with Actuators: Describes the control functions for a modulating valve fitted with an actuator.
- Valve Control – Modulating with Positioners: Describes the control functions for a modulating valve fitted with a positioner and an analog position feedback.

The Design Contractor shall modify the standard control templates, if necessary, to suit the project specifics. Any modification shall be approved by the Design Manager. All other types of required control that are not included in the Water Authority control templates shall be developed by the Design Contractor.

6.4.2
Flow Control Facilities

A. Control Modes

In Flow Control Facilities (refer to Chapter 4), flow is generally controlled by a modulating control valve in conjunction with a flowmeter. The modulating control valve adjusts position, whereas the flowmeter measures flow and provides a feedback signal to the flowrate controller. Usually the operator feeds the control system with the desired controlling parameter setpoint. The control system will then modulate the control valve to achieve the desired setpoint. The Design Contractor shall design the control system with enough flexibility to enable control using any of the following possible control modes:

- Flow – The system operator inputs the flow setpoint. The control valve, in combination with the flowmeter as a feedback to the control loop, adjusts position to provide the desired flow.
- Downstream Pressure – The system operator inputs the downstream pressure setpoint. The control valve, in combination with the downstream pressure gauge as a feedback to the control loop, adjusts position to provide the desired setpoint.
- Upstream Pressure – The system operator inputs the upstream pressure setpoint. The control valve, in combination with the upstream pressure gauge as a feedback to the control loop, adjusts position to provide the desired setpoint.
- Valve Position – The system operator inputs the valve position setpoint. The control valve, in combination with the valve position as a feedback to the control loop, opens or closes to maintain the desired position.
- Manual – The operator in the field manually opens or closes the valve.

B. Control Configuration

The Design Contractor shall use the Setpoint Control template referenced in Section 6.4.1 in configuring the control system for flow control facilities. The Design Contractor shall set the proportional gain and integral time parameters of the PID controller so that large control valve movements are completely avoided. Derivative control is usually not recommended in flow/pressure control loops.

Special valve actuator gearing may be required to control the closing and opening times of the flow control valve to avoid sharp changes in flow. The Design Contractor shall be responsible for tuning the flow control loop. The PID controller shall be tuned so that a control mode such as the quarter wave decay or the critically damped decay may be implemented.

6.4.3 Pump Stations

A. Control Modes

Pump systems in use by the Water Authority are normally controlled by a flowrate- setpoint control system, which is normally maintained using variable flow output pumping units (i.e., equipped with variable speed drives). Refer to Section 3.6.2 of Chapter 3 (Pump Stations) for more information on variable speed drives. Pump control through flow control valves shall not be allowed.

The Design Contractor shall develop the control strategy based on the number of pumps, the flow capacity of each pump, the pump(s) characteristic curve(s), the system head curve(s), and the results of the transient analysis (refer to Section 3.4.5 of Chapter 3, Pump Stations, for more information). The Design Contractor shall determine the pump speed range (minimum and maximum speed) for controlling each pump by examining the pump efficiency curves versus the pump flow curves at various speeds. The minimum and maximum speeds shall be as follows:

- Absolute minimum speed - Usually recommended by the variable speed drive manufacturer.
- Minimum speed - Used when more than one pump is running. It is usually higher than the absolute minimum speed. The Design Contractor shall determine the minimum speed that provides smooth control of pumps and avoids excessive start/stop cycles.
- Absolute maximum speed - Usually recommended by the variable speed drive manufacturer.
- Maximum speed - Used when less than all pumps are running. It is usually lower than the absolute maximum speed. The Design Contractor shall determine the maximum speed that provides smooth control of pumps and avoids excessive start/stop cycles.

The pump speed shall vary depending on the difference between the actual flowrate, as measured by a flowmeter downstream of the pump station, and the flowrate setpoint. The control system shall allow for manual and automatic rotation between lead and lag pumps to avoid overworking the lead pump.

B. Control Configuration

The Design Contractor shall use the Setpoint Control template referenced in Section 6.4.1 in configuring the control system for the pump station. The Design Contractor shall set the proportional gain and integral time parameters of the PID controller so that large flow upsets are completely avoided. Derivative control is usually not recommended in flow/pressure control loops. The Design Contractor shall be responsible for tuning the flow control loop. The PID controller shall be tuned so that a control mode such as the quarter wave decay or the critically damped decay may be implemented.

Usually the control system is configured so that the PID controller is disengaged when starting a new pump (lag pump) following the first one (lead pump). This causes the running pump(s) to maintain their maximum speed. Following ramping the speed up of the new pump, and after a specified period of time, the PID controller is re-engaged to start commanding all running pumps. To shut down a pump, follow the same steps in reverse – disengage the PID, ramp down one pump, turn it off, reengage the PID.

C. Other types of Control

Flowrate control of pumps may be achieved with different methodologies other than the one discussed above in paragraphs “A” and “B”. The Design Contractor may propose a different methodology, as appropriate, to suit the project specifics and to meet the equipment manufacturer needs and recommendations.

6.5 Contract Documents

6.5.1 General Requirements

The Design Contractor shall develop contract documents that promote commonality of hardware, the use of proven and established hardware and software products, and the use of current technology that is compatible with hardware and software products.

Industrial grade instrumentation and control devices shall be specified. Design shall emphasize safety, process control, reliability, maintainability and economics. The Design Contractor shall use and specify the Water Authority documents referenced in Section 6.1.1, as applicable.

Contract documents shall follow the standards outlined in Chapter 14 (Technical Specifications, Drawings and Calculations) of the Design Contractor Guide (ESD-160; Volume One), and shall reflect industry standard practices that promote consistency, clarity, and informative illustrations.

6.5.2 Piping and Instrumentation Diagrams

Piping and Instrumentation Diagrams (P&IDs) shall show (refer to the EI-GD - see Attachment 6-3 - for an example):

- Field instruments, equipment and devices including their control panels.
- Major piping including diameter.
- All output signal and input signals.
- PLC and its sub-components.
- Communication devices and cabinets.
- Monitoring and control capability at the ECC.

Loop numbering, and tagging and naming conventions for facilities, equipment, instruments, and other devices shall follow the standards and guidelines outlined in the following Water Authority documents:

- EI-GD (refer to Attachment 6-3).
- PLC Implementation Standards (refer to Attachment 6-4).

6.5.3 Other Documents

In addition to P&IDs, the Design Contractor shall also prepare the following documents for a complete Instrumentation and Control (I&C) design:

A. Input and Output Summary Lists

The Design Contractor shall compile lists of all input/output (I/O) points required for the I&C system. Several lists, one for each type of I/O, shall be prepared for each PLC. The number and type of I/O lists are a function of the project specifics. The following are examples of I/O lists:

- Digital Input (DI) to the PLC – Input from an equipment/instrument or from a digital device-level network (e.g., Foundation Fieldbus) representing a real digital input (e.g., on/off equipment status, alarms, etc.).
- Digitized Digital Input (DDI) to the PLC – Input from a digital device-level network (e.g., Foundation Fieldbus) representing a digitized analog input (e.g., pressure reading, valve position reading, valve open limit switch).
- Analog Input (AI) to the PLC – Input directly from an equipment/instrument representing an analog input (e.g., pressure reading, valve position reading, valve open limit switch, current, voltage).
- Digital Output (DO) from the PLC – Output initiated from the local HMI station or the remote ECC to the PLC, or directly from the PLC as a result of programmed logic. Examples of DOs include signals for turning equipment on and off, and signals to open and close valves.
- Analog Output (AO) from the PLC – Output initiated from the local HMI station or the remote ECC to the PLC, or directly from the PLC as a result of programmed logic. Examples of AOs include specifying rate of flow for a flowrate controller, and specifying the valve open position.

The I/O lists shall be tabulated and include a "Remarks" column to present clarifications as needed (e.g., future point requirement). Each I/O summary list shall be organized by PLC name/number and shall include the following information:

- Tag number of I/O point.
- Loop number of I/O point.
- Register number.
- Process description of I/O point.
- P&ID drawing number on which the I/O point is included.
- I/O type (DI, DDI, AI, DO, or AO).
- Associated control panel number (PLC).
- Total number of I/O points

B. Equipment and Instrument Summary Tables

The Design Contractor shall compile separate tables for each type of equipment and all instruments required for the project. Instruments that are provided by the Construction Contractor, as part of a packaged system from a single manufacturer, may not be included in the summary tables. The information in the summary tables shall include the following:

- Type (e.g., flowmeter, pressure gauge, etc.).
- Tag name and loop number.
- Specification section number.
- Applicable installation detail.
- Associated panel name/number.
- Associated I/O list.
- P&ID drawing number.
- Installation detail drawing number.
- Process description.
- Instrument range and calibrated span.
- Instrument setpoints, trip points, etc.
- A remarks column indicating items such as NEMA enclosure rating, if used, specific material requirements, and all other data needed to precisely define the instrument requirements
- Tally for each type of equipment or instrument; a number index that starts from one (1) and increases sequentially

C. List of Alarms

Out-of-range or abnormal conditions shall be annunciated by alarms. The Design Contractor shall prepare a list of all alarm conditions with priorities according to alarm severity. Five priority classes are generally used. Refer to the Water Authority HMI Standards for more information. See Attachment 6-7 for the cover page of these Standards. The Design Contractor shall also develop a list of alarms that require an autodialer for immediate reporting to third parties. Close coordination with the Water Authority Operations and Maintenance Department is required for determination of need of autodialers.

D. Equipment and Instrument Specifications

The Design Contractor shall prepare equipment and instrument specifications for each type of field and panel-mounted piece of equipment or instrument. The Design Contractor shall coordinate the specifications with applicable sections of the Water Authority Standard Specifications.

The Design Contractor shall require the Construction Contractor to prepare and submit a data sheet conforming to ISA S20 for each piece of equipment used.

E. Control Strategies

The Design Contractor shall develop the control strategies (control descriptions) for each control loop. Control descriptions shall include:

- A list all applicable inputs and outputs.
- A general description of the control strategy.
- Description of the type of controller (feedforward, feedback, cascade, etc.) and the controller parameters (i.e., PID).
- Description of the control sequence, including safety interlocks and control resets.
- Description of how each element in the control loop functions.
- Description of monitoring, alarm, interlock, and control functions for both local and remote control.
- Description, in detail, of the sequence of operations required to start or stop a device under normal and abnormal conditions.
- Quantification of all process trip points, set points and timers.
- Description of what happens under abnormal conditions such as an I&C system failure, transmitter failure, abnormal process values, and loss of communication between PLCs.
- Description of shutdown sequence under normal, equipment malfunction and emergency shutdown modes.

Control strategies shall be annotated using the instrument and equipment tag numbers shown on the P&IDs and reference the relevant P&ID drawing.

F. Block Diagrams

The Design Contractor shall provide the necessary communication block diagrams showing all components for communication between the ECC, facility PLCs, and device-level network(s). The block diagrams shall:

- Indicate conductor types (fiber optic, coaxial, etc.).
- Include items such as fiber optic modems, wiring interface cabinets (WIC), patch panels, switches, routers, etc.
- Indicate the physical location of every communication component shown on the diagrams.
- Include any HMI equipment such as workstations.

The Design Contractor shall also provide block diagrams for any digital device-level network (e.g., Foundation Fieldbus), if used, showing the location of the network components such as wiring cabinets, etc.

G. Control Panels and Cabinets (Enclosures)

The Design Contractor shall provide layout drawings for major enclosures such as control panels, consoles, and cabinets, all of which house electrical and instrumentation components and devices. Panels and consoles shall be differentiated from cabinets in that they will have externally mounted control switches, indicator lights, digital readouts or displays. Components and devices within these enclosures shall be shown with their physical locations. The Water Authority standard rating for enclosures is NEMA-12; however, the standard rating requirement may be modified subject to the environment in which it is installed. Refer to the EI-GD (see Attachment 6-3) and "Cabinets and Consoles" specification section of the GC&SS (see Attachment 6-1) for additional information.

H. Electrical and Instrumentation Drawings and Wiring Diagrams

The Design Contractor shall prepare electrical and instrumentation drawings showing each field instrument with electrical connections from the power source to the instrument. Particular care shall be taken to ensure that adequate space is reserved for instrument panels and cabinets. The Design Contractor shall also show electrical signal cables and raceways on the electrical drawings. Prepare conduit and wiring schedules per the Water Authority Drafting Manual (ESD-120). See Attachment 6-8 for the cover page of the Water Authority Drafting Manual.

The Design Contractor shall develop wiring diagrams for the control system network and device-level network (e.g., Foundation Fieldbus), if used. Refer to the EI-GD (see Attachment 6-3) for additional information.

I. Training Requirements

The Design Contractor shall specify training requirements in the Contract Documents. Control systems related training is to be performed before the Site Acceptance Testing starts (refer to Section 6.6.2). Training is always conducted twice to allow for adequate coverage of normal activities. Technical training is to be conducted using the equipment that is identical to the installed equipment (the spares may be used for this purpose). A syllabus of the training and a description of the equipment to be used in the training shall be submitted 30 days before the training starts. Some of the training requirements are included in the following documents:

- Design Contractor Guide (ESD-160; Volume One): Section 16.2.3-4 of Chapter 16 (O&M Manuals, and Lifecycle Cost Analysis and O&M Impact Reports).
- Design Contractor Guide (ESD-160; Volume One): Section 20.4 of Chapter 20 (Startup and Commissioning, Closeout and Warranty).

- The following specification sections in the GC&SS (see Attachment 6-1):
    - Programmable Logic Controller.
    - Programming Software for Programmable Logic Controller.
    - General Instrumentation System Requirements.

J. Construction Contractor's Requirements

In addition to installation, testing, debugging, startup, and commissioning of the I&C system, the Design Contractor shall specify in the contract documents the following requirements to be followed by the Construction Contractor:

- Attend regular I&C system meetings to discuss, resolve, and assign responsibilities for all I&C system issues. These meetings shall be separate from the regular construction progress meetings. The frequency of these meetings is determined based on project-specific needs.
- Fully coordinate with the Design Contractor, and/or the I&C system integrator, during testing and startup of the control system.
- Be responsible for preparing loop diagrams and equipment/instrument calibration sheets. Refer to the "General Instrumentation System Requirements" specification section in the GC&SS (see Attachment 6-1) for more information on instrument calibration requirements.
- Coordinate with the Water Authority Operations and Maintenance Department while making communication connections to the Water Authority network.
- Drawings and diagrams submitted by the Construction Contractor as part of the O&M Manual shall be according to the ISO standards for presentation (ISO TC 46/SC9), and shall reflect final field conditions.

6.6 Testing and Acceptance

6.6.1 General

The Design Contractor shall follow the requirements outlined below for testing, startup, and commissioning of the instrumentation and control system. The Design Contractor shall refer to Chapters 19 (Construction Phase), and 20 (Startup and Commissioning, Closeout and Warranty) of the Design Contractor Guide (ESD-160; Volume One) for additional requirements.

6.6.2 Factory Acceptance Testing (FAT)

The project specification prepared by the Design Contractor shall require factory acceptance testing (FAT) of the project I&C system. The FAT greatly reduces the difficulty of debugging during field testing. The difficulty and expense of fixing anything onsite is much greater than at the factory. Also, the schedule pressure to get the control system in operation intensifies after the equipment and instruments have been delivered, often resulting in poor startup practices.

The FAT shall:

- Be conducted prior to shipping any element of the control system to the site.
- Demonstrate the complete functionality of the control system including proper operation, sequencing, logic and diagnostics.
- Be conducted jointly by the Design Contractor and the I&C subcontractor (i.e., control-system supplier) to the Construction Contractor.

A. Operational Test Procedures

The Design Contractor shall prepare the I&C system preliminary FAT plan, covering all requirements and logistics. The preliminary FAT plan shall include written descriptions of how individual tests shall be performed. The preliminary FAT plan shall be submitted by the Design Contractor with design submittals at the mid-point and final design levels. Refer to Chapter 4, Design Development, of the Design Contractor Guide (ESD-160; Volume One) for more information. The Design Contractor shall specify in the Contract Documents that the preliminary FAT plan be finalized by the control-system supplier and submitted for review and approval.

The control-system FAT shall include:

- Major control panels and cabinets.
- Devices within panels and cabinets including terminal blocks, power supply, I/O modules, communication devices, etc.
- PLC I/O points, including all control sequences, along with

their respective HMI status. If logistically possible, equipment shall be included during the I/O testing. If this is not possible, simulation logic shall be written to provide responses to the actual control logic, or simulators shall be programmed to respond as the equipment would.

- Panel and cabinet wiring shall be checked for continuity and for compliance with wiring diagrams.
- Networks including communication with at least one of each type of field devices.
- Digitally communicating devices (e.g., Foundation Fieldbus) shall be installed, wired, and tested for the network type.

The FAT shall be conducted at the control-system supplier facilities and witnessed by the Construction Manager and the Water Authority. The control-system supplier shall supply all control-system PLCs, panels, instruments and devices. The control-system supplier shall be responsible for setting all the panels, PLCs, instruments, etc. at their testing facility. The control-system supplier shall be responsible for coordinating with other device manufacturers for proper communication over digital device-level networks (e.g., Foundation-Fieldbus), if used.

The Design Contractor shall be responsible for:

- Developing the programs for the PLC(s).
- Uploading the programs into the PLC(s) at the control-system supplier facility.
- Ensuring that the elements of the FAT are conducted per the FAT submittal.

B. FAT Report

The project specification prepared by the Design Contractor shall require the control- system supplier to submit a FAT report. The project specification shall list the following minimum information to be included in the FAT report:

- Methodology used to carry out the FAT and whether it is in conformance with the specification FAT plan.
- Items that have been tested and whether they are physically present or a simulator is used.
- Record of the results of all tests.
- Problems/Issues that came up as a result of the FAT.
- Proposed methodology for rework / retest to correct all errors discovered during the FAT and the rework schedule.

The Design Contractor shall prepare a FAT report using the one submitted by the control-system supplier as a base. The Design Contractor shall attest to the information included in the control-system supplier's FAT report and shall highlight deviations from the FAT plan. The Design Contractor shall recommend to the Construction Manager whether approval be granted for shipping the control-system components from the location of testing to the project site.

6.6.3 Site Acceptance Testing (SAT)

A. Operational Test Procedures

The project specifications prepared by the Design Contractor shall specify requirements for site acceptance testing (SAT). These requirements shall include a schedule of operational tests, to be witnessed by the Construction Manager and the Water Authority O&M Department, that demonstrate the proper operation of the control system. Following installation of the I&C system, the control-system supplier shall be required to demonstrate the proper operation of all components of the I&C system including equipment, instruments and devices. The testing shall be conducted jointly by the control-system supplier and the Design Contractor.

B. Equipment and Instrument Certificates

The project specifications shall require the Construction Contractor to submit written certifications that all equipment are installed, tested, and are operating according to the manufacturer's recommendations. In most cases, these certifications are written by the Construction Contractor's subcontractors and suppliers. Certifications shall be provided for the following equipment:

- Flow meters.
- Valves.
- Pressure gauges and switches.
- Other equipment, instruments, and appurtenances as required.

C. Facility Testing

All testing requirements outlined above in Section 6.6.1, FAT, shall be repeated for the project site testing. In addition, the following shall also be tested:

- All analog inputs and outputs shall have their calibration checked by injecting current or voltage at a minimum of four values spanning the range of the analog signal.
- Monitoring and control of devices via device-level digital network (e.g., Foundation-Fieldbus) shall be tested.
- System testing including automatic control modes (operational scenarios) and interlocks.

D. Startup and Commissioning Report

The control-system supplier shall prepare and submit a Startup and Commissioning Report that includes:

- Test procedure(s).
- Summaries of recorded I/Os.
- List of all instruments used in the testing.
- Revised settings of various equipment and instrumentation, if any.
- Revised performance data of equipment as obtained during the startup testing.
- Failures and corrective actions.

The Design Contractor shall prepare a SAT report using the Startup and Commissioning Report submitted by the control-system supplier as a base. The Design Contractor shall attest to the information included in the control-system supplier's SAT report and shall highlight deviations from the SAT requirements. The Design Contractor shall recommend to the Construction Manager whether acceptance of the control system shall be granted.

Attachment 6-1: Cover Page of the Water Authority General Conditions and Standard Specifications

General Conditions and Standard Specifications

2005 Edition

John A. Economides
Director of Engineering

San Diego County Water Authority

Attachment 6-2: Cover Page of the Water Authority Standard Drawings & Standard Details

STANDARD DRAWINGS
& STANDARD DETAILS

San Diego County
Water Authority

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

OCTOBER 2003 ISSUE

Attachment 6-3: Cover Page of the Water Authority Electrical/Instrumentation Guide Drawings

ELECTRICAL/INSTRUMENTATION GUIDE DRAWINGS

San Diego County Water Authority

JUNE 2006 ISSUE

JOHN A. ECONOMIDES
DIRECTOR OF ENGINEERING

USE OF GUIDE DRAWINGS

THESE DRAWINGS ARE INTENDED TO BE USED AS A STANDARDIZATION G
FOR THE PREPARATION OF ELECTRICAL AND INSTRUMENTATION DRAWINGS
AUTHORITY FLOW CONTROL FACILITY PROJECTS. MODIFICATIONS TO THES
DRAWINGS MAY BE MADE TO CONFORM TO SPECIFIC PROJECT REQUIREM
ALL OR A PORTION OF THESE GUIDE DRAWINGS MAY BE INCORPORATED
THE PROJECT CONTRACT DOCUMENTS.

Attachment 6-4: Cover Page of the Water Authority PLC Implementation Standards

San Diego County
Water Authority

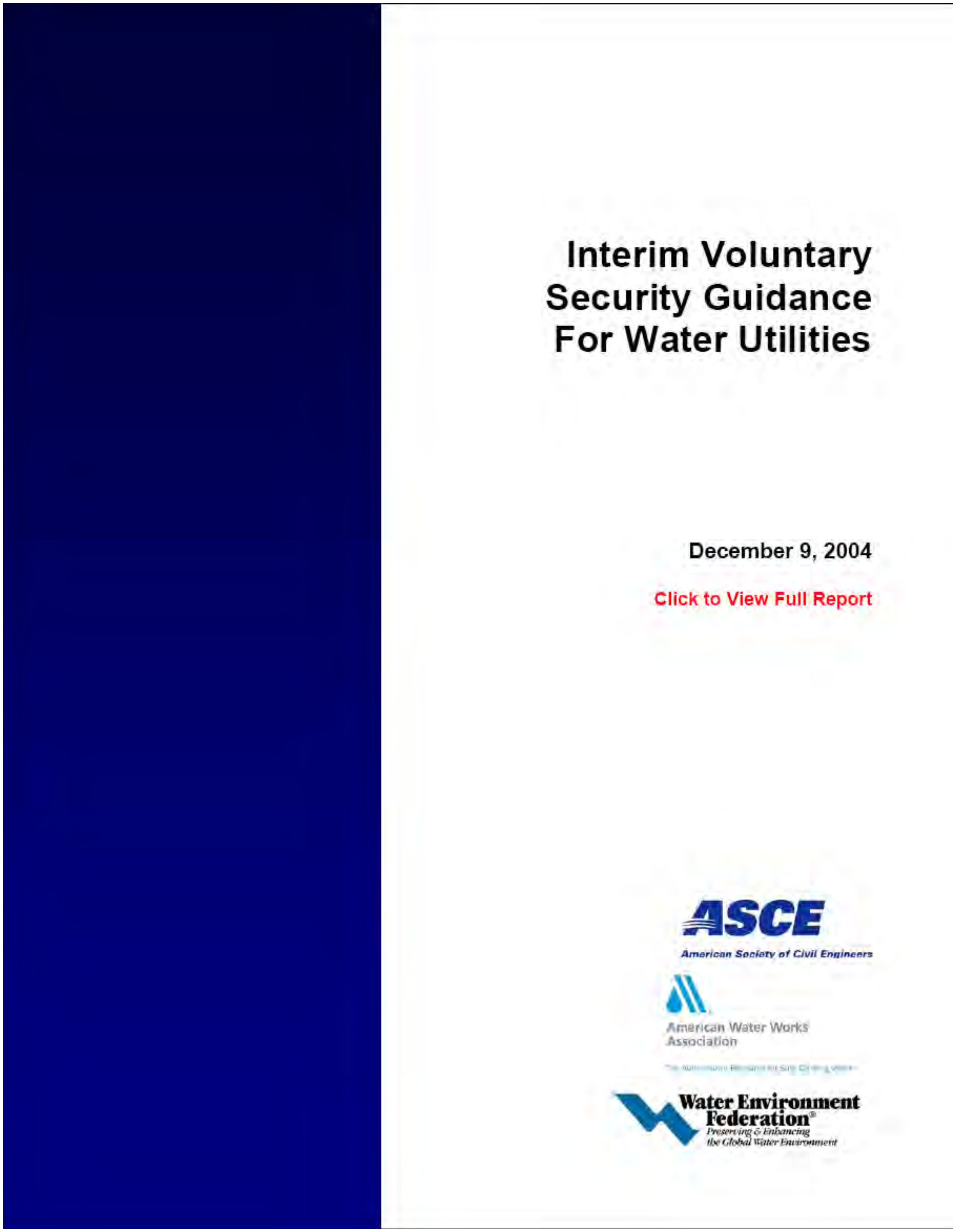
SDCWA

PLC IMPLEMENTATION STANDARDS

Version 2
(Released 03-14-05)

TMV Systems Engineering, Inc.

Attachment 6-5: Cover Page of the ASCE/AWWA/WEF Interim Security Guidance for Water Utilities



Interim Voluntary Security Guidance For Water Utilities

December 9, 2004

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ASCE
American Society of Civil Engineers

American Water Works Association

Water Environment Federation®
Preserving & Enhancing the Global Water Environment

Attachment 6-6: Cover Page of the ASCE/AWWA/WEF Guidelines for Physical Security of Water Utilities

ASCE/AWWA Draft American National Standard for Trial Use

Guidelines for the Physical Security of Water Utilities

December 2006

ASCE
American Society of Civil Engineers

American Water Works Association

Water Environment Federation®
Preserving & Enhancing the Global Water Environment

Publication of this draft standard for trial use and comment has been approved by the American Society of Civil Engineers and the American Water Works Association. Distribution of this draft standard for comment shall continue for no longer than six months from the date of publication. It is expected that following this public comment period, this draft standard, revised as necessary, will be submitted to the American National Standards Institute for approval as an American National Standard. A public review in accordance with established ANSI procedures is required at the end of the trial use period and before a draft standard for trial use may be submitted to ANSI for approval as an American National Standard. This draft standard is not an American National Standard. Comments should be directed to:

ASCE	AWWA
1801 Alexander Bell Drive	6666 W. Quincy Avenue
Reston, VA 20191	Denver, CO 80235
Attn: Standards Department	Attn: Standards Department
Or email: wise@asce.org	Or email: standards@awwa.org

Attachment 6-7: Cover Page of the Water Authority Human Machine Interface Standards

San Diego County Water Authority

SDCWA

Human Machine Interface (HMI) STANDARDS

Version 1
(Released 10-22-04)

TMV Systems Engineering, Inc.

Attachment 6-8: Cover Page of the Water Authority Drafting Manual (ESD-120)

SDCWA
San Diego County Water Authority
Engineering Department

Drafting Manual

ESD-120 ***March 2004***

APPENDIX A

of the

FACILITY DESIGN GUIDE

Supplemental Seismic Design Criteria for Water Facilities

NOTE: Appendix A is provided as supplemental information only. Any use of the information contained herein does not absolve the Design Contractor of its responsibility for the design as engineer of record.

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Appendix A

Supplemental Seismic Design Criteria for Water Facilities

A.1 General

A.1.1 Appendix A is provided as supplemental information only. Any use of the information contained herein does not absolve the Design Contractor of its responsibility for the design as engineer of record.

A.2 Site Criteria

The facilities are located in an area where the level of seismicity ranges from moderate to high. The hazards associated with such potential seismic activity include:

- Fault rupture at site traversed by active faults;
- Ground motions generated by earthquakes occurring on nearby or distant faults;
- Instability of slopes at or near the site;
- Liquefaction, in saturated cohesionless soil strata underlying the site of a facility, that may lead to loss of bearing for shallow foundations, lateral support of deep foundations, settlements, lateral spreads and/or lateral flows, and buoyancy effects;
- Loss of strength in cohesive soil strata underlying a facility that may lead to comparable consequences.

Some of these hazards need to be identified and evaluated on an area or system-wide basis and some require site-specific investigations. Evaluation of fault activities and the potential for fault rupture across a facility and estimation of earthquake ground motions generated for a generic site condition (e.g., rock outcrop) need to be performed on an area or system-wide basis. The other hazards, including estimating earthquake ground motions to account for a local site condition, instability of slopes, liquefaction of saturated cohesionless soils, or loss of strength of cohesive soils require site-specific investigations.

These hazard evaluations must include geologic, seismologic, and geotechnical studies.

A.2.1 Geologic Studies

Regional and site geologic studies may be required. These hazard evaluations should include identification of faults and other geologic features that may affect project facilities. Both distant and nearby faults should be identified for the purpose of assessing the potential of each fault for generating earthquake ground motions. The following parameters should be identified for each fault:

- Fault location and geometry (length, strike, dip etc.);
- Style of faulting (strike slip, thrust, normal);
- Relative degree of activity (average slip rate);
- Historical earthquakes that can be ascribed to the fault;
- Maximum earthquake;
- Recurrence relationship.

The following additional parameters should be ascertained for faults that may traverse a project facility

- Sense of displacement;
- Historic fault displacements along the fault, including maximum, minimum and average;
- Estimated fault displacement at the project facility.
- Uncertainties should also be provided for each parameter.

A.2.2 Seismologic Studies

Seismologic studies may be needed to assess the seismicity of the region and to establish earthquake events that will be used in the analyses, evaluation, and design of the project facilities. These studies should cover historic seismicity, including recurrence relationships for the region and for each source identified in the geologic studies. The information gathered should be sufficient to conduct both a deterministic and probabilistic evaluation of earthquake ground motions for a generic site condition (e.g., rock outcrop).

Estimation of earthquake ground motions at rock outcrops using either deterministic or probabilistic evaluations should follow accepted practice (refer to Paragraph A.2.4.2). These motions should be described in terms of target response spectra. Representative time histories should also be used in conjunction with these spectra. The spectra as well as the time histories should account for forward directivity and for fling considering the relative position of the project facilities with respect to the location of the potential seismic sources.

A.2.3 Geotechnical Studies

The following site-specific information may be required at each project facility.

- Subsurface conditions (including stratigraphy, water level) at a select number of locations at the site
- Topographic variations at the site, especially presence of slopes within or adjacent to the site
- Engineering characteristics of the various soil strata.

A California-licensed geotechnical engineer determines whether previous investigations and field work performed for the site are sufficient. If not, a field investigation or laboratory testing program, or both, may be required. The extent of geotechnical studies should be detailed for facilities that are classified per Facility Design Guide, Chapter 5, Table 5-2, as SPC 2 or 3, or PFC 3 or 4.

These data, together with the results of the geologic and seismological studies, should be used for appropriate evaluations. The following are examples of typical evaluations:

- Modification of target spectra determined in the seismological studies to account for local site effects–such modifications may be accommodated with appropriate empirical or numerical procedures.
- The potential for liquefaction, in saturated cohesionless soil strata underlying the site of a facility.
- Consequences of liquefaction that may lead to loss of bearing for shallow foundations, loss of lateral support of deep foundations, settlements, lateral spreads, and/or lateral flows, and buoyancy effects. Remediation to mitigate such consequences, as appropriate.
- Loss of strength in cohesive soil strata underlying the site of a facility that may lead to consequences comparable to those caused by liquefaction. Remediation to mitigate such consequences, as appropriate.
- Landslides that may be initiated in slopes at or near the site of the project facility.
- Seismic lateral pressures on retaining walls, basement walls and other belowground structures.
- For long linear systems such as pipelines, the effects of traveling waves and ground deformation should be considered.

Investigations, laboratory testing, and engineering evaluations should be conducted and supervised by qualified personnel, conform to established standards, and use established standards and procedures as described in the references included below and elsewhere.

- Tokimatsu, K. and H. B. Seed, 1987, “Evaluation of Settlement in Sands Due to Earthquake Shaking,” Journal of Geotechnical Engineering, Vol. 113, No. 8.
- O’Rourke, T.D., “An Overview of Geotechnical and Lifeline Earthquake Engineering.” Geotechnical Special Publication No. 75, ASCE, Reston, VA, Proceedings of Geotechnical Earthquake Engineering and Soil Dynamics Conference, Seattle, WA, Aug. 1998, Vol. 2, pp.1392-1426.
- Bird, J., O’Rourke, T.D., Bracegirdle, A., Bommer, J. and Tromans, I., “A Framework for Assessing Earthquake Hazards for Major Pipelines.” Proceedings of the International Conference on Terrain and Geohazards Facing Onshore Oil and Gas Pipelines, London, UK, June, 2004.
- ASCE (1984) “Guidelines for the Seismic Design of Oil and Gas Pipeline Systems”, Committee on Gas and Liquid Fuel Lifelines, Technical Council on Lifeline Earthquake Engineering, ASCE, Reston, VA.

- O'Rourke, T. D., Wang, Y., and Shi, P. (2004). "Advances in Lifeline Earthquake Engineering." *Proceedings of 13th World Conference on Earthquake Engineering,* Vancouver, British Columbia, Canada, Aug., 2004, Paper No. 5003.
- O'Rourke, M.J. and X. Liu, 1998, "Response of Buried Pipelines subject to Earthquake effects," Monograph Number 3, MCEER.
- ALA 2005, Seismic Guidelines for Water Pipelines, American Lifelines Alliance, March 2002.
- Seed, M. B. and R. V. Whitman, 1970, "Design of Earth Retention Structures for Dynamic Loads," ASCE Journal of Soil Mechanics and Foundations Division, June 1970.
- Ostadan and White, 1987, "Lateral Seismic Soil Pressure—an Updated Approach," U.S.-Japan Workshop on SSI Analysis, U.S. Geological Survey, Menlo Park, California, 1987.
- Ebeling et al., 1992, "The Seismic Design of Waterfront Retaining Structures," Department of the Army, Waterway Experiment Station, U.S. Army Corps of Engineers, technical report ITL-92-11.
- Ishihara, K., and Yoshimine, M., 1992, "Evaluation of settlements in sand deposits following liquefaction during earthquakes," Soils and Foundations*, Japanese Geotechnical Society,* Tokyo, Vol. 32, No. 1, pp. 173–188.
- Bray, J. D., Sancio, R. B., Riemer, M. F., and Durgunoglu, T., 2004a. "Liquefaction susceptibility of fine-grained soils." 11th Int. Conf. on Soil Dynamics and Earthquake Engineering and 3rd Int. Conf. on Earthquake Geotechnical Engineering, D. Doolin et al., eds., Stallion Press, pp. 655-662.
- Idriss, I. M. and Boulanger, R. W. (2004). "Semi-empirical procedures for evaluating liquefaction potential during earthquakes." Proc., 11th Int. Conference on Soil Dynamics and Earthquake Engineering, and 3rd Int. Conference on Earthquake Geotechnical Engineering, D. Doolin et al., eds., Stallion Press, Vol. 1, 32-56.
- Kulhawy, F. H., and Mayne, P. W., 1990. Manual on estimating soil properties for foundation design. Report EPRI EL-6800, Electric Power Research Institute, Palo Alto, California.
- Boulanger, R. W., and Idriss, I. M., 2004. "Evaluating the potential for liquefaction or cyclic failure of silts and clays." Report No. UCD/CGM-04/01, Center for Geotechnical Modeling, Dept. of Civil & Envir. Engrg., Univ. of California, Davis, 129 pp. http://cee.engr.ucdavis.edu/faculty/boulanger/PDFs/2004/Boulanger_Idriss_CGM04-01_2004.pdf.
- Makdisi, F. I., and Seed, H. B., 1978. "Simplified procedure for estimating dam and embankment earthquake-induced deformations." Journal of Geotechnical Engineering Division, ASCE, 104(GT7), 849-867.
- Seed, R. B., Cetin, K. O., Moss, R. E. S., Kammerer, A., Wu, J., Pestana, J., Riemer, M., Sancio, R. B., Bray, J. D., Kayen, R. E., and Faris, A., 2003. "Recent advances in soil liquefaction engineering: A unified and consistent framework." Keynote presentation, 26th Annual ASCE Los Angeles Geotechnical Spring Seminar, Long Beach, California.

A.2.4 Ground Shaking

A.2.4.1 Ground Motion Parameters

The parameters required to characterize the seismic loads for engineering analysis or design of a structure will depend on the method used to analyze the structure. For purposes of engineering design, the effects of ground shaking on facilities and components at a site are typically characterized by elastic acceleration response spectra. These spectra provide acceleration response as a function of period or frequency of a single-degree-of-freedom system attached to the ground, for a certain damping level. Unless it can be justified otherwise, 5% damping should be used in both designs and evaluations, except for reservoirs and tanks. For reservoirs and tanks, design spectra for 2% damping and 0.5% damping should be used for the impulsive and convective modes of response, respectively. When required, acceleration time histories should be developed to be compatible with the spectra prescribed herein. For above ground structures with first mode period of 1 second or longer, as well as the first sloshing mode for tanks and reservoirs, and located within 10 km of an active fault, the ground motions should account for fling effects. The following reference includes a model for fling:

- Abrahamson, N. A. (2002), Velocity pulses in near-fault ground motions, Proceedings, UC Berkeley-CUREE Symposium in Honor of Ray Clough and Jspeh Penzien, May 9-11, 2002, Berkeley, CA, p 40-41.

A.2.4.2 Deterministic and Probabilistic Estimates of Ground Motions

Estimates of ground motions for a given earthquake scenario are often called deterministic. The process to make such estimates generally consists of the following steps:

- Define the magnitude for the selected earthquake scenario and the closest distance from the corresponding source to the site.
- Using attenuation relationships appropriate for the source mechanism, tectonic environment, and site soil conditions, calculate response spectral values at a selected percentile level (e.g., 84th percentile level) for several structural periods over the range of engineering interest. Incorporate directivity effects for long period (T over 0.5 seconds) motion.
- Construct the spectrum from the calculated spectral values.

Probabilistic analysis is used to estimate earthquake ground motions associated with a selected probability level, say a probability of exceedance over the life of the structure. Such analysis is commonly referred to as probabilistic seismic hazard analysis (PSHA). For example, a PSHA can be used to estimate acceleration response spectral values with a 2%, 5% or 10% probability of exceedance in 50 years at a site. These are equivalent to 2,475 year, 975 year and 475 year return periods.

The probability that any earthquake will occur on a given source and will produce ground motions exceeding a selected ground motion parameter value, say a selected spectral acceleration, is equal to the product of several probabilities. They are:

- The probability that the earthquake (as defined by its magnitude) will occur on the given source (e.g., active fault),
- The conditional probability of the dimension of the rupture (length and width) given the magnitude of the earthquake,
- The conditional probability of the location of the rupture on the source, resulting in the closest distance from the site, and
- The conditional probability that the ground motions will exceed the selected acceleration (or other parameter) given the earthquake occurs at the given distance from the site within a given directivity parameter.

Because ground motions exceeding a selected acceleration at a site can be produced by various earthquakes, the overall probability of exceeding the acceleration is obtained by aggregating the probabilities that the acceleration will be exceeded by the ground motions from all possible earthquakes.

The following scenario earthquakes on active faults may be used to bound the worst case performance of the system as a whole:

- Rose Canyon M 7.1, with rupture extending from the northern San Diego County southwards to include the extension of the Silver Strand fault.
- Elsinore M 7.4 with rupture extending from southern Riverside County southeastwards.
- San Andreas M 7.9 with rupture extending from northern Los Angeles County southeastwards through Riverside County. While this scenario earthquake will not likely produce the highest ground motions within the service area, it can produce high ground motions and potential damage to the MWD system including the Colorado River Aqueduct and the California Aqueduct; damage to the MWD system can impact the performance of the system.

A.2.4.3 Design Ground Motions

The design ground motions (response spectrum and time history) requirements prescribed herein should be considered minimum requirements. Additional requirements may apply, depending on the agencies having jurisdiction in the geographical area of the facilities, or on the type of the facilities (e.g., dams).

For the assessment of seismic geohazards and the design of system facilities other than buildings, tanks, and equipment anchorage, ground motions should be determined by probabilistic procedures.

Design ground motions with 10% probabilities of exceedance in 50 years (475-year approximate return period) should be used for facilities in SPCs 1, 2 and 3. In lieu of using the 475 year earthquake motions directly, the design ground motions may be taken as 2/3 of the 2,475 year (2% in 50 year) motions, but in no case less than the 475 year motion. The design ground motion need not exceed a deterministic limit taken as the 84th-percentile level spectrum for the scenario earthquakes listed in Section A.2.4.2.

Design spectra for facilities in SPCs 1 and 2 may be constructed from the spectral acceleration values presented in the latest edition of national seismic hazard maps published by the USGS and available on the Internet at the following url: http://geohazards.cr.usgs.gov/eq/, or may be obtained from site-specific studies, if available. Facility Design Guide, Chapter 5, Figure 5-1, shows the 2% in 50 year horizontal rock PGA motion. If constructed from the USGS maps, the spectra should be adjusted for the soil or rock conditions at the site using either the site class factors prescribed for the maps in the following references or site specific response studies, if available.

- Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E.V., Dickman, N., Hanson, S., and Hopper, M., 1996, National seismic-hazard maps; documentation: U.S. Geological Survey Open-File Report 96-532, 110 p.
- Frankel, A., Peterson, M., Mueller, C., Haller, K., Wheeler, R., Leyendecker, E., Wesson, R., Harmsen, S., Cramer, C., Perkins, D., and Rukstales, K., 2002, Documentation for the 2002 update of the national seismic hazard maps: U.S. Geological Survey Open-File Report 02-420, 33 pp.

Design spectra for facilities in SPC 3 should be obtained from a site-specific study. Such study should account for the regional seismicity and geology, the expected recurrence and maximum magnitudes of earthquakes, the location of the site with respect to known seismic sources, the site subsurface conditions, and near-source effects.

Design motions (generally ground velocities) for pipelines should be taken as the 475 year, 975 year or 2,475 year motions for PFC 2, 3 or 4, respectively, as adjusted to reflect rock, firm soil or soft soil conditions along the alignment of the pipeline. Design velocities for pipelines may be constructed using suitable acceleration-to-velocity relationships from the one-second spectral acceleration values presented in the latest edition of national seismic hazard maps published by the USGS and available on the Internet at the following url: http://geohazards.cr.usgs.gov/eq/, or may be obtained from site-specific studies, if available.

Vertical response spectra should be determined in a manner consistent with that for horizontal response spectra. Simplified procedures such as vertical motion throughout the frequency range equal to 2/3 of the horizontal PGA should not be used. In lieu of site-specific calculations, for sites within 5 km of active faults, the vertical response spectra may equal or exceed the horizontal spectra at high frequencies (over 2 hertz), may be assumed to be 50% of the horizontal spectra at frequencies under 0.5 hertz, and may be linearly interpolated at intermediate frequencies.

A.2.4.4 Selection of Fault Displacement Parameters

When a facility must be placed across a primary active fault, it should be designed with the recognition that surface faulting or folding may occur. Surface rupture characteristics to be considered include the amount and direction of primary fault displacement, as well as the amount, type, and distribution of secondary deformation associated with the surface fault rupture.

A.2.4.5 Liquefaction

Liquefaction is a phenomenon in which loose, saturated, granular soils (silts, sands, and gravels) lose a substantial amount of strength when subjected to intense ground shaking. In the simplest terms, when these soils are strongly shaken they tend to compact and densify. If the soils are saturated, the tendency for densification increases the pore water pressure, softening the soil as a result. Liquefaction can create a quick condition in which the strength and bearing capacity of the soils is temporarily reduced. Also, if the generated pore water pressures become large enough, material can be ejected from the ground in characteristic geysers of soil-laden water.

Liquefaction of a site can be highly damaging to aboveground as well as underground structures and utilities. Liquefaction can impose significant demands on structures located at liquefiable sites and on the foundations that support them. These demands result from the vertical and lateral movement of the soil both during and after liquefaction.

Potential consequences of liquefaction include bearing capacity failure, flotation of lightweight embedded structures, landsliding (lateral spreads and flow slides), and differential settlement. Among these consequences, large permanent ground deformations due to lateral spreads or flow slides are generally considered to be the most significant potential hazards. Structures supported on pile foundations can be more resistant to liquefaction damage than structures supported on shallow foundations, although buried utilities entering such pile-supported structures may be particularly vulnerable unless suitably designed. It is possible to reduce the liquefaction potential at a site by a number of means, including replacement or densification of liquefaction-susceptible soils, drainage (pore water dissipation), or artificially lowering the groundwater table.

Comprehensive soil liquefaction susceptibility mapping has not been completed throughout the San Diego County area. In order to design or evaluate pipelines with PFC 2, 3, or 4, it is necessary to establish the liquefaction hazard along the alignment. It is therefore a requirement of this standard that site-specific studies be performed to better characterize the potential for liquefaction (or other types of soil failure) along the alignment for newly construction pipelines with PFC 2, 3, or 4. Attention is drawn to any site with a water table within 50 feet of grade where loose sandy soils exist.

The potential for liquefaction at a site of a facility should be addressed on a project-specific basis by a California-licensed geotechnical engineer. The following paragraphs provide general guidance on the approach to follow for these types of evaluations.

The first step in a liquefaction hazard evaluation should be the determination of liquefaction susceptibility. It has long been recognized that loose, clean, sandy soils (i.e., sands with few fines) are potentially susceptible to seismically induced liquefaction. Coarse, gravelly soils are also susceptible to excess pore water pressure generation and can potentially liquefy if drainage is impeded by bounding layers of less permeable material, finer-grained soils within the voids of the gravelly soil, or large distances to potential drainage boundaries. Low-plasticity fines, particularly non-plastic silts and silty sands, can also be susceptible to liquefaction.

A preliminary assessment of the presence of liquefaction-susceptible soils at a site may be made by reviewing geologic maps published by the CGS for the state. CGS geologic maps are available online from the Internet at the following address: http://earthquake.usgs.gov/ regional/scamp/. The following lists the currently available maps (provided on a CD) for various quadrangle sheets in San Diego and nearby Riverside Counties:

- Bonsall (Fig 5-3)
- El Cajon (Fig 5-2)
- Escondido (Fig 5-3)
- Fallbrook (Fig 5-3)
- Jamul Mountains (Fig 5-2)
- Las Pulgas (Fig 5-3)
- Margarita Peak (Fig 5-3)
- Morro Hill (Fig 5-3)
- Otay Mesa (Fig 5-2)
- Pala (Fig 5-3)
- Pechanga (Fig 5-3)
- San Clemente (Fig 5-3)
- San Onofre (Fig 5-3)
- San Vicente Reservoir (Fig 5-2)
- San Diego (Downtown City, La Jolla,)
- Temecula (Fig 5-3)
- Vail Lake (Fig 5-3)
- Valley Center (Fig 5-3)

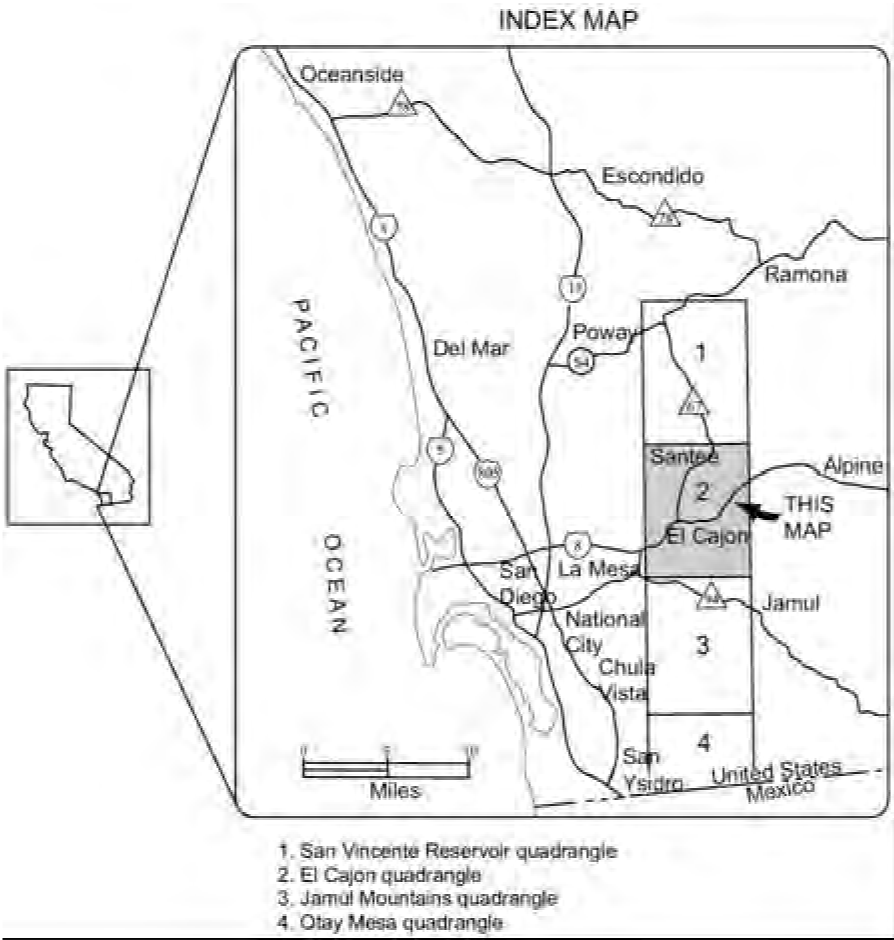

Figure A-1: Available Geologic Maps, Southern San Diego County

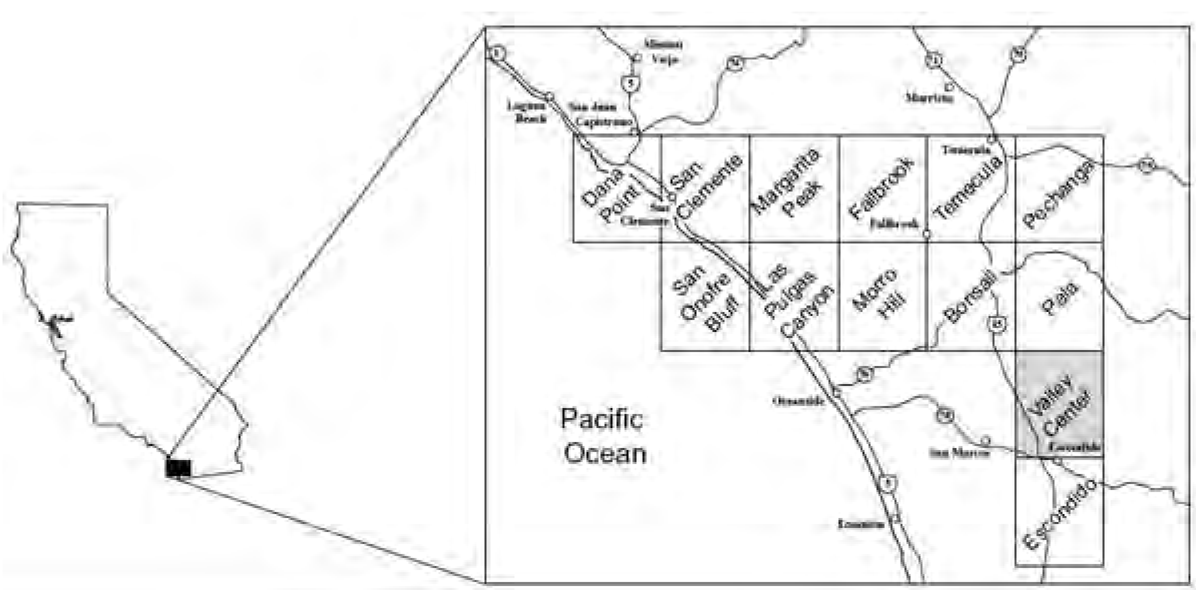

Figure A-2: Available Geologic Maps, North and Eastern San Diego County

The preliminary assessment should be followed by a more detailed assessment based on site-specific information and the liquefaction screening procedure given in the following reference:

- Youd, T.L., 1998. Screening Guide for Rapid Assessment of Liquefaction Hazard at Highway Bridge Sites, Multidisciplinary Center for Earthquake Engineering Research Technical Report MCEER-98-0005, 58 pp.

The susceptibility of fine-grained soils to exhibiting liquefaction-like behavior should be examined using the procedures described in the following references:

- Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A., Wu, J., Pestana, J., Riemer, M., Sancio, R.B., Bray, J.D., Kayen, R.E. and Faris, A., 2003, "Recent advances in soil liquefaction engineering: a unified and consistent framework," Report No. EERC 2003-06, Earthquake Engineering Research Center, University of California, Berkeley, June.
- Boulanger, R.W. and Idriss, I.M. 2004. "Evaluating the potential for liquefaction or cyclic failure of silts and clays," Center for Geotechnical Modeling, Report No. UCD/CGM-04/01, University of California, Davis, December.

Once a soil deposit has been determined to include liquefaction-susceptible soils, the potential for triggering of liquefaction must be evaluated. Such an evaluation involves comparison of the loading imposed on the soil by earthquake shaking with the liquefaction resistance of the soil.

Two basic approaches are generally available to evaluate the liquefaction resistance of soils: (1) empirical correlations between the results of in situ testing and field performance during past earthquakes, and (2) laboratory testing of representative samples. The first is now the most commonly used approach and is recommended. However, for special projects, laboratory testing may be an appropriate supplement to in situ testing for evaluation of the liquefaction susceptibility and resistance of certain fine-grained soils.

The in situ tests most commonly used to evaluate the liquefaction resistance of soils are: (1) the standard penetration test (SPT), (2) the cone penetration test (CPT), (3) the Becker-Hammer Penetration Test (BPT), and (4) measurements of shear wave velocity, Vs.

The SPT is viewed as offering the greatest reliability for estimating liquefaction resistance at present, provided it is applicable to the site soil conditions. The soil conditions for which the SPT resistance is deemed a reliable indicator of liquefaction resistance correspond to cohesionless sandy and silty soils with limited amounts of gravel-sized particles. For highly stratified soil conditions the CPT is a good supplement to the SPT to identify potential problem soils. The BPT should be used to supplement the SPT in evaluating the liquefaction resistance of deposits of gravelly soils. In general, the BPT is required for a reliable assessment of the liquefaction resistance of soils with more than about 20% gravel. The choice of in situ test for a project should be made on a project-specific basis depending on the applicability of each method to the site conditions.

Of the currently available correlations, the correlations in the following two references incorporate the most extensive database of field performance case histories and the most rigorous analysis of the data.

- Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A., Wu, J., Pestana, J., Riemer, M., Sancio, R.B., Bray, J.D., Kayen, R.E. and Faris, A. 2003 "Recent advances in soil liquefaction engineering: a unified and consistent framework," Report No. EERC 2003-06, Earthquake Engineering Research Center, University of California, Berkeley, June.
- Idriss, I.M. and Boulanger, R.W. 2004. "Semi-empirical procedures for evaluating liquefaction potential during earthquakes," Proceedings of 11th International Conference on Soil Dynamics and Earthquake Engineering and 3rd International Conference on Earthquake Geotechnical Engineering, Berkeley, California.
- Youd, T.L. et al., 2001. Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, New York, NY, Vol.127, No.10, Oct., 817-833.

Accordingly, it is recommended that these be used as the primary correlations for estimating liquefaction resistance based on the SPT. The selection of correlations for the CPT and BPT should be made on a project-specific basis. Additional guidance on the selection of those correlations is provided in the above-mentioned references.

A.2.6 Lateral Spreads and Slope Movements

Lateral spreads and slumping are ground-failure phenomena that can occur on sloping ground. If the site has a significant slope, or is adjacent to an open cut (e.g., depressed stream or road bed), liquefaction and soil failure can cause the flow of materials down slope or towards the cut. The effect of lateral spreading on adjacent structures should be considered. The empirical procedure presented in the following references should be used to estimate lateral spreading displacements. The uncertainty inherent in these displacement estimates should be considered.

- Youd, T.L., Hansen, C.M. & Bartlett, S.F., 1999. Revised MLR equations for predicting lateral spread displacement. ASCE Journal of Geotechnical and Geoenvironmental Engineering, 128 (12), 1007-1017.
- Bardet, J.P, N. Mace, T. Tobita, and J. Hu, 2002, "Regional Modeling of Liquefaction-induced Ground Deformation" *Earthquake Spectra*, EERI, Vol. 18, pp. 19-46.

Flow slides can occur in embankments or slopes when the residual strength of liquefied soil within the embankment/slope or its foundation drops below the shear stress required to maintain static equilibrium. The potential for flow slide instability should be evaluated using conventional limit-equilibrium stability analysis procedures. In such analyses, the residual strength should be assigned to any soil layer in which liquefaction is expected.

Even in the absence of flow slides, all embankments and slopes may experience movement during strong shaking. Such movements may cause gross deformation of an embankment or slope or impart additional loads on buried pipelines and other facilities and components embedded in an embankment or in the vicinity of a slope. Simplified procedures such as those given in the following reference may be used to estimate slope movements.

- Makdisi and Seed, 1977, "A Simplified Method for Estimating Earthquake-Induced Deformation in Dams and Embankments," Report No. UCB/EERC-77/19, College of Engineering, University of California, Berkeley, August 1977.

The above method may also be used for estimating slope movement when limited loss of soil shear strength is expected. For such cases, appropriate shear strength reduction should be used in the evaluation.

A.2.7 Landslides

Landslides occur when the combination of gravitational and ground shaking-induced inertial forces temporarily exceeds the strength of the earth materials in the slope. Landslides are often triggered by strong ground shaking, particularly in areas close to the causative fault. Any site on or adjacent to a steep slope or bluff should be considered susceptible to landslide damage. The concern is that a facility may lie within a landslide zone, below a slope whose failure may send debris into the facility, or above an unstable slope whose movement could undermine key facilities.

Landslides commonly are complex features that may consist of both rotational and translational movements in their upper parts, sometimes transforming to debris flows in their lower parts. Water generally plays an important role in landslides by oversteepening of slopes through surface erosion, by increasing pore water pressures, and/or by adding weight to a soil mass when it is saturated. Other factors that influence landslides are: (1) pre-existing slope movements; (2) strength of the rock/soil material; (3) slope angle; and (4) the orientation and density of rock structures, such as bedding, joint, and fault planes. Earthquake ground shaking can reduce the stability of a slope and cause sliding or falling of the soil or rock materials composing the slope.

The potential for landslides at hillside sites, or sites adjacent to steep slopes, bluffs, and/or cuts, should be addressed by a California-licensed geotechnical engineer or engineering geologist. A typical landslide investigation could include review of available references (maps, reports); air photo interpretation; site reconnaissance; subsurface exploration, e.g., test pits, test borings, seismic profiling; laboratory testing; and engineering analysis.

If necessary, recommendations for mitigating the effects of potential landslides should be provided. This could include earthwork activities, e.g., slope flattening, buttress fills; structural solutions, e.g., retaining walls, tiebacks; or drainage measures (surface and subsurface) as well as re-siting of the existing or proposed facility, if possible.

A.2.8 Settlements

Because liquefaction involves the generation of excess pore water pressure, some settlement of the ground surface should be expected as those pore water pressures dissipate following liquefaction. Settlements may also occur in loose to medium-dense, unsaturated cohesionless soils above the groundwater table. The amount of settlement is related to the density of the soils and the level of cyclic strain induced in the soil by earthquake shaking.

Differential settlement can damage structures. Differential settlement may be expected when different soil types vary in thickness and extent over a site. Buried pipes at locations where they enter vaults have the potential hazard of differential settlement.

Settlements caused by seismic motions in granular soil deposits and in saturated loose granular deposits may be estimated following the procedures in:

- Tokimatsu, K. and H. B. Seed, 1987, “Evaluation of Settlement in Sands Due to Earthquake Shaking,” Journal of Geotechnical Engineering, Vol. 113, No. 8.
- Ishihara, K., and Yoshimine, M. (1992) "Evaluation of settlements in sand deposits following liquefaction during earthquakes," Soils and Foundations*, Japanese Geotechnical Society,* Tokyo, Vol. 32, No. 1, pp. 173–188.

The above procedures account for the denseness of the soil and the level of shaking induced at different depths. These procedures should be used with care in highly stratified deposits where its accuracy is not as well established, partly due to potential settlement of non-liquefied layers trapped between liquefied layers as described in the following reference.

- Martin, G.R., Tsai, C.F., and Arulmoli, K., 1991. “A Practical Assessment of Liquefaction Effects and Remediation Needs,” Proceedings, Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Missouri.

A.2.9 Wave Propagation Hazards

For long linear systems such as pipelines, the effects of traveling waves and ground deformation should be considered in the design and evaluation. Traveling waves have detrimental and accumulative effects on long extended structures such as pipelines. The following references provide guidance on determining wave propagation effects on pipelines:

- O’Rourke, T.D., “An Overview of Geotechnical and Lifeline Earthquake Engineering.” Geotechnical Special Publication No. 75, ASCE, Reston, VA, Proceedings of Geotechnical Earthquake Engineering and Soil Dynamics Conference, Seattle, WA, Aug. 1998, Vol. 2, pp.1392-1426.
- O’Rourke, T. D., Wang, Y., and Shi, P. (2004). “Advances in Lifeline Earthquake Engineering.” *Proceedings of 13th World Conference on Earthquake Engineering,* Vancouver, British Columbia, Canada, Aug., 2004, Paper No. 5003.
- Wang, Y., T.D. O’Rourke, and P. Shi, “Seismic Wave Effects on the Longitudinal Forces and Pullout of Underground Lifelines”, Proceedings, 8th National Conference on Earthquake Engineering, San Francisco, CA, Apr. 2006, EERI, Oakland, CA,
- O’Rourke, M.J., and X. Liu, 1998, “Response of Buried Pipelines subject to Earthquake effects,” Monograph Number 3, MCEER.
- ALA 2005, Seismic Guidelines for Water Pipelines, American Lifelines Alliance, March 2002.

A.2.10 Seismic Soil Pressure on Structures and Retaining Walls

In the design of structures and retaining walls, appropriate static and seismic soil pressure increments should be considered. Seismic incremental pressures depend on the yielding condition of the retaining structure. The following references provide guidance in determining the soil pressures on structures and retaining walls:

- Seed, M. B. and R. V. Whitman, 1970, “Design of Earth Retention Structures for Dynamic Loads,” ASCE Journal of Soil Mechanics and Foundations Division, June 1970.

- Ostadan and White, 1987, "Lateral Seismic Soil Pressure—an Updated Approach," U.S.-Japan Workshop on SSI Analysis, U.S. Geological Survey, Menlo Park, California, 1987.
- Ebeling et al., 1992, "The Seismic Design of Waterfront Retaining Structures," Department of the Army, Waterway Experiment Station, U.S. Army Corps of Engineers, technical report ITL-92-11.
- Nadim, F. and Whitman, R. V., 1981, "Seismic analysis and design of retaining walls," Soil Dynamics and Earthquake Engineering, pp. 387-407.
- Whitman, R. V. (1990) "Seismic design and behavior of gravity retaining walls," Design & Performance of Earth Retaining Structures, ASCE, P.C. Lambe and L.A. Hansen eds., Ithaca, NY, pp. 817-842.

A.3 Buildings and Building-Like Structures

A.3.1 Applicability

This section is applicable to new buildings and building-like structures, including pipe bridges, except above ground storage tanks which are addressed in Section A.7. For general policy on the evaluation and retrofit of existing structures, see Section A.12.

For the purposes of this section, a building is defined as any enclosed or partially enclosed above grade structure that provides for shelter of persons or equipment, and that is occasionally occupied. A building-like structure is any unenclosed above grade structure that has one of the lateral-force-resisting systems defined in Table 12.2-1 of ASCE 7-02.

A.3.2 Design Basis of New Buildings

The design of all elements of buildings, including structural elements of the lateral-force-resisting system, structural elements not part of the lateral-force-resisting system, and non-structural elements should as a minimum comply with all applicable sections of the 2006 IBC, except as modified herein.

A.3.2.1 Classification of Buildings

Seismic Use Groups for new buildings are defined in Section 1616.2 of IBC 2006. A Seismic Use Group of 1, 2, and 3 should be assigned to facilities with SPC 1, 2, and 3, respectively.

A.3.2.2 Importance Factors

Importance factors for SPC 1, 2, and 3 are equal to 1.0, 1.25, and 1.5, respectively. The Importance Factor (I) for non-structural elements should be 1.5 for facilities with SPC 2 and 3, and 1.0 for Class 1 facilities.

A.3.3 Special Detailing Requirements

In addition to the applicable detailing requirements of the 2006 IBC, the following should apply.

A.3.3.1 Timber Structures

1. Design of timber structures should be in accordance with IBC 2006, Chapter 23, except as modified herein. The provisions of the IBC 2006 Section 2308 – Conventional Light-Frame Construction, should not be used to satisfy the requirements for a lateral-force-resisting system.
2. The following construction should not be used as elements of the lateral-force-resisting systems for new buildings or new components of existing buildings, but may be used at 50% of code value as existing archaic materials (Note – if seismic upgrade is performed, archaic materials may continue to be used at 50% of code value):
    - Diagonally or straight sheathed timber diaphragms or shear walls
    - Gypsum board diaphragms or shear walls
    - Shear walls constructed of metal studs with diagonal strap braces
    - Braced shear panels consisting of let-in braces
    - Oriented Strand Board (OSB) should not be used in applications subject to high moisture conditions or if it will be exposed to inclement weather during construction

3. Wood diaphragms should be provided with continuous chord elements at the perimeter of the diaphragm. Where chords change direction (e.g., T or L shaped structures) and for wall anchorage of concrete and masonry structures, local collector elements should develop the resulting secondary forces into the main diaphragm or into a sub-diaphragm, meeting the required span/depth requirements, which spans between continuous collectors in the main diaphragm.

4. Wood diaphragms and shear walls should be provided with local chords around all penetrations exceeding 2 feet in dimension. Chords should be designed to develop the secondary forces due to flexure in the diaphragm. They should extend a minimum of 2 feet beyond the edge of the opening of each direction. A recommended procedure can be found in Diekmann (1989).

5. Requirements for panel field and edge nailing, nailing to chords, collectors, splices in members, and similar connections should be clearly called out on the design drawings (see IBC 2006 Chapter 23).

6. Joists and rafters framing horizontal diaphragms should be solidly blocked where bearing on shear walls or other vertical elements of the lateral-force-resisting system. Shear transfer between timber diaphragms and vertical elements of the lateral-force-resisting system should not be accomplished with toe nails (use framing angles or other means not relying on toe nails).

7. Diaphragms should be provided with continuous seismic force collectors, capable of resisting both tension and compression at all shear walls or other vertical elements of the lateral-force-resisting system.

8. Shear walls, whenever practical, should be continuous from the roof to the foundation. Shear walls at an upper story of a structure should not terminate on wood framing, unless that framing is designed for Ω times the required seismic forces (ASCE 7-05, Table 12.2-1).

9. Tensile ties between wood framing elements of diaphragms and shear walls should be designed considering all eccentricities inherent in the connection and resulting from such eccentricities. In particular, posts containing hold down devices should be designed for both bending and direct stresses considering eccentricities and reduction of section due to bolts or let-ins. Nailing of plywood sheathing should be detailed to prevent tearing loose of the corner adjacent to the hold down device.

10. All connections of wood framing incorporating bolted connections with metal side plates should provide for shrinkage and contraction of the wood elements, perpendicular to the wood grain. Malleable iron or cut plate washers should be provided on all bolt heads and nuts bearing against wood members.

A.3.3.2 Reinforced Masonry Structures

1. All masonry structures should be of reinforced construction. No unreinforced concrete masonry unit walls should be used for any portion of any project

2. Determination of masonry strength should be in accordance with IBC requirements and empirical design of masonry should not be used. All hollow unit masonry should be grouted solid. Running bond or stack bond construction is acceptable.

3. All solid unit masonry should be multi-wythe running bond construction with fully grouted reinforced cores present between wythes. Wythes of masonry should be fully bonded to the reinforced cores using wire-type joint reinforcement or other similar mechanical attachment.

4. Special inspection, per 2006 IBC, Section 1701,should be specified for all reinforced masonry construction. Special inspection should include verification of source and strength of masonry units, proportioning and mixing of mortar and grout, placement of reinforcement and embedded items, clean out of grout spaces prior to grouting, and grouting procedures.

A.3.3.3 Reinforced Concrete Structures

1. All concrete construction should be reinforced. Plain, unreinforced concrete should not be used.

2. Critical anchorage to concrete structures for seismic force resistance should be accomplished by cast-in-place anchors wherever practical. Cast-in-place anchors should be designed in

accordance with the strength design provisions of IBC 2006 Section 1913. The use of drilled-in anchors, either adhesive or mechanical type, should include design values published in an ICC-ES evaluation report. Drilled-in anchors should be subject to special inspection, and 25% of all installed anchors should be field tension tested to 160% of their published allowable capacities.

3. Anchor design, whenever practical, should be controlled by yielding of the steel anchor as opposed to shear failure of the concrete (i.e., “ductile” design). Ductile design precludes brittle failure and, at the same time, limits the damage to the supported equipment. If ductile design is not feasible, anchors should be designed to have a strength equal to system overstrength factor Ω (ASCE 7-05, Table 12.2-1) times the calculated seismic forces (with load factors of unity).

4. Precast concrete elements should not be used as continuous diaphragms or shear walls unless shear transfer between adjacent units is accomplished through the embedment of dowels from adjacent units in a common cast-in-place joining strip. Precast concrete elements may be used as individual, independent above grade shear walls, when designed for the overturning and shear demands on each panel.

5. Mechanical couplers used to splice reinforcing bars should be of uniaxial design and should be certified capable of transferring 125% of the nominal strength of the coupled bars.

6. Reinforcing bar to be welded should conform to American Society for Testing and Materials (ASTM) Standard A-706, “Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement”. Stud welded bars should conform to ASTM Standard A-496, “Specification for Steel Wire, Deformed, for Concrete Reinforcement.”

7. Prestressed concrete elements should be provided with mild steel reinforcement to resist stresses resulting from seismic forces (including vertical) unless pretensioning is designed to resist Ώ (ASCE 7-05, Table 12.2-1) times the calculated seismic forces.

A.3.3.4 Steel Structures

1. Design of steel structures should conform to the applicable requirements of 2006 IBC, Chapter 22, except as modified herein.

2. All moment resisting frames should be detailed in conformance with special moment frame requirements of ANSI/AISC 341-05 and FEMA 350 (2000).

3. Hollow sections (tubes and pipes) used as diagonal braces with thinner walls than that required by IBC 2006 may be utilized if the section is completely filled with cementitious material with unit weight ≥ 110 pcf. The effect of the cementitious fill on section properties (area, section modulus, moment of inertia, radius of gyration) should otherwise be neglected.

A.3.4 Foundations

Soil-foundation-interaction effects for massive structures should be considered in the evaluation of foundations. A California-licensed geotechnical engineer should provide information regarding liquefaction and other geotechnical hazards and appropriate mitigation measures as discussed in Section A.2.

Pile foundations should be designed to resist vertical and lateral loads within the acceptable displacement limits. Consideration should be given to negative skin friction and group effects where applicable. Negative skin friction is caused by soil settlement adjacent to the pile shaft. The settlement may be due to loading on the soil around the piles or dissipation of excess pore water pressure subsequent to liquefaction.

A.3.5 Inspection Criteria

All buildings, building components and equipment necessary for the post-earthquake function of the facility should be inspected during construction to assure that the construction meets the intent of the design. Inspection of the completed facility should also be performed to assure that possible seismic interactions between nearby components will not affect functionality of the facility.

A.3.6 References

- ACI 1999, “Building Code Requirements for Structural Concrete,” American Concrete Institute, ACI 318
- AISC 1989, “Allowable Stress Design (ASD),” Ninth edition, American Institute of Steel Construction, Chicago, IL.

- AISC 1993 "Load and Resistance Factor Design (LRFD)," Second edition, American Institute of Steel Construction, Chicago, IL.
- AISC 2005 "Seismic Provisions for Structural Steel Buildings," American Institute of Steel Construction, Chicago, IL.
- AISC 2005 "Steel Construction Manual," Thirteenth Edition, American Institute of Steel Construction, Chicago, IL.
- ASCE 2002, "Seismic Evaluation of Existing Buildings," American Society of Civil Engineers, ASCE31-02, New York, N.Y.
- Diekmann, E.F., "Diaphragms and Shear Walls," Chapter 8 from Wood Engineering and Construction Handbook, 2nd Edition, Keith F. Flaherty and Thomas G. Williamson, editors, McGraw-Hill.
- FEMA 2000, "Recommended Seismic Criteria for New Steel Moment-Frame Buildings," Federal Emergency Management Agency, FEMA 350, July 2000.
- FEMA 2000b, "Prestandard and Commentary for the Seismic Rehabilitation of Buildings," Federal Emergency Management Agency, FEMA 356, November 2000.
- International Building Code, IBC 2006, by the International Code Council, Inc. (ICC).
- FEMA 450, "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures," FEMA 450, Federal Emergency Management Agency, 2003. Building Seismic Safety Council.

A.4 Underground and Aboveground Piping

Facility Design Guide, Chapter 5, Table 5-3, provides a description of the characteristics of pipelines associated with each Seismic Performance Class (SPC) described under Section 1.5 and Facility Design Guide, Chapter 5, Table 5-1. Also shown in Facility Design Guide, Chapter 5, Table 5-3, is the equivalence between SPC and Pipe Function Class (PFC) as provided in the Seismic Guidelines for Water Pipelines prepared under the auspices of the American Lifelines Alliance (ALA, 2005). The ALA Guidelines may be used as a reference document for design and Facility Design Guide, Chapter 5, Table 5-3, facilitates use of the ALA Guidelines in this context. Reference to the ALA Guidelines in Appendix A is intended to provide information that supplements the information available to and experience of the designer, and does not relieve the designer from his/her own judgment, experience, and use of alternate design approaches.

Guidance regarding the principal sources and types of transient and permanent ground movements affecting pipeline systems has been provided by ASCE (1984), O'Rourke (1998), and Bird, et al (2004). Seismic hazards are grouped into transient and permanent ground deformation (TGD and PGD, respectively). For lifeline systems, TGD includes the strong motion characteristics needed for structural and secondary system response of buildings and aboveground facilities. It also includes factors that influence geographically distributed networks, such as site response, near source and forward directivity effects of fault rupture, sedimentary basin and valley effects, ridge shattering, and ground oscillation triggered by soil liquefaction. The main sources of PGD include surface faulting, landslides, and soil liquefaction (O'Rourke, et al, 2004). It has long been realized that the most serious damage to underground lifelines during an earthquake is caused by PGD or at transition locations where pipes enter structures or bridges. A distinguishing feature of designing buried pipelines for earthquakes is the emphasis that must be placed on PGD.

Failure Mechanisms

Underground pipeline systems have been damaged in past earthquakes. Failure of pipeline 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. Liquefaction-induced lateral spreading and flow failure, as well as landslides, are among the most damaging types of ground failure. Large deformation of the ground from these effects imposes deformation on underground pipelines. Failures at points of weakness are common, including joints, tees, air valves, hydrant laterals and similar fittings, as well as at connections to structures.

Fault ruptures. Underground pipelines that cross zones of fault rupture are subject to extensive damage. Pipelines crossing fault rupture zones can be affected by abrupt shear, bending and longitudinal tension or compression.

Differential settlement of soils, particularly adjacent to firm soils or structures founded on deep foundations. Essentially, embedded pipelines 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 pipelines frequently experience damage at connections to tanks, buildings, basins, and similar facilities. This damage results from earthquake-induced differential movement of the structure 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 and/or ductility are provided in the connection.

Response to ground shaking. A pipeline embedded in the ground during an earthquake is subjected to shearing, bending, compressive, and tensile forces associated with the waves transmitted by the ground. These forces can occasionally lead to failure of weak, corroded or brittle pipeline components, or pipeline joints vulnerable to pullout and/or compression.

Unrestrained joints. Bell and spigot joints with rubber gasketed, unwelded joints are common in certain classes of ductile iron pipe, steel pipe, prestressed concrete cylinder pipe (PCCP), and other types of pipe in the system. In areas of ground failure, complete pullout and detachment and of these joints can occur.

General Design Guidelines

Selection of Pipe Classification. Each pipeline requiring design consideration is classified as either SPC 1, 2, or 3.

- Pipelines not classified as SPC 1, 2, or 3 are equivalent to PFC 1 pipelines and need not be designed for seismic provisions. All system pipelines are SPC-classified pipelines.
- SPC 1 pipelines are normal and ordinary distribution pipelines, generally but not exclusively 6 to 10 in. in diameter. The purpose of such pipelines is for local distribution of water to housing tracts and commercial users. Aqueducts are not SPC 1 or PFC 2 pipelines.
- SPC 2 pipelines are critical pipelines serving a large number of member agencies that present significant economic impact to the community or a substantial hazard to human life and property in the event of failure. Some non-aqueduct pipelines, such as blowoff and flow control facility inlet pipelines, may be classified as SPC 2 (PFC 3) pipelines.
- SPC 3 pipelines are essential pipelines that are required for post-earthquake response and recovery and intended to remain functional and operational during and following a design earthquake. All aqueduct pipelines are classified as SPC 3 pipelines. Other types of pipelines may be classified as SPC 3 as well.

Selection of ground shaking. For buried pipelines, the effect of ground shaking should be evaluated by specifying the Peak Ground Velocity (PGV) along the length of the pipeline. The PGV should be set at the 475-year motion for SPC 1 pipelines, 975-year motion for SPC 2 pipelines, and the 2,475-year motion for SPC 3 pipelines.

Selection of 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 locations of landslides hazards should be based on site-specific information. In addition, the planning and design for all new major pipeline projects should include a geologic/geotechnical reconnaissance of the proposed routing.

Bypass pipelines. Bypass pipeline systems can be used to accommodate large PGDs, such as fault offset, as long as the time and resources involved to deploy such systems are considered satisfactory and accounted for as part of the post-earthquake emergency response.

High seismic hazard areas. Any distribution or transmission pipeline of SPC 1, 2, or 3 that traverses a zone of high to very high liquefaction potential, landslide potential (site specific), or fault offset at active faults, should be designed to accommodate the ground deformation. Generally, this means that push-on joint pipes (including Tyton and similar type joints) are not compliant with these criteria and should not be used for new construction.

Transmission Pipelines

The general approach for seismic design of transmission water pipelines is as follows:

- All transmission pipelines are classified as SPC3.
- Establish the SPC for the pipeline (SPC 1, 2, or 3). Reduce the SPC as appropriate to account for available redundancy of the water system. Only essential and non-redundant pipelines need be classified as SPC 3.
- Establish the PGV values for the pipeline (may vary spatially along the length of the pipeline) as either the 475, 975, or 2,475-year return period per Selection of Ground Shaking above.
- Using a combination of regional hazard maps, coupled with alignment-specific geotechnical hazard studies, identify the portions of the alignment subject to PGDs (whether from liquefaction, landslide, or active fault offset).
- Select the pipe material, lining, and coating systems in a manner that reflects cost, reliability, and seismic issues. In general, pipe joints should either be continuous (welded for steel, bolted for ductile iron, fusion-welded for HDPE, etc.) or “chained” (limited expansion with full stop capability). Segmented transmission pipelines (such as PCCP with push-on joints, ductile iron with push-on joints, etc.) are vulnerable to PGD and very high levels of PGV and are not usually acceptable for use in the transmission pipeline system.
- Restrained joints are often used with steel pipe. These may be single lap welds, double lap welds, or full butt welds. Single lap welds can accommodate modest amounts of settlement or lateral spread PGD. Double lap welds can provide more tensile capability than that of single lap welds, but will generally not provide significantly more compression capacity. Butt welds are preferred for active fault offset designs.
- When using thin-walled steel pipe (D/t ratios over 125), compression wrinkling of the pipe may be the failure mode in any area subject to PGD. Through active fault zones, use D/t ratios under 100. For pipes subject to significant compression due to PGD, the D/t ratio may be smaller (on the order of 50 to 75), depending on the materials, local conditions, and extent of PGD.
- For pipelines subject to PGD, the coating and lining systems must be chosen to accommodate the soil loading and strains in the pipe. Ideally, the lining system should not fail in a manner to cause downstream damage to pumps (such as cement lining) if the pipe is to sustain strains over 1%. The coating system should be chosen to limit soil-pipe friction as needed for the design; yet still be robust enough for corrosion protection and installation requirements.
- When designing a new pipeline that will parallel an existing pipeline, the new pipeline should be designed to accommodate failure of the old pipeline, in a rational and cost-effective manner. This should factor in the type of soil bedding (e.g., sandy, cohensionless soils are more prone to erosion than clayey soils) and the ability of the new pipeline to span moderate distances if undermining from failure of the existing should pipeline occur.
- Special purpose hardware, such as EBAA Flex-Tend flexible expansion joints, can provide about 12 in. of pipe movement when the pipe is located above ground. This type of hardware has not been engineered or qualified to take major fault offset for buried pipelines. Reliance on manufacturer-stated claims as to the capability of such hardware should not relieve the Design Contractor from verifying that the actual hardware will perform as intended in buried conditions, considering each part of the manufacturer-supplied assembly, the soil-pipe friction, and the worst combination of fault offset (angle, width of zone, knife edge or distributed) suitable for the specific crossing.
- If suitable emergency response capability exists, and depending on the importance of the transmission pipeline, a transmission pipeline may be allowed to break in an earthquake, as long as the goals of Appendix A are maintained. It may be possible with a portable aboveground hose, as well as suitable pipeline valves and manifolds, to restore water service in smaller communities (served population under 20,000 people or so) within a suitable amount of time after an earthquake,

excluding high fire risk zones. For communities in high fire risk zones, there should be available water (reliably available from either pipes/pumps or from local storage) to last for about 24 hours post-earthquake. Fire service is provided by local water distribution companies.

- Any transmission pipeline (whether new or existing) that traverses a zone with highly likely PGDs (either landslide, liquefaction or active fault offset) that is likely to break given the PGD, should be designed/retrofitted so that its failure does not grossly impact the ability to deliver fire flows to unaffected parts of the community in the same pressure zone. This is commonly achieved by installing suitable isolation valves on both sides of the PGD zone.

Earthquakes will introduce hydrodynamic loading in pipelines. ALA (2005) provides a simplified method to estimate the extent of this hydrodynamic loading. For transmission pipes with low hydrostatic pressures (much under 50 psi), with wall thicknesses and girth joints chosen to meet just the minimum hydrostatic internal pressure, the incremental hydrodynamic loading from earthquakes may be controlling and might lead to pulling apart of push on joints near pipe bends, or pin hole leaks in thin-walled pipe (especially if wall thickness has been reduced due to corrosion). All transmission pipelines should be designed with suitable capability at bends to withstand pullout of joints due to earthquake-induced hydrodynamic loads; this can normally be accomplished with suitable tension joints near bends for segmented pipe, or using suitable reaction blocks. For low-pressure pipelines (below 25 psi internal pressure), hydrostatic plus earthquake-induced hydrodynamic loads may control the selection of the wall thickness and girth joints of the pipe; for this load combination, the combined hoop stresses should be kept under yield, and the combined thrust loads at bends must not pull apart the joints.

Distribution Pipelines

In general, the system has no distribution pipelines. However, small diameter (under 12-inch) pipelines at facilities (water treatment plants, turnouts, blow offs) that are not exposed to PGDs or differential movements at soil-to-structure interfaces can be designed for seismic loading using methods suitable for distribution pipelines. For most distribution pipe installations, seismic design following the chart methods in ALA may be used. When following the ALA chart method, the following major steps should be followed:

- Establish the design level ground motion (PGV) for the pipeline. The recommended basis for design is a PGV with a 475-year-return-period per ALA.
- Establish the design level permanent ground deformation (PGD) for the pipeline. PGDs may occur due to liquefaction (settlement and/or lateral spread); landslide or surface fault offset.
- For distribution pipelines (PFC 2) with PGV≤30 inches per second, and not subject to PGD, no special seismic design is required, and the design should follow standard AWWA and other requirements.
- For distribution pipelines (PFC 2) with PGV>30 inches per second, and not subject to PGD, the design should follow standard AWWA and other requirements, but with extra valves (isolation valves at each branch at a pipe intersection, and no more than about 500 feet between valves or the distance needed to sectionalize the pipe to limit service disruptions).
- For PFC 2, 3, and IV pipelines with 0 < PGD ≤ 2 inches, and PGV ≤ 30 inches/second no special seismic design is required.

For PFC 2, 3, and IV pipelines with PGD > 2 inches, including those used for hydrant laterals, blow offs, air and vacuum release valves, service laterals and service connections, special seismic design is required. ALA 2005 provides these design provisions for seven types of pipe: ductile iron, PVC, welded steel, gasketed steel, concrete cylinder, HDPE, and copper pipe. Depending on the magnitude and orientation of the PGD and the classification of the pipe, different pipe designs are recommended in ALA 2002.

Fault Crossing Design Guidelines

For PFC 1 pipelines, fault rupture does not need to be considered. For PFC 2 pipelines, the fault rupture should have a return period of 475 years and for PFC 3 or IV pipelines, the fault rupture should have a return period of 975 years.

Empirical models such as Wells and Coppersmith (1994) can be used to compute the median value of the average displacement. If site-specific information is available on the amplitude of the fault rupture in past earthquakes, this can be used in place of the empirical models.

New installations of PFC 2, 3 or IV pipelines that traverse active faults should consider the following 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, and;
  - (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.
- The pipeline route should be configured, whenever practical, so as to cause net tension in the pipe given the fault offset. If a butt welded steel pipeline system is used, maximum strains should be no higher than 5% given the occurrence of a characteristic earthquake.
- Pipelines that are designed per (c) should include suitable in-line valves on both sides of the fault zone, spaced far enough apart so as not to significantly increase the chance of failure of the pipe due to fault offset. The in-line valves may be manually (could be done by remote actuation) 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 (PGA over 0.3g). Remote operation of any automatic actuation valve may be desirable. Any actuation system should be capable of operating without reliance on the standard electrical supply system for at least one full close-and-open cycle.
- Pipelines that are provided with design feature (c), but not (b), should include suitable sized bypass manifolds. The bypass manifolds should be sized to accommodate the maximum of (i) 1,000 gpm flow, (ii) the required fire flow, or (iii) the winter day demand for the area served by this pipeline. Suitable aboveground pipelines (flex hose or pipe) should be available to be installed within 8 hours following a major earthquake, to restore fire flows to the area, in conjunction with a suitable emergency response and recovery plan.
- The type of fault crossing design adopted for a new pipeline (a, b, or c) should recognize all of 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 design of the area considered should be governed by the pressure zone hydraulics and geotechnical hazards of the pipe system serving the area.

Small-diameter distribution pipelines (10-in.-diameter and less) need 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. In these cases, gate valves can be included on the distribution pipelines within 200 ft either side of the fault zone, with hydrants located just outside these gate valves.

Aboveground Piping, Conduit, Cable Trays, and HVAC Ducts

Newly installed piping, conduit, cable trays, and HVAC ducts should at a minimum, be provided with braces that satisfy SMACNA (Sheet Metal and Air Conditioning Contractors National Association) requirements for Seismic Hazard Level A (the highest hazard level) unless demonstrated capable of resisting the required seismic forces under other support conditions. Existing pipeline, conduit, cable trays, and HVAC ducts should be capable of reasonably surviving the design earthquake and adequately reliable to meet the Level of Service Goals.

- SMACNA 1998, “Seismic Restraint Manual Guidelines for Mechanical Systems,” Sheet Metal and Air Conditioning Contractors National Association, Inc., 1998.

Connection Level 1 (corresponds to approved research report values) should be used for structures of all importance levels. For pipes larger than those covered in the SMACNA document, design loads should be based on this Standard. In all cases, pipes should be checked for buckling at supports under seismic loading.

Plastic piping should be braced laterally at intervals not exceeding twice that recommended by the manufacturer for vertical support.

Piping crossing expansion joints between adjacent structures should be provided with expansion fittings, multiple bends, or other suitable provisions to ensure capacity to sustain expected differential movement between the structures.

Piping systems connected to tanks and vessels should consider the potential movement of the connection points during earthquakes and provide sufficient flexibility to avoid failure of the piping system.

Piping system and supports should be designed so as to not impart significant mechanical loading on the attachment to the tank or vessel shell. Local loads at piping connections should be considered in the design of the tank or vessel shell. Mechanical devices that add flexibility, such as bellows, expansion joints, and other flexible apparatus, may be used when they are designed for seismic loads and displacements.

Seismic effects that should be considered in the design of a piping system include the dynamic effects of the piping system, its contents, and when appropriate, its supports. The interaction between the piping system and the supporting structures, including other mechanical and electrical equipment, also should be considered.

Piping should be designed to minimize the impact into other pipes or components if such impact will likely damage the pipe or components in a manner so as to create a loss of functionality.

Special care should be taken to ensure that small branch lines off piping headers do not, by virtue of their attachment to structures or equipment, act as the brace for the header unless demonstrated by calculation to have suitable capacity for this service.

Existing piping should be capable of reasonably surviving the design earthquake without collapse. Addition of lateral braces for such commodities should only be necessary if the engineer verifies that such lateral braces will materially lower the pipe (conduit/duct/cable tray) stresses or forces to below the pipe's (conduit/duct /cable tray) capacity or otherwise increase the pipe's (conduit/duct/cable tray) reliability to be immediately functional post-earthquake.

Piping Passing Through or Below Bodies of Water

Piping passing through bodies of water (e.g., reservoirs, creeks, rivers, bays, etc.) should be evaluated for internal and external hydrodynamic effects and the effects of saturated soils with regard to interaction with piping systems. Consideration should be given to both the effort of support provided to piping and loading resisted by piping for such conditions.

Pipes that cross below bodies of water should also be checked for scour forces, as well as all other loads described elsewhere in Appendix A. If scour is possible, then the pipe should be suitably protected. If the soils at the crossing zone are subject to liquefaction, then these effects will be considered in the design of the pipe.

A.5 Soil Retaining Structures

Soil retaining structures, such as retaining walls and U-walls, should be designed for appropriate static and seismic soil pressure depending on the restraining conditions of the wall. For yielding walls, active soil pressure may be used for design. The incremental seismic load should be obtained by the Mononobe-Okabe method as modified in the following reference:

- Seed, M. B. and R. V. Whitman, 1970, "Design of Earth Retention Structures for Dynamic Loads," *ASCE Journal of Soil Mechanics and Foundations Division*, June 1970.

For gravity retaining walls, the methods described in the following reference may be used to determine the seismic soil pressures:

- Whitman, R. V. (1990) "Seismic design and behavior of gravity retaining walls," Design & Performance of Earth Retaining Structures, ASCE, P.C. Lambe and L.A. Hansen eds., Ithaca, NY, pp. 817-842.

For non-yielding walls, at-rest soil pressure should be considered for static loading. Seismic soil pressure may be obtained from methods used in ASCE 4-98 or the method given in the following reference:

- Ostadan, F., "Seismic Soil Pressure for Building Walls – an Updated Approach," Proceedings 11th International Conference on Soil Dynamics and Earthquake Engineering and 3rd International Conference on Earthquake Geotechnical Engineering, Berkeley, CA, pp. 68-73.

Where applicable, the effects of hydrodynamic loads should be considered in the design.

A complete discussion of various methods to evaluate seismic soil pressure and hydrodynamic loads is presented in the following:

- Ebeling et al., "The Seismic Design of Waterfront Retaining Structures," Department of the Army, Waterway Experiment Station, U.S. Army Corps of Engineers, technical report ITL-92-11.

A.6 Underground Structures

A.6.1 Bored and Cut and Cover Tunnels

A.6.1.1 Seismic Response

Seismic responses of aboveground structures are primarily force controlled. On the other hand, seismic responses of underground structures are controlled by ground deformation related to ground motions and/or fault rupture. In general, tunnels and cut and cover structures perform satisfactorily in response to strong ground shaking. Exceptions to this performance history have been observed for deep structures subject to significant amplification of ground motions over the height of the structure and/or unaccounted for additional ground loads resulting from soil liquefaction. Depending on the stiffness of the structure and the stiffness of the soil excavated to build the structure, deformation of the structure may be larger or smaller than the free-field ground deformation. For such structures, soil-structure interaction (SSI) analysis should be performed to obtain seismic response of the structure. Depending on the structure layout and dimensions, two- or three-dimensional SSI analysis can be performed. For tunnels and cut-and-cover structures, the techniques proposed in the following references may be used:

- Hashash, Y.M.A., J.J. Hook, B. Schmidt, and J.I.-C. Yao, Seismic design and analysis of underground structure. Tunneling and Underground Space Technology, 2001. 16: 247-293.
- Penzien, J. 2000, "Seismically Induced Racking of Tunnel Linings," *Earthquake Engineering and Structural Dynamics*, Vol. 29, 2000.
- Wang, Jaw-Nah, 1993, "Seismic Design of Tunnels—A Simple State-of-the-Art Design Approach," Monograph 7, Parsons Brinckerhoff Quade & Douglas, Inc., June 1993.

For cut-and-cover structures, a viable technique is provided in the following reference:

- Ostadan and Penzien, 2001, "Seismic Design of Cut-and-Cover Sections of the Bay Area Rapid Transit Extension to San Francisco, Airport," 2nd U.S.-Japan SSI Workshop on Soil-Structure Interaction, Tsukuba, Japan.

Such techniques permit development of an optimal design that would conform to the ground deformation without attracting large seismic loads, yet satisfying the performance level. Using the force method, such as using seismic soil pressure, may amount to a rigid design that would, in fact, attract larger seismic loads and amount to an inefficient design. Depending on the structure and its contents, fully dynamic soil-structure interaction or quasi-static structure interaction may be used. The generic racking curves provided in the above references may also be used if it can be shown that they are applicable to the structure under consideration.

A.6.1.2 Detailing Requirements

Detailing of embedded concrete structures should conform to that required by IBC 2006, Section 1907, and in Appendix A. All dowels across construction joints should be fully developed by embedment or mechanical anchorage on either side of the joint.

A.6.1.3 Fault Crossing Guidelines

If possible, new tunnels should be aligned so that they do not cross active or potentially active strands of faults having slip rates much in excess of 1 mm per year. When a tunnel must be placed across a primary active fault, it should be designed with the recognition that surface faulting or folding may occur. Surface rupture characteristics to be considered include the amount and direction of primary fault displacement, as well as the amount, type, and distribution of secondary deformation associated with the surface fault rupture.

A.6.1.4 Retrofit of Existing Tunnels

Existing tunnels should be investigated using procedures of A.6.1.1 and should include assessment of impacts due to fault crossings. Where fault crossings occur, analysis methods including effects or soil structure interaction and evaluation of performance at fault crossings is subject to independent peer review. Such peer review should as a minimum include both structural engineering and geotechnical engineering disciplines.

New construction for retrofit where fault crossings occur should be fully compliant with requirements for new construction.

A.6.2 Valve Vaults and Similar Structures

A.6.2.1 Firm Soil Sites

Past earthquakes have not caused extensive damage to building walls below grade. In some cases, however, it may be advisable to verify the adequacy of retaining walls to resist increased pressure due to seismic loading. These situations might be for walls of poor construction quality, unreinforced or lightly reinforced walls, walls of archaic materials, unusually tall or thin walls, damaged walls, or other conditions implying a sensitivity to increased loads.

The seismic earth pressure acting on a wall retaining non-saturated, level soil above the groundwater table may be approximated as:

$$\Delta p = 0.4 k_h I \gamma_s H_{rw} \qquad \text{[Equation 5-1]}$$

where $\Delta p =$ Additional earth pressure due to seismic shaking, which may be assumed to be a uniform pressure over the height of the wall.

$k_h =$ Horizontal seismic coefficient in the soil, which may be assumed to be equal to the site horizontal PGA.

I = I-Factor as suitable for this structure from Facility Design Guide, Chapter 5, Table 5-1.

γ_s = The total unit saturated weight of the soil

H_{rw} = The height of the wall that is retaining the soil

The seismic earth pressure given by Equation 5-1 should be added to the unfactored static earth pressure to obtain the total earth pressure on the wall. The expression in Equation 5-1 is a conservative approximation of the Seed and Whitman simplified formulation based on the Mononabe-Okabe solution (Seed and Whitman, 1970). The pressure on walls during earthquakes is a complex action. If walls do not have the apparent capacity to resist the pressures estimated from the above approximate procedures, or further detail for site specific conditions is warranted than provided by Equation 5-1, detailed investigation by a California-licensed geotechnical engineer is recommended.

In addition to designing walls of the structures for the increased pressures indicated above, the structure as a whole should be designed to resist sliding as a result of such pressures. Sliding may be resisted by a combination of friction beneath the base of the structure and by soil bearing against the opposite wall of the structure, if embedded. Such pressures may be assumed to have a triangular pressure distribution, with the resultant located at 1/3 the depth of the backfill above the base of the structure on the resisting side. If excessive movement that could functionally damage the structure is needed to mobilize the full passive resistance of soil bearing against the walls, then only a portion of the passive pressure resistance should be relied upon.

A.6.2.2 Soft Soil Sites and Liquefiable Sites

Important and standard structures (SPC 1 or 2) embedded in soils subject to liquefaction, or in unconfined silts, poorly consolidated clays or other soft materials, should be designed for the most severe of the following two conditions:

- At-rest earth pressures (depending on condition of restraint) acting on all sides of the structure, together with the seismic earth pressure of Equation 5-1 acting on one side of the structure.

- For soils predicted to liquefy, static pressures due to liquefied soil acting on all sides of the structure.

Critical structures (SPC 3) embedded in these soils should be designed for dynamic earth pressures based on site specific geotechnical investigation.

All embedded structures located on sites subjected to liquefaction should be investigated for potential buoyant effects.

A.6.2.3 Detailing

Detailing of embedded structures should conform to that required by IBC 2006 and Appendix A. All dowels across construction joints in embedded structures should be fully developed by embedment or mechanical anchorage on either side of the joint.

A.7 Water Retention Structures

A.7.1 Steel Tanks

New steel tanks should be anchored and provided with fixed steel roofs. The tanks should be designed in accordance with the latest edition of AWWA D-100, including the modifications herein.

- Tanks should be anchored and have fixed steel or aluminum roofs.
- Tanks should be designated as either Important or Critical facilities.
- The use factor, I, should be taken from the Facility Design Guide, Chapter 5, Table 5-1.
- The zone coefficient, Z, should be replaced by a suitable PGA value from a site specific ground motion. The site amplification factors, S, should be taken as 1.0, unless a site investigation finds that the site is not likely to be characterized as a rock site. In this case, S may be taken from Table 27 of AWWA D100 or a site specific ground motion spectra may be developed to establish the PGA for the site, in consideration of local soil conditions.
- A site specific response spectrum may be used to characterize local seismic conditions (D100-96, sections 13.3.3.2.3 and 13.4; and/or D103-97, sections 12.3.2.3 and 12.4) with the following modification:
  - The mean recurrence interval should be 475 years (10% probability of exceedance in 50 years) and the reduction factor R_F should be R_W.
- Design should include vertical earthquake acceleration effects wherever indicated in D100-96 or D103-97. The vertical stress in the tank shell should include vertical acceleration effects. Shell buckling should be checked by increasing the weight of the tank shell and the tributary roof on the shell by the vertical acceleration.
- Anchor bolts should be spaced equally around the circumference of the tank. Bolts should be designed for a tensile load using AWWA methods (D100-96, equation 13-19; and/or D103-97, equation 27) except that the dead load should be reduced by the vertical acceleration. Maximum spacing of anchor bolts should be 20 feet. Each tank over 100,000 gallons should have a minimum of 12 bolts. Minimum size of anchor bolts is 0.75 inch diameter. Threads in anchor bolts will be designed such that failure of the bolt in the threads does not occur before general yielding up to 2% strain in the bolt.
- Attachments of anchor bolts to tank shell and embedment in footing should be capable of developing the tension yield force of the bolt.
- The effect of internal liquid pressure should not be used to increase permissible buckling stresses on the shell for unanchored tanks, as permitted by D100-96, Section 13.3.3.7.4.
- Critical piping connected to sides of tanks should be designed to accommodate 2 inches of uplift movement of the tank shell without severe damage or uncontrolled loss of contents. This amount of movement may be increased if the tank is unanchored or if the available anchorage system might still allow some amount of uplift under the design earthquake, when evaluated using R_w = 1. It is preferable that piping connected to the floor of the tank be located outside the zone of uplift identified

by D100-96 (or D103-97) for unanchored tanks. If this is not possible, piping connected to the floor of the tank, which is within the "uplift" zone (of an equivalent unanchored tank), should be designed assuming that 2 inches of uplift occurs at the tank wall (12 inches if the tank is unanchored).

- Frictional resistance should not be used to reduce the unbraced distance in designing roof members as permitted by D100-96, Section 3.6.
- Interior columns supporting the roof should be designed with a maximum slenderness ratio (length/radius of gyration) of 120 instead of 175 as permitted by D100-96, Section 3.4.
- In addition to the requirements of D100 (or D103), tank foundations should be designed to resist sliding and overturning due to seismic forces. The overall stability against sliding and overturning should be achieved with a minimum safety factor of 1.1 (sliding) or 1.5 (overturning) or greater. Vertical accelerations need not be included in the calculation of overall sliding and overturning stability. The one-third increase in allowable stress permitted in D100-96 applies only to soil bearing stresses under the combined maximum load case of seismic and gravity loads acting simultaneously.

A. Base Shear and Overturning Moment

In lieu of AWWA Equations 13-4 and 13-8 for calculation of base shear and overturning moment, substitute the following:

$$V = \frac{S_{ai} I}{R_w}\left(W_s + W_r + W_1\right) + S_{ac} I W_2$$ [equation 5-2]

$$M = \frac{S_{ai} I}{R_w}\left(W_s X_s + W_r H_t + W_1 X_1\right) + \frac{S_{ac} I}{1} W_2 X_2$$ [equation 5-3]

where R_w should be taken as 4.2.

$S_{ai} =$ spectral acceleration of the first impulsive mode at 2% damping. Higher damping can be used if justified based on tank-specific analysis. This may be appropriate for soil sites.

$S_{ac} =$ spectral acceleration of the first convective mode, at 0.5% damping

$W_s =$ weight of tank shell, lbs

$X_s =$ height from bottom of tank shell to the center of gravity of the shell, ft

$W_r =$ weight of the tank roof plus permanent loads if any, lbs

$H_t =$ total height of tank shell, ft

$W_1 =$ weight of effective mass of tank contents that moves in unison with the tank shell per AWWA D-100 Sec. 13.3.3.2 – lbs

$X_1 =$ height from the bottom of the tank to the centroid of lateral force applied to W_1 per AWWA D-100 Sec. 13.3.3.2 – ft

$W_2 =$ weight of effective mass of tank contents that moves in the first sloshing mode, per AWWA D-100 Sec. 13.3.3.2 – lbs

$X_2 =$ height from the bottom of the tank shell to the centroid of lateral force applied to W_2 per AWWA D-100 Sec. 13.3.3.2 – ft

S_{ai} and S_{ac} are the spectral accelerations of the first impulsive and convective (sloshing) modes, using site specific response spectra with 2% and 0.5% damping, respectively. The period for the impulsive mode may be calculated using Equation 7-52 and Figure 7.18 of (ASCE, 1984). It can be determined from the site-specific or IBC default response spectra adjusted for 2% damping. For a steel tank containing water, the equation for the period for the impulsive mode is as follows:

$$T_i = \frac{H}{2640 C_w}$$ [Equation 5-4]

where C_w is obtained from Figure 7-18 of (ASCE, 1984).

In lieu of calculating the period for the impulsive mode, S_{ai} may conservatively be taken as the peak response acceleration on the site-specific response spectrum.

The period of the convective mode should be calculated in accordance with AWWA D-100, Equation 13-7. Where a site specific response spectrum curve has not been developed for the site, S_{ac} may be taken as:

$$S_{ac} = PGA * C_s$$ [Equation 5-5]

where

$$C_s = {3S}/{T_w} \; when \, T_w < 4.5 \, seconds$$
$$C_s = {13.5S}/{T_w^2} \; when \, T_w \geq 4.5 \, seconds$$ [Equation 5-6]

Note that the base shear and overturning moment determined by Equations 5-2 and 5-3 is that applied to the shell. The effects of the weight of the bottom of the tank shell should be included in a rational manner. The tank foundation is subjected to an additional moment due to the lateral displacement of the tanks contents as discussed in (Wozniak and Mitchell). This may need to be considered in the design of some foundations such as pile-supported concrete or slabs.

B. Hydrodynamic Seismic Hoop Tensile Stress

Seismic hoop tensile stress should be determined in accordance with AWWA D-100, Equations 13-21 to 13-24, (D103-97, equations 28 to 33) as modified herein. Vertical acceleration should factor in the considerations in Section A.2.4.3.

when D/H > = 1.33:

$$N_i = \frac{4.5 S_{ai}}{R_w} IGDH \left(\frac{Y}{H} - 0.5 \left(\frac{Y}{H} \right)^2 \right) \tanh \left(0.866 \frac{D}{H} \right)$$ [Equation 5-7]

when D/H < 1.33 and Y < 0.75D:

$$N_i = \frac{2.8 S_{ai}}{R_w} IGD^2 \left(\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right)$$ [Equation 5-8]

when D/H < 1.33 and Y> = 0.75D:

$$N_i = \frac{1.4 S_{ai}}{R_w} IGD^2$$ [Equation 5-9]

For all values of D/H:

$$N_c = S_{ac} \frac{IGD^2 \cosh\left(3.68 \frac{H-Y}{D}\right)}{\cosh\left(3.68 \frac{H}{D}\right)}$$ [Equation 5-10]

C. Freeboard and Roof Design

Tanks should be designed with freeboard above the upper range of the normal operating liquid level as follows:

$$d = 0.42 D S_{ac} I$$ [Equation 5-11]

If the available freeboard is less then d, then the roof system should be designed to resist the impact from the sloshing liquid.

A.7.2 Prestressed Concrete Tanks

Prestressed concrete tanks should be designed in accordance with the latest edition of AWWA D110 as modified by Appendix A.

A. Base Connection

Tanks should be designed with either a reinforced, non-sliding, fixed base (type A.2.l(a), Figure 4A) or anchored flexible base (type A.2.l(b), Figure 4B) as defined in AWWA D110.

Anchorage between the tank shell and floor, should be designed to resist base shear and overturning moment V and M calculated in accordance with Equations 5-2 and 5-3 with the coefficient R_w taken as 4.5 for a flexible anchored base, and 2.75 for a fixed base.

Anchorage between the tank shell and floor, consisting of embedded dowels or prestressing cable should be designed to resist a base shear force V using equation 5-2.

Base shear should be resisted entirely by shear friction, calculated in accordance with ACI 318, or by use of seismic cables.

Bearing pads and water seals in tanks with type A.2.1(b) flexible anchored base should be designed to withstand the displacement resulting from the base shear calculated in accordance with Equation 5-2 using R_w = 1.2. A higher value of R_w may be used if it can be justified that the bearing pads will remain leak tight while accommodating the total nonlinear-calculated displacements of the structure in the design basis earthquake.

In addition to the effects of horizontal acceleration, tanks and their foundations should be designed to resist the effects of vertical acceleration as indicated in Section A.2.4.3. The combined effects of vertical and horizontal accelerations may be combined by the root sum of the squares method.

Foundations for tanks should be designed to resist the total overturning and shear effects resulting from the forces and moments calculated as follows:

$$V_f = V + S_{ai} W_f$$ [Equation 5-12]

$$M_f = M + V_f H_f$$ [Equation 5-13]

Steel reinforcement and anchor cables provided at the base of tanks should be fully embedded on both sides of the base joints to permit the development of the full yield strength of the steel.

B. Roof Connection

Wall-to-roof connections should 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.

C. Hydrodynamic Seismic Hoop Tensile Stress

In lieu of the equations given in AWWA D110, circumferential stresses N_i and N_c should be calculated by replacing Z with the site specific PGA. I should be based on Facility Design Guide, Chapter 5, Table 5-1. Designs should include provision for steel reinforcement to carry 100% of the circumferential tensile stresses due to seismic accelerations.

D. Cover

A minimum of 2 inches of cover should be provided over prestressing wires 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.

E. 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 that 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 should be used.

A.7.3 Water Retention Basins

Open roofed, water retention basins should be designed in accordance with the latest edition of ACI 350.

Circular basins should be designed for seismic forces calculated in accordance with Section A.7.2.

Rectangular basins and their foundations, should be designed by combining earthquake forces aligned with each principal axis of the basin using the square root of the sum of the squares method.

- The base shear and overturning moments resulting from seismic response in each direction should be separately calculated using the procedures of Section A.7.2, except that the length of the basin in the direction under consideration should be substituted for the diameter “D” in all equations.
- The coefficient R_w should be taken as 4.0.
- In addition to hydrostatic forces, retained earth static and seismic forces, and any other applied loadings, end walls of rectangular basins should be designed to resist earth pressures as determined using the procedures in Section A.6.

Division walls in retention basins and reservoirs should be designed as end walls of individual basins having an adjusted dimension “D” equal to the distance between adjacent walls. For this purpose, the weights of fluid active in the impulsive and convective modes (W_1, W_2) should be calculated as if for a tank of adjusted dimension “D”. Unbalanced hydrostatic forces resulting from different liquid levels, including one basin empty, should be accounted for.

The sanitary durability coefficient of ACI 350 need not be used in conjunction with the design basis earthquake load case.

Structures that cover open water retention basins where the water within may be required for fire flows should be designed with a maximum R value of 3. Portions of roof structures that provide access to or provide support for valve operators that may be required to be operated immediately after an earthquake should be designed with a maximum R value of 2.2.

Liners should be designed to not leak excessively or in a manner as to be unrepairable within 30 days after a major earthquake.

Embankments not otherwise covered by DSOD should be designed to withstand a 475 year earthquake (increased by I=1.25 or I=1.5) with at least 3 inches of freeboard available.

A.7.4 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. It is based on a research report by (Cambra), but has been simplified and modified.

In addition to other loads, resulting from self weight, operating forces, etc., internals should be designed to resist a uniform seismic lateral force per unit height of internal structures as follows:

$$f_p = \frac{2.5 C_a I \left(w_p + w_w \right) + f_w}{R_w} \qquad \text{[Equation 5-14]}$$

where R_w is taken as appropriate from Table A-1, and:

$$f_w = \frac{0.75\gamma}{g} D_c \left(\pi D_c \hat{u} + C_d |u| u \right) \qquad \text{[Equation 5-15]}$$

$$u = 0.77 S_{ac} T_w g \frac{\cosh\left(\frac{3.68\left(H + Y_i\right)}{D} \right)}{\cosh\left(\frac{3.68H}{D} \right)} \left(0.5 - \frac{2r^2}{D^2} \right) \cos\left(\frac{2\pi t}{T_w} \right) \qquad \text{[Equation 5-16]}$$

$$\hat{u} = -1.54 S_{ac} g \frac{\cosh\left(\frac{3.68\left(H + Y_i\right)}{D} \right)}{\cosh\left(\frac{3.68H}{D} \right)} \left(0.5 - \frac{2r^2}{D^2} \right) \sin\left(\frac{2\pi t}{T_w} \right) \qquad \text{[Equation 5-17]}$$

and terms are as shown in Figure A-3.

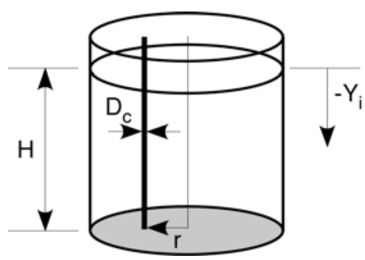

Figure A-3. Internal Components of Tanks and Basins

The expressions given by Equations 5-15, 5-16 and 5-17 must be evaluated at several locations along the height of the submerged object, to obtain a distribution of hydrodynamic force along the length of the object for design purposes. In order to maximize the force f_w, its value must be evaluated at different values of time t. As a conservative approximation, the cos term in Equation 5-16 may be set to +1 and the sin term in Equation 5-17 may be set to –1.

When the submerged object is vertical, rises the full height of the tank, and is of uniform cross section, the hydrodynamic force on the submerged object may be approximated as a uniform load over the height of the component as follows:

$$f_w = \frac{0.157 \gamma D D_c T_w S_{ac} \left(0.5 - \frac{2r^2}{D^2} \right)}{\pi H \cosh\left(\frac{3.68H}{D} \right)} \left(B_1^2 + B_2^2 \right)^{0.5} \qquad \text{[equation 5-18]}$$

where:

$$B_1 = 2\pi^2 D_c \frac{\sinh\left(\frac{3.68H}{D}\right)}{T_w}$$ [equation 5-19]

$$B_2 = 0.193 T_w C_d S_{ac} g \left(\frac{\sinh \frac{7.36H}{D} + 7.36\frac{H}{D}}{\pi \cosh\left(\frac{3.68H}{D}\right)} \right) \left(0.5 - \frac{2r^2}{D^2}\right)$$ [equation 5-20]

The above assumes that the internal component is totally or nearly totally immersed in the fluid. In the case of components that have significant length projecting out of the fluid, the above may be overly conservative, and it may be more appropriate to assume that the uniform load f_p in Equation 5-14 is applied over the portion of the component immersed in the fluid plus the slosh height given in Equation 5-11.

Components located just above fluid surfaces may be subject to damage due to sloshing and should be investigated by rational methods.

Table A-1: R_w Coefficients for Submerged Components

Component	R_w
Structural columns with axial stress ratio fa/Fa < 0.15	8
Structural columns with axial stress ratio fa/Fa > = 0.15 and < 0.4	6
Structural columns with axial stress ratio fa/Fa > = 0.4	3
Welded steel pipe (welds as strong as the pipe, for example butt welds)	8
Other pipe	6
Ladders, davits, similar appurtenances	6
Baffles	8
Launders	3
Rotating parts, scrapers	3

Other Reservoir Systems

Redwood tanks should 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 should be designed as defined elsewhere in Appendix A.

A.7.5 References

- ASCE, "Guidelines for the Seismic Design of Oil and Gas Pipeline Systems," Committee on Gas and Liquid Fuel Lifelines of the ASCE Technical Council on Lifeline Earthquake Engineering, American Society of Civil Engineers, 1984.
- ACI 1989, "Reinforced Concrete Water Retention Structures – Environmental Engineering Concrete Structures," ACI 350-R89, American Concrete Institute.
- AWWA 1995, "Prestressed Concrete Tanks – Wire- and Strand-Wound Circular, Prestressed Concrete Water Tanks," ANSI/AWWA D110-95, (including Addendum AWWA D110a-96), American Water Works Association.
- AWWA 1996, "Welded Steel Water Tanks – Welded Steel Tanks for Water Storage," ANSI/AWWA D100-96, American Water Works Association.
- AWWA 1997, "Bolted Steel Tanks – Factory-Coated Bolted Steel Tanks for Water Storage," ANSI/AWWA D103-97, American Water Works Association.
- Cambra, F. J., 1982, "Earthquake Response Considerations of Broad Liquid Storage Tanks," Earthquake Engineering Research Center, UCB/EERC 82/75, Nov. 1982.
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- U.S. Army Corps of Engineers (USACE), 1992. Strength Design for Reinforced Concrete Hydraulic Structures, EM 1110-2-2104.
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- U.S. Army Corps of Engineers (USACE), 2003a. Structural Design and Evaluation of Outlet Works, EM 1110-2-2400.

- U.S. Army Corps of Engineers (USACE), 2003b. Time-History Dynamic Analysis of Concrete Hydraulic Structures, EM 1110-2-6501.
- Wozniak, R.S. and Mitchell W.W. “Basis of Seismic Design Provisions for Welded Steel Oil Storage Tanks.” Presented at the Session on Advances in Storage Tank Design, API, Toronto, Ontario, Canada, May, 1972.

A.8 Pump stations

Enclosure structures for pump stations should be designed in accordance with Section A.3 or A.6.2. This includes structures that fully or partially enclose any mechanical or electrical components that are needed to operate the pump station.

Equipment, including pumps, switchgear, transformers, and similar items, as well as above ground piping should be designed in accordance with Section A.11. Underground piping at pump stations should be designed in accordance with Section A.4.

A.9 Equipment

A.9.1 General

Some equipment components are inherently rugged and maintain structural integrity and functionality during and after earthquakes. For these components, little special seismic design needs to be paid to these elements. On the other hand, some equipment components are vulnerable to seismic hazards, and appropriate design measures to limit risks from these vulnerabilities should be implemented where practical.

A.9.2 Vulnerabilities

Described below are vulnerabilities that can reduce the reliability of the equipment.

A. Horizontal Pump

- Evaluate anchorage for seismic loads. Expansion anchors are not acceptable.
- Engine (or motor) and pump must be connected by a rigid base or skid.
- Sufficient slack and flexibility must be provided in cooling, fuel, and electrical lines.
- Avoid attaching heavy valves to pipe near pumps.
- Avoid seismic interactions of pumps 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.

B. 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.

C. 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 that supplies air, fluid or power needed to operate the valve.

- Valves should not be near surrounding structures or components that could impact the valve during seismic excitation.

D. 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.

E. 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.

F. Battery Racks

- Battery cells should be lead-calcium, weighing 450 lbs. or less.
- Batteries should be supported on two-step or single tier racks that 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.

G. 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.

H. Diesel Engines

- Diesel engines should be anchored directly to the structural floor or mounted on a skid that 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.

I. 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 in Section A.11.6.

A.9.3 Equipment Anchorage

Equipment anchorage is an important consideration in the design to assure functionality. A majority of equipment failures due to seismic loads can be traced to anchorage failure. Below is a brief discussion regarding equipment anchors and situations to avoid during installation.

A. Expansion Anchors

The wedge type (or torque controlled expansion anchor) has been widely tested and has reasonably consistent capacity when properly installed in sound concrete. Other types of non-expanding anchors such as lead cinch anchors, plastic inserts, and lag screw shield are not as reliable and should not be used. Proper bolt embedment-length should be assured. Inadequate embedment may result from use of shims or high grout pads. Bolt spacing of about ten diameters is required to gain full capacity. Comparable spacing (ten bolt diameters) is required between bolts and free concrete edges. Expansion anchors should not be used for vibrating equipment as they may rattle loose and provide no tensile capacity. The exposed heads of all expansion anchors should be stamped with a letter that indicates its full length and the lettering system should be shown on the drawings.

B. Epoxy Anchor Bolts

Epoxy anchorage systems may be used for retrofits or new construction in areas with limited edge distances or limited embedment depths, or in other areas, subject to the environmental limitations on epoxy systems. Inadequate embedment may result from use of shims or high grout pads. Bolt spacing of about ten diameters is required to gain full capacity. Comparable spacing is required between bolts and free concrete edges. Epoxy anchors should not be used for vibrating equipment. The exposed heads of all epoxy anchors should be stamped with a letter that indicates to its full length and the lettering system should be shown on the drawings.

C. Cast-in-Place Anchors

Properly installed, deeply embedded cast-in-place headed studs and j-bolts are desirable since the failure mode is ductile (steel governs). Properly installed undercut anchors with long embedment lengths behave essentially like cast-in-place bolts and are similarly desirable. Care should be taken to extend anchors through grout to provide required embedment in the concrete below. Bolt spacing and edge distance requirements are the same as for expansion anchors.

D. Welded Anchors

Well designed and detailed welded connections to embedded plates or structural steel provide high capacity anchorage. There are some precautions: Avoid welding to light gage steel members if possible. Line welds have minimal resistance to bending moments applied about the axis of the weld. Puddle welds and plug welds used to fill bolt holes in equipment bases have relatively low capacity. Welded anchors in damp areas or harsh environments should be checked periodically for corrosion.

A.9.4 Anchorage Forces

The minimum design forces for anchorage and bracing of equipment and non-structural components should conform to 2006 IBC. Amplification of ground motions within a building to establish in-structure response spectra may be developed using rational methods, such as in-structure response spectra (ASCE 4-86).

A minimum factor of safety of four should be used for expansion anchors used for equipment anchorage.

The following equipment can be considered as structurally and functionally rugged, and need be designed only for the minimum anchorage forces and the other recommendations in Appendix A:

- Valves
- Engines
- Motors
- Generators
- Turbines
- Horizontal Pumps
- Vertical Pumps (limited unsupported shaft length)
- Hydraulic and Pneumatic Operators (limited yoke length)
- Motor Operators (limited yoke length)
- Compressors

- Transformers with anchored internal coils

A.9.5 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 Appendix A. 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

A.9.6 Electrical Distribution and Transmission

High Voltage Substation Equipment. All new high voltage equipment should be designed for earthquakes in accordance with IEEE 693, “IEEE Recommended Practice for Seismic Design of Substations,” Institute of Electrical and Electronics Engineers (latest edition). High voltage equipment includes all equipment at substations rated at 34.5 kV or higher. Transmission towers should be designed for earthquake, wind and ice, wind and conductor mechanical loads in accordance with latest IEEE 693, ASCE 7 and all applicable NESC/NES standards.

A.9.7 Vibration Isolation

In general, equipment should be rigidly mounted to supporting foundations and structures, without the aid of vibration isolation devices. Exceptions are mechanical equipment in which vibrations transmitted from the equipment would be troubling to building occupants or other equipment within the building.

When vibration isolation mountings are required for equipment, the mountings, and their attachments to the supporting structures, should be designed as flexible mountings in accordance with Section 17 of IBC 2006. The supplier of vibration isolation mounting hardware should submit certified calculations, sealed by a State of California registered Civil or Structural Engineer, indicating the adequacy of the hardware and attachment anchorage to meet its criteria. ASCE Manual of Practice 96 contains examples of suitable installations.

Batteries used for startup of emergency equipment should be installed in a manner to avoid rattling or toppling under the design earthquake. This generally requires suitable battery racks with suitable insert spacers, and/or suitable tie down systems. ASCE Manual of Practice 96 contains examples of suitable installations.

A.9.8 References

- ASCE 1998, “Seismic Analysis of Safety-Related Nuclear Structures and Commentary,” American Society of Civil Engineers, ASCE 4-98, New York, N.Y.
- ASCE 1999, “Guide to Improved Earthquake Performance of Electric Power Systems,” ASCE Manuals and Reports on Engineering Practice No. 96, American Society of Civil Engineers.
- International Building Code, IBC 2006, by the International Code Council, Inc. (ICC),

A.10 Existing Facilities

A.10.1 Additions, Alterations and Change of Function

The purpose of the section is to assist in determining whether or not a seismic evaluation is required for an existing facility.

Any of the following actions will trigger a requirement for a seismic evaluation of an entire facility including site stability, equipment, structures, piping, etc.:

- Facility upgrade that increases nominal operating capacity by 20% or more.
- Facility upgrade in which 30% or more of the major pieces of operating equipment are replaced, such that the expected design life of the facility is extended.
- Facility repair, as for example from fire or other damage, that has a construction cost in excess of 30% of the replacement cost of the facility.
- Addition of floor space in excess of 20% of existing space.
- Addition of a partial or full story.
- Change in occupancy or structure utilization.
- Change in live load or equipment load by more than 20%.
- Additions or alterations that introduce structural irregularities that substantially adversely affect the seismic capacity of the original structure.

Emergency power may be desirable and should be considered in the evaluation. The seismic evaluation of individual foundations and underground piping connections for items of major equipment (pumps, switchgear, tanks, vessels, etc.) should be reviewed whenever such piping and foundations are re-used at the time new equipment is installed.

A.10.2 Upgrade Requirement

If a trigger to re-assess a facility occurs, and that reassessment shows the facility does not meet the basic life safety goal, then some type of upgrade of that facility is warranted.

If the basic life safety goal is met, then no item in the system is required to be seismically upgraded or retrofitted as long as the basic Level of Service goal described in Section A.1.4 is satisfied. Earthquake-induced damage to selected components and systems is acceptable, as long as the system-wide performance remains acceptable. In cases where industry guidelines, such as FEMA 356, are more restrictive than section A.12.2, Section A.12.2 should govern unless approved.

A.10.3 Assessment Criteria

Prior to performing seismic assessments of existing facilities, the importance of the overall facility to be evaluated, and each of its components should be set in accordance with the criteria of Facility Design Guide, Chapter 5, Table 5-1.

When evaluating the seismic adequacy of existing facilities, exercise judgment in application of current design criteria contained in Appendix A and referenced design guides. Coefficients such as R or R_w, that account for overall construction quality, ductility, and toughness, may have to be adjusted to more conservative values than those used for new facilities, depending on their structural and mechanical detailing and condition.

A number of industry guidelines are available to provide guidance as to when an existing structure is sufficiently weak as to warrant seismic retrofit. Examples include ASCE 31 (formerly FEMA 310), FEMA 356 and others. Most of these guidelines are targeted towards the rehabilitation of regular occupied buildings and may not be ideally applicable to a water system with redundant facilities spread over a large geographic area. Some structures within the system are irregularly occupied, and damage to non-occupied structures may be tolerable if the basic service goal can still be met. Experience suggests that the failure of a single requirement in these documents is often shown in evaluation, even though the overall structure / facility may be reasonably seismic robust; therefore it is important to carefully interpret seismic deficiencies as being either local and relatively unimportant, or more global and more serious.

In lieu of industry guidelines, the following relaxed seismic evaluation criteria may be used for evaluation of existing occupied facilities.

- Facilities (or components of facilities) of Standard importance in this Section should be considered acceptably reliable if they provide 75% of the strength required by Appendix A for new construction of Standard importance.
- Facilities (or components of facilities) of Important importance in this Section should be considered acceptably reliable if they provide 80% of the strength required by Appendix A for new construction of Important importance.
- Facilities or components of Critical importance should be considered acceptably reliable if they provide 90% of the strength and essentially all of the operability safeguards specified by Appendix A for new construction of Critical importance.

To help the evaluation engineer assess whether or not to require upgrade of an existing facility, seismic benefit cost analyses may be performed of the type mandated by FEMA in establishing cost-effectiveness tests for seismic mitigation of existing structures (FEMA – What is a Benefit?). If the benefit cost ratio is much greater than 1, then it is reasonable to seismically mitigate the structure. If the benefit cost ratio is much less than 1, then it is not economically justified to retrofit the structure. The benefit cost test should not be the only factor in deciding whether or not to retrofit a structure.

A.10.4 Retrofit Design Criteria

Facilities found to have unacceptable seismic adequacy, in accordance with the criteria presented in A.12.3 should be brought into full strength and operability compliance with the requirements of Appendix A for new construction, to the extent practical.

It should always be kept in mind that the intent of retrofitting structures, systems, or components of the system is not to bring them up to current code. In many instances this may not be practical. Seismic retrofits should focus on remediation of the most vulnerable aspects of the structure, system or component. Aspects of the structure, system, or component that have acceptable vulnerability (acceptable meaning that the consequences of failure are slight, or the cost to mitigate the vulnerability is excessive compared to the benefit) may be left unmitigated at the approval of the engineer. The retrofit design should be consistent with this guidance. It is always advisable to meet code requirements to the extent practical.

An important point to consider when retrofitting is that over-strengthening areas of the structure, system or component that are currently deficient in strength can force the weak link(s) to occur in other elements that are perhaps more brittle. This can have a negative effect on overall structural performance during a major earthquake. A structure that is presently weak, but ductile, should not be strengthened to the point that its failure mode becomes brittle with a lower energy absorbing capacity, unless the structure is designed to elastically accommodate the earthquake.

A.10.5 References

- ASCE 2002, “Seismic Evaluation of Existing Buildings,” American Society of Civil Engineers, ASCE31-02, New York, N.Y.
- FEMA 2000, “Prestandard and Commentary for the Seismic Rehabilitation of Buildings,” Federal Emergency Management Agency, FEMA 356, November 2000.
- FEMA 2001, "What is a Benefit? Guidance on Benefit Cost Analysis of Hazard Mitigation Projects", draft Revision 2.0, May 1, 2001. APPENDIX 1: Symbols and Notation