

EXPLO National Manual for Projects Management

Volume 6, chapter 7

Utilities Design Guideline



Document No. EPM-KEC-GL-000004 Rev 003



Utilities Design Guideline

Document Submittal History:

Revision:	Date:	Reason For Issue
000	26/10/17	For Use
001	09/01/18	For Use
002	19/11/18	For Use
003	15/08/2021	For Use



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1.0 GENERAL

1.1 Introduction

The purpose of this document is to provide the Entity's utility design guidelines to be followed by the A/E as minimum requirements for the following systems:

- 1) Potable Water
- 2) Sanitary Sewer System
- 3) Storm water Drainage
- 4) Recycled/Irrigation Water System

1.2 Definitions

The following definitions apply to this Section

Definitions	Description
Primary Drainage System	The overall drainage network, generally servicing an entire district. This system generally consists of large concrete lined open channels.
Secondary Drainage System	The drainage network that services each sector, this system generally consists of underground drainage pipes, catch basins, and curb and gutter to handle overflow. Secondary drainage systems generally discharge into primary drainage channels.
Detention Ponds	Ponds that reduce peak stormwater discharges from individual sectors by temporarily storing flood waters and metering the outflow.
Industrial Retention Ponds	Also known as first flush ponds. These are ponds that completely contain stormwater and do not discharge to downstream drainage facilities. Retention ponds are generally required in industrial areas.
Rational Method	A simplified method of calculating the worst case peak runoff rates for a small watershed with rainfall intensity, runoff coefficients, and time of concentration.
SCS Method	An empirical model for computing runoff hydrographs developed by the former Soil Conservation Service (currently NRCS) in 1972. This technique is often used for detailed hydrologic modeling.

1.3 Abbreviations

The following abbreviations apply to this Section:

Abbreviations	Description
AASHTO	American Association of State Highway and Transportation Officials
ADD	Average Day Demand
ADF	Average Daily Flows
ANSI	American National Standard Institute
AWWA	American Water Works Association
APWA	American Public Works Association
ASTM	American Society for Testing and Materials
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
CN	Curve Number, an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess.
D ₅₀	50 th -percentile rip-rap diameter, which is a specification typically provided for rip-rap channel linings
DI	Ductile Iron
EGL	Energy Grade Line
FRP	Fiber Reinforced Plastic
GIS	Geographic Information Systems



Abbreviations	Description
HDPE	High Density Polyethylene
HEC-HMS	The Hydrologic Engineering Center's, Hydrologic Modeling System software
HEC-RAS	The Hydrologic Engineering Center's, River Analysis System software
HGL	Hydraulic Grade Line
IBC	International Building Code
SBC 801	Saudi Building Code, Fire Protection Requirements (SBC 801)
IPC	International Plumbing Code
ISO	International Organization for Standardization
kW	Kilowatt
L	Liters
L/s	Liters Per Second
Lpcd	Liters per Capita per Day
L/m ²	Liters per Square Meter
M	Meter
Mm	Millimeter
m/s	Meters per Second
m ³ /s	Cubic Meter per Second
NRCS	National Resource Conservation Service
NSF	National Sanitation Foundation (NSF) International
O & M	Operation and Maintenance
PDD	Peak Day Demand
PHD	Peak Hour Demand
PVC	Polyvinyl Chloride
SCS	Soil Conservation Service
SWMM	Storm Water Management Model
TR-20	NRCS Technical Release 20
TR-55	NRCS Technical Release 55
US EPA	United States Environmental Protection Agency
UV	Ultraviolet

2.0 POTABLE WATER

2.1 General

2.1.1 Introduction

This Section provides the design guide for the design of potable water utilities. The potable water utilities include the transmission and distribution piping systems.

2.1.2 General Requirements

Relevant design requirements and practices for water works can be found in the following publications:

- AWWA Design Manuals - American Water Works Association Design Manuals

2.1.3 Codes, Standards and Regulations

- US EPA National Drinking Water Regulations
- AWWA Standards - American Water Works Association Standards

2.2 Potable Water Transmission System



2.2.1 Potable Water Transmission System (Primary System)

The potable water transmission system conveys water from the source of supply to the treatment facility and from the treatment facility to the distribution system.

- A transmission system may include the following components:
 - Suction water storage tanks (at water treatment plants)
 - Chlorination injection facilities
 - Pumping stations with multiple large pumps with constant speed drives
 - Transmission pipelines
 - Discharge water storage tanks (provides suction for the distribution booster pump stations)
- Operational Objective
 - The operational objective of the potable water transmission system is to convey water from the water sources to the distribution system.
- Service Connections
 - There is no direct service connection to the transmission system.
- Flow Rate
 - Typical operation of transmission system pumping stations is to operate in constant speed conditions.
 - The flow rate shall vary to meet demand by turning pumps on and off.
- Pressure Range
 - Typical operating pressure ranges from 1.0 bar to 2.0 bars at the pump station point of discharge.

2.3 Potable Water Distribution Systems

2.3.1 The Potable Water Distribution System

The Potable Water Distribution System conveys water from district water storage tanks to the water users within the respective district, such as residences, schools, restaurants, commercial businesses and industrial areas.

- The Distribution Systems includes the following components:
 - Chlorine injection facilities
 - Large, multiple pumps, variable speed pumping station(s)
 - Distribution pipelines
 - Water storage tanks
- Service Connections
 - The Distribution System has service connections to its pipelines.
- Operational Objective
 - The operational objective of the potable water distribution system is to deliver water to the end users such as homes, schools, commercial businesses and industrial areas.
- Flow Rate
 - Typical operation of distribution system pumping stations is to operate with variable speed pumps to meet potable demands at a constant discharge pressure.
 - The flow rate shall vary to meet variable demand by varying pump speeds of multiple pumps and turning pumps on and off as demand dictates to maintain a relatively constant discharge pressure.
- Pressure Range
 - The distribution system shall be designed to provide minimum pressures during various scenarios.



2.4 Water Supply, Water Treatment and Water Quality

2.4.1 Maintaining Water Quality

A/E shall address the following design considerations:

2.4.1.1 Storage Tank Pre-chlorination

Depending on the size of the pressure zone infrastructure and the initial water demand when water deliveries begin, a pre-chlorination system may be required in front of water storage tanks. These systems will likely to be temporary in nature and abandoned after adequate water use has developed within the pressure zone.

2.4.1.2 Reduced Water Tank Storage Level During Early Years

- Storage may be reduced during the early stages of development of new distribution pressure zones to prevent the loss of chlorine residual by decreasing the level of water stored in water storage tanks.
- Storing less water shall decrease the detention time in the water storage tanks resulting in a decreased loss of chlorine residual.
- The minimum water storage volume shall be fire storage plus the two days of average day demand (ADD) storage.

2.4.1.3 Storage Tank Post-Chlorination

- The A/E are required to design a post-chlorination dosing system downstream of transmission discharge storage tanks, typically at Distribution System Booster Pump Stations.
- The dosage will be designed to insure an adequate chlorine residual level is in the distribution system to protect against any possible subsequent contamination during distribution.
 - Dosages will depend on the chlorine concentration leaving the water storage tank upstream of the Distribution Booster Station.
 - The chlorine residual leaving the Distribution Booster Stations shall be 0.5 – 0.8 mg/L (ppm).

2.4.2 Water Supply

A/E may assume that adequate water supplies are available for the developments which are being designed.

2.4.3 Water Quality

- The A/E may assume the water supply meets the quality requirements of:
 - US Environmental Protection Agency,
 - International Standards for Drinking Water (World Health Organization), and
- The water is non-corrosive.

2.5 Projecting Water Demands

2.5.1 Potable Water Demands

2.5.1.1 Projecting Potable Water Demands

- In order to effectively size key infrastructure associated with transmission and distribution water systems, water demands shall be calculated for all new projects. This includes areas where land use may have changed from a previously approved Urban Development Plan.
- Water demands shall be projected by the A/E.

2.5.1.2 Residential Water Demands, Measured in Lpcd

The following offers typical unit consumptions based on typical land uses. Project specific figures shall be determined for each project based on available data and engineering judgment.



- Average Day Demand = 415 Lpcd
- The per capita amount may be multiplied by the typical number of residents per unit type to determine unit flow rates for a wide variety of residential development types.
The basis for the average day residential demand is outlined below for information only:
- Indoor Uses: 250 Lpcd
- Outdoor Uses: 145 Lpcd
- Safety Factor: 5%
- Total: 415 Lpcd

2.5.1.3 Commercial

The specific water use in the different categories of institutional, recreational and commercial areas shall be calculated using the entity criteria.

2.5.1.4 Light and Heavy Industries

- It is not feasible to set up guidelines for the water consumption in areas with light and heavy industries (being industries with an extensive consumption for the industrial production). The A/E shall interview the potential industrial users when making an assessment of the expected consumption.
- The A/E shall look at historic uses of similar industries.
- The A/E shall provide potable water, irrigation (treated domestic sewage), and treated industrial wastewater consumption projections for new light and heavy industries.

2.5.1.5 Physical Losses (Leakage)

- The physical losses from pipes in the water supply system shall depend on the age of the pipes, pipe material and joints, pressure in the system, and construction conditions.
- For older pipelines a twenty percent (20%) increase factor for the total daily water consumption shall be added to account for unknown water losses.
- Some studies of water distribution system have shown losses less than 10%. Therefore, the A/E may make an individual assessment of the expected unaccounted water losses to substantiate the use of less than 10% for unknown losses. The minimum factor for unaccounted water loss is five percent (5%).

2.6 Fire Flow Requirements

2.6.1 Calculating Fire Flow Demands

The water system shall be capable of meeting the Fire Flow Demand in addition to the Peak Day Demand of the system. Fire flow includes the required hydrant flow as well as fire sprinkler flow.

- Hydrant Flow – quantity and duration shall be calculated in accordance with the latest edition of the Saudi Building Code (SBC 801).
 - Hydrant flow shall vary between residential and nonresidential areas.
 - It shall be noted that the SBC 801 does allow a reduction in hydrant flow based on buildings equipped with fire sprinklers.
 - A corresponding reduction of duration is not allowed.
 - Coordination with other disciplines shall be required to determine the fire flow based on the buildings planned and the type of construction.
 - The minimum required hydrant flow is 2000 L/min at required pressures.
- Fire Sprinkler Flow – The fire sprinkler flow shall be calculated by the A/E and/or EPC's mechanical engineer.
 - The mechanical engineer shall determine appropriate sprinkler flows for inclusion in the water system evaluation.
- In industrial areas, each industry shall in principle be responsible for making their own arrangements for firefighting within their boundaries.



- The hydraulic calculations of the network system shall evaluate the extent to which a major prolonged fire may be fought with water outside the industry's boundary.

2.7 Hydraulic Modeling

2.7.1 Purpose

- Hydraulic modeling shall be used as a design tool to evaluate new or existing development as it relates to the design of water system improvements.
 - Effects on existing systems shall be evaluated if appropriate.
 - Hydraulic modeling shall illustrate that proposed improvements meet required pressure and flow requirements of this Section.
 - See AWWA M32 for full procedures associated with computer modeling of water distribution systems.
- Urban Development Plans
 - Hydraulic modeling shall be completed based on the approved Urban Development Plan and shall be included in the "Utility Load Requirement."

2.7.2 Modeling Software

Modeling may be completed in standalone, CAD integrated, or GIS integrated modeling platforms. Acceptable modeling software include:

- WaterCAD (Bentley) or equivalent

2.7.3 Required Modeling Scenarios

Model Scenarios shall be prepared for the following scenarios:

- Average Day Demand
- Peak Day Demand
- Peak Hourly Demand
- Peak Day + Fire Flow

2.7.4 Peak Use factors

To complete the design of the water system, water lines, pump stations, storage and other key facilities shall be sized based on appropriate peak demand scenarios and required minimum and maximum pressures. Peak use factors shall be multiplied by the average daily demand (ADD) to determine the peak flow. The minimum allowed peaking factors are as follows:

- Peak Day – 2 times ADD
- Peak Hour – 4 times ADD
 - Consideration shall be given to the period of use when applying peaking factors. For example, peaking factors shall be applied based on the actual period of use in a given day. Some commercial and industrial uses shall likely not use water at night.

2.7.5 Model Setup

- Hydraulic distribution models shall consist of pipes, nodes (including fire hydrants), tanks, and pump stations.
- Pipes
 - Diameter
 - Diameter shall be input for every pipe



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- Input of nominal diameters is allowable for most water line materials including PVC.
 - True inside diameters shall be used for evaluation of HDPE PE 100 water lines.
 - Friction Coefficient
 - Hydraulic models shall be configured to evaluate the water system using the Hazen-Williams formula. Use the following C_{H-W} for model inputs:
 - PVC, $C_{H-W} = 140$
 - HDPE, $C_{H-W} = 150$
 - Minor Losses
 - Minor losses for fittings and valves may be included in the model by adding local minor losses to each pipe. Alternatively, a reduction of the C_{H-W} used in the model may provide an allowance for minor losses. The typical reduction value is 10% of the above listed industry accepted coefficient.
 - If applicable, minor losses for master flow meters and backflow protection shall be considered with the modeling scenarios.
 - Length
 - Models shall be created to scale to ensure accurate length of water lines.
- Nodes
 - Elevation shall be assigned to nodes at ground elevation within 0.5 m.
 - Demands shall be spatially allocated based on demand calculations for each given land use and density.
 - Demands shall be entered for each of the above-mentioned modeling scenarios listed above.
 - Required fire flow shall also be included for hydrants within the distribution system.
- Tanks
 - Volume: Though volume is not required for steady state simulations, it is a good practice to include accurate tank information for diameter, wall height, floor elevation, etc. in the event that an extended period simulation is required in the future. It also provides a means to document required tank volumes.
 - Water Surface Elevation, the following are the required tank stage settings for each required model scenario:
 - Average Day Demand – Tank Full
 - Peak Day Demand – Top of Fire Storage Elevation
 - Peak Hour Demand – Top of Fire Storage Elevation
 - Peak Day + Fire Flow – Bottom of Tank
- Pump Stations
 - Floor Elevation within 0.5 m
 - Pump Curves – if using the distribution model to confirm pump selection, actual pump curves shall be entered into the model.

2.7.6 Hydraulic Model Reporting

2.7.6.1 The following Table of Contents shall be used when submitting a Hydraulic Modeling Report:

- Introduction – Include a project description, existing system discussion, and proposed additions of the project.
 - Include a system map to illustrate proposed expansion area and land uses.
- Water Demand Criteria & Summary
 - Summarize demand calculations for average day demand, including system loss, by land use for both indoor demands and outdoor demands on the potable system; Include detailed calculations in an Appendix.



- Confirm applicability of peaking factors based on specific project requirements.
 - Fire Flow Demands – Summarize needed fire flow for each land use area. Document hydrant flow and sprinkler flow requirements.
- Methodology and Analysis – Document the modeling software used, the type of model (steady state or extended period), assumptions, and field calibration, if any.
- Modelling Input

Computer programs for network hydraulic modelling distinguish between two general groups of input data which are Junctions and Links. Although the way some components are modelled may differ from one to another software, the following input information may require:

 - Sources: identification, location and elevation of water surface level.
 - Nodes: identification, location and elevation, base demand and pattern of demand variation.
 - Reservoirs: identification, position, top and bottom water level, description of the shape (cross-section area, either the volume–depth diagram), initial water level at the beginning of the simulation, inlet/outlet arrangement.
 - Pipes: identification, length, diameter, description of roughness, minor loss factor.
 - Pumps: identification, description of pump characteristics, speed, operation mode.
 - Valves: identification, type of valve, diameter, head-loss when fully open, operation mode.
- Results and Conclusions
 - Document that results for scenarios meet the requirements of this manual for pressure and velocity for each scenario.
 - Document node or nodes with lowest pressure for each scenario
 - Document pipe or pipes with highest velocity for each scenario
 - Include a system map illustrating final pipe sizes based on the model.
 - Map shall include labels for all model elements such as nodes, pipes, and pump stations.
 - Map shall be color coded based on pipe diameter.
 - Document the detail input file and data of the existing network used for the modeling.
 - Document available fire flow for each land use area while meeting minimum pressure requirements.
 - Input and output/model files shall be submitted to entity.

2.8 Water System Design Criteria

2.8.1 General

2.8.1.1 Typical Soil and Ground Water Conditions

- For projects along the coastal zone in Saudi Arabia, the A/E shall be aware that the coastal soils have unusual properties, and a thorough study of those properties by the A/E is essential before any designs are undertaken. In general, the soil is highly saline.
- In conjunction with natural sulfides and sulfites, the saline conditions could cause serious deterioration even in Type V Portland Cement Concrete.
- In addition, weak and unstable soils may cause uneven support for pipes, which are then subject to unequal settlements even under light loadings
- The A/E shall be aware of the likelihood for high groundwater. Buoyancy conditions shall be accounted for with the design to prevent flotation of pipes, buried tanks, vaults, etc.

2.8.1.2 Pipes, Valves and Fittings

- The saline conditions are very corrosive to all ferrous piping, valves and fittings. Non-metallic materials are used for pipelines.
- In addition to the aggressive soil conditions, the presence of saline ground water seriously intensifies electrolytic action, particularly on long metal pipe runs and even on reinforcement in concrete



structures. Further, the presence of several independent cathodically protected facilities in the near vicinity of each other may create interference problems.

2.8.1.3 Design Service Life

- Before the design processes are commenced and the design parameters and the design conditions are established, it is necessary to estimate the design service lives for the key design elements in the water supply system, as the elements shall be designed for the conditions encountered during the expected design service life time.
- Expected design service lives for different design elements shall be considered as per entity requirement.

2.8.2 System Pressure

2.8.2.1 Transmission System Pressures

- Minimum Pressure – To prevent intrusion of the groundwater into the transmission main, positive pressure (1.0 to 2.0 bars) shall be maintained within the transmission main. This may be accomplished through effective design of the distribution storage tanks.
- Maximum Pressures should be evaluated against design pressure ratings of the piping and components for operational scenarios and surge events.
- A surge analysis and hydraulic modeling must be performed then followed by the design of a surge control system that is in accordance with the results of the surge analysis. The design conditions and performance characteristics of the surge control device shall consider the following:
 - Maximum design conditions for pumps and piping
 - Worst flow supply scenario
 - Positive (over) pressure: positive surge pressures shall not exceed the design pressure of the pipeline
 - Negative (under) pressure: negative surge pressures shall not exceed 5 m of vacuum (-5 m)
 - Contamination during negative pressure cases and leakage during excessive pressures
 - Recommendations from piping manufacturers
 - Water supply system stoppage during piping maintenance periods
 - Pump cavitation and damage to pipe lining
 - Input and output/model files shall be submitted to entity.

2.8.2.2 Distribution System Pressures

- Typical operating pressure ranges from 1.5 bars to 3.5 bars.
- Minimum Pressure – System pressures shall be evaluated during design by completing a hydraulic model for the project. The following pressure criteria shall be applied to the modeling scenarios during design:
 - Average Day Demand (ADD) - The minimum system pressure shall be 3.5 bars
 - Peak Day Demand (PDD) - the minimum system pressure shall be 2.5 bars
 - Peak Hour Demand (PHD) - the minimum system pressure shall be 1.5 bars
 - Peak Day Demand + Fire Flow Demand - the minimum system pressure shall be 1.5 bars. The minimum residual pressure at the flowing hydrant shall be 1.5 bars.
 - 1.5 bars is the minimum required system pressure at any point within the distribution system under fire flow and PDD conditions.
 - The minimum required pressures of 1 bar at fixtures with flush valves inside buildings pursuant to the Saudi Building Code. A/E's civil engineer shall coordinate the minimum connection pressure with A/E's building mechanical engineer during design.
- Maximum Pressure - The maximum pressure in the distribution system shall be evaluated against design pressure ratings of the piping and components for operational scenarios and surge events, it may be necessary to divide the distribution service area into multiple districts.
- A surge analysis and hydraulic modeling must be performed and then followed by the design of a surge control system that is in accordance with the results of the surge analysis.



- Maximum design conditions for pumps and piping
- Worst flow supply scenario
- Positive (over) pressure: positive surge pressures shall not exceed the design pressure of the pipeline
- Negative (under) pressure: negative surge pressures shall not exceed 5 m of vacuum (-5 m)
- Contamination during negative pressure cases and leakage during excessive pressures
- Recommendations from piping manufacturers
- Water supply system stoppage during piping maintenance periods
- Pump cavitation and damage to pipe lining

2.8.3 Water Lines (Water Pipes)

- Normal Operations – Water line velocities shall be below 1.5 m/s for all normal operating scenarios.
- Peak Day + Fire Flow - Water line velocities shall be below 2.5 m/s for fire flow scenarios.
- For systems without elevated storage, consideration shall be given for slower maximum velocities to reduce required pumping horsepower.

2.8.4 Storage

- Two days of ADD + fire flow is required for ground level distribution storage.
- One elevated tank is required to provide pressure for each water system district/sector.
 - The volume of the elevated storage shall equal the Fire Flow Demand plus the Average Day Demand.

2.9 Water Distribution System Piping and Valves

2.9.1 Water Distribution Pipelines

2.9.1.1 General Design Requirements

- Pipe, joints, fittings, valves and fire hydrants shall conform to applicable sections of ANSI/AWWA Standards, and all materials which may contact drinking water shall be ANSI-certified as meeting the requirements of NSF Standard 61.
- In order to provide increased reliability of service and reduce head loss, dead ends shall be minimized by making appropriate looped tie-ins whenever practical.
- All dead ends shall have a fire hydrant.
- Fire hydrants are used for flushing water pipelines.
- The properties of the soil and water table depth through which water mains are to be laid shall be considered. The design engineer shall also consider the materials to be used when corrosive soils or waters shall be encountered (coastal soils are highly saline and corrosive, a thorough study of the conditions is essential before beginning design).
 - All water mains shall be sized based on flow demands and minimum pressure requirements.
 - The pressure rating for all components such as valves and fittings shall be equal to or greater than the required pipeline pressure rating.
 - The minimum water main size to be installed shall be 200 mm in diameter. The minimum water lateral size to a fire hydrant shall be 150 mm in diameter.
 - Minimum pipeline slope shall be 0.10%. Maximum pipeline slope shall be 10%, unless project specific approval is requested and approved.
 - Longitudinal bending of PVC pipe is not allowed.
 - Longitudinal bending of HDPE pipe shall be limited to 80% of the manufacturer's installation recommendations.
 - PVC pipe joint deflection shall be limited to 80% of the manufacturer's installation recommendations.
 - Pipeline Location:



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- Vertical: minimum burial depth is 1.0 m, measured from finished grade to top of pipe. Maximum burial depth is 2.0 m.
- Horizontal: 2.0 m beyond edge of pavement or back of curb, unless otherwise approved.
- Proximity to other utilities:
 - The use of joint (combined) utility trenches is not permitted.
 - Potable water lines shall be located at a distance no less than 3.0 m horizontally (outside to outside) and 500 mm vertically above any non-potable (reclaimed) water line, sewer line, or storm drain line.
 - Potable water lines shall be located a distance of no less than 1.0 meter horizontally from other potable water mains, gas mains, or other dry utilities.
- Transition of Disciplines
 - Civil Disciplines begin at 1.5 meters from the edge of buildings and goes away from the building.
 - Mechanical Disciplines begin at 1.5 meters from the edge of buildings and goes into the building.
- Acceptable Pipe Materials
 - High Density Polyethylene Pipe (HDPE)
 - Sizes 160 mm to 1400 mm:
 - Polyvinyl Chloride Pipe (PVC)
 - Sizes 150 mm to 300 mm:
 - Sizes 350 mm to 900 mm:
 - Glass Reinforced Plastic Pipe (GRP)
 - Sizes 150 mm to 1200 mm

2.9.2 Isolation Valves

2.9.2.1 General Design Requirements

- Valve Locations: a sufficient number of isolation valves shall be provided on water pipelines to minimize inconvenience, sanitary hazards, and degradation of fire protection during maintenance and repairs. Valves shall be generally located as follows, unless otherwise approved:
 - At intervals to isolate no more than two fire hydrants at any time.
 - In residential areas to isolate a maximum of 30 services.
 - A maximum of five valves shall be required to isolate any location.
 - Isolation valves are required on all sides of tees, 3 valves and crosses, 4 valves.
 - For straight pipe runs in commercial and industrial areas, the maximum spacing between isolation valves shall be 200 m.
 - For straight pipe runs in other areas, the maximum spacing between isolation valves shall be 400 m.
 - A valve immediately adjacent to the water main shall be provided for all laterals greater than 50 mm in diameter, and for all fire hydrant laterals.
- Valve boxes shall be installed on all buried isolation valves. Valve stem extensions are required within 500 mm of finished grade where the distance from the top of the valve box to the top of the operating nut exceeds 1500 mm.
- Valve boxes and lids shall be cast iron, three sectional, and screw-type adjustable; designed for highway traffic loads.

2.9.2.2 Acceptable Valve Types

- Gate Valves
 - Valve sizes 150 mm to 400 mm
- Butterfly Valves
 - Valve sizes 450 mm to 1400 mm



2.9.3 Air Valves

2.9.3.1 General Design Requirements

- Locate and size air valves per AWWA and valve manufacturer requirements.
- Three types of air valves shall be used as appropriate:
 - Air release valve
 - Air/Vacuum valve
 - CAV: Combination air valve (combines the functions of both an air release valve and an air/vacuum valve)
- The following types of air valves are required at the following points along a pipeline (to exhaust air and admit air to prevent vacuum conditions and air related surges):
 - High Point: Combination Air Valve
 - Long Horizontal Run: Air Release Valve or Combination Air Valve at 1000 m maximum intervals.
 - Long Descent: Combination Air Valve at 600 m maximum intervals.
 - Long Ascent: Air/Vacuum Valve at 600 m maximum intervals.
 - Decrease in an Up Slope: Air/Vacuum Valve.
 - Increase in a Down Slope: Combination Air Valve.
- Pipeline grades shall be smooth and constant, and the required number of air valves limited to the extent practical. Pipeline grade changes shall be noted on the construction drawings.
- High points and grade changes that are less than one half of the pipeline diameter typically shall not require an air valve, because the water flow shall flush accumulated air downstream.
- Sizing
 - Air valve sizing shall be project specific, and per AWWA and valve manufacturer requirements and recommendations.
 - Air/Vacuum Valve and Combination Air Valve: sizing shall generally be one tenth of the pipeline diameter.
 - Air Release Valve sizing varies depending on the potential for entrained air in the water source. As a minimum the Air Release Valve inlet connection shall be as large as the air valve size.
 - Valves 76 mm and smaller shall have threaded inlets and outlets. Valves larger than 76 mm shall have a flanged inlet.
- The open end of the air relief vent pipe from the air valves shall be extended to at least 0.5 m above grade and provided with a downward elbow which is screened using 1.4 mm stainless steel mesh. The vent pipe shall be the same diameter as the air valve being vented.
- Alternately, the open end of the pipe may be extended to 0.5 m above the top of the pipe if the air valve manhole is not subject to flooding and provided with a drain-to-daylight. Air valves shall not be connected directly to any sewer.
- Connection of air valves to water mains
 - Wrap-around type body. When installed the body shall wrap around the main for a minimum of 160 degrees.
 - On HDPE mains: sidewall fusion tap
 - On PVC mains: stainless steel double strap saddle
 - All components shall be corrosion resistant

2.9.4 Joint Restraint

2.9.4.1 General Design Requirements

- Joint restraint shall be used at all bends and fittings
- HDPE Pipelines:
 - All bends and fittings shall be butt fusion welded or flanged using flange adapters.
- Polyvinyl Chloride (PVC) Pipelines:



- Joint restraint shall be mechanical joint with a Megalug restraining gland system designed for mechanical joint restraint of PVC pipes, per ASTM F1674.
 - Field solvent welded joints are not allowed.
 - Concrete thrust blocks shall be installed at all bends and fittings, in addition to mechanical joint restraint.
- Fiber Reinforced Polymer (FRP):
 - All bends and fittings shall be mechanically restrained with one of the following options:
 - Concrete thrust blocks
 - Restrained joints

2.9.5 Bends and Fittings

2.9.5.1 General Design Requirements

- For HDPE Pipelines:
 - Injection molded HDPE or fabricated HDPE (for the specific application).
 - Butt fusion welded, side fusion welded, or flange adapter.
 - Electrofusion couplings are not allowed.
- For PVC Pipelines:
 - Mechanical joint ductile iron.
- All exposed components shall have corrosion protection.

2.9.6 Fire Hydrants

2.9.6.1 Hydrant Location Requirements

- The locations of fire hydrants shall be included on civil site plans.
- Hydrant spacing and locations shall be per SBC 801. Maximum hydrant spacing shall not exceed 150 m in residential areas and 100 m in commercial/industrial areas.
- Fire hydrants shall be located relative to buildings so fire trucks may easily locate the hydrants and connect to the nozzles.
- Hydrants shall not be hidden within or behind landscaping.
- Hydrants shall be a minimum of 15 m away from the building or structure
- Hydrants shall not be located more than 10 m away from the edge of the curb or roadway
- Any portion of a building extending beyond 100 m from an accessible access road to the nearest fire hydrant requires installation of an additional fire hydrant.
- The number of fire hydrants shall be determined on an average spacing of 100 m computed on an imaginary line parallel to and not less than 15 m from the structure. All hydrants are to be accessible to fire trucks over roads capable of supporting such fire apparatus.

2.9.6.2 Hydrant Design Requirements

- Hydrants shall be wet barrel type.
- Fire hydrants shall have a bottom valve size of at least 125 mm, one pumper nozzle and two hose nozzles.
- One Siamese connection shall be provided for each 100 m of exterior building wall or fraction thereof facing upon each street or public space.
- Three steel bollards shall surround all fire hydrants that are not protected by a curb, and in all industrial areas whether a curb is present or not.
- The hydrant lateral which interconnects the pipeline and the hydrant shall be not less than 150 mm in diameter and the maximum lateral length shall be 50 m.
 - A larger size lateral shall be required for greater distances.
- An isolation valve shall be installed on all hydrant laterals, adjacent to the main.
- Water service or fire service connections are not allowed on fire hydrant laterals.



- All joints and fittings between the main and the hydrant shall be restrained.

2.9.7 Flow Meters and Services

2.9.7.1 General Design Requirements

- Service Lines:
 - All water service lines 100 mm in diameter and smaller shall be constructed of HDPE tubing.
 - Polyethylene tubing shall be blue and have UV color stabilizers so that the pipe is not affected in color or flexibility for a minimum of four years.
 - Service connections and service lines shall be installed at a 90 degree angle from the main.
 - Each separate building supplied with water shall have its own separate service connection and meter.
- Service Line Fittings such as corporation stops, curb stops, saddles
 - All stops shall be full port and have a flow passage area equivalent to the fitting outlet flow area.
 - The inlet connection shall be AWWA Taper thread. The outlet connection shall be a pack-joint outlet for HDPE tubing.
 - Curb stops shall be ball valve, roundway, with check, and lock wing cast on stop body and operating tee cap to provide for locking the stop in closed position. Curb stops for use with HDPE service shall have an inlet connection with a compression joint and an outlet connection with female iron pipe thread.
 - Service saddles:
 - Wrap-around type body. When installed, the body shall wrap around the main for a minimum of 160 degrees.
 - On HDPE mains: sidewall fusion tap.
 - On PVC mains: stainless steel double strap saddle.
 - All components shall be corrosion resistant.
 - All service saddles shall have corporation tap threads.
- Flow Meters
 - To be installed at the property line, in a HDPE or PVC meter box
 - Size flow meters per AWWA M22 and IPC
 - Flow meters 100 mm or larger shall be installed in a vault (chamber)

2.9.8 Cross Connection Control

2.9.8.1 General Design Requirements

- No physical connection shall be allowed between potable and non-potable sources without an approved backflow prevention device.
- An approved backflow prevention device is required on all buildings which have fire suppression sprinklers. These devices are typically installed inside the buildings on the ground floor.
- Backflow prevention devices shall be installed above grade.
- An approved backflow prevention assembly (appropriate to the degree of hazard) shall be installed on each service line wherever one of the following conditions exist:
 - A building or property having an auxiliary water supply which is not or may not be of safe bacteriological or chemical quality.
 - A building or property on which industrial fluids or other objectionable substances are handled in such a fashion as to create an actual or potential hazard to the potable water system.
 - A building or property having an internal cross-connection that cannot be permanently corrected or controlled, intricate plumbing and/or piping arrangements, or where entry to all portions of the premises is not readily accessible for inspection purposes, making it impracticable or impossible to ascertain whether or not dangerous cross-connections exist.



2.9.9 Tracer Wire and Underground Warning Tape

2.9.9.1 General Design Requirements

- Tracer Wire:
 - Shall be installed on all non-metallic pipe main installations.
 - The wires shall be attached to the pipeline using minimum 50 mm wide duct tape, applied on each side of a joint and spaced every 1.5 m.
 - Locating wires shall terminate at each valve box, manhole, and vault.
 - Continuity tests shall be conducted on the installed tracer wire to substantiate continuity for the tracer wire loop.
- Underground Warning Tape:
 - Tape shall be a minimum of 75 mm wide.
 - Lettering shall be a minimum of 25 mm high.
 - Color to conform to APWA Color Code, and be permanently printed.
 - Install tape at least 200 mm above the pipe otherwise unless directed.

2.9.10 Blow-off Assemblies

2.9.10.1 General Design Requirements

- Blow-off valves are required on all permanent dead-end pipe runs, major in-line low points, and may be required at stub-out locations.
- Fire hydrants shall be used as blow-offs and for flushing. A minimum velocity of 0.75 m/sec in the water main being flushed is required to provide adequate flushing.
- Temporary blow-offs shall be provided as necessary to pressure test and chlorinate the water mains. Temporary blow-offs shall be removed upon acceptance of the water line.
- Blow-off outlets and drains shall terminate in a location with an acceptable air gap for backflow protection.
- No blow-off assembly shall be located in roadways, or connected directly to any sewer.

2.10 Water Distribution Pumping Equipment

2.10.1 General

- Pumping facilities shall be designed by an A/E with specific related experience in design and construction of pumping facilities.
- Pumping facilities shall be located so that the proposed site shall meet the requirements for sanitary protection of water quality, hydraulics of the system and protection against interruption of service by fire, flood or any other hazard.
- Closed loop pumping systems are not allowed.
- Facility designs shall consider and make provisions for long-term demands including space for future expansion if needed, and operation and maintenance requirements.
- All equipment and components shall be AWWA and NSF approved.

2.10.2 Booster Pumps

- Booster pumps shall be centrifugal or vertical turbine type.
- At least two pumps shall be provided in all potable booster pump stations. With any pump out of service, the remaining pump or pumps shall be capable of providing the maximum pumping demand of the system. Where two or more pumps are installed, provisions shall be made for alternating operation.
- The A/E shall submit and obtain approval of the following operating conditions and performance criteria during preliminary design:



- Required Pump Discharge
 - Total Dynamic Head at Required Discharge
 - Minimum Suction Pressure and Net Positive Suction Head Required and Available (if applicable)
 - Maximum Pump Speed
 - Minimum Motor Horsepower
 - Minimum Efficiency
 - Proposed Pump and Motor Selection
- Suction lift shall be avoided if possible. If required it shall be less than 4 m and provisions shall be made for priming the pump(s).
- Transmission Booster Pumps
 - Generally operate at a constant flow rate – pump speed, and take suction from the transmission suction storage tanks and convey to the transmission pipeline to the transmission discharge storage tanks. These pump motors may typically utilize a reduced voltage soft starter (RVSS).
 - The pumping facility shall have the capacity to provide the peak day demand of the system or the specific portion of the system serviced.
 - The operation of the pumps shall be controlled by the level in the transmission discharge storage tanks, via a level transducer, with sufficient tank volume between pump start and pump stop tank levels to prevent excessive cycling.
 - A provision to maintain a minimum level in the transmission discharge storage tanks for distribution pump station suction shall also be included in the control logic.
- Distribution Booster Pump Stations
 - Generally operate at a constant flow rate and pump speed, and take suction from the transmission discharge storage tanks and discharge to the distribution system pipelines and distribution elevated storage tank. These pump motors may typically utilize a reduced voltage soft starter (RVSS), although the use of variable frequency drives (VFD) may be preferred in some cases to meet demand requirements.
 - Capacity shall be provided such that the pumping facility shall be capable of providing the peak day demand of the system or the specific portion of the system serviced.
 - The operation of the pumps shall be controlled by the level in the distribution elevated storage tank (via a level transducer, with sufficient volume between pump start and pump stop tank levels to prevent excessive cycling.
 - A provision to maintain a minimum level in the transmission storage tanks for the pump station suction shall also be included in the control logic.

2.10.3 Mechanical Requirements

- Pump station piping shall be designed such that each pump has an individual suction line, or that the lines are manifolded so that they shall insure similar hydraulic and operating conditions.
- Piping shall be welded epoxy-lined and coated steel piping with flanged joints.
- All pumping facilities shall have sufficient surge control with surge anticipator valves and/or surge tanks to protect piping and other equipment. Pressure fluctuations shall be maintained within 15 percent of normal operating pressures during pump starting and stopping. Adequate provisions shall also be made for pressure surges caused by power outages.
- All pumping facilities shall be equipped with pressure relief valve(s).
- Pumps motors larger than 15 kW shall be equipped with a booster pump control valve on the pump discharge.
- The pump discharge line shall be equipped with a magnetic flow meter which indicates total flow volume (liters) and rate of flow (liters/minute) with a 4-20 milli-amp output.
- An air vacuum valve shall be installed directly downstream of the pump discharge.
- A pressure gauge, pressure transducer (with a 4-20 milli-amp output), and pressure switch shall be installed downstream of the air vacuum valve and pump control valve (if present).
- A bypass line shall be included in the pump station, to allow the connection of emergency pumps.



Utilities Design Guideline

- Sufficient isolation valves which are typically butterfly valves and restrained dismantling couplings shall be provided.
- Equipment shall be labeled/tagged to correspond to the maintenance record and for proper identification.
- Adequate clear space for access, maintenance and removal and replacement shall be provided around all piping and equipment. At a minimum there shall be 0.75 m clear between all piping and equipment and all obstructions.

2.10.4 Chlorination

- All pumping facilities shall be equipped with a chlorine dosing system using Cl₂ gas cylinders, located in a separate room with an exhaust fan and isolated from the rest of the pumping facility. The design of the room shall comply with the applicable requirements of the IBC and IPC.
- Hypochlorite generators with a dosing pump may also be used.
- Minimum onsite chlorine storage shall be seven days.
- All of the system components shall be according to the manufacturer's recommendations to insure efficient chlorination system operation.
- Chlorine analyzers, and sample taps shall be provided both upstream and downstream of the injection point.
- An emergency eye wash station, shower, and appropriate signs shall also be provided.

2.10.5 Building

- All booster pumps, mechanical equipment, chlorination facilities, control equipment, electrical equipment and telemetry equipment shall be enclosed in a building.
- All booster pumps stations shall be equipped with a manual transfer switch and provisions for connecting a roll-up generator to operate the pump station in the event of a prolonged power outage.
- Pumping stations finished floor elevations shall be elevated to a minimum of 1.0 m above the 100-year flood elevation, or protected to such elevation; graded around the station so as to lead surface drainage away from the station. The finished floor elevation of the pump station shall be a minimum of 150 mm above finished grade.
- Adequate provisions shall be made for removal and replacement of the motor, discharge column, pump, and other equipment. Provisions include roof hatches, crane-ways, hoist beams, eyebolts, or other acceptable means.
- Suitable HVAC shall be required. Interior temperatures shall be maintained at no more the 45°C.
- Emergency/back-up power shall be provided for all critical pumping facilities (life safety services).
- Floor drains shall be provided, except in the chlorine room. The building floor shall slope to the drains.
- All pumping facilities shall be fenced with a minimum 2.0 m high fence. The site access, size and layout shall provide adequate room for maintenance of the facility, including removal of pumps; including adequate room for the removal and replacement of all mechanical and electrical equipment.

2.11 Water Storage Tanks

2.11.1 General

2.11.1.1 Ground Surface Water Storage Tanks

- Water storage tank design shall comply with the following AWWA standards and manuals:
 - Welded Carbon Steel Tanks for Water Storage, AWWA Standard D100-11
 - Steel Water Storage Tanks, AWWA Manual M42
 - Factory-coated Bolted Carbon Steel Tanks for Water Storage, AWWA D103-09
 - Wire- and Strand-wound, Circular, Prestressed Concrete Water Tanks, AWWA D110-13
 - Tendon-Prestressed Concrete Tanks, AWWA D115-17



2.11.1.2 Elevated Water Storage Tanks

- Composite Elevated Tanks for Water Storage, AWWA D107-16
 - The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Steel structures shall follow the current AWWA standards concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable.
 - The lowest elevation of the floor of ground level reservoirs shall be placed at least 0.5 m above the surrounding grade, 1.0 m above the 100-year flood elevation, and at least 2 m above the groundwater table.
 - A geotechnical investigation and foundation design shall be prepared for all tank sites.
 - Sewers, drains, standing water, and similar sources of possible contamination shall be kept at least 15 m from the reservoir.
 - All finished water storage structures shall have suitable watertight roofs which exclude birds, animals, insects, and dust. The installation of appurtenances, such as antenna, shall be done in a manner that ensures no damage to the tank, coatings or water quality.
 - Fencing, locks on access manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage.

2.11.2 Sizing

- Storage facilities shall have sufficient capacity, as determined during preliminary design, to meet domestic demands; and where fire protection is provided, fire flow demands.
 - Fire flow and storage requirements shall be established by the SBC 801.
 - Excessive storage capacity shall be avoided to prevent potential water quality deterioration problems.
 - Transmission Ground Level Storage Tank(s) capacity: five days of average daily demand.
 - District Distribution Ground Level Storage Tank(s) capacity: two days of average daily demand and fire storage.
 - District Distribution Elevated Storage Tank(s): one day of average daily demand and fire storage.

2.11.3 Piping

- Inlet: a dedicated supply line from the distribution booster pump station to the district distribution elevated storage tank(s) is required.
- Outlet: the discharge pipe(s) from water storage structures shall be located in a manner that shall prevent the flow of sediment into the system. Removable silt stops shall be provided.
- Overflow: all water storage structures shall be provided with an overflow which is brought down to an elevation of 0.5 m above the ground surface, and discharges over a drainage inlet structure or a splash plate. No overflow may be connected directly to a sewer or a storm drain. All overflow pipes shall be located so that any discharge is visible.
 - When an internal overflow pipe is used on elevated tanks, it shall be located in the access tube. For vertical drops on other types of storage facilities, the overflow pipe shall be located on the outside of the structure.
 - The overflow shall open downward and be screened with 5 mm and 2 mm stainless steel non-corrodible screens. The screen shall be installed within the overflow pipe at a location least susceptible to damage by vandalism.
 - The overflow pipe shall be of sufficient diameter to permit waste of water in excess of the filling rate.
- Drains: the design shall allow draining the storage facility for cleaning or maintenance without causing loss of pressure in the transmission and/or distribution system. No drain on a water storage structure shall have a direct connection to a sewer or storm drain.
- Sampling: smooth-nosed sampling tap(s) shall be provided in the tank valve vault to facilitate collection of water samples for both bacteriological and chemical analysis. The sample tap(s) shall be easily accessible.



2.11.4 Stored Water Age

- Finished water storage shall be designed with an inlet mixing and distribution manifold to facilitate turnover of water in the finished water storage to minimize stagnation and/or stored water age.
- The inlet and outlet pipes shall be separated, to promote mixing. Poor water circulation and long detention times may lead to loss of disinfectant residual, microbial growth, formation of disinfectant byproducts, taste and odor problems, and other water quality problems.
- The tank design engineer shall provide a computational fluid dynamics (CFD) model of the tank's inlet mixing system and outlet positioning.

2.11.5 Access

- Storage structures shall be designed with reasonably convenient access to the interior for cleaning and maintenance. At least two access hatches or manways shall be provided above the high waterline for each tank compartment.
- Elevated Storage or Dome Roof Structures
 - At least one access hatch or manway shall be framed a minimum of 100 mm above the surface of the roof at the opening. The access shall be fitted with a solid, water tight cover which overlaps the framed opening and extends down around the frame at least 50 mm ("shoebox style lid"), be hinged on one side, and have a locking device.
 - All other manways or access ports shall be water tight using bolted and gasketed means, or shall meet the requirements above.
- Ground Level or Flat Roof Structures
 - Each access hatch or man way shall be elevated at least 0.75 m above the top of the tank or covering, whichever is higher.
 - The accesses shall be fitted with a solid, water tight cover which overlaps the framed opening and extends down around the frame at least 50 mm, with a minimum 100 mm frame height ("shoebox style lid"). Each cover shall be hinged on one side and have a locking device.

2.11.6 Vents

- Finished water storage structures shall be vented. The overflow pipe shall not be considered a vent. Open construction between the sidewall and roof is not permissible. Vents:
 - A minimum of two shall be provided for each tank compartment.
 - Shall prevent the entrance of surface water and rainwater.
 - Shall exclude birds and animals; and shall exclude insects and dust, as much as this function may be made compatible with effective venting.
 - Shall, on ground-level structures, open downward with the opening at least 0.75 m above the roof and covered with a 5 mm and 2 mm stainless steel mesh screens. The screen shall be installed within the pipe at a location least susceptible to vandalism.
 - Shall, on elevated tanks and standpipes, open downward, and be fitted with a 4.76 mm and 1.410 mm screens or available finer mesh screen.

2.11.7 Roof and Sidewall

- The roof and sidewalls of all water storage structures shall be watertight with no openings except properly constructed vents, manways, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow. Particular attention shall be given to the sealing of roof structures which are not integral to the tank body.
 - Any pipes running through the roof or sidewall of a metal storage structure shall be welded, or properly gasketed.
 - Openings in the roof of a storage structure designed to accommodate control apparatus or pump columns, shall be curbed and sleeved with proper additional shielding to prevent contamination from surface or floor drainage.



- The roof of the storage structure shall be well drained. Drainage downspout pipes shall not enter or pass through the reservoir. Parapets, or similar construction which would tend to hold water on the roof, are not allowed.

2.11.8 Safety

- Safety shall be considered in the design of the water storage structure. The design shall conform to pertinent laws and regulations of the area where the water storage structure is constructed.
 - Ladders, ladder guards, balcony railings, and safely located entrance hatches shall be provided where applicable.
 - Elevated tanks with riser pipes over 200 mm in diameter shall have protective bars over the riser openings inside the tank.
 - Railings or handholds shall be provided on elevated tanks where persons shall transfer from the access tube to the water compartment.
 - Confined space entry requirements shall be considered.

2.11.9 Painting and/or Cathodic Protection

- Proper protection shall be given to metal surfaces by cathodic protective devices and by paints or other protective coatings, or by both.
 - Paint systems shall meet NSF/ANSI Standard 61. Interior paint shall be applied, cured, and used in a manner consistent with the NSF/ANSI certification requirements. After curing, the coating shall not transfer any substance to the water which shall be toxic or cause taste or odor problems. Prior to placing into service, an analysis for volatile organic compounds is required to establish that the coating is properly cured. All paint systems shall be 100 % solids coatings.
 - Wax coatings for the tank interior are not allowed.
 - A corrosion specialist shall evaluate the water chemistry and provide a written report and recommendations for a cathodic protection system. Cathodic protection, if required, shall be designed and installed by competent technical personnel (per AWWA), and a maintenance contract shall be provided.

2.12 Leakage Control

- Leakage could be avoided by giving proper consideration to corrosion control and pressure control measures.

2.12.1 Corrosion Control

- A proper material choice can reduce corrosion. Several alternative materials shall be compared based on the cost, availability, ease of installation and maintenance, as well as resistance to corrosion
- Network design shall be carried out keeping in view the following consideration to make system more resistant to corrosion
 - Avoid dead ends and stagnant areas,
 - Provision of adequate drainage where needed
 - Selection of an appropriate flow velocity,
 - Selection of an appropriate metal thickness,
 - Reduction of mechanical stresses,
 - Avoiding sharp bends and elbows,
 - The elimination of grounding electrical circuits in the system,
 - Providing easy access to the structure for periodic inspection, maintenance and replacement of damaged parts.



- Cathodic protection could be used for corrosion protection based on the pipe material selection. Cathodic protection is an electrical method for preventing metallic corrosion. It forces the protected metal to behave as a cathode and therefore unable to release electrons.
- Corrosion can be kept away from the pipe wall if it is lined with a protective coating. The linings are usually applied mechanically, either during the manufacturing process or before pipe laying. The most common pipe linings are:
 - epoxy paints,
 - cement mortar,
 - Polyethylene.
- Epoxy paints are used for steel and DI pipes. Cement mortar is a standard lining for DI pipes, sometimes used for steel and cast iron. Polyethylene coating is used for DI and steel pipes.
- Inhibitors could be added in water to reduce corrosion. Chemicals added to the water that form a protective film on the pipe surface are called inhibitors. Inhibitors provides a barrier between the water and the pipe, which reduces corrosion. Various products are used for this purpose, which can be classified in three main groups:
 - Chemicals which cause CaCO_3 formation,
 - Inorganic phosphates,
 - Sodium silicate.

2.12.2 Pressure Control

- Water network shall be divided into different isolated zone for better control of pressure.
- Pressure reducing valves could be used to control the pressure in isolated parts of networks if it becomes too high.
- A surge analysis modeling must be performed then followed by the design of a surge control system that is in accordance with the results of the surge analysis.

2.12.3 Rocker Pipe

- Both rigid and flexible pipelines are vulnerable to ground movements as a consequence of the significant levels of stress induced in them. Any form of unanticipated differential ground movements between a structure on a yielding foundation and a pipeline attached to it, can further exacerbate the stresses in the pipeline to unacceptable levels. Therefore, rocker pipe shall be used for all pipe chamber to counter the impact of unanticipated differential ground movements

3.0 SANITARY SEWER SYSTEM

3.1 General

This Section provides the basis for the design of sewer utilities. The sewer utilities include the collection and conveyance systems.

3.2 Sewer Force Main System

- The Sewer Force Main Systems are the main systems which convey raw sewage from lift stations to the wastewater treatment plants.
- The Sewer Force Main systems include:



- Sewage Lift Stations
- Sewage force mains

3.3 Sewer Collection System

- The Sewer Collection Systems collect sewage from residences and businesses and convey it to the sewage lift stations.
- The Sewer Collection Systems use gravity flow and pumped systems; both operate in open channel flow conditions.
- The Sewer Collection Systems include:
 - Gravity flow sewage collection pipelines
 - Collection pumps
 - Sewage pipelines

3.4 Sanitary Sewer Design Flow Criteria

3.4.1 General

- This Section provides the general design criteria for calculation of Average Daily Flow (ADF) rate.
 - Peaking factors shall be applied to the ADF to size key infrastructure associated with the sewage collection system.
- The A/E shall be aware of the likelihood for high groundwater. This shall be accounted for with design to prevent flotation of pipes and manholes.

3.4.2 Sewage Production

- Determination of Average Daily Sewer Flow (ADF)
ADF is to be equal to the indoor Average Day Water Demand
 - There is no infiltration factor.
 - This applies to residential, commercial, and industrial per capita flows.
 - Do not include industrial process flows as the industrial waste water is collected by a separate system
 - A/E shall consider infiltration from the ground into the collection system
 - Infiltration calculations shall follow US EPA guidelines, and shall be based on depth of pipe, location of groundwater table (if any), pipe type and number of joints, and soil and other external load conditions.
- Low Flow
 - Low flow evaluations shall be conducted as needed for areas throughout the collection system that may have issues caused by solids deposition.
 - Use 25% of the ADF to calculate low flow.
- Peak Design Flow
 - Sanitary Sewer Line Sizing Peaking Factors (PFs)
 - For gravity line sizing calculations, peaking factors shall be used.

3.5 Hydraulic Modeling

3.5.1 Purpose

- Hydraulic modeling shall be used as a design tool to evaluate new and existing development as it relates to the design of sewer system improvements.
 - There are two types of hydraulic evaluations that shall be evaluated with the design of the sewer collection system, as follows:
 - Gravity collection shall be calculated using an appropriate network model that shall complete required flow calculations based on user inputs.



- Modeling software is recommended as it provides great flexibility for modifications based on changes to land development plans.
 - Force main evaluations may be completed using a modeling software or by separate spreadsheet calculations based on the Hazen-Williams formula.
- Effects on existing systems shall be evaluated if appropriate.
- Urban Development Plans
 - Hydraulic modeling shall be completed based on the approved Urban Development Plan and shall be included in the "Utility Load Requirement."

3.5.2 Modeling Software

- Modeling may be completed in standalone, CAD integrated, or GIS integrated modeling platforms. Acceptable modeling software include:
 - SewerCAD or SewerGEMS (Bentley)
 - H2OMAP Sewer, InfoSewer, InfoWorks ICM SE, or H2ONET (Innovyze)

3.5.3 Required Modeling Scenarios

- Sewer collection models shall be completed for the low flow, average daily flow, and peak design flow scenarios.
- Flows shall be spatially allocated based on the area where flow is generated.
- Evaluations based on phasing of the Urban Development plan to identify potential low flow problem areas.

3.5.4 Model Setup

- Hydraulic distribution models shall consist of pipes, nodes, and lift stations.
- Pipes
 - Diameter
 - Diameter shall be input for every pipe
 - Input of nominal diameters is allowable for most sewer line materials including PVC and rigid HDPE.
 - Actual inside diameters shall be used for evaluation of HDPE PE 100 sewer lines.
 - Friction Coefficient
 - Models shall be configured to evaluate the sewer collection system based on the Manning equation for calculating open channel flow. The Manning's roughness coefficient shall be 0.013 for all pipe materials.
 - Length
 - Models shall be created to scale to ensure accurate length of sewer lines.
- Nodes (Manholes)
 - Elevations
 - Rim and invert elevations shall be assigned to the thousandth of a meter (0.001).
- Lift Stations
 - Floor Elevation within 0.5 m.
 - Pump Curves – if using the distribution model to confirm pump selection, actual pump curves shall be entered into the model.



3.5.5 Hydraulic Model Reporting

3.5.5.1 The following Table of Contents shall be used when submitting a Hydraulic Modeling Report:

- Introduction – Include a project description, existing system discussion, and proposed additions of the project.
 - Include a vicinity map to show how the development relates to existing sanitary sewer systems.
 - Include a system map to illustrate proposed expansion area and land uses.
- Sewage Flow Criteria & Summary
 - Summarize flow calculations for ADF; by land use for the generated sewer flow. Include detailed calculations in an Appendix.
 - Include infiltration rates.
 - Confirm applicability of peaking factors for sewage flows based on specific project requirements.
- Methodology and Analysis – Document the modeling software used, the type of model (steady state or extended period), assumptions, field measurements, and calibration, if any.
- Results and Conclusions
 - Document that results for scenarios meet the requirements of this manual for minimum velocity and depth of flow.
 - Document pipes with potential concerns related to low flow scenario
 - Include a system map illustrating final pipe sizes based on the model
 - Map shall include labels for all model elements such as nodes and pipes
 - Map shall be color coded based on pipe diameter
 - Map shall include background layers for proposed development including roads and land uses
 - Input file used for modeling and the output/model files shall be submitted to entity.

3.6 Gravity Sewer Collection System Piping

3.6.1 Gravity Sewer Lines

3.6.1.1 General Design Requirements

- This Section applies to gravity sewers.
- No gravity sewer line shall be less than 200 mm in diameter.
- In general, sewers shall be sufficiently deep to receive sewage from the lowest floor level of adjacent development. Minimum burial depth to top of pipe shall be 1.0m.
- Trunk sewers are defined as primary infrastructure. Minimum burial depth for trunk sewers shall be 2.5m; maximum burial depth shall be 6 m.
- The depth of flow in the sanitary sewer pipes through 375 mm in diameter shall not exceed 0.5D where D is the nominal diameter of the pipe. The depth of flow in a sanitary sewer greater than 375 mm in diameter shall not exceed 0.75D. Sewage collection systems for a given area shall be sized to carry the peak design flow from the entire tributary area at build-out, even if the tributary area is not within the project boundaries.
- Buoyancy of sewers shall be considered and flotation of the pipe shall be prevented with appropriate means where high groundwater conditions are anticipated.
- All sewers shall be designed to prevent damage from superimposed live and dead loads. Proper allowance for loads on the sewer shall be made because of soil and potential groundwater conditions, as well as the width and depth of trench. Where necessary, special bedding, haunching and initial backfill, concrete cradle, or other special construction shall be used to withstand anticipated potential superimposed loading or loss of trench wall stability. Refer to ASTM D2321.
- Slopes



- All sewers shall be designed and constructed to give mean velocities, when flowing half full, of not less than 0.6 m/sec, based on Manning's formula using an "n" value of 0.013.
- Rigid sewer pipes larger than 300 mm shall be designed and constructed to give mean velocities, when flowing full, of not less than 0.9 m/sec, based on Manning's formula using an "n" value of 0.013.
- The pipe diameter and slope shall be selected to obtain the greatest practical velocities to minimize settling problems. Oversize sewers shall not be approved to justify using flatter slopes. If the proposed slope is less than the minimum slope of the smallest pipe which may accommodate the design peak flow, the actual depths and velocities at minimum, average, and design (peak) maximum daily flow for each design section of the sewer shall be calculated by the design engineer and submitted for review.
- Sewers shall be laid with uniform slope between manholes.
- Where velocities greater than 4.5 m per second are attained, special provision shall be made to protect against displacement by erosion and impact.
- Alignment
 - Sewers shall be laid with straight alignment between manholes.
 - Curvilinear sewers are not permitted.
- Location
 - Shall be located outside of the asphalt travel lanes and shoulder section of the roadway.
- Changes in Pipe Size
 - When a smaller sewer joins a larger one in a manhole, the invert of the larger sewer shall be lowered sufficiently to maintain the same energy gradient. To approximate this, place the 0.8 depth point of both sewers at the same elevation.
- Joints
 - Sewer joints shall be designed to minimize infiltration and to prevent the entrance of roots throughout the life of the system.

3.6.1.2 Acceptable Pipe Materials

- Polyvinyl Chloride Pipe (PVC) (gravity and pressure pipe)
 - Sizes 200 mm to 1050 mm
- A-2000 PVC Sewer Pipe (gravity pipe only)
 - Sizes 200 mm to 900 mm
- High Density Polyethylene Pipe (HDPE) (pressure pipe only)
 - Sizes 200 mm to 1050 mm

3.6.2 Manholes

3.6.2.1 General Design Requirements

- Location
 - Manholes shall be installed: at the end of each line; at all changes in grade, size, or alignment; and at all intersections.
 - Manholes shall be installed: at distances not greater than 120 m for sewers 375 mm or less, 150 m for sewers 450 mm to 750 mm, and 180 m for sewers larger than 750 mm.
 - Cleanouts may be used only for special conditions and shall not be substituted for manholes nor installed at the end of laterals greater than 45 m in length.
- Drop Type
 - A drop pipe shall be provided for a sewer entering a manhole at an elevation of 600 mm or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 600 mm, the invert shall be filleted to prevent solids deposition.
 - Drop manholes shall be the "outside drop" style.
- Diameter
 - For sewer lines up to 450 mm, the minimum diameter of manholes shall be 1200 mm.



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- For sewer lines between 525 mm and up to 750 mm, the minimum diameter of manholes shall be 1500 mm.
- For sewer lines between 825 mm and up to 1050 mm, the minimum diameter of manholes shall be 1800 mm.
- A minimum access diameter of 750 mm shall be provided.
- Flow Channel
 - For lines smaller than 300 mm, the maximum change in angle of the flow path through a manhole shall not exceed 90-degrees.
 - For lines 300 mm and larger, the maximum change in angle of the flow path through a manhole shall not exceed 45-degrees.
 - For a change in angle of the flow path between 0-degrees and 25-degrees, the grade through the manhole shall be no less than the grade of the downstream pipe.
 - For a change in angle of the flow path between 25-degrees and 75-degrees, the grade drop through the manhole shall be 30 mm.
 - For a change in angle of the flow path between 75-degrees and 90-degrees, the grade drop through the manhole shall be 60 mm.
- Bench
 - A bench shall be provided on each side of the manhole channel.
 - The bench shall be sloped no less than 5%.
 - No lateral sewer, service connection, or drop manhole pipe shall discharge onto the surface of the bench.
- Water Tightness
 - Inlet and outlet pipes shall be joined to the manhole with a gasketed flexible watertight connection that allows differential settlement of the pipe and manhole wall to take place.
 - Watertight manhole covers are to be used wherever the manhole tops may be flooded by street runoff or high water.
 - Locked manhole covers may be desirable in isolated easement locations or where vandalism may be a problem.

3.6.2.2 Acceptable Manhole Materials

- Glass-Fiber Reinforced Polymer FRP
- (FRP) Manholes or equivalent
 - Per ASTM D3753.
 - H-20 wheel load rating.
 - Connections shall be watertight compression connections per manufacturer recommendations, or approved equal.
 - Resin and glass fiber reinforced manhole bottoms required.
 - Invert and bench shall be factory installed utilizing non-corrosive materials encapsulated in fiberglass a minimum of 25 mm thick.
 - Manholes shall be anchored to counteract buoyancy forces. Anchors shall be design for project specific applications.
 - Gel-coat, paint, or other coatings are not allowed.

3.6.3 Service Connections

3.6.3.1 General Design Requirements

- Service connections to the sewer main shall be water tight and not protrude into the sewer. If a saddle type connection is used, it shall be a device designed to join with the types of pipe which are to be connected. All materials used to make service connections shall be compatible with each other and with the pipe materials to be joined and shall be corrosion proof.
- Service tap inverts shall be above the crown of the sewer main, and extend perpendicular to the main.
- All abandoned sewer service taps shall be capped.
- Service connections (laterals) 200 mm and larger shall be made only at a manhole.



- Service connections on lines 375 mm and larger shall be installed directly into a manhole, with no more than four taps in a single manhole.
- Laterals shall have a minimum slope of 2%.
- Clean outs shall be provided at the property line, and in locations and at a spacing as required by the IPC.

3.6.3.2 Pressure Sewer Laterals

- In locations where buildings cannot be discharged to the sewer main by a gravity flow lateral, flows may be pumped by automatic pumping equipment and discharged into a gravity flow lateral; connecting at the main, or connecting in a manhole, with an approved restrained coupling(s).
- Pumping equipment and pressure sewer laterals shall be designed to meet or exceed the anticipated use requirements.
- The total maximum system head shall not exceed the pump manufacturer's recommended allowable head for the pump system being proposed.
- Pressure sewer laterals shall be constructed of HDPE.
- Pressure sewer laterals shall be sized to provide a minimum velocity of 0.6 m/sec at the design pumping rate.
- Pressure sewer laterals shall be designed and constructed on a constant reverse grade.

3.6.4 Low Pressure Sewer (LPS) Systems

- These systems may be allowed on a case by case basis.
- If allowed, specific design requirements shall be per manufacturer requirements and recommendations.

3.7 Sewage Pumping Stations

3.7.1 General

- Sewage pumping station structures and electrical and mechanical equipment shall be protected from physical damage by the 100-year flood. Sewage pumping stations shall remain fully operational and accessible during the 25-year flood.
- The pumping station shall be readily accessible by maintenance vehicles during all weather conditions. The facility shall be located off the traffic way of streets and alleys. Security fencing and access hatches with locks shall be provided.
- Where it is necessary to pump sewage prior to grit removal, the design of the wet well and pump station piping shall receive special consideration to avoid operational problems from the accumulation of grit.
- Adequate provision shall be made to effectively protect maintenance personnel from hazards. Equipment for confined space entry in accordance with OSHA and regulatory agency requirements shall be provided for all sewage pumping stations.
- Submersible pump type sewage lift stations are the only type permitted whereas wet well/dry well type, suction lift type, and screw pump type pumping stations are not allowed).
- Mechanical and electrical rooms shall be completely separated from the wet well. Common walls shall be gas tight.
- Provision shall be made to facilitate removing pumps, motors, and other mechanical and electrical equipment. Individual pump and motor removal shall not interfere with the continued operation of remaining pumps.
- Where high groundwater conditions are anticipated, buoyancy of the wastewater pumping station structures shall be considered and, if necessary, adequate provisions shall be made for protection.
- Materials shall be selected that are appropriate under conditions of exposure to hydrogen sulfide and other corrosive gases, greases, oils, and other constituents present in wastewater. This is particularly important in the selection of metals and paints. Contact between dissimilar metals shall be avoided or other provisions made to minimize galvanic action.



- Alarm systems with a backup power source shall be provided for sewage lift stations. The alarm shall be activated in cases of power failure, if the pump fails to shut off in a low wet well sump and wet well high water levels, pump failure, unauthorized entry, or any other cause of pump station malfunction.
- Sewage lift stations and portable equipment shall be supplied with a complete set of operational instructions, including emergency procedures, maintenance schedules, tools and such spare parts as may be necessary.

3.7.2 Pumps

- All pumps shall be close-coupled, submersible, radial flow centrifugal pumps.
- Motors, (both constant and variable speed) shall not be loaded to use more than 80 percent of the rated capacity of the motor, measured in kilowatts.
- The design engineer shall submit system-head calculations and curves. System-head curves for C values of 100, 120 and 140 in the Hazen William's equation for calculating head loss corresponding to minimum, median and maximum water levels shall be developed.
- With the largest pump out of service, the pumping system including the discharge piping and mains shall be designed to pump a minimum of four times the average daily flow when the average daily flow is less than 3,500 m³/day.
- With the largest pump out of service, the pumping system including the discharge piping and mains shall be designed to pump a minimum of 2.5 times the average daily flow when the average daily flow is greater than 3,500 m³/day.
- Pumps shall be selected that provide at least 75% efficiency at the anticipated average flow during all phases of expansion.
- Multiple pumps shall be provided. Where only two units are provided, they shall be of the same size.
- The pumps and controls shall be selected to operate at varying delivery rates. Pump stations shall be designed to deliver as uniform a flow as practicable in order to minimize hydraulic surges.
- Pumps handling sewage from 750 mm or larger diameter sewers shall be protected by bar racks (35 mm maximum clear opening). Appropriate protection from clogging shall also be considered for small pumping stations.
- Pumps shall be capable of passing spheres of at least 80 mm in diameter. Pump suction and discharge openings shall be at least 100 mm in diameter.
- The pump shall be so placed that under normal operating conditions it shall operate under a positive suction head.
- Pumps shall be readily removable and replaceable (with a dedicated, permanently mounted motorized crane) without personnel entering or dewatering the wet well, or disconnecting any piping in the wet well.
- Each pump shall have an individual intake. Wet well and intake design shall be such as to avoid turbulence near the intake and to prevent vortex formation.
- Water level control sensing devices shall be so located as not to be unduly affected by turbulent flows entering the well or by the turbulent suction of the pumps.
- Provision shall be made to automatically alternate the pumps in use.

3.7.3 Pump Station Piping, Valves and Flow Meters

- Piping shall be fusion-bonded epoxy-lined and coated steel piping with flanged joints. All fasteners used for joining pipes shall be stainless steel.
- All discharge valves on the force main(s) shall be installed above grade and adjacent to the wet well.
- Suitable shutoff and air-cushioned swing check valves shall be placed on the discharge line of each pump. The check valve shall be located between the shutoff valve and the pump. Check valves shall be suitable for the material being handled and shall be placed on the horizontal portion of discharge piping. Outside levers are recommended on swing check valves.
- All shut-off/isolation valves shall be full-port eccentric plug valves.
- The pump station shall include piping, valves and quick-connect couplings to allow bypass pumping from the wet well to the force main using a portable pump.



- Flow meters shall be provided at all pumping stations. Indicating, totalizing, and recording flow measurement shall be provided at pumping stations.

3.7.4 Air Valves

- Air valves shall be designed specifically for sewage applications shall have screwed ends, and backflush attachments.
- Valve bodies and all moving metal parts shall be Type 316 stainless steel.
- In pump stations:
 - A combination air valve shall be installed on the vertical leg of a T-fitting on the discharge piping prior to any other valve. Additionally, an air release valve shall be installed downstream the check valves and upstream of the flow meter, again on the vertical leg of a T-fitting. The air release outlet shall be piped back to the wet well for discharge.
- On force mains:
 - An air relief valve shall be placed at high points in the force main to prevent air locking. Vacuum relief valves may be necessary to relieve negative pressures on force mains. The force main configuration and head conditions shall be evaluated as to the need for and placement of vacuum relief valves.
 - Air release valves on force mains outside the pump station shall have odor control and a method of disposing of the moisture released with the air.

3.7.5 Wet Wells

- Where continuity of pumping station operation is critical, consideration shall be given to dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning.
- The design fill time and minimum pump cycle time shall be considered in sizing the wet well. The effective volume of the wet well shall be based on design average flow and a filling time not to exceed 30 minutes. The pump(s) shall cycle between 2 and 6 times per hour.
- The pump manufacturer's duty cycle recommendations shall be utilized in selecting the minimum cycle time. When the anticipated initial flow tributary to the pumping station is less than the design average flow, provisions shall be made so that the fill time indicated is not exceeded for initial flows.
- The "pump off" level shall be high enough to keep the pumps submerged per manufacturer's recommendations and prohibit vortexing. The "pump on" level shall be set no higher than 0.3 meters below the invert of the lowest influent pipe
- The wet well floor shall have a minimum slope of 1 to 1 to the hopper bottom. The horizontal area of the hopper bottom shall be no greater than necessary for proper installation and function of the inlet.
- Wet wells shall be lined with a material that is suitable for immersed sewer service. The lining shall be completely resistant to hydrogen sulfide and sulfuric acid.
- Wet wells shall also have a corrosion resistance and waterproofing system installed on the exterior of the wet well.
- Provide an access hatch with safety chains above the pumps in the top of the wet well. Hatch shall be at least a two leaf design with enough area to safely and easily remove the pumps
- Covered wet wells shall have provisions for air displacement to the atmosphere, such as an inverted "j" tube or other means.

3.7.6 Ventilation

- Adequate ventilation shall be provided for all pump stations. If screens or mechanical equipment requiring maintenance or inspection are located in the wet well, permanently installed ventilation is required. There shall be no interconnection between the wet well and other ventilation systems.
- All intermittently operated ventilation equipment shall be interconnected with the respective pit lighting system.
- The fan wheel shall be fabricated from non-sparking material. Automatic heating and dehumidification equipment shall be provided in all dry wells.
- Ventilation may be either continuous or intermittent. Ventilation, if continuous, shall provide at least 12 complete air changes per hour; if intermittent, at least 30 complete air changes per hour. Air shall be



forced in by mechanical means rather than solely exhausted. The air change requirements shall be based on 100 percent fresh air.

3.7.7 Emergency Operation

- Emergency pumping capability is required unless on-system overflow prevention is provided by adequate storage capacity. Emergency pumping capability shall be accomplished by connection of the station to at least two independent utility substations, or by provision of portable or in-place generator that has sufficient capacity to start up and maintain the total rated running capacity of the station.
- Regardless of the type of emergency standby system provided, a portable pump connection to the force main with rapid connection capabilities and appropriate valving shall be provided outside the dry well and wet well.

3.7.8 Yard Piping

- A potable water supply is required at all pump stations to supply yard hydrants, hose bibs and emergency shower and eyewash systems.
- At least three yard hydrants shall be installed. One shall be installed near the wet well, in a location that provides sufficient slack for work in and around the wet well but that does not hinder efforts to pull pumps or maintain valves.
- In addition to yard hydrants and racks, combination eye wash and emergency shower stations shall be installed where appropriate. All combination eye wash and emergency shower stations shall be installed with a concrete pad and drain and anti-scald valve.
- There shall be no physical connection between any potable water supply and a sewage pumping station which under any condition might cause contamination of the potable water supply. The potable water supply to a pumping station shall be protected against cross connection or backflow.

3.7.9 Odor Control

- All stations shall have an odor control system. This system typically has two components: a component for treating foul air from the head space in the wet well and a component for preventing odors at the force main discharge and further downstream.

3.7.10 Force Mains

- At design pumping rates, a minimum velocity of at least 1.0 m/s shall be maintained. Maximum velocity shall not exceed 2.1 m/s.
- The minimum force main diameter shall not be less than 100 mm.
- Force mains shall maintain a positive uphill slope from the pump output to the manhole receiving the force main discharge. Changes in force main slope and direction shall be minimized. To limit accumulations of gases, no segment of a force main shall have a zero slope. Low points which are subject to solids accumulation shall be avoided.
- Force mains shall be designed with a minimum depth of 2 m cover over the top of the pipe.
- The force main shall enter the receiving manhole with a smooth flow transition to the gravity sewer system at a point not more than 0.3 m above the flow line.
- Friction losses through force mains shall be based on the Hazen and Williams formula; using a “C” = 140, “C” = 120, and “C” = 100 to demonstrate the performance of force mains at start-up and after extended service.
- Acceptable Pipe Materials:
 - HDPE pipe



4.0 STORMWATER DRAINAGE

4.1 General

- This subsection provides the basis for the design of site stormwater drainage facilities.
- Hydrologic and hydraulic engineering shall be required for the design of all surface and subsurface drainage systems.

4.2 Storm Water Infrastructure System

4.2.1 Storm Water Description

- The following storm drain features in Storm Water Infrastructure System:
 - Site Drainage
 - Overland Flow Facilities (Curb and Gutter)
 - Underground Facilities (Pipes)
 - Drainage Channels

4.3 Design Criteria

4.3.1 Hydrologic Methodologies

4.3.1.1 Summary of Hydrologic Modeling Requirements

Hydrologic modeling shall consist of the following steps:

- Drainage Basin Delineation, all contributing drainage area shall be delineated including off-site drainage. Drainage basin boundaries shall be realistic and based on topographic conditions, grading, fill material, and other drainage structures in the area.
- Time of Concentration Calculation, the time of concentration of each drainage basin shall be determined using the TR-55 methods for sheet flow and shallow concentrated flow.
- Runoff Loss Coefficient Determination, runoff loss coefficients (or Curve Numbers) shall be determined based on soil type and land-use.
- Design Rainstorm Determination, design rainstorms and return intervals shall be determined based on drainage basin size and modeling application.
- Hydrologic Modeling and Routing, build the hydrologic model and determine design discharges. The appropriate modeling technique must be determined based on drainage basin size and design application. Refer to appropriate modeling methodologies below.

4.3.1.2 Rational Method

The rational method may be used for designing small sites (≤ 8 hectares) as shown in **TABLE 3.1**. This method requires the following:

- Rainfall Intensity at the basin time of concentration.
- Runoff coefficient “C”.
- Drainage basin area.
 - Equation for calculating peak discharge

$$Q = \frac{CiA}{360}$$

$$Q = \text{Peak flow, m}^3/\text{s}$$

$$i = \text{Rainfall intensity, mm/hr}$$

$$C = \text{Runoff coefficient, dimensionless}$$

$$A = \text{Drainage area, hectares}$$



TABLE 3.1: HYDROLOGIC DRAINAGE MODELING REQUIREMENTS

Application	Computation Procedure
Secondary Drainage Systems; Drainage Area ≤ 8 hectares	Rational Method, HEC-HMS (SCS Unit Hydrograph or Kinematic Wave), HEC-RAS, TR-20 or TR-55
Primary Drainage Systems	HEC-HMS (SCS Unit Hydrograph or Kinematic Wave), HEC-RAS, TR-20 or TR-55
Secondary Drainage Systems; Drainage Area > 8 hectares	HEC-HMS (SCS Unit Hydrograph or Kinematic Wave), HEC-RAS, TR-20 or TR-55
Detention Ponds	HEC-HMS (SCS Unit Hydrograph or Kinematic Wave), HEC-RAS, TR-20 or TR-55

- **Time of Concentration:** Time of Concentration is necessary to determine design rainfall intensity. Time of concentration shall be calculated using the NRCS methodology for sheet flow, shallow concentrated flow, and Manning's equation for channel flow.

- **Sheet Flow:** Sheet flow is generally found in the upper reaches of a watershed during the rainfall event and is usually 50 to 150 m in length.

$$Sheet\ Tc = \frac{0.0912(nL)^{0.8}}{(P_2)^{0.5}S_f^{0.4}}$$

Sheet Tc = Time of concentration, (hours)

n = Manning's roughness coefficient for overland flow

L = flow length, m

P₂ = 2 – year, 24 – hour rainfall, mm

S_f = Land slope, m/m

- **Shallow Concentrated Flow:** Shallow concentrated flow generally consists of concentrated drainage in gutters, channels, waterways or rills. There are two different equations:

Unpaved Surfaces:

$$Shallow\ Tc = \left(\frac{L_f}{4.907 * S_f^{0.5}} \right) \left(\frac{1hr}{3600\ sec} \right)$$

Paved Surfaces:

$$Shallow\ Tc = \left(\frac{L_f}{6.1961 * S_f^{0.5}} \right) \left(\frac{1hr}{3600\ sec} \right)$$

Shallow Tc = Time of concentration, hours

L_f = flow length, m

S_f = Slope, m/m

- **Channel Flow:** Channel flow is assumed to begin in major drainage basins where large channel cross-sections may be defined. The travel time within channels is calculated using Manning's equation for open channel discharge:

$$Velocity\ is\ calculated\ using: V = \left(\frac{1}{n} \right) \left(\frac{A}{P} \right)^{\frac{2}{3}} (S)^{\frac{1}{2}}$$



n = Manning coefficient of roughness

A = Cross Sectional Area of Flow (m^2)

P = Wetted Perimeter of Flow (m)

S = Slope of Channel (m/m)

V = Average Velocity of Flow (m/s)

Travel Time is calculated using:

$$\text{Channel } T_c = \left(\frac{L}{V}\right) \left(\frac{1hr}{3600 sec}\right)$$

L = Length of Channel (m)

V = Average Velocity of Flow (m/s)

T = Wetted Perimeter of Flow (m)

S = Slope of Channel (m/m)

- Total Time of Concentration:

$$\text{Total } T_c = \text{Sheet } T_c + \text{Shallow } T_c + \text{Channel } T_c$$

- Rainfall Intensity for Rational Calculations

Use the set of IDF curves that has already been developed or entity to develop IDF for the development.

4.3.1.3 SCS (NRCS) Method (HEC-HMS)

- The SCS method shall be used for designing:
 - Larger Sites (> 8 hectares)
 - Primary Drainage Channels
 - Detention Ponds
- For modeling watersheds using the SCS curve number method, use a software package such as HEC-HMS to generate hydrographs. This method requires the following input:
 - Rainfall depth and rainfall distribution.
 - Drainage basin curve number.
 - Time of concentration (lag time).

- Equation for Calculating Runoff Volumes:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

Q = Runoff (mm)

P = Rainfall (mm)

S = Potential Maximum Retention after Runoff Begins (mm)

Ia = Initial Abstraction (mm)

$$Ia = 0.2 * S$$

$$S = \frac{1000}{CN} - 10$$

CN = Curve Number

- Rainfall
 - Depth: Use the rainfall depth data has already been developed or entity to develop IDF for the development
 - Temporal Distribution: The SCS types curve shall be adopted which is developed by entity for the development.



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- Curve Numbers
 - Curve number shall be based on land-use and soil type and Antecedent Moisture Content (AMC).
- Lag Time
 - The SCS method requires the input of Lag Time and not Time of Concentration. Lag Time is calculated using the following equation:

$$\text{Lag Time} = 0.6 * T_c$$

T_c = Total Time of Concentration

4.3.2 Hydraulic Modeling

- Refer to

TABLE for freeboard requirements and hydraulic design criteria.

TABLE 3.2 HYDRAULIC DESIGN CRITERIA

Purpose	Criteria
Primary Drainage Channels	Capacity for a 50-year event with no freeboard. Floodplain storage up to a 100-year event with 0.3 m of freeboard up the adjacent property lines.
Secondary Drainage Underground Facilities (pipes)	Capacity for 25-year event with no surcharge
Secondary Drainage Overflow Channel (curb and gutter)	100-year overflow capacity with adequate freeboard and no excessive gutter spread.
On – site (upstream of detention basins)	Design for 10-year storm storage capacity
Detention Basins	100-year event with 0.3 m of freeboard up to the top of the impoundment and an emergency overflow structure to handle the peak 100-year 24-hour inflow discharge.
Industrial Water Quality/First Flush Ponds	Collect the first 30 mm of rainfall and maintain at least 0.3 m of freeboard up to the top of the impoundment.
Water Quality/First Flush Ponds	Collect the first 30 mm of rainfall
On-site (up-stream of inlet boxes)	10-year storm event

Refer to Table 3.3 for the required hydraulic computations based on the design application.



TABLE 3.3 HYDRAULIC MODELING METHODOLOGIES

Application	Computation Procedure
Secondary Drainage Systems; Drainage Area ≤ 8 hectares	Manning's Modified equation.
Secondary Drainage Systems; Drainage Area > 8 hectares	Dynamic Storm Drain Network Modeling (SWMM)
Primary Drainage Systems	Gradually Varied Flow (HEC-RAS) or Dynamic Storm Drain Network Modeling (SWMM)

- Manning's Modified Equation for Gravity Flow
 - Manning's equation for gravity flow may be used to design site storm drain lines and open channels, in normal flow regime, for small drainage areas.

$$Q = \frac{1}{n} (AR^{2/3}S^{1/2})$$

Q = Peak flow, m^3/s

A = Area of flow at right angle to direction of flow, m^2

R = Hydraulic radius, m

S = Slope of grade, m/m

n = Coefficient of roughness

- Gradually Varied Flow Analysis
 - For designing large primary drainage channels more detailed modeling methods are required. Manning's equation for gravity discharge is not an acceptable modeling technique and the assumption of normal depth is not appropriate. HEC-RAS is the suggested model because it is the most commonly adopted hydraulic model in the industry, readily available and can simulate a variety of flow inputs and drainage structures such as tide gates.
- Dynamic Storm Drain Network Modeling
 - For designing large storm drain networks, a dynamic hydraulic model such as SWMM shall be used to determine pipe capacity and manhole surcharge depths.
 - Other dynamic flow routing models may be used.

4.3.3 Stormwater Quality

- First Flush Ponds
 - Water quality control ponds known as first flush ponds are required for all industrial drainage areas.
 - Ponds shall collect the first 30 mm of rainfall from each event. After the collection of the first flush, any additional rain falling on industrial process areas may be diverted directly into the storm drainage system.
 - First flush ponds shall be lined so that they are completely impervious.
 - Industrial areas must meet all Environmental Regulations regarding drainage and stormwater retention.

4.3.4 Overland Relief

- Overland Relief for Storm Drain Overflows
 - All storm drain structures shall be designed to accommodate storm drainage overflows which could result from an obstructed storm drain line for a 10-year storm event.
 - Storm drainage overflows shall be routed via overland flow, drainage swales, or roadway drainage conveyance that eventually connect to a primary drainage channel.



- All storm drain designs shall show the flow routes and eventual discharge point of all drainage overflows. These flow routes must accommodate all locations where a storm drain obstruction could occur.
- Finished grading shall be such that any storm drain overflows are routed away from buildings or structures.
- Storm drain overflows which use overland flow as a conveyance shall be lined with grass, pavement or other erosion protection measures.

4.4 Drainage Systems and Structures

4.4.1 Culverts

4.4.1.1 General Design Requirements

- Minimize storm drain pipelines size is 300 mm.
- Minimum burial depth to top of pipe shall be 1.2 m. Maximum burial depth shall be 4.0 m, unless project specific approval for deeper depths is granted.
- Buoyancy of storm drain shall be considered and flotation of the pipe shall be prevented with appropriate means where high groundwater conditions are anticipated.
- All storm drain shall be designed to prevent damage from superimposed live and dead loads. Proper allowance for loads on the storm drain shall be made for soil and potential groundwater conditions, as well as the width and depth of trench. Where necessary, special bedding, haunching and initial backfill, concrete cradle, or other special construction shall be used to withstand anticipated potential superimposed loading or loss of trench wall stability. Refer to ASTM D 2321.
- Slopes
 - For calculations which assume that the pipe is flowing full.
 - A minimum velocity of 1.0 m/s is required.
 - This requirement results in a 0.6 m/s velocity when the flow depth is 25% of the pipe diameter,
 - Storm drains shall be laid with uniform slope between manholes.
 - Where the engineering design results in velocities greater than 4.5 m/s special provisions shall be made to protect against displacement by erosion and impact.
- Alignment
 - Storm drains shall be laid with straight alignment between manholes.
 - Curvilinear storm drains are not permitted.
- Location
 - Shall be located within roadways where possible.
- Bedding and Backfill
 - Continuous and uniform bedding shall be provided in the trench for all buried pipe. Stones larger than the backfill materials described below shall be removed for a depth of at least 150 mm below the bottom of the pipe.
 - Backfill material shall be compacted in layers around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe.
 - Backfill material with a maximum particle size of 20 mm shall be used to surround the pipe.
- Acceptable Pipe Materials
 - Designer shall select one of the following acceptable materials:
 - Polyvinylchloride (PVC) Pipe
 - Sizes 300 mm to 400 mm
 - SDR 35 or SDR 26
 - Per ASTM D3034
 - Gasketed sewer fittings
 - Sizes 450 mm to 1050 mm
 - PS46 or PS115
 - Per ASTM F679



- Gasketed sewer fittings
- Corrugated PVC Storm Sewer Pipe
 - Sizes 300 mm to 900 mm
 - Meet the requirements of ASTM F477, F949, F794, D1784, D2122, and D2412
 - Double-sealing gasketed joint, exceeding the requirements of ASTM D3212
 - 3 bar pressure rating
- Butt Fused HDPE
 - Per ISO 1167 and ISO 4427.
 - Sizes 300 mm to 1050 mm:
 - PE100 material
 - Cell classification of 445474C/E
 - Minimum pressure rating:
 - DR 26 (ISO 4427 pipe series)
 - PE 100 nominal working pressure = 6 bar
 - Pipe shall have four equally spaced, continuous longitudinal brown stripes.
 - Use of butt fused HDPE requires a minimum pipe slope of 1.00%.
- Double Wall Corrugated HDPE
 - Per ASTM F2306 and AASHTO M294, Type S
 - Joint to meet ASTM D3212
 - Sizes 300 mm to 1500 mm:
 - HDPE material
 - Cell classification of 435420C

4.4.2 Manholes and Junction Structures

4.4.2.1 General Design Requirements

- Steps are not permitted in manholes.
- Location
 - Manholes shall be installed at:
 - The end of each line
 - All changes in grade, size, or alignment
 - All intersections.
 - Manholes shall be installed at distances not greater than:
 - 120 m for storm drains 375 mm or less in diameter
 - 150 m for storm drains 450 mm to 750 mm in diameter
 - 180 m for storm drains larger than 750 mm in diameter.
 - Cleanouts may be used only for special conditions and shall not be substituted for manholes nor installed at the end of laterals greater than 45 m in length.
- Diameter
 - For storm drain lines up to 450 mm, the minimum diameter of manholes shall be 1200 mm.
 - For storm drain lines between 525 mm and up to 750 mm, the minimum diameter of manholes shall be 1500 mm.
 - For storm drain lines between 825 mm and up to 1050 mm, the minimum diameter of manholes shall be 1800 mm.
 - A minimum access diameter of 750 mm shall be provided.
 - Where more than two pipes enter a manhole, the minimum diameter shall be evaluated on a case by case basis.

4.4.2.2 Acceptable Manhole Materials

- Glass-Fiber Reinforced Polymer (FRP) Manholes or equivalent
 - Per ASTM D3753



- H-20 wheel load rating
- Connections shall be watertight compression connections per manufacturer recommendations, or approved equal.
- Resin and glass fiber reinforced manhole bottoms required.
- Invert and bench shall be factory installed utilizing non-corrosive materials encapsulated in fiberglass a minimum of 25 mm thick.
- Manholes shall be anchored to counteract buoyancy forces. Anchors shall be design for project specific applications.
- Gel-coat, paint, or other coatings are not allowed.

4.4.3 Open Channels

4.4.3.1 General Design Requirements

- Open channels shall be used for the primary drainage system.
- Open channels that outfall to the sea outfall shall be tide-locked.
 - Primary drainage open channels shall be designed to convey a 50-year event and the 100-year event per **Table 3.2**.

4.4.3.2 Acceptable Channel Lining Materials

- Normally it will be sufficient to prevent erosion by extending aggregate erosion protection material on embankment side slopes across the full width of the ditch. In addition, rip-rap shall be provided adjacent to the wing walls at the inlet and outlet ends of drainage box culverts to prevent local scour.
- Concrete lined channels shall be required in the following situations:
 - Where this is the only method of providing required capacity.
 - At connections with lined primary channels. In this case the concrete lining shall extend back from the primary channel for a length equal to 3 times the width of the primary channel.

4.4.4 Detention Basins/Ponds

4.4.4.1 Surface Basins

- Shall have side slopes of 3:1
- Access must be provided for maintenance vehicles.
- Depth of ponding for the 100-year 24-hour rainfall event shall not exceed 1000 mm.
- The pond must maintain at least 300 mm of freeboard during the 100-year 24-hour event.
- The pond must have an overflow structure with the capacity to handle the peak inflow during the 100-year 24-hour storm event.
- Pond must be sized to reduce peak runoff discharge to 0.14 m³/s per hectare during a 100-year 24-hour rainfall event.

4.4.4.2 Underground Detention Storage

- Underground detention chambers shall not be allowed.

4.4.5 Outfall Structures

- All outfall structures shall be protected by rip-rap aprons or concrete lined aprons.
- Outfall structures are required where pipes are discharged into the ocean, channels, or basins.
- Rip-rap shall be sized using the Isbash method based on the maximum outfall velocity during a 100-year storm event:

$$D_{50} = \frac{692(KV)^2}{(2g(S_s - 1))}$$
$$D_{50} = \text{Riprap size, mm}$$
$$V = \text{Velocity, m/s}$$



Utilities Design Guideline

S_s = Specific gravity of the riprap (usually 2.65)

$K = 1.0$

- The minimum D_{50} riprap size shall be 100 mm.
 - Minimum rip-rap thickness shall be 1.5 times the D_{50} of the rip-rap.
- All outfalls shall be evaluated for the potential for hydraulic jump and the need for an outfall energy dissipater.
- Refer to The Kingdom of Saudi Arabia, Ministry of Communications (Currently Ministry of Transport) Highway Design Manual Section 1.10 Hydraulic Design for the methodology on energy dissipater design.

4.4.6 Exfiltration Systems

- Exfiltration systems (subsurface drainage) shall be provided for foundation walls, cut areas, roadways, parking lots, and landscape areas etc., where it becomes necessary to control perched water or high groundwater.
- Exfiltration systems may tie into secondary storm drain structures or primary
- Design Requirements
 - Requirements for hydraulic designs shall be based on the following:
 - Soil permeability
 - Area to be drained, as based on site evaluation and exploration.
 - Anticipated head.
 - No underdrain shall have a diameter of less than 100 mm for circular sections or any dimension of less than 200 mm for any other section.
- System Design
 - System design shall be combined with practical considerations to assure satisfactory performance under actual field conditions, including the following:
 - Joints shall be constructed in such a manner by utilization of opening size, gaskets and/or filter media that the surrounding soil will not enter the underdrain itself.
 - The maximum length between cleanouts or access holes shall be 100 m.
 - All subsurface drains shall have a free-flowing positive outlet. Use of blind drains, French drains or any other configuration which does not have a positive conduit will not be permitted due to potential for sediment buildup

5.0 RECYCLED/IRRIGATION WATER SYSTEM

5.1 General

This Section provides the basis for the design of Recycled Water Systems. The Recycled Water Systems include transmission and distribution systems.

5.2 Recycled Water Transmission Systems

- Recycled Water Transmission System (Primary System): The irrigation water transmission system conveys water from the domestic sewage treatment plants to the transmission discharge water storage tanks.
 - The operational objective of the irrigation water transmission system is to convey water from the domestic sewage treatment plants to the irrigation transmission discharge water storage tanks.
 - Typical operation of transmission system pumping stations is to operate in constant speed conditions. The flow rate shall vary to meet demand by turning pumps on and off.
- The Recycled Water Transmission Systems includes the following components:
 - Suction water storage tanks,



- Chlorine booster pumping system,
- Large, multiple pump, constant speed pumping station(s),
- Transmission pipeline
- Discharge water storage tanks

5.3 Recycled Water Distribution Systems

- The Recycled Water Distribution System conveys water from district water storage tanks to the water users within the respective district, such as residences, schools, restaurants, and commercial businesses.
- The Recycled Distribution Systems includes the following components:
 - Chlorine booster pumping system,
 - Large, multiple pump, variable speed pumping station(s),
 - Distribution pipelines.

5.4 Outdoor Recycled Water Demands

- Outdoor water use (irrigation of plants) in public spaces outside of private residential or commercial sites is typically accomplished with recycled water
- Kindergartens shall use potable water for outdoor irrigation of plants.
- The following discusses the calculation of irrigation demands for areas required to be served by the potable system:
 - Evaluate the irrigated area with the consumption rate of the landscaping based on the irrigation application type such as spray, drip, and flood.
 - For spray irrigation of lawn areas, the average weekly demand is in the range of 50 mm per week.
 - Drip irrigation rates shall be evaluated on a case by case basis that considers the plant species and irrigation methods.
 - Recycled water is allowed for drip-irrigation system in areas of public use.
 - Spray irrigation may be allowed in non-public areas.

5.5 Irrigation Systems

5.5.1 General

- The design of irrigation systems shall promote standardization of materials, equipment and hardware so as to minimize service and maintenance.
- A complete automatic irrigation system shall be fully specified and detailed for any proposed projects. It shall serve all plantings. The planting schedule shall be coordinated with water availability dates. No planting shall be done until the irrigation system is installed, tested, approved and fully operational.

5.5.2 Location of Irrigation Systems

- All landscaped areas shall be irrigated.
- In grassed boulevards fronting institutional, commercial and residential uses with potential for heavy pedestrian traffic between the curb and sidewalk, grass areas shall be irrigated. Boulevard trees, shrubs and ground covers shall be watered from an automatic irrigation system.
- Landscaped medians in roadways shall be irrigated with subsurface systems.
- Urban trees in pavement shall be irrigated with multiple outlet emitter drip irrigation devices.



5.5.3 Irrigation Design Requirements

- Systems shall be installed underground. All components shall be designed and installed to minimize public access and contact. Locked lids and doors shall be used whenever necessary. Under no circumstances shall water containing effluent be sprayed in areas normally occupied by the public. For irrigation and misting of indoor planting, only potable water shall be used.
- The design of the irrigations systems shall be as such so that water shall not come into contact with vehicular and pedestrian hardscape surfaces and buildings.
- Irrigation systems shall install a flow meter with an electronic signal to be sent to the main irrigation system meter.
- The flow meter shall be a low flow sensor style of meter connected to the central control unit.
- All irrigation systems shall be metered (normally at point of connection to main supply).
- Design service connections from water main to water meter chamber and up to the emitters.
- For potable water systems only: install backflow prevention.
- Measure static water pressure at or near the point of connection and include with irrigation system design.
- Maximum design flow velocity to be 1.5 meters per second.
- Design head-to-head coverage for turf and shrub areas.
- Design sprinkler circuits with matched precipitation heads. Do not mix heads with varied precipitation rates on the same circuit.
- Specify low flow heads for sloping areas.
- Where surface sprinklers are used, ensure unobstructed sprinkler coverage to tree bases from at least two sides.
- Every drip circuit shall be designed with a filter, pressure regulator, flush valve and air relief valve. The drip component manufacturer's instructions for installation and maintenance shall be included in the project specifications.
- Minimize overspray on paved surfaces.
- Irrigation systems shall be designed to supply water on a demand basis by employing a soil moisture probe to override the controller during periods of adequate soil moisture.
- All valve covers and other access points be tagged with the inscription "Contaminated Water - Do not Drink" in Arabic and English. Similar tags are required on any potable-sourced lines whenever fertilizer is injected.
- All effluent-sourced systems require filters and/or strainers downstream of solenoid valves serving drip emitters.
- Algae-resistant hose is required on all emitter lines. High temperatures promote algae growth.
- For the above reasons, deep burial of all lines is advantageous. A minimum mainline burial depth of 900 mm is suggested.
- HDPE and PVC piping are the approved materials for irrigation systems.
- Irrigation of dissolved fertilizer in the irrigation system is an efficient method of application and is appropriate to the large scale facilities. Small mobile injection units may be used. Where economies of scale warrant, larger injection units are appropriate. Computer assisted control centers; similar to those used on large golf courses, may be appropriate where air-conditioned space is available.
- In many cases, drip emitter systems which are effluent-sourced are subject to phosphate accumulation (scaling) and resultant emitter clogging. Injection of sulfuric acid, in sufficient quantities to prevent scaling, is often suggested in these cases and may be accomplished by designing injection equipment to utilize fertilizers, acids and systemic insecticides.

5.5.4 Water Sources for Irrigation Systems

- The main source of irrigation shall be treated effluent water.
- Potable irrigation shall be used in Kindergarten areas only.
- Potable lines shall be protected from contamination by use of reduced pressure principle backflow preventers.



- The system layout shall provide adequate separation between potable lines and the effluent and sewage lines. A parallel duplication of potable and effluent irrigation lines shall be avoided.

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5.6 Hydraulic Modeling

5.6.1 Purpose

- Hydraulic modeling shall be used as a design tool to evaluate new or existing development

5.6.2 Modeling Software

Modeling may be completed in standalone, CAD integrated, or GIS integrated modeling platforms. Acceptable modeling software include:

- WaterCAD (Bentley) or equivalent

5.6.3 Required Modeling Scenarios

Model Scenarios shall be prepared based on the irrigation cycle.

5.6.4 Model Setup

- Hydraulic distribution models shall consist of pipes, nodes (including fire hydrants), tanks, and pump stations.
- Pipes
 - Diameter
 - Diameter shall be input for every pipe
 - Friction Coefficient
 - Hydraulic models shall be configured to evaluate the water system using the Hazen-Williams formula.
 - Minor Losses
 - Minor losses for fittings and valves may be included in the model by adding local minor losses to each pipe.
 - If applicable, minor losses for master flow meters and backflow protection shall be considered with the modeling scenarios.
 - Length
 - Models shall be created to scale to ensure accurate length of water lines.
- Nodes
 - Elevation shall be assigned to nodes at ground elevation within 0.5 m.
 - Demands shall be spatially allocated based on demand calculations
- Tanks
 - Volume: Though volume is not required for steady state simulations, it is good practice to include accurate tank information for diameter, wall height, floor elevation, etc. in the event that an extended period simulation is required in the future.
- Pump Stations
 - Floor Elevation within 0.5 m
 - Pump Curves – if using the distribution model to confirm pump selection, actual pump curves shall be entered into the model.



5.6.5 Hydraulic Model Reporting

5.6.5.1 The following Table of Contents shall be used when submitting a Hydraulic Modeling Report:

- Introduction – Include a project description, existing system discussion, and proposed additions of the project.
 - Include a system map to illustrate proposed expansion area and land uses.
- Irrigation Demand Criteria & Summary
 - Summarize demand calculations for irrigation demand; Include detailed calculations in an Appendix.
- Methodology and Analysis – Document the modeling software used, the type of model (steady state or extended period), assumptions, and field calibration, if any.
- Modelling Input

Computer programs for network hydraulic modelling distinguish between two general groups of input data which are Junctions and Links. Although the way some components are modelled may differ from one to another software, the following input information may be required:

- Sources: identification, location and elevation of water surface level.
 - Nodes: identification, location and elevation, base demand and pattern of demand variation.
 - Reservoirs: identification, position, top and bottom water level, description of the shape (cross-section area, either the volume–depth diagram), initial water level at the beginning of the simulation, inlet/outlet arrangement.
 - Pipes: identification, length, diameter, description of roughness, minor loss factor.
 - Pumps: identification, description of pump characteristics, speed, operation mode.
 - Valves: identification, type of valve, diameter, head-loss when fully open, operation mode.
- Results and Conclusions
 - Document that results for scenarios meet the requirements of this manual for pressure and velocity for each scenario.
 - Document node or nodes with lowest pressure for each scenario
 - Document pipe or pipes with highest velocity for each scenario
 - Include model input and output files in the modeling report
 - Include a system map illustrating final pipe sizes based on the model.
 - Map shall include labels for all model elements such as nodes, pipes, and pump stations.
 - Map shall be color coded based on pipe diameter.