Chapter 1

Water Network Design Guidelines

Water Network Development & Design Standards

Table of Contents

I. GENERAL INFORMATION

I.1 Purpose

These water network design guidelines present the basic criteria and considerations for the design of components for the extensions, upgrades, additions, replacements, or rehabilitation of KM's water network system.

These design guidelines, with the aid of computer modeling of the water distribution system, intend to provide a set of guidelines and minimum criteria for the design of water network in Qatar. It also applies for other public and private development projects that will be constructed and connected to KM water system.

I.2 Scope

These design guidelines summarize the design criteria for elements of the water system reservoir, pumping system, and transmission/delivery system including:

- Service area coverage
- Water demand projections
- Water main pressure requirements
- Pipe velocities
- Typical configuration requirements for network piping design for transmission lines, rising mains, and distribution mains,
- Water main location
- Line valves, fire hydrants, and special valves requirements
- Reservoir and pumping station design criteria,
- Hours of operation
- Paralleling of transmission lines/rising mains, reservoir inlets
- Acceptable commercial size of pipe diameters
- Safety and security

I.3 Responsibilities & Authorities

All KM staff and consultants providing design services to KM are responsible for using the criteria and guidelines provided in this manual. Any deviations from these standards/guidelines outlined in this document must be reviewed and approved by KM.

Any deviation from the standards/guidelines outlined in this document must be reviewed and approved by KM

I.4 Abbreviations, Definition Of Terms

Abbreviations and definition of terms used in this report are consistent with the Standard Terminologies, Abbreviations, Acronyms and Definitions presented in the Glossary of Documents which is located under this Manual.

I.5 Specifications, Guidelines, & References

Water network concept through final design shall conform to the following specifications, guidelines, and references:

1. General Specifications of Main Laying Materials for Waterworks
2. General Specifications for Main Laying Contracts
3. Water Network Standard Drawings
4. Regulations of Internal Water Installations and Connection Works (KM Plumbing By-laws)
5. Qatar Construction Specifications (QCS), 2010
6. Ministry of Municipality and Urban Planning (MMUP) Policy Plan
7. Qatar Highway Design Manual

I.6 Design Conditions

I.6.1 Physical Environment in the State of Qatar

The regional and local physical description of the project area should be discussed including the geophysical and climatic conditions.

I.6.2 Geophysical Conditions

Figure I-1 illustrates that Qatar is a peninsula. It borders Saudi Arabia and the United Arab Emirates to the south with the remaining land mass extending into the Arabian Gulf. The terrain is mostly flat and barren desert covered with loose sand and gravel. There are some small hills and high ground to the northwest and a few scattered sandstone and limestone hills. The higher elevations are generally found to the southwest from Dukhan south where elevations rise to approximately 35 m.

Figure I-1 Map of Qatar

I.6.3 Climatic Conditions

Qatar has a tropical climate. In summer, extreme heat, dust, and humidity are experienced. The design engineer should consider the impact of climatic conditions for both design and construction of the project. Climatic data to be used for planning and design purposes are found in Table I-1.

I.6.4 General Considerations:

- Proximity to the Gulf creates a high salt laden air atmosphere. During periods of high humidity, this results in a severe corrosive atmosphere. Corrosion protection should be considered during design.
- Groundwater may be brackish and/or soils may be corrosive resulting in increased potential for corrosion.
- Distribution and occurrence of rainfall events are very erratic. Rainfall events are generally of a high intensity with a short duration and usually occur between December and March.
- The prevailing wind directions are from the north and west.

Table I-1 Climatic Design Conditions

Description	Design Value
Maximum Temperature	50° C
Minimum Temperature	5° C
Maximum Temperature for enclosures and exposed metal	85° C
Maximum Humidity	100%
Minimum Humidity	20%
Maximum Wind Velocity	150 km/hr
Annual Rainfall	80-150mm

I.7 Design Survey Requirement

It is required to have a vertical profile for the primary mains and existing & finished ground surface profile of the alignment reckoned from the latest Qatar National Datum and tied to at least two(2) official survey benchmarks. Additional semi-permanent benchmarks shall be established every 100m along the route by closed loops of third order accuracy. The existing ground profile shall consist of ground surface elevations along the proposed transmission main centerline at every 25m station and at pronounce grade breaks.

Topographical features within the street or right-of-way and any topographic feature outside the right-of-way, which may interfere with the operation or installation of the primary main shall be accurately surveyed and depicted on the plans. Topographic features may be compiled by aerial photogrammetry or field survey methods. In areas where the ground slope perpendicular to the centerline of the primary main exceeds 5%, cross sectional data shall be surveyed at all 25m station profile points and shall extend at least 10m at each side of the centerline.

I.8 Geotechnical Investigation

When required, a geotechnical investigation shall be performed for the purpose of determining the soil bearing capacity, soil backfill suitability, presence of groundwater, bedrock, corrosion potential and other conditions, which may affect the design, construction and maintenance of the entire water network. Test holes shall be located at maximum spacing not more than 200m and at highway and canal crossings. The geotechnical investigation shall be carried out in accordance with the guidelines set forth in the latest Qatar Construction Specifications (QCS), Section 3 – Ground Investigations.

II. ENGINEER'S REPORT

Prior to preparation of the Engineer's Report, a planning meeting shall be conducted with Water Planning Department to discuss the project concept and obtain system information required for design.

The Engineer's Report presents the following information where applicable, which shall be submitted to KM for review and approval.

II.1 Introduction

Provide a brief description of the purpose and scope of the project. Identify the Owner, Engineer, and all major stakeholders of the project.

Provide a summary description of the contents of the Report by section, describe the contents of the appendices, and identify supplementary volumes and their contents.

II.2 Overview and Background

Include general project related information and identify the planned objectives. Briefly describe the following:

- existing conditions,
- background data,
- previous studies and recommendations,
- related work done by others,
- special considerations, and
- reasons underlying the need for new or modified facilities.

The major elements of the proposed design should be introduced.

- Acknowledgments. Identify key regulatory agency personnel who provided data, input, review, etc.; and the identities of outside groups that have provided input or review.

II.2.1 General Information

- A description of the project including geographical location.
- Demographics of the existing waterworks facilities.
- Identification of the target service area/s.
- A list of existing studies, reports, surveys and other available information to be used in evaluating the project.
- A list of applicable standards, codes, units, and datum to be utilized.
- Interactions with Owner, governmental, utility, and permitting agencies.
- The schedule for completion.

II.2.2 Extent of Water Works System

- Description of the nature and extent of the area to be served.
- Provisions for extending the water works system to developed/developing uncovered areas.
- Provisions for replacement / upgrading of the waterworks system.
- Appraisal of the future requirements for service, including existing and potential industrial, commercial, institutional, and other water supply needs.

II.2.3 Justification of Project

The proposed project requires to be justified based on the following:

- Extension to uncovered developed/developing areas,
- Improving the existing facilities,
- Future expansions,
- Adapting to new technology and environment.

II.3 Alternative Evaluation

Where two or more solutions exist for providing public water supply facilities, each of which is feasible and practicable, discuss the alternatives.

Prepare multiple conceptual schematic layouts based on discussions with KM. These layouts should be evaluated using:

- Limited hydraulic and hydrologic modeling, and
- Conceptual level engineering calculations of
  - civil,
  - geotechnical,
  - structural,
  - mechanical,
  - communications systems,
  - instrumentation systems, and
  - electrical features.

Each conceptual layout should include:

- A description of the conceptual layout and features.
- A summary of the analysis and results in evaluating the layout and
- A summary of the advantages and disadvantages of each solution. Give reasons for selecting the one recommended, including:
  - potential impacts to:
    - public use,
    - environmental factors,
    - other projects within the region, and
    - Right-of-Way needs.
  - ability to meet the goals and objectives of the project,
  - financial considerations,

   - operational requirements,
   - operator qualifications,
   - reliability, and
   - water quality considerations.
- Whole-life-cycle cost analyses to be carried out for all alternatives to demonstrate that the recommended development plan is the least-cost or the most economical option.

II.4 Elements of Design

The Engineer's Report should include the following information to allow proper evaluation and design of the selected solution:

II.4.1 Geotechnical Conditions

- The character of the soil through which water structures and/or pipelines are to be constructed.
- Foundation conditions prevailing at sites of proposed structures and
- The level of ground water in relation to subsurface structures.

II.4.2 Water Demand Data

- Population projection,
- Land use,
- Historical production / forwarding figures,
- Historical water consumption,
- Historical water losses,
- Historical storage volume and pumping discharges,
- Fire flow requirement,
- Historical & updated per capita consumption,
- Bulk demand on commercial, industrial, institutional & irrigation (optional),

II.4.3 Flow and Pressure Requirements

- Hydraulic analyses based on flow demands and pressure requirements,
- Fire flows, when fire protection is provided, meeting the KM and CD recommendations,
- Surge Analysis to determine the required surge protection devices and surge vessels.

II.4.4 Sources of Water Supply

Describe the proposed source or sources of water supply. If one is to be developed include the reasons for selection.

II.4.5 Cost Estimate

- Estimated cost of integral parts of the system,
- Detailed estimated annual cost of operation over the life of the project, to include
   - labor categories and hours
   - material costs
   - equipment costs
   - power costs

- Proposed methods to finance both capital investment cost and operating expenses.

II.4.6 Future Extensions

Summarize planning for future needs and services for the development. Plan the start date to allow new facilities to be on-line when needed based on projected demand. A description of the goals and objectives to be achieved by the pipelined project should be described.

III. ROAD OPENING AND DESIGN APPROVALS

III.1 Road Opening Approvals

Q-PRO (Qatar Permit of Road Opening) is the State of Qatar's on-line RO (Road Opening) permitting, reporting, and analysis web-application. Q-PRO allows agencies to apply for RO permit on-line to carry out any work on public right-of-away in the states of Qatar. Q-PRO allows authorized agencies to approve permits on-line.

KM will coordinate Road Opening permit applications through Q-PRO.

III.2 Design Approvals

The following utility departments and agencies shall review, comment and approve all the designs:

1. KM- Electricity Network Affairs
2. Public Works Authority- Roads Affairs
3. Public Works Authority- Drainage Affairs
4. Ministry of Municipality and Urban Planning (MMUP)
5. Qatar Telecom- Q-Tel
6. Qatar Petroleum
7. Water Producers (If required)
8. Ministry of Environment
9. Municipalities

IV. WATER NETWORK DESIGN STEPS

Table IV-1 presents general design steps to be followed for network design development. Note that these steps are iterative and may need to be revisited during the course of a project in order to complete the design.

Table IV-1 Water Network Design Procedures

Design Step	Description
1. General: Determine Service Area	Define the project service area and identify the pressure zones in which it is located; coordinate this effort with Water Planning Department. For this and the remaining items in this table, utilize Appendix B for checklists relating to hydraulic analysis and transmission and distribution main design.
2. General: Determine Water Demands	For preliminary design, assess the demand required from the new service area based on typical land use categories and ranges of water demands listed in Table V-6 and Table V-7. Refer to Appendix A for detailed guidelines for project requirements and preparation of demands for bulk customers.

Table IV-1 Water Network Design Procedures	
Design Step	**Description**
3. General: Determine Flow Demands	Determine water demands and apply peaking factors listed in Table V-6, Table V-7 and Table V-8 to establish design flow demand values.
4. Pipe Network:	Determine the required project network piping based on the service area map, customer locations and the design standards and guidelines including associated fire hydrants and valving.
5a. System Planning: Determine Requirements Network	Prepare the proposed network hydraulic model analysis based on criteria in Sections V and VIII. If the results of the modeling efforts show that a pump station is necessary, proceed to Step 5b. Otherwise, proceed to Step 6.
5b: RPS Planning: Determine Pumping Requirement	Prepare a preliminary RPS station design based on Section VII and the duty points identified in the hydraulic model. Provide storage facilities as required and incorporate into the piping and pump station networks.
5c: Pump Planning: Refine Booster Pumping Requirement	Based on the results of the initial modeling, modify the design if needed and re-run the model with the revised pump data until a design is created which satisfies the requirements.
5d. System Planning: Determine Surge Protection Configuration	Perform a transient analysis of the network model to determine the extent of surge protection required.
6. General: Determine required monitoring requirements	Determine based on each specific project needs which of the monitoring devices listed in Section VI, Table VI-5 are required.
7. Fire Flow Simulation	Application of fire hydrant criteria as presented in Table VI-9 should be discussed both with CD and KM with respect to the specific requirements of the development projects being designed.
8. Option Analysis & Recommendation	Perform network analysis by setting all criteria and necessary inputs. Consider all options and present recommendations.
9. Prepare Engineer's report	Prepare Engineer's report based on criteria presented in Section II.
10. Seek KM approval	Present the Engineer's Report to Water Planning Department for review and approval before proceeding.

V. DESIGN CRITERIA OF WATER PIPELINES

The design engineer is directed to adhere to the following design criteria unless project conditions require deviation from these standards. If the design engineer determines a deviation is warranted, approval should be obtained from Water Planning Department prior to continuing with design.

V.1 Public and Private Water Mains

All pipelines and appurtenances upstream of the customer's main meter are the responsibility of KM. All pipelines and appurtenances downstream of the customer's meter are the responsibility of the Owner and should comply with all Qatar and KM standards, guidelines, procedures, processes, and specifications.

All engineering plans shall clearly differentiate between all portions of the public and private water distribution system.

V.2 Easements for Water Mains

The Qatar Highway Design Manual and Ministry of Municipality and Urban Planning (MMUP) designated utility corridor arrangements/reservations should be followed where applicable. In general, deeper utilities are to be installed prior to shallower utilities.

Any deviation from the MMUP standards not located in designated corridor must be approved by Water Planning Department.

Water lines shall be placed on the north and east side where possible except where it is impractical or more expensive to do so, or where there is already an existing line.

V.3 Routing and Layout Requirements

Below are the minimum requirements in routing and layout for pipes:

- All water mains shall be constructed in streets within the water utility reserves as per Road Affairs Road Hierarchy for safe and quick access to all KM water mains at all times for repair of pipe breakages, install service connections and perform preventive maintenance.
- Pipelines should never be laid on private boundaries to ensure accessibility of the line during maintenance and repair of the pipes.
- There maybe some instances where the standards cannot be applied. Hence, adjustments or deviations from the standards for individual special cases will be made through mutual agreement with other utility departments and with the approval of KM Water Planning Department.
- In main highways or wide roads, the economics of laying secondary distribution mains on both sides of the road must be considered to minimize the need for long service pipes across the road. A secondary distribution line should be laid along side a primary distribution line 400mm and larger, except where there are no houses yet. In this case, outlets or stub-outs should be provided for future parallel secondary distribution line.
- Provision (such as Tees) for future extensions should be considered at all road intersections.
- All water lines shall be laid as straight as possible. Avoid excessive number of high points and low points along the line and between cross street connections as they create air pockets.
- Minimum radius of curve and maximum deflection angle of pipe joints will be restricted to 75% of manufacturer's recommendation, after which the use of horizontal or vertical bends will be required.

V.3.1 Continuity of Service

When existing service areas are impacted by new construction, provide continued operation of existing facilities or provide temporary facilities to maintain uninterrupted service to customers. If disruption of service cannot be avoided, schedule such outages to the least disruptive time of day or night. Notify affected customers and minimize the time period of outage.

V.3.2 Redundancy for System Reliability

For bulk customers, two connection points to the distribution network are recommended. The primary connection point is metered. The secondary point is connected by a normally closed isolation valve that can be opened to allow uninterrupted service in case the primary supply point is shut down for maintenance or repair. An adjacent District Metering Area (DMA) with a connecting main is suitable for a secondary connection point.

V.3.3 Paralleling Piping System

If the system analysis recommends increasing existing pipe sizes for future pipelines, consider installation of parallel mains to minimize disruption of service during construction.

For critical customers such as hospitals, consider parallel mains to provide redundancy for increased reliability of service in case repairs or maintenance require that one main is shut down. Parallel pipelines should also be considered for pipelines critical to system operation such as distillate mains, rising mains, and reservoir inlets.

Parallel mains should be physically separated by a minimum of three (3) meters to allow excavation for maintenance without impacting the second main.

V.4 Water Main Classification for Design

Table V-1 classifies pipelines for design purposes.

Table V-1 Pipeline Classification Chart

Type Main	Size (mm)
Transmission/Rising mains	400mm and larger
Distribution Mains	
Primary	400 mm and larger
Secondary	150 – 300 mm
Tertiary	100 mm
Service Connection Mains	25 – 63 mm

V.5 Pipe Material

Only pipe materials included in the KM Specifications for Main Laying Materials are allowed. These include:

V.5.1 Ductile Iron Pipe (DIP)

Distillate, Distribution Primary, Distribution Secondary Mains and Tertiary Mains; 100 mm to 2600 mm.

V.5.2 High Density Polyethylene (HDPE)

Although HDPE pipe has been allowed in the past and pipelines up to 600 mm are currently in service as of the writing of this document, HDPE is no longer allowed as a suitable material.

V.5.3 Medium Density Polyethylene (MDPE)

Service piping 63 mm and smaller.

V.5.4 Material Specifications and References

All main laying installations should be made under the direct supervision of KM and should conform to the most current versions of the following references and specifications:

1. General Specifications of Main Laying Materials for Waterworks (Latest Edition)
2. General Specifications for Main Laying Contracts (Latest Edition)
3. Water Network Standard Drawings
4. Qatar Construction Specifications
5. Regulations of Internal Water Installations and Connection Works

V.6 Minimum Water System Design Period

Water system elements are designed to meet the demands of its service area over a design period. The economical period of design of water system elements is related to its first cost, service life, present population and present growth rate of its service area, interest rate and the ease and cost of increasing its capacity. Most of the above factors invariably vary from locality to locality, hence resulting in a variable economical period of design.

The ideal design period is based on historical data and projected future events. Experience has shown the design period given in Table V-2 can be used. If information is available to justify variance from these values consult with Water Planning Department for guidance.

Table V-2 Water System Design Period

Type of Works	Design Period (Years)
Tertiary Distribution Mains	20
Secondary Distribution Mains	20
Primary Distribution Mains	30
Source Transmission Mains	50
Pump Station	20
Reservoirs	20

The chosen design period shall be the economic life to be used in carrying whole life-cycle cost analyses of development alternatives.

V.7 Pipe Sizing

V.7.1 Minimum Pressures, Velocities and Head Losses

The pipe network should be designed to deliver safely and economically the required volume of water at the minimum acceptable pressure to consumers within district/pressure zones as provided in Table V-3.

Table V-3 Residual Pressures	
Pipe Size (mm)	**Minimum Residual Pressure (bars)**
Distribution Mains[1]	1.5
Transmission Mains	2.0

Note [1] : The residual pressure shall be met at the critical (highest and farthest) nodes of the system, regardless of whether this node is on a primary or secondary line.

Water systems shall be sized to carry the larger of the designed peak hourly flow or the average daily flow required plus fire flow without exceeding the minimum / maximum pipe velocities and the maximum head loss listed in Table V-4.

Table V-4 Allowable Velocity and Head Losses			
Pipe Size (mm)/Scenario	**Minimum Allowable Velocity (m/s)**	**Maximum Allowable Velocity (m/s)**	**Maximum Allowable Head loss at Peak Domestic Demand (m/km)**
Distribution Mains			
ADD	0.5	1.5	-
ADD+FF	-	2.5	2-5
Transmission Mains			
ADD	0.5	1.0	-
PHD	-	2.0	2-3

V.7.2 Standard Pipe Diameters

Limit pipe selection to nominal pipe sizes that are provided in Table V-5 below.

Table V-5 Standard Pipe Sizes
Pipe Nominal Diameter (mm)
100
150
200
300
400
600
900
1200
1400
1600
2000
2600

Any deviation from the above sizes must be approved by KM.

V.8 Water Demand Projection

V.8.1 Service Area

The design engineer should use the Ministry of Municipality and Urban Planning (MMUP) Policy Plan and other maps to define the project service area, land use and occupancy rates. Also, the design engineer should obtain approval of the service area boundaries from Water Planning Department. Consideration should be given to projected land uses and demand based on phasing and full development of the service area.

V.8.2 Land Use, Population, and Unit Water Demands

Table V-6 and Table V-7 present typical ranges of unit water consumption rates for various land use categories and should be used to establish water demand for development projects. However, it is the sole responsibility of the consultant/developer to accurately determine the demand required with due consideration to the nature and type of the proposed development. Justification for variance from this table should be submitted to KM for concurrence. KM must concur with the water demand forecast prior to project approval.

Table V-6 Unit Water Demands (Domestic Category)

Land Use Category	Unit	Daily Water Consumption (Liters)
Residential Building	(Per Capita)	250-400
Qatari Villas	(Per Capita)	500-800
Worker Labor Accommodation	(Per Capita)	80-150
Mixed Use Residential	(Per Capita)	250-400

(Source: KAHRAMAA Water Development Guidelines for Bulk Customers, April 2012)

Table V-7 Unit Water Demands (Non-domestic Category)

Land Use Category	Unit	Daily Water Consumption (Liters)
Mixed Use Commercial	(Per Capita)	60-80
Commercial Building	(Per Capita)	60-100
Mosque	(Per Capita)	10-50
Restaurant	(Per Meal)	10-20
Hotel	(Per Room)	200-300
Shop	(Per Capita)	60-80
Office	(Per Capita)	60-80
School	(Per Capita)	60-80
University	(Per Capita)	60-80
Medical	(Per Bed)	60-80
Public Amenities	(Per Capita)	20-50
Nursery	(Per Capita)	60-80
Guard House	(Per Capita)	60-80

Table V-7 Unit Water Demands (Non-domestic Category)		
Land Use Category	**Unit**	**Daily Water Consumption (Liters)**
Retail	(Per Capita)	60-80
Theatre	(Per Capita)	10-50
Stadium	(Per Capita)	15-20
Town Centre	(Per Capita)	60-80
Manufacturing	(Per Capita)	60-80
Workshop	(Per Capita)	60-80
Swimming Pool		Pool Volume plus the rate of re-filling/year
Warehouse/ Store/ Showroom	(Per Unit)	2, 889
MEW Electricity Substation	(Per Unit)	509
Clinics	(Per Unit)	26, 458
Gardens/ Parks/ Nurseries	(Per Unit)	85, 106
Car Wash	(Per Unit)	20, 991
Embassies	(Per Unit)	21, 205
Petrol Station (No Car Wash)	(Per Unit)	2, 559
Sports Stadiums	(Per Unit)	109, 712
Industry		
Heavy Water Using	(cum/hectare/day)	120
Light Water Using	(cum/hectare/day)	30
Precast Factory	(cum/hectare/day)	85
Garage for Heavy Truck	(cum/hectare/day)	30
Food Stores	(cum/hectare/day)	30
Industrial Store	(cum/hectare/day)	30
Livestock, (liter/head/day)		
Camel	(liter/head/day)	30-55
Cow	(liter/head/day)	100-126
Sheep	(liter/head/day)	8-20
Goat	(liter/head/day)	7-12
Chicken	(liter/head/day)	13-62
Type of Crops		
Vegetables	(liter/m^2/day)	5.37
Cereals	(liter/m^2/day)	3
Fodder	(liter/m^2/day)	18
Fruits & dates	(liter/m^2/day)	8.8

(Source: KAHRAMAA Water Development Guidelines for Bulk Customers, April 2012)

Future population projections may be used to determine water demand for large developments and projects where development categories are not yet determined. The population forecast used to develop the required demand should be based on the population of Qatar as per MMUP Annual Statistical Abstract. Also, to be considered are the current development of multi-structured facilities that require high end demands and are eventually considered as bulk demands, such as industrial, commercial, institutional and irrigation requirements.

Over the 20-year population period in Qatar from 1986 to 1997, the average population growth rate was 3.20% per year. It increased to 5.15% per year from 1997 to 2004, and from 2005 to 2010, it was projected to 5.6% per year. Thus, for a constant population projection, a growth rate of 5.60 % per year may be used for design purposes.

In the absence of census data for a given area to be served, a rough population estimate may be made based on the number of existing households and the number of persons per household as given below:

Average No. of Persons per Household = 6 persons per household

For bulk customers (including industrial, commercial, institutional and irrigation uses), individual data is required to be surveyed and analyzed.

V.8.3 Peaking Factors

The water demand over a 24 hour period averaged over the period of service is defined as the Average Day Demand (ADD). The 24 hour period of the highest demand during the study period is defined as the Peak Day Demand (PDD). In a 24 hour period, the hour of the highest demand on the PDD is defined as peak hour demand (PHD).

Listed in Table V-8 are the recommended peaking factors for design.

Table V-8 Water Demand Peaking Factors

Type Demand	Peaking Factor	
	Rising Mains	Distribution Mains
Average Daily Demand (ADD)[1]	Determined from Actual Data or Estimated from Unit Demand Values or population projections	Determined from Actual Data or Estimated from Unit Demand Values or population projections
Peak Daily Demand (PDD)[2]	ADD x 1.5	ADD x 1.5
Peak Hour Demand (PHD)[3]	ADD x 2.0	ADD x 2.5

[1]ADD determined by design engineer from worksheets
[2]PDD = ADD x PDD Peak Factor
[3]PHD = ADD x PHD Peak Factor

V.8.4 Water Loss

The design flow calculations should include allowance for losses including regular flushing volume, leakages and etc. referred to as “Unaccounted-for-Water” (UFW) as indicated in Table V-9.

Table V-9 Non-Revenue Water	
Pipe Elements	**Percent UFW**
Proposed Pipe	15%
Existing Pipe	20 to 30%

V.8.5 Fire Flow Demand (FFD)

KM provides aboveground and underground fire hydrants at regular intervals within their distribution network. As part of the hydraulic network modeling, it is required to consider at least two fire hydrants located at the remotest and highest elevation simultaneously flowing during a particular fire event. KM requirement for fire flow demand per hydrant is presented in Table V-10:

Table V-10 Fire Flow Demand Per Hydrant		
FIRE HYDRANT (FH) PARAMETER	**Unit**	**Underground and Aboveground Hydrant**
Fire Flow per FH	Li/min	1,000 (17 lps)

The designer is required to coordinate with KM and CD on the criteria to be applied for a specific project development.

V.8.6 Design Formulas and Calculations

For hydraulic analysis and pipe sizing, Peaking factors are applied to the ADD and used for system development.

Average Water Consumption (AWC)

AWC = P x Per Capita Water Consumption

Where:

P = Design Population

AWC = Average Water Consumption

Average Daily Demand (ADD)

$$ADD = \frac{P \times AWC}{1 - \%UFW}$$

Where:

P = Design Population

AWC = Average Water Consumption

ADD = Average Daily Demand

UFW = Unaccounted-for-Water

Peak Daily Demand (PDD)

PDD = PF x ADD= 1.50 x ADD

Where:

PF = Peaking Factor

PDD = Peak Daily Demand

Peak Hour Demand (PHD)

PHD = PF x ADD= 2.50 x ADD

Where:

PF = Peaking Factor

PHD = Peak Hour Demand

Water network analysis using computer modeling should evaluate the following scenarios in order to obtain the proposed system:

- ADD, Average Daily Demand
- PDD, Peak Daily Demand
- PHD, Peak Hour Demand
- ADD + FFD, Average Day Demand plus Fire Flow Demand
- PHD + FFD with Pump Shut-down Surge Condition (When Pumping is included in design)

Modeling results should include analysis of the pipe network under both new and existing conditions.

V.9 Working and Test Pressure

The distribution mains shall be designed to convey the PHD with a minimum service/residual pressure of 1.50 Bar (15m) at critical (highest and farthest) nodes of the system, regardless of whether this node is on a primary or secondary line except on transmission line with minimum residual pressure of 2.0 bar.

Working and test pressures for the pipeline classifications are provided in Table V-11.

Table V-11 Pipeline Design Pressure Chart

Type Main	Size (mm)	Maximum Working Pressure	Minimum Test Pressure
Transmission/Rising mains	400mm and larger	12 bar	18 bar
Distribution mains:			
Primary	400 mm and larger	6 bar	9 bar
Secondary	150 – 300 mm	6 bar	9 bar
Tertiary	100 mm	6 bar	9 bar
Service Mains	25 – 63 mm	6 bar	6 bar

V.10 Pipe Cover

All pipes shall have a minimum pipe cover of 900 mm from the crown of the pipeline to the finished road level or ground. However, as the primary mains increases in size, the minimum cover requirement may increase.

V.11 Separation of Utilities and Facilities

V.11.1 Separation with Utilities

Water facilities should meet the separation requirements with other utility infrastructure stated in Table V-12.

Table V-12 Separation with Utilities

Utility	Minimum Separation	
	Vertical (m)	Horizontal (m)
Sewerage		
Gravity Sanitary Sewer Mains	0.5	3.0
Sewer Service lines		0.5
Sanitary Sewer and Treated Sewer Effluent Forced Mains	0.5	3.0
Wastewater Structure	-	3.0
Storm Drains and Culverts	0.5	3.0
Electricity, MV / HV	0.5 / 1.0	1.50
Q-Tel	0.5	1.50
QP Oil/Gas	0.6	2.00
Qatar Cooling	0.5	1.50
Existing Water Main	0.1-0.3	0.5

Potable water mains should always pass above sewerage mains. Where separation with sewerage facilities cannot be met, the following modifications may be approved:

- Relay parallel sewer pipes using equivalent water system pipe and provide 0.5 m vertical separation.
- Install crossing pipes using full pipe section lengths centered at the crossing and provide a minimum of 0.25 m vertical separation.

Water main separation from wall structures should comply with setback distances stated in Table V-13.

Table V-13 Setback Distances from Structures

Pipe Size	Centerline of Pipe Set back Distance (m) to the edge/face of Structure
Pipes up to 150mm	1.5
150mm to 900mm	2.0
Greater than 900mm	4.0

V.11.2 Utility Conflicts

Where utility conflicts cannot be resolved through design modifications to the new facilities and relocation of the existing utility is required, resolution of the conflict must be coordinated and approved by both KM and the affected utility owner.

V.12 Connections to Existing Water Mains

V.12.1 General

All connections to existing water mains should be made under the direct supervision of KM and should conform to General Specifications of Main laying Contracts.

V.12.2 Connections to Transmission or Rising Mains

Connections for single connections or distribution systems to any transmission or rising mains are not allowed (Figure V-1). However, in areas where there is no reasonable alternative for providing service, KM may approve a 300 mm diameter minimum size connection and pipeline configured for a future parallel distribution system for additional services. The connection should include a minimum 300 mm tee to allow for expansions, an isolation valve, a pressure reducing valve and a flow meter at the point of connection should be installed. See Figure V-2 for this type of connection.

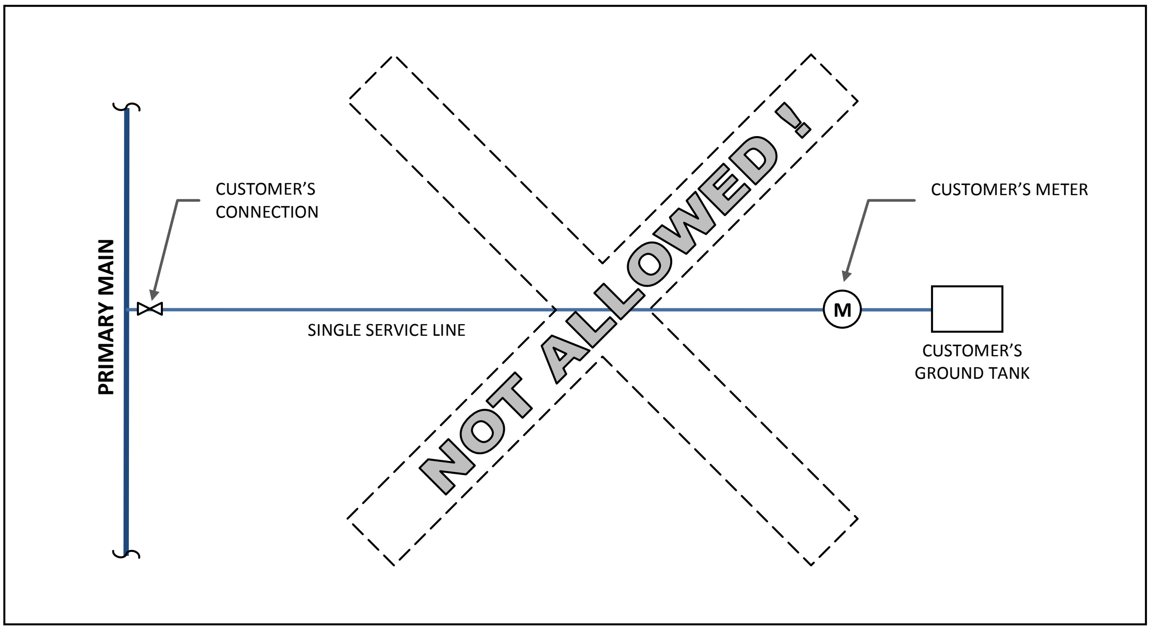

Figure V-1 Single Service Connections to Transmission or Rising Mains (NOT ALLOWED)

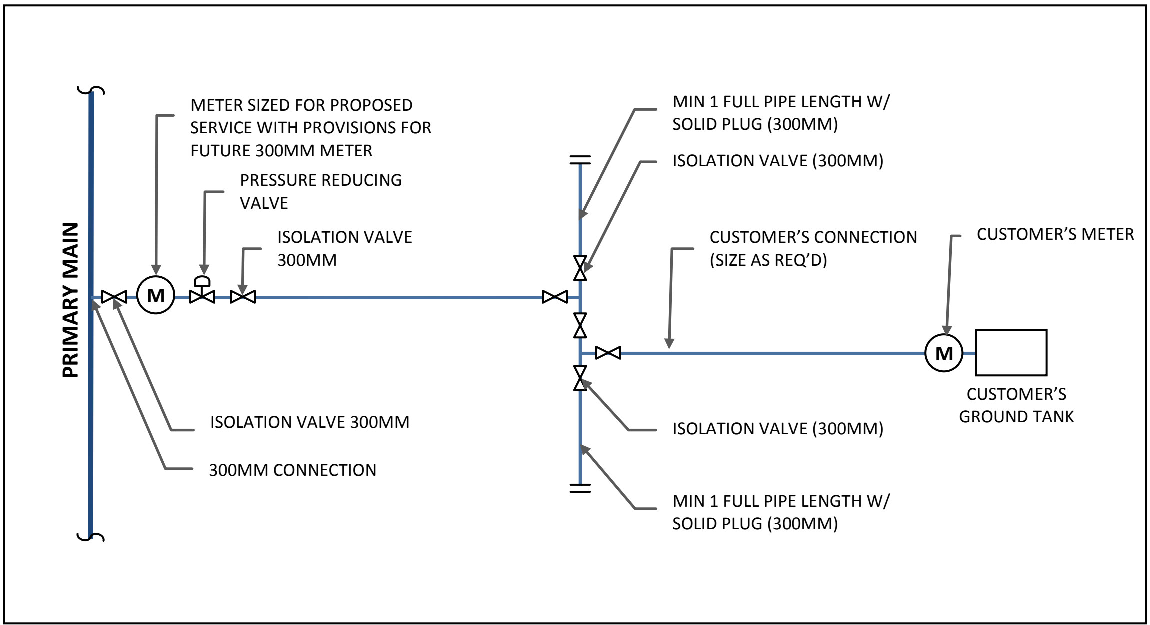

Figure V-2 Connections to Transmission or Rising Mains

V.12.3Connections to Primary Mains (Distribution)

Connections smaller than 150 mm (for single connections or distribution systems) to primary distribution mains 400 mm or larger are not allowed. In areas where there is no reasonable alternative for providing service, KM may approve a 150 mm minimum size connection and pipeline configured for a future parallel distribution system for additional services. The connection should include an isolation valve at the point of connection, a minimum 150 mm tee to allow for expansions, and isolation valves on each extension. See Figure V-3 for diagram of this type of connection.

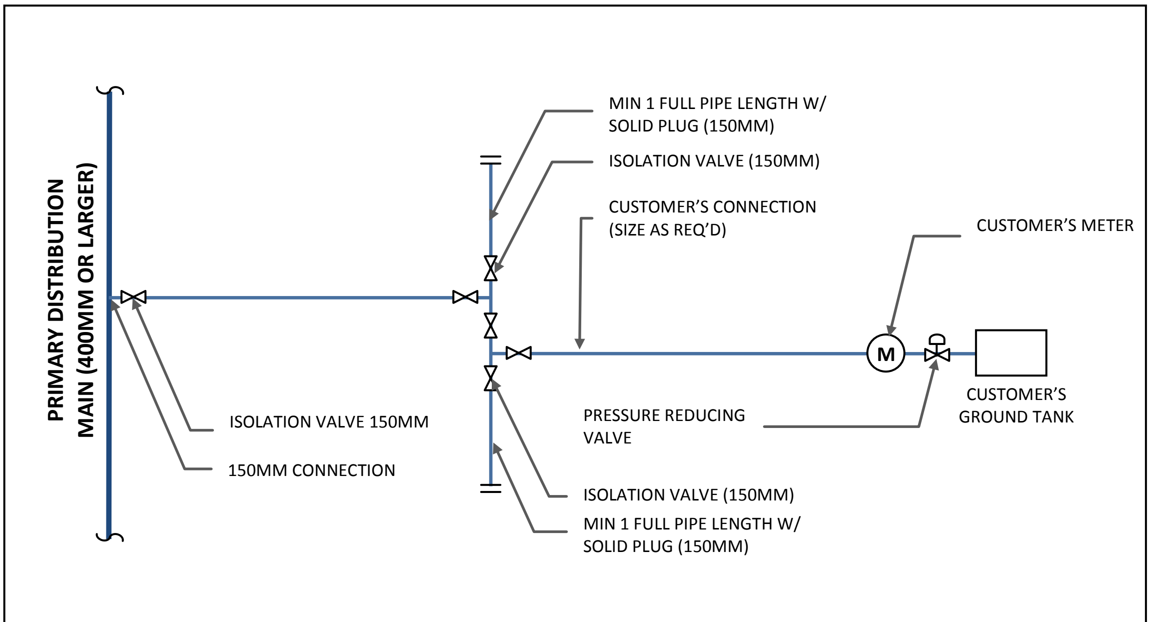

Figure V-3 Connections to Primary Distribution Mains

V.12.4 Cross-Connection Control

No physical connection should be allowed between potable and non-potable sources. Install back-flow prevention where connections between any part of the potable water system and any other environment containing other substances can result in reverse flow due to back pressure. The type of protection used should be selected based upon the service conditions as identified in Table V-14.

Table V-14 Back-Flow Prevention Selection Table

Type Connection	Type Back-flow Prevention
Service connection	Air gap at storage tank
Direct connection to potable water system with elevated tank or pressurized pipe network	Double check valve assembly
Direct connection to chemical feed system	Reduced pressure principle non-return valve assembly
Hydrant of other hose station with direct connection to pipe network	Check valve or vacuum breaker (except for emergency firefighting)

V.12.5 Seismically Vulnerable Areas

Qatar is considered a Zone 1 classification for seismic design purposes. This is minimal and generally not of concern. One exception is to address seismic risk when designing pipelines supported on a bridge. See KM Standard drawings for details to be incorporated and comply with Public Works Authority.

V.13 Reconnaissance Works

During the design stage, a site investigation should be conducted by the designers to determine if the condition at the site imposes special requirements. Corrosive soil, level of the water table, extreme traffic loading, ground conditions, route/placement of pipe, etc. are among the environmental factors that should be considered in the design.

V.14 Drawings

Pipeline drawings should include existing utilities, existing structures, existing roadways and topographic information that may impact construction. Drawings for all primary distribution and transmission mains (pipelines 400 mm and greater) should include a profile view indicating existing ground surface elevations directly above the pipeline alignment and size and vertical clearance of existing utilities (with elevations, if known) crossing the pipeline alignment. Crossings shall be shown in both plan and profile. Plans should include details of pipe restraints if applicable.

Drawings for water lines shall show stationing, pipe size and material, bearings, and curve data to adequately define the water line location. Water line dimensions including distances to structures, right-of-way, face of curb, edge of pavement, and property lines shall be shown. The drawings shall also show all appurtenances, water service connections and water meters.

V.15 Oversizing Requirements

The water main can be oversized based on the future development as per the policy plan.

Where proposed pipe networks are impacted by future water demand projected by KM, those future demand values should be provided to the consultant and included in the water network design. Pipe sizes larger than those required for the specific development may be considered when including future demands provided by KM.

VI. VALVES AND APPURTENANCES

All the required appurtenances should be laid in accordance with KM General Specification of Main Laying Materials for Water works.

VI.1 Isolation Valves

Mainline valves should be the same diameter as the pipeline. On distribution mains in residential areas valves are placed at street intersections and on each smaller main as it leaves the larger main. In general, valves are placed at the tees in 2 directions. In commercial and industrial areas valves should be placed on each branch of tees (all sides).

Pipe cross fittings are not allowed.

The maximum spacing of valves for long pipe lines shall meet the requirements of Table VI-1. Pipe grid systems shall be along the run at intervals of four blocks and not more than the spacing shown in Table VI-1.

Table VI-1 Valve Types and Spacing

Pipe Size (mm)	Maximum Spacing Between Valves (m)	Valve Type
900 and greater	2000	Butterfly Valve
600	1000	Butterfly Valve
400	600	Butterfly Valve
100 to 300	300	Sluice Valve
Less than 100	300	Sluice Valve

Note : In addition to maximum spacing indentified in the table, valves should be located at critical interconnections and inside pumping stations as required by WTDD.

Where future water main extensions are anticipated valves are placed, where possible, so that customers are not out of service during connection work. In most cases, this calls for a line valve within six (6) meters from the end of the main.

Valves for fire hydrants are perpendicular to the water main and in line with the fire hydrant; no offsets are allowed. Valves in the distribution system should be placed so that pipe sections can be isolated such that no more than 2 fire hydrants are out-of-service at any one time in the event of a main break. Place valves at the connection to the main for all fire services including hydrants.

If KM requires the installation of Electronic Monitoring and remote operation equipment, the line valve must be a butterfly valve with rectangular vault, housing the valve operator and telemetry equipment.

VI.2 Air Valves

Air valves are required at strategic locations along pipelines to prevent air binding during filling operations, allow the continual release of air during normal operations, and to facilitate draining of the main. Design should follow recommended practice as described in AWWA Manual M51 or similar design reference. Types of air valves are described in Table VI-2.

Table VI-2 Air Valve Types

Type	Description
Single Air Valve Small Orifice Type (Air-Release)	Small orifice valves designed to automatically release small pockets of accumulated air while system operates under pressure.
Single Air Valve Large Orifice Type (Air/Vacuum)	Large orifice valves designed to exhaust large quantities of air automatically during pipeline filling and admit large quantities of air when the internal pressure drops below atmospheric pressure. Negative pressure may be caused by column separation, pipeline draining, pump failure, or a pipeline break.
Double Air Valve (Combination)	Both small and large orifice valves designed to provide both functions of air-release valves and air/vacuum valves.

Typical locations for air valves are shown on the sample profile in Figure VI-1 and in Table VI-3.[1]

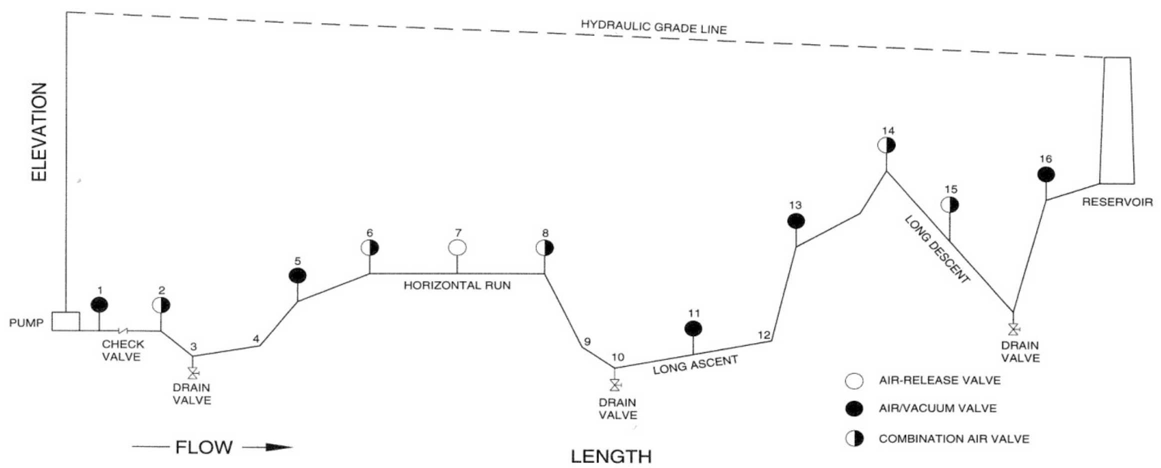

Figure VI-1 Sample Profile

Table VI-3 Typical Air Valve Locations

No.	Description	Recommended Type	No.	Description	Recommended Type
1	Pump Discharge	Air/Vac	9	Decreasing Down slope	None required
2	Increasing Down slope	Combination	10	Low Point	None required
3	Low Point	None required	11	Long Ascent	Air/Vac or Combination

[1] AWWA M51: Air-Release, Air/Vacuum, and Combination Air Valves

Table VI-3 Typical Air Valve Locations					
No.	**Description**	**Recommended Type**	**No.**	**Description**	**Recommended Type**
4	Increasing Upslope	None required	12	Increasing Upslope	None required
5	Decreasing Upslope	Air/Vac or Combination	13	Decreasing Upslope	Air/Vac or Combination
6	Beginning Horizontal	Combination	14	High Point	Combination
7	Horizontal	Air Release or Combination	15	Long Descent	Air Release or Combination
8	Ending Horizontal	Combination	16	Decreasing Upslope	Air/Vac or Combination

All air valve design calculations require KM review and approval.

Air inlet and discharge vents for valve chambers should be at least 0.5 m above finished grade when possible. It should have a downward-facing vent opening with insect screen. Where it is not practical to install an air vent above grade the below-grade chamber must be rated for appropriate traffic loading in traffic areas, and the chamber must drain to daylight.

VI.2.1 Air Valve Assemblies

Primary mains between valves shall be treated as an independent unit with provisions for dewatering, filling, removing air and adding air as appropriate for the primary main construction and maintenance. Air valve assemblies shall be installed at all profile high points in the primary mains at locations approved by Water Planning Department with sizes as presented Table VI-4

Table VI-4 Air Valve Sizing	
Main Diameter (mm)	**Washout Size (mm)**
2000	300
1600	250
1400	250
1200	200
900	200
600	150
400	100

VI.3 Control Valves

Hydraulic modeling must verify the need for the control valve function and location, and requires KM approval. A description of the application of each type of valve is included in Table VI-5.

Table VI-5 Application of Control Valves in System Design	
Valve Type	**Application**
Pressure Reducing Valve (PRV)	A control valve that opens to allow flow if the downstream pressure is less than a certain value and that closes when the set pressure is reached. A pressure reducing valve ensures that the downstream pressure does not become too high. It is used between Transmission / Distribution mains where the distribution pressure is lower and in other situations that require reductions from higher-pressure planes to lower-pressure planes.
Pressure Sustaining	A pressure sustaining valve controls the pressure between two zones of high demand maintaining the appropriate pressure on the upstream system while allowing flow to move into the lower pressure demand area. These valves also protect against the demand in the lower pressure area depleting the pressure from the area supplying it. Pressure sustaining valves are fully automatic and are easily adjustable based on system operational parameters.
Pressure/Surge Relief	A pressure/surge relief valve is a fast opening valve used to dissipate excess pressure in a system during events such as pump start up, but slow closing to avoid surge within the system. Pressure/surge relief valves are automatic and easily adjustable based on system operational parameters.
Flow Control	A flow control valve regulates the flow and pressure of a pipe system. Flow control valves respond to signals from separate systems such as flow meters or flow control PLC units.
Level Control Valves (Altitude Valves)	Level control valves are automatic valves that close when a reservoir or other system reaches a predetermined elevation (i.e. tank full) and opens once the tank is depleted to a level requiring filling. Level control valves can be either pressure controlled or electronically controlled. Tank levels can be controlled locally at the tank or remotely via PLC controller.

Design should follow recommended practice as described in design references such as AWWA M44. All control valve design calculations require KM review and approval.

VI.4 Non-Return Valves

Non-return valves should be installed where backflow from a pressurized source can occur should system pressure be lost. This includes vaults that may be flooded, fire hydrants, and any location where a hose may be connected to the water system. Refer to cross-connection control for appropriate non-return valve types and applications.

VI.5 Wash-Out Valves (Flushing)

Install washouts or hydrants at low points and dead-ends. They should be designed to achieve a minimum velocity of 0.5 m/s in the main. Washouts should be sized using Table VI-6.

Table VI-6 Washout Sizing	
Main Diameter (mm)	**Washout Size (mm)**
Greater than 1200	250
1200	250
900	200
600	200

Table VI-6 Washout Sizing	
Main Diameter (mm)	**Washout Size (mm)**
400	100
Less than 400	No less than 2 diameter sizes smaller than the main diameter

VI.6 Flow Metering

Metering and monitoring points are required at strategic locations. Installation requirements vary based upon the meter configuration category. All meter installations should be provided with isolation valves.

VI.6.1 Domestic Meters

Domestic meters can be broken down into small and large configurations. Customer meters are provided for all service connections and should be placed at the property line.

VI.6.1.1 Small Meters

Flows less than 165 m^3/day (6.9 m^3/hr) are considered small meters.

VI.6.1.2 Large Meters

Flows greater than 165 m^3/day (6.9 m^3/hr) but less than 600 m^3/day (25 m^3/hr) are considered large meter customers.

VI.6.2 Service Connections & Water Meter Requirements

All service connections and water mete materials and installations shall be as per KM specifications. Other requirements are given below:

- In new developments where new mains are installed, service connections and electronic water meters shall be installed to each prospective consumer.
- Every separate property or building shall be supplied with a separate service connection and water meter. A single service line and a master meter could be used for two or more buildings located on the same lot or for housing complex or like within one lot/property.
- New service connections, as much as possible, shall be limited in size to 50% of the water main diameter. On looped mains, there shall be a limited number of service connections comparable to the equivalent existing main capacity.
- Electronic water meters shall be used.
- Service connections shall be MDPE.

VI.6.3 Bulk Customer Meters

Flows equal to or in excess of 600 m^3/day (25 m^3/hr) are considered bulk customers. A bulk customer meter will be required to measure flow into the development. Depending upon the nature of the development, such as a housing complex, additional meters inside the customer's property may be required.

In addition to measuring flow, other parameters to be monitored include pressure and water quality. Locations of monitoring facilities will be as directed by KM during project development.

VI.6.4 District Meters

Flow meters should be installed at the points where major supplies enter the network, downstream of main divergence points on the transmission or distribution system main, and at entry points to District Metered Areas (DMAs) and other distribution blocks. A monitoring insertion point should be provided at each meter location.

VI.6.5 Facility Meter

IWPP connection points and inlet and outlet piping to RPS facilities require metering and pressure sensing instruments with SCADA for continuous real-time monitoring.

VI.7 Monitoring Stations

Monitoring stations to allow insertion of instruments to monitor various functions are required for special purposes as identified in the meter classification descriptions above. Quadrina Insertion points at each district and bulk metering point are required. Insertion stations are required in DMAs at high and low points for monitoring system pressures. Insertion points are also required at select locations as determined by KM throughout the distribution network where water quality or system parameters must be determined for reliable operation.

Monitoring stations consist of a ferrule with an isolation valve that provides a minimum of 50 mm clear opening. The station should be located in a straight section of pipe at a minimum of 10 pipe diameters upstream and 5 pipe diameters downstream of any fittings or connections that may influence the water flow pattern. At locations where flow may reverse, the minimum downstream straight pipe length should be increased to 10 pipe diameter.

Examples of typical metering and monitoring appurtenances/applications include:

- Flow Metering – Provide meters at all service connections and elsewhere in the pipeline network as determined by KM.
- Pressure Transmitters – Provide pressure monitoring stations at locations selected by KM.
- Pressure Regulating Valves – Install pressure regulating valves when connecting to higher pressure network system components.
- Water Quality Controls - Analyzer Stations for measuring pH, residual chlorine, conductivity and temperature should be installed at locations identified by KM.
- Water SCADA Requirements - KM requirements for SCADA systems shall be discussed and complied with KM Water Control Section (NWCC), Technical Affairs and Water Planning Department.

Table VI-7 presents water monitoring and sampling location design steps.

Table VI-7 Sampling Point Location Design Steps			
Design Steps	**Type of Sampling Point**		
	Manual	**Quadrina Station**	**Automatic with Telemetry**
1. Review Distribution Network Map Layout and Water Quality Analysis from Computer Modeling (if done).	-	-	-
2. Identify KM required monitoring points:			
A. Standard locations for Distribution Network			
i. Dead end lines	X	-	-
ii. DMA Metering Point	-	X	-
iii. DMA High & Low Points	-	-	X
iv. Upstream and Downstream of Disinfection Points	-	-	X
v. IWP Metering Point	-	-	X
B. RPSs			
i. Inlet Piping from Source	-	-	X
ii. Outlet Piping to Distribution System	-	-	X
C. RO and Wellfield Facilities - as directed by HSE and Water Laboratory	X	X	X
3. Identify KM Project Specific monitoring points: This step requires coordination with network water quality modeling to identify areas of potential poor water quality. In addition, KM may desire to monitor miscellaneous points in the system for other reasons. The location and type of sampling point equipment to be installed will be directed by HSE and Water Laboratory.	X	X	X

Additional monitoring requirements for district metering locations are to be determined by KM during the project development phase which may include the following parameters:

- Pressure
- Water Quality Stations
  - pH
  - residual chlorine
  - conductivity
  - temperature
  - Oxidation-Reduction Potential (ORP)

VI.8 Appurtenance Chambers and Boxes

In-situ concrete chambers shall be provided in primary & transmission pipes 400 mm and larger pipes and pre-cast concrete boxes for 300 and below mains.

All valves assembly, chambers, boxes and covers shall conform to the specifications of main laying materials and specifications of main laying construction.

VI.8.1 Chambers and Access Manholes

For developments that are proposed to be phased, the chamber and piping must be sized for the meter or valves required for the ultimate build out of the development. However, the initial meter installed must be sized to accurately capture the range of flows for the first phase. It is expected that in most cases the water meter size will be at least 1-2 sizes smaller than the water service connection pipeline.

Access manholes shall be provided in 400mm and larger pipes to allow for inspections during construction and to serve later on during repairs.

VI.8.2 Meter Boxes

Consideration should be given for future conditions when sizing the box for meters and instruments. Provide adequate space for future modifications if anticipated. Provide precast structures unless sizes or special conditions require in-situ placed concrete.

VI.9 Corrosion Protection

Engineers should consider protection from external corrosion in areas where corrosive soils are prevalent or when pipelines, for whatever reason, leave the soil environment. This protection is especially true for bridge crossings in salt-water (coastal) environments or other harsh environments. Engineers should also evaluate and, if appropriate, protect metal pipes from corrosion due to stray electrical currents in the soil. This usually occurs when metal pipes are near or cross major oil or natural gas pipelines protected by impressed current.

VI.9.1 Protective Coatings

Install protective tape wrap and coating systems on all ductile iron pipe and appurtenances complying with KM's *General Specifications for Main Laying Materials for Waterworks*.

VI.9.2 Cathodic Protection

In general, cathodic protection in conjunction with highly effective dielectric coatings should be provided if any of the following conditions exist:

- Soil resistivity is 12,000 ohm-cm or less (measured in the field only) or 5,000 ohm-cm or less (measured in a laboratory in saturated condition), or when a wide range of soil resistivities exists regardless of their absolute values.
- Soil with high chloride or sulfate concentrations.
- Waters with high chloride concentrations, high TDS, or high dissolved oxygen concentration
- Areas subject to stray electrical currents.

VI.10 Thrust Restraint

All bends, fittings, isolation valves, and bulkheads should be restrained to counteract joint movement where unbalanced, internal pressures exist.

Design thrust restraint systems shall be based on soil parameters obtained from geotechnical investigations when available or use typical soil values for the type soils anticipated to be encountered plus a minimum factor of safety of 2.

All thrust blocks and anchorage shall be designed to resist the specified field hydrostatic test (minimum of 9 bar or 1.50 times working pressure whichever is higher). Thrust blocks and anchorages for restraint joints or thrust blocks shall be used for all bends (vertical and horizontal) and fittings or where joint devices are required.

When multiple vertical bends are required for utility clearances, all fittings are to be designed with restrained joints or rigid connections in addition to concrete thrust blocking.

VI.10.1 Joints

Use restrained joints where concrete thrust blocks are not practical due to space limitations or where future excavation may disturb the thrust block supporting soils. Restrained joints may be used independently or in combination with concrete thrust blocks.

When multiple vertical bends are required for utility clearances, all fittings are to be designed with restrained joints or rigid connections in addition to concrete thrust blocking.

VI.10.2 Blocking

Concrete thrust blocks may be used where adequate space is available and future excavation adjacent to the installation will not disturb the supporting soils. Blocking must be poured against undisturbed soils.

Refer to the Standard Drawings for typical details of each type of thrust block. Results from geotechnical investigations should be compared with the design parameters used for design of the standard blocking shown on the Standard Drawing.

VI.11 Fire Hydrant Requirements

VI.11.1 Use of Fire Hydrants

KM installs fire hydrants along the water distribution system. However, KM fire hydrants serve multiple purposes as defined in Table VI-8.

Table VI-8 Fire Hydrant Use Descriptions

Use	Location and Description
Firefighting	Located at specified separation distances to provide access to water source for fighting fires
Air Release (Line filling)	Located at high point in line to allow release of air when filling a pipeline only (not for release of accumulated air during normal operations)
Flushing and Draining	Located at low point in line to allow discharge of water when flushing or draining a pipeline
Water Quality Monitoring	All locations provide access to system to obtain water samples for testing purposes.

Table VI-8 Fire Hydrant Use Descriptions	
Use	**Location and Description**
Flow and Pressure Characteristics Monitoring	All locations provide access to system for flow and pressure measurements for system evaluation and modeling calibration

VI.11.2 Fire Hydrant Design Criteria

Several factors contribute to the configurations of fire hydrants. Table VI-9 summarizes the current design criteria and guidelines in the development of fire hydrants for KM. The application of these criteria shall be discussed with KM with respect to the specific requirements of the development projects being designed.

Table VI-9 Fire Hydrant Design Criteria

FIRE HYDRANT (FH) PARAMETER	Unit	KAHRAMAA (KM) Underground and Aboveground Hydrant
Fire Flow per FH	Li/min	1,000 (17 lps)
Residual Pressure @ FH	Bar	1.50
No. of FH Operating Simultaneously	#	2
Flow Duration	Hours	2[2]
Hydraulic Modeling Scenario	-	ADD + Fire Flow
FH Size	mm	▪ 150mm for 150mm mains and bigger ▪ 100mm for 100mm mains
FH Location	-	All areas
FH Spacing	m	▪ 150m for urban ▪ 250m for rural ▪ 150m for industrial/ commercial ▪ 250m max. for high/low points
Minimum main size	mm	100

Other fire hydrant requirements are as follows:

- Fire hydrants shall be placed on water utility reserves and shall be installed at convenient spots for firefighting such as at street intersections and junctions.
- Where long block lengths require the use of intermediate fire hydrants, they shall be placed in line with the property boundary between adjacent lots or parcels of land.
- Dead end lines shall be provided with hydrants or terminal hydrants, not necessarily for firefighting but for draining off the pipeline from foreign materials.
- Hydrants shall be CD approved aboveground double pillar type with a minimum 100mm nominal diameter barrel.
- Hydrants with more than two outlets shall have appropriately sized larger barrel size.

[2] NFPA 13 Table 11.2.3.1.2

- Each hydrant shall have at least two outlets. Outlets shall be 65mm nominal diameter.
- The minimum size water line used for fire protection shall be 150 mm in size and shall be looped to provide feed from at least two directions. However, for areas having 100 mm diameter distribution pipeline, a 100 mm belowground fire hydrant could be installed.
- Hydrants shall be located such as to maintain a minimum of 6m clearance from any building or hazards.
- Hydrants shall be so located such that they will not be obstructed by parking, loading and unloading of vehicles, landscaping features and other obstructions.
- Consideration shall be given to protection from mechanical damage.

VII. RESERVOIR AND PUMPING STATION

VII.1 Reservoir Basic Function

Adequate storage plays in important role in sustaining KM water distribution network. All pumping stations draw its water from a number storage reservoirs strategically arranged within the confines of a typical RPS. Regardless of the type of construction and material used, a potable water reservoir has the following essential functions:

- To provide adequate storage and emergency reserve in case of outages and interruptions from the production/treatment plan and transmission main.
- To balance or equalize downstream daily variations in demand with relatively constant rates of inflow and to cover peaks in demand.
- Permit high service pumps at desalination plants to operate at a relatively uniform rate.

VII.2 Reservoir Shape and Type of Construction

Reservoirs should be designed and constructed with at least two compartments so that one can be drained for maintenance without having to put the whole reservoir out of service. The tank's shape generally follows the type of construction adopted and materials used for construction:

- A rectangular tank is suitable for a cast in-situ reinforced concrete tank while a circular (cylindrical) tank goes well with a pre-stressed concrete or steel tank.
- For a two-compartment rectangular reservoir, the most economical plan shape is when its length is one and half times its breadth.
- Buried and partially buried tanks minimize heating of the water and have fewer aesthetic issues than tanks at grade, but have poor accessibility for cleaning, maintenance and repairs.
- Concrete tanks generally need coating re-application on a much less frequent basis than do steel tanks.
- Rectangular tanks can be compartmentalized offering more flexibility for the flow paths and outages for maintenance and cleaning.
- Circular tanks, other than a concentric tank design (small tank within a larger tank), do not offer the same flexibility. However, circular tanks are less likely to have dead zones where solids can settle, and they have no corners, making them easier to clean.

VII.3 Storage Sizing

Storage facilities shall have a capacity to meet projected water demand including fire water storage, emergency and standby reserve. It is the design engineer's responsibility to understand the applicability of the requirements stated in this section as it relates to storage reservoirs.

The KM system has several storage reservoirs coupled with pumping stations to provide pressure to the distribution system. There are five storage volume components designers must consider when sizing total storage volume:

1. Operational storage (OS)
2. Equalizing storage (ES)
3. Standby storage (SB)
4. Fire storage (FS)
5. Dead storage (DS)

Figure VII-1 illustrates each of these components. Only effective storage volume, as defined in Section VII.1, can be used to determine the actual available, or design storage volume. In KM context, the minimum effective storage volume should not be less than twice the projected average day demand (ADD) derived at the design year.

If the project is to be phased and two or more storage reservoirs are ultimately required, the initial or first phase storage reservoir shall include the capacity for the total project (all phases) fire flow storage and emergency storage plus the peak hour storage requirement for the first phase water demand.

VII.3.1 Effective Storage Volume

Effective storage volume is equal to the total volume less the dead storage (DS) built into the reservoir (i.e., Effective Storage Volume = OS + ES + SB + FS). Total reservoir volume, as measured between the overflow and the reservoir outlet levels, is typically not equal to the effective volume available to the water distribution system. A minimum storage water level may be needed to provide sufficient suction head for pumps to withdraw water from a reservoir to feed directly into a distribution system. Conversely, the rate and pressure of the water feeding into a reservoir may limit the top water level, making the upper volume of the reservoir unavailable and not a part of the effective storage of the reservoir.

VII.3.2 Operational Storage (OS) Volume

Operational Storage Volume is the volume of the reservoir devoted to supplying the water to the distribution system under normal operating conditions, but with no source water entering the reservoir. When the reservoir is full, OS provides a safety factor beyond that provided by the ES, SB, and FS as shown in Figure VII-1.

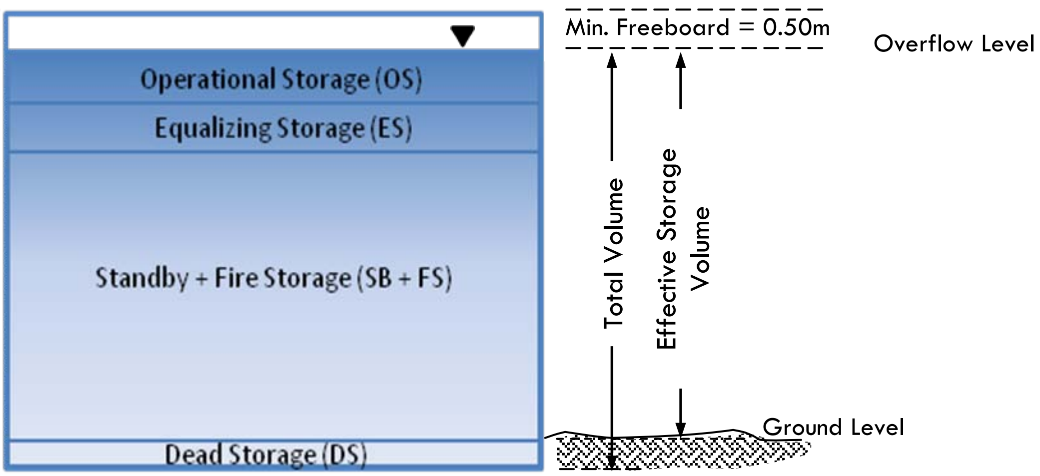

Figure VII-1 Reservoir Storage Components

VII.3.3 Equalization Storage (ES) Volume

When the source flow rate into the reservoir cannot meet the periodic daily (or longer) peak demands placed on the water distribution system, equalization storage (ES) volume must be provided to maintain water supply to all service connections. Several factors influence the ES volume, including peak diurnal variations in water system demand, source production capacity, and the mode of source water operation. The design engineer must consider source water hydraulic capabilities to properly evaluate ES requirements and design of each storage system.

1. ES sizing will require developing a peak day demand (PDD) diurnal curve for the water distribution system demand. Diurnal demand varies due to water system size, season, and type of demand (residential, commercial, industrial, and recreational). After developing the PDD diurnal curve, the design engineer can calculate the required ES by determining the difference between supply and demand over the course of the day. Extended period simulation hydraulic models can be used for this purpose. As a general guideline, the volume of ES needed using constant pumping is about 10 to 25 percent of the PDD.
2. For multiple day demand, the ES volume will increase significantly if the source(s) cannot meet the PDD. In such cases, the design engineer can calculate the difference between supply and demand over multiple days to determine the required ES. This approach requires developing water system-specific diurnal demand curves. Extended period simulation hydraulic modeling may be needed to confirm that system demand can consistently be met.

VII.3.4 Standby Storage (SB) Volume

Standby storage (SB) provides a measure of reliability in case source water systems fail or unusual conditions impose higher demands than anticipated in the distribution system. The SB volume recommended for storage reservoirs with one source of water may differ from storage reservoirs being fed by multiple sources. It is the responsibility of the design engineer to investigate and understand the hydrodynamics and reliability of all sources that will be feeding into a storage reservoir to determine the appropriate SB volume needed.

1. **Water Storage Reservoirs Supplied by a Single Source.** It is recommended that storage reservoirs fed by a single source have a SB volume at least equal to the average daily demand (ADD) or one day of storage as defined by Equation (2).

$$SB_{TSS} = (ADD) \qquad \text{Eq. (2)}$$

Where:

SB_{TSS} = Total standby storage for a single source water system (m^3)

ADD = Average day demand for the design year (m^3/day)

2. **Water Storage Reservoirs Supplied by Multiple Sources.** Water systems supplied by multiple sources should have SB volume based on Equation (3).

$$SB_{TMS} = (ADD) - tm\,(Q_S - Q_L) \qquad \text{Eq. (3)}$$

Where:

SB_{TMS} = Total standby storage component for a multiple source water system (m^3)

ADD = Average day demand for the design year (m^3/day)

Q_S = Sum of all installed and continuously available supply source capacities, except emergency sources (m^3/day)

Q_L = The largest capacity source available to the water system (m^3/day)

tm = Time the remaining sources are pumped on the day when the largest source is not available (minutes). Unless restricted otherwise, assume 1,440 minutes

3. **Reduction in Standby Storage.** SB volume can be reduced if additional water supply sources are available and there is emergency power that starts automatically if power is lost at the primary water source.

VII.3.5 Fire Storage (FS) Volume

When a dedicated fire standpipe system is being supplied from the water reservoir, a fire storage shall be provided.

This fire storage (FS) level depends on the maximum flow rate and duration requirements needed in the supplying distribution system in accordance with KM fire hydrant guidelines. The minimum FS volume for water systems served by single or multiple supply sources is the product of the required flow rate (expressed in liters/min) multiplied by the flow duration (expressed in minutes) as provided in Equation (4).

$$FS = (FF)(t_m) \qquad \text{Eq. (4)}$$

Where:

FF = Required fire flow rate (l/min)

t_m = Duration of FF rate (min)

VII.3.6 Dead Storage (DS) Volume

Dead storage (DS) is the volume of stored water not available at all times. It is the total storage below the invert level of the lowest discharge outlet from the reservoir. The dead storage usually contains accumulated silts and suspended solids which should not enter into the distribution system. The dead storage volume should not be more than 5% of the reservoir's volume.

VII.4 Disinfection System Requirements

The treatment of water within the reservoir and pumping station may include the use of chemical disinfection methods including chlorine and chlorine dioxide, or other disinfection methods.

Due to the storage projects, no set design criteria can be maintained for all sites. A general set of criteria has been developed in order to provide guidelines for the design of each site as follows:

- Monitor the chlorine residual in a continuous sample taken from a location that will represent the chlorine level in the reservoir.
- If the chlorine residual falls below the set point of 0.20 ppm, for example, then the chlorine additive system is activated.
- When the chlorine system is activated, a reticulation pump starts and a chlorine solution is added to the water to raise the free chlorine level in the reticulation water to approximately 1 ppm.
- The reticulation pumps will be sized to turn the full volume of the reservoir over in a maximum of 3 days. Each site will have somewhat different point/points from which the reticulation pump will draw its suction. The typical discharge point will be approximately 180 degrees from the inlet/outlet piping. Using this piping system, the chlorinated water will be dispersed into the stored water and eventually turn the volume of the reservoir over with chlorinated water.
- When the chlorine residual in the continuous sample reaches a set point of approximately 0.40 ppm, the reticulation pump, without the chlorination system, will be started. This will help to circulate any newly added water with adequate chlorine residual and a minimum chlorine level in the reservoir.

Chlorination facility maximum design criteria are presented in Table VII-1.

Table VII-1 Chlorination Facilities Maximum Design Criteria

Item	Design Criteria
Low Level Chlorine	0.20 ppm
High Level Chlorine	1 ppm
Design Chlorine Dosage	1 ppm
Volume Turnover Maximum Time Required	3 days
Chlorine Monitoring	Constant, amperometric method

VII.5 Pumping System Planning Criteria

The Pumping Station Design Standards include:

- Pumping unit types and selection criteria.
- Matching pump curves to meet the required system hydraulics characteristics.
- Number of pumps, including stand-by and maintenance pumps.
- Vibration and cavitation considerations.
- Provisions for expansion of the pump station for future flows with minimal disruption of operations.
- Pump station layout and appurtenances to be provided.
- Power requirements including variable frequency drives and motor selection criteria.
- Pump control philosophy and data to be relayed to the NWCC.

The minimum requirements for pumping facilities and booster stations are as follows:

- The pumps shall be selected to provide the minimum required pressure of 1.5 bar (15m) at the farthest and highest node of the distribution network.
- The pumping station shall consist of group of pumps of equal operating capacity and installed in parallel.
- The number of duty and stand-by pumps shall always be n+2, where "n" is the number of duty pumps + 1 (stand-by pumps)+ 1 (maintenance pumps).
- Two (2) numbers of pump slots for future use shall always be included in the design of pump arrangements.
- The pumps total capacity sizing shall be based on a peak hour demand (PHD).

Piping configurations shall include the following:

- All the piping within the pump stations shall be provided with restrained or rigid joints.
- Isolations valves shall be provided for each pump assembly
- Discharge piping shall include:
    - End spools
    - Non-return valves
- Pump discharges shall be joined to a common header, which shall pass through a flow meter as per KM Standard for Meter Assembly.
- Surge protection for the pump shall be installed after the discharge header as well as surge protection devices for the pipes.

VII.6 Number of Pumping Units

The pumping station peak design flow rate should be achieved with all duty pumps operating at the design head condition. A minimum of two duty pumps should be provided in each pump station. As a general guideline, the maximum capacity of any one pump should be limited to approximately 1.0 m^3/s unless this leads to an excessive number of pumps. Table VII-2 provides general guidance for the required number of pumping units.

Table VII-2 Number of Pumping Units				
Rising Main Min. Flow Rate (m^3/s)	Rising Main Peak Flow Rate (m^3/s)	Capacity/ Pump, (m^3/s)	Number of Duty Pumps	Number of Standby and Maintenance Pumps
0.5	1.5	0.5	3	2
1.0	3.0	0.5	6	2
2.0	6.0	1.0	6	2

VII.7 Pump Drives

Water supply and distribution pumps will be driven by electric motors. Power supply is fed from KM Electrical Network. Other power sources such as diesel and other fuel types will be used for emergency power only.

The following characteristics will be included as considerations for the design engineer:

- Motor to be in conformance with Section 4 – Electrical Works, of KM standard specifications.
- Minimum motor efficiency of 93% at the specified operating point.
- Allow a maximum rotational speed of 1500 RPM.
- Limit the starts per hour to motor manufacturer's recommendation.
- Nameplate horsepower shall exceed the maximum required by the pump under all operating conditions. For best efficiency, the motor specified should operate in a range within 90% to 100% of its rated power (avoid over sizing motors since efficiency and power factor drop in motors running below load rating).
- Provide a 1.15 service factor at ambient temperature plus 50 deg C of the nameplate voltage.
- Provide an Underwriter's Laboratory (UL) or Factory Mutual (FM) rating.
- The frame is cast iron.
- Windings are copper, not aluminum.
- Provide heavy-duty 100,000 hour rated bearings. Bearings to be grease lubricated and protected from water ingress by appropriate means. Bearings shall be insulated. The starting code letter/locked rotor kVA shall comply with NEMA code "F" criteria or better.
- Provide an over-temperature safety switch installed on the motor windings and bearing temperature and vibration sensors.
- Provide a heater element installed to reduce condensation. The motor heater element is strip type that automatically disconnects when the motor starts.
- Provide instrumentation for conditions monitoring such as vibration (x,y) at DE and NDE of motor, temperatures of bearings, etc.
- Acceptable valves to be used within the KM pump and booster station piping systems include isolation valves, control valves, air release and vacuum relief valves, drain valves, check valves and relief valves.

VII.8 Surge Analysis

A surge analysis and hydraulic modeling must be performed for all pump stations and then followed by the design of a surge control system that is in accordance with the results of the surge analysis. Even slight velocity and/or pressure changes caused by surges can rupture piping and cause major damage to the pumping system.

Hydraulic surge control is a specialized field and it should be performed by an engineer that has either specialized or extensive experience in the field. A Third Party Specialist shall be engaged during detailed design and construction stages. A detailed surge analysis is recommended for all water system pump stations.

VII.8.1 Surge Control

Surge control methods and devices that may be considered independently or in combination include the following:

- Water pipeline alignment revisions to eliminate potential column separation zones.
- Installation of spring or weight-loaded check valves that are designed to close before the hydraulic wave reverses.
- Installation of a surge anticipator relief valve which senses a loss of power and/or pressure surge wave and opens on set time delay or high pressure respectively. Install piping and valves to provide pressure relief from the pump discharge side to the suction side.
- Installation of a pressure relief valve from discharge manifold to suction manifold for routine pressure rises due to rapid changes in system demand. Cannot rely on mechanical actuator or diaphragm for operation of relief valve.
- Surge tanks are determined if required on discharge pipelines.

VII.9 Pump Station Control Philosophy & Telemetry

Pumps are controlled by pressure designed to maintain a pressure set point at the delivery header. When running under automatic discharge pressure control, the pumps are operated based on the discharge pressure and flow signals from the discharge header pressure in the pump station and the rising main flow meter.

The control philosophy is based on the number of pumps, the flow capacity of each pump, the pump curves, and the system head curve. To meet the pressure requirements at wide flow rate ranges, the pumps' speeds are varied through variable frequency drives (VFDs) or in the case of fixed speed pumps, varying the numbers of pumps operating. Pressure surges caused by the transition from one-pump to two-pump operation, two to three, etc., must be avoided as described in the following control sequence.

It should be possible to control the pump station from either the local control room or from NWCC. The field signals are wired to common marshalling panel in the local control room/instrument room. The signals are then split to the pump station local PLC and to the NWCC RTU. The local control room will have a selector switch for Local/NWCC which will transfer the command from local control room to NWCC and vice versa. The communication between the RTU located in the pump station control room and the NWCC shall be as per the communication section of the Specifications.

Pump station data transmission to the NWCC should include the following data at a minimum:

- Pump running
- Pump speed
- Motor high temperature and vibration alarm
- Pump circuit breaker/motor starter failure
- Control power failure
- Main power phase unbalance/failure
- Distillate inlet pressure and associated alarms
- Rising main flow rate
- Rising main pressures
- Distillate inlet flow control valve position command and feedback
- Distillate inlet flow control valve open/close command with status feedback and trip
- Distillate inlet bypass valve position command and feedback
- Distillate inlet bypass valve open/close command with status feedback and trip
- Distillate direct supply valve to network position command and feedback
- Distillate direct supply valve to network command with status feedback and trip
- Distillate inlet isolation valves open/close command with status feedback and trip
- Individual inlet reservoir valves open/close command with status feedback and trip
- Pump suction/ discharge valves open/close command with status feedback and trip
- Rising main interconnection valves open/close command with status feedback and trip
- Recirculation valves position command and feedback
- Recirculation valves open/close command with status feedback and trip
- Rising main valve position command and feedback
- Rising main valve open/close command with status feedback and trip
- Pump station power supply
- Reservoir or tank level
- Pump room flooding
- Intrusion alarm
- Generator run status and failure
- Ventilator fan failure, etc.
- Pumping station ambient temperature
- Communication failure
- Fire alarm control panel and air conditioning signals
- Water leakage or flooding inside pump station
- Status signal of electrical power distribution equipment
- All signals required for supervising the communication link
- Remote/Local status for the valves should be in series from the field equipment
- All water quality instrument signals with associated alarms including:
    - Residual Chlorine
    - Chlorine Dioxide
    - Turbidity
    - pH

- o Conductivity
- o Temperature
- o Dissolved Oxygen

VIII. HYDRAULIC ANALYSIS AND NETWORK MODELING

Development of the hydraulic models include compilation, review, and analysis of all available information related to the physical system (production, transmission, storage, pumping and distribution facilities) and the distribution of demands (including meter records, water district area mapping, community plans and zoning maps, and aerial or satellite imagery), together with system inspections. These data and information shall be used to generate the computer models, then the production and storage level records together with system pressure recordings shall also be used to calibrate the models. The model is then modified as required to generate results as close as possible to actual system behavior.

VIII.1 Modeling Software Requirements

The hydraulic modeling software selected for network modeling should have the following capabilities:

- Ability to perform a steady-state analysis of pipe conditions to evaluate average day, peak day, peak hour, and fire flows.
- Ability to perform a sequence of analyses with the output from each forming the input to the next one, known as extended-period simulation (EPS). EPS is used to model variations in demand, storage, reservoir operations, water quality, and water transfers through transmission pipes. It requires incorporation of diurnal demand curves for nodes and varying tank configurations, if any.
- Ability to import and export data from and to other applications such as spreadsheets, databases and Geographical Information Systems (GIS) systems.
- Ability to perform automated fire flow calculations.
- Ability to model the water quality within the distribution system, particularly the decay of chlorine residual and water age.

It is noted that while most models can use either the Hazen-Williams or the Darcy-Weisbach equation to compute head losses, the Hazen-Williams is only applicable to a limited range of Reynolds numbers (Re). Thus, it is recommended to use the Darcy-Weisbach equation, which includes all flow regimes.

It should be noted that KM requires all simulations to be carried out using InfoWater hydraulic modeling software.

VIII.2 Analysis Scenarios

VIII.2.1 Steady-State Simulation

A steady-state simulation predicts the response of a water distribution system assuming a hypothetical condition where the effects of all operational and demand changes have stopped. A steady-state analysis should include the following steps (AWWA, 2005):

- Calibrate model to ensure that it predicts distribution system responses with sufficient accuracy.

- Select limiting conditions for design scenarios. These conditions should be the most severe demand conditions to ensure that the system will operate satisfactorily for all other conditions. The most common steady-state scenarios are average day, peak day, peak hour of the maximum day, minimum hour of the maximum day, and average day plus fire flows. The selected condition to model depends on the question that the modeler needs to answer. Table VIII-1 summarizes some typical types of analyses and the recommended steady-state scenarios used to model the network.

Table VIII-1 Typical Model Scenarios

Purpose of the Analysis	Recommended Steady-State Demand Scenario
Studies of normal operation	Peak day
Production and pumping requirements	Peak day
Design-subdivisions	Peak hour of maximum day
Design-large system	Peak hour of maximum day
Tank capabilities	Peak hour of maximum day
Transmission lines	Peak day
Master planning	Peak day
System reliability during emergency or planned shutdown	Condition when the emergency or shutdown is likely to occur
Model calibration	Condition during time when measurements were collected

VIII.2.2 Extended-Period Simulation

During an extended-period simulation (EPS), a series of steady-state simulations at specified intervals (time steps) are performed over a time period to simulate the way the system responds to changing demands and operational conditions. EPS models can refine designed system improvements developed from steady-state simulations. Analyses are typically simulated over a minimum of 24 hours, during average and maximum demand days.

VIII.3Model Applications

VIII.3.1 KM Distribution Network Expansion

The Water Planning Department shall be consulted if modeling is warranted for the expansion of KM water distribution network or addition of new pumping station and rising mains. This hydraulic modeling exercise is performed by KM.

VIII.3.2 Bulk Customer Development

Bulk customers, defined as water customers using flows greater than 600 m^3/day, shall consult with Water Planning Department to determine if computer modeling is required. The modeler should consider:

- The internal network design of the service area,
- Connections to existing system,
- Future downstream development, and
- Fire flows.

The model outlines the details of how the area should grow in a sequential manner. The modeler should consider the effects of staging on system reliability.

VIII.4Modeling Process

The development and application of a water distribution system hydraulic model can be summarized in the following steps presented in Table VIII-2.

Table VIII-2 Hydraulic Modeling Steps

Step	Description
1. Determine model purpose and requirements.	This will dictate the necessary accuracy of the model and the level of detail required.
2. Develop network representation.	This includes determining pipes to be included in the model (skeletonization) and making assumptions for parameters values for pipes.
3. Calibrate model.	Adjust non-measurable model parameters (generally roughness coefficients) so that model results compare well to observed field data. This step cannot be included if the model represents a new development since field data will not be available.
4. Verify model.	Compare model results to a second set of field data (independent of that used for calibration) to confirm that the network and model parameters represent actual conditions adequately.
5. Use model.	Identify the design or operation problem/ alternative to be modeled and incorporate in the model (e.g., higher demands, pipe status, new pipes, operational decisions, etc.).

Table VIII-3 lists typical elements for the KM InfoWater model representation.

Table VIII-3 Network Modeling Elements		
Element	**Type**	**Primary Modeling Purpose**
Reservoir (at desalination plants)	Node	Provides water to the system. Boundary condition.
Storage Tanks (Primary and Secondary)	Node	Stores excess water within the system and releases that water at times of high usage
Junction	Node	Removes (demand) or adds (inflow) water from/to the system
Pipe	Link	Conveys water from one node to another
Pump	Node or link	Raises the hydraulic grade to overcome elevation differences and friction losses
Control Valve	Node or Link	Controls flow or pressure in the system based on specified criteria

VIII.4.1 Hazen-Williams C-factors:

Typical values for Hazen-Williams pipe roughness coefficients are given in Table VIII-4.

Table VIII-4 Typical Hazen-Williams Pipe Roughness Coefficients					
Pipe Material	**C-factor Values for Nominal Pipe Diameters**				
	<150mm	**150-200mm**	**300-400mm**	**600-900mm**	**≥1200mm**
Uncoated cast and ductile iron - smooth and new	121	125	130	132	134
Coated cast iron - smooth and new	129	133	138	140	141
30 years old					
Slight attack	100	106	112	117	120
Moderate attack	83	90	97	102	107
Appreciable attack	59	70	78	83	89
Severe attack	41	50	58	66	73
60 years old					
Slight attack	90	97	102	107	112
Moderate attack	69	79	85	92	96
Appreciable attack	49	58	66	72	78
Severe attack	30	39	48	56	62

Table VIII-4 Typical Hazen-Williams Pipe Roughness Coefficients					
Pipe Material	C-factor Values for Nominal Pipe Diameters				
	<150mm	150-200mm	300-400mm	600-900mm	≥1200mm
Galvanized iron - smooth and new	129	133			
Lined steel - smooth and new	137	142			
Uncoated steel - smooth and new	142	145	147	150	150
Smooth pipe (lead, brass, copper, polyethylene, and PVC) – clean	147	149	150	152	153
PVC wavy – clean	142	145	147	150	150
HDPE	155				
Fiberglass (smooth)	150				
Cement lined ductile iron	120-140				
Concrete					
Class 1 - Cs=0.27, clean	69	79	84	90	95
Class 2 - Cs=0.31, clean	95	102	106	110	113
Class 3 - Cs=0.345, clean	109	116	121	125	127
Class 4 - Cs=0.37, clean	121	125	130	132	134
Best - Cs=0.40, clean	129	133	138	140	141
Prestressed concrete – clean			147	150	150

Sources: Walski et al. 2003 and Lindeburg, 2003

VIII.4.2 Darcy-Weisbach frictions:

Typical values for Darcy-Weisbach pipe roughness values are given in Table VIII-5.

Table VIII-5 Typical Darcy-Weisbach Pipe Roughness (ε)			
Pipe Material	Equivalent Sand Grain Roughness, ε (mm)		
	New	Average	Old
Uncoated cast iron		0.226	
Coated cast iron		0.102	
Galvanized iron	0.15		
Coated steel		0.005-0.05	
Uncoated steel		0.028	
Smooth pipe (glass, brass)	0.0015		
PVC	0.002	0.013	
HDPE		0.021	
Fiberglass		0.000017	
Cement lined ductile iron		0.1	0.3

Table VIII-5 Typical Darcy-Weisbach Pipe Roughness (ε)			
Pipe Material	**Equivalent Sand Grain Roughness, ε (mm)**		
	New	**Average**	**Old**
Concrete			
Smooth with small joints	0.015-0.2	0.3	
Wood-floated or brushed	0.2-0.4		
Unusually rough/rough joints	0.6-1.0	0.3	3
Butt-welded steel			
New	0.04		
Light rust	0.15	0.2	0.37
Heavy brush-coated enamels	0.37		0.95
Incrustation/tuberculation		0.95-2.5	2.6-6

Sources: Allen, 1996, Walski et al., 2003 and Driscopipe Polyethylene Piping Systems Manual, 1998.

VIII.5Design and Analysis Criteria

Criteria factors to be used for network hydraulic analysis and development of a network computer model are presented in the following tables:

VIII.5.1 Allowable Velocity and Head Losses

Pipe size shall be selected to meet the minimum/maximum pipe velocities and the maximum head loss per kilometer (km) listed in Table V-4.

VIII.5.2 System Pressures

The minimum residual pressures shall be maintained at the furthest and highest point in the network. Design values are presented in Table V-3.

VIII.5.3 Pump Station Modeling

Pumps should be selected following the steps below:

- Determine design flow
- Develop system head curve
- Check agreement of:
  - Design flow
  - Operating point(s)
  - Best efficiency point
- Check pump combinations and select pump operating criteria including number of working and stand-by pumps and pump duty points (flow/pressure).
- Verify operation in model. Evaluate pump capacity against required flow/pressure in the network.
- Check combinations of pumps and resulting hydraulic parameters of pressure, velocity and pressure drop in the network.

VIII.5.4 Water Quality Modeling

Water quality does not stay constant during its passage from the treatment plant through the transmission and distribution systems to its ultimate point of use. Water quality in storage and distribution networks may be highly variable.

The key data requirements for water quality modeling of distribution systems include the properties and chemical composition of the source water(s), hydraulic properties of the system, and reaction rate constants for the processes of interest.

VIII.5.5 Hydraulic Transient and Surge

A surge protection analysis study shall be performed to confirm that the surge protection equipment design requirements are met. The study should include the complete system consisting of piping, reservoirs and pumping station(s) and future pipeline systems connected or to be connected to the system being designed. The study should include recommendation of suitable equipment (surge vessels, anti-surge valves, bypass lines, etc.) to be installed in the piping system to protect against surge effects. The surge analysis shall also include analysis and recommendations for surge protection measures for the ultimate system.

Surge Analysis of the system shall be based on water demand plans and pipeline design with proposed pump characteristics and pumping station design (pump performance curve).

VIII.5.6 Pipe Network Analysis

Pipe flows and pressures throughout the pipe network are determined by hydraulic analysis by employing the relevant hydraulic parameters:

- Water demand scenarios (peaking factors),
- Allowable velocities,
- Allowable headlosses,
- Required system pressures,
- Pipe material and etc.

IX. LIST OF TABLES

X. LIST OF FIGURES

XI. APPENDICES

IX.1 Appendix A – KM Project Guidelines for Bulk Customers

المؤسسة العامة القطرية للكهرباء والماء
Qatar General Electricity & Water Corporation

WATER DEVELOPMENT GUIDELINES
FOR BULK CUSTOMER

April 2012

Contents

Issue Record		
Issue No.	**Date**	**Reason for Re-Issue**
0	August 2012	First issue
1	April 2012	Updated Water Demand Table
2		
3		
4		
5		

1. Introduction

The aim of this guideline is to provide more detailed provision to bulk customer and the consultant while preparing bulk customer application submission for approval by Kahramaa.

For each new development project, the customer or consultant shall submit to Kahramaa with the estimated water demand planned for the project from its inception through to its completion and full occupancy.

Depending on the scope, the work involved will be to install a service connection and the incidental requirement of laying or building associated water facilities (such as requirements to upgrade/replace existing reservoir & pumping Stations or existing pipelines and/or constructing new reservoir & pumping stations and/or laying/reinforcing of new pipelines) necessary in order to efficiently deliver the water services to the bulk customer by taking into consideration the available information on the development in areas covered by the required water facilities development and in turn the customer will be required to bear the “shared” cost proportionate with its requested full demand against the capacities of the facilities involved.

This document may be updated or amended as deemed necessary.

2. Water Demand

As the customer demand and its staging represent the most crucial element for identification and/or determination of their internal water system facilities during the planning process, customers are advised to submit the following list of information available for Kahramaa review ahead of time in order to cater for different lead times needed for each type of development:

a) Reasonably Projected Demand Figures along with yearly phasing up to its ultimate build-out, occupancy phasing until 100% is achieved and phasing wise percentage of land used;

b) Reasonable Demand Phasing throughout the Project Development Period. The Customer must give emphasis on each phase that will be represented by expected occupancy commissioning dates and occupancy saturation date, rather than construction starting and completion dates. For Multi Structure, Complex and Mega Projects categories, information for each phase should include similar information on the relevant individual projects and their demands;

c) The following demand categories are recognized by Kahramaa:

   i. Residential;
   ii. Commercial;
   iii. Government;

d) The developer shall prepare Project Demand Mapping by Phases and by Demand Categories. This is required to facilitate in the demand forecast process and later in the performance of hydraulic analysis.

e) Base information and calculations used to determine the water demands, such as population, land use, district cooling, even the liters of water demand per area categories, liters per capita consumption, etc.

f) Kahramaa emphasizes that it does not supply potable water for Construction purposes when there is no existing developed network at the Project Area and in such cases may be opted to resort in Tanker Supply.

3. Customer Requirements

a) The customer shall sign MoU with Kahramaa prior to execute water connection.

b) The customer shall allocate during the development stage on the property side, a site and water pipeline route corridor within the Project area that the parties agree is sufficient for that purpose. This allocation shall continue for the entire life of the project. The property of allocated site beyond the customer meter shall remain as the property of the customer.

c) The meter will be installed in the identified area outside of the premises which shall be an accessible area for interconnection of Kahramaa mainline and its service connection provision to the customer water facilities, and shall be accessible for inspection and maintenance.

d) A separate house connection pipes for each premise should be metered. In case of buildings, a main meter is installed on the main inlet pipe before the underground storage tank and sub-meters are installed on the roof of the building on the discharge side of the elevated storage tanks. The customer shall cover all internal water facilities related inside the project premises being covered by the Bulk Selling and may or may not be subjected for review by Kahramaa;

e) The customer shall be required to provide an area and water facilities sufficient enough to accommodate their own terminal water reservoir equivalent to 2-days storage of customer highest forecasted daily demand requirement. This area shall normally be to accommodate the required associated pumping facilities to effectively and efficiently deliver water internal to the customer's water system facilities that can reach to their highest and farthest location.

f) The customer, developer and consultant shall be required to comply the design submissions with existing standards and guidelines, which are recommended by Kahramaa, in executing the planning and design works for the customer Internal Water Systems Facilities.

4. Network Design Criteria

The following Network Design Criteria for water network modeling shall be taken into account by customer's consultant during network design stage.

a) Maximum applied Pipeline Velocity is 1.5 m/s for Distribution lines.
b) Height of storage reservoir shall not be greater than 3 meters from the ground level.

c) Minimum expected Pressure is 1.5 bar at highest and farthest point within the developer (distribution) network.

d) A minimum number of connections should be adopted for better network management. Pressures assumed at connection points should satisfy the design criteria above for the adopted network layout. However, these pressures will be reviewed by Kahramaa and changes if necessary will be recommended as appropriate, including additional pumping or pressure reduction requirements.

e) Zoning by District Metered Area (DMA) and network pressure control as applicable should be considered in the design.

f) Hydraulic Model demands should correspond to the Demand figures submitted in the demand calculation sheets.

g) The developer or their consultant should submit the minimum, average and peak demand and Fire Flow Network Models for each main phase of the development as applicable.

h) Models should be created using Kahramaa adopted software or any compatible software.

i) Network Models should be geo-referenced to the actual physical Geographic location's coordinates using the standard Qatar National Datum.

j) If the development expands through major phases, it is required to submit separate models representing each phase. As well as one overall network model as appropriate.

k) Kahramaa will review the models in contrast with its requirements and planning information, and as required, recommendations for changes will be made accordingly.

l) The network design layout should consider looping the system wherever possible, for better water circulation and system reliability.

5. Demand Requirements

The following Table presents typical ranges of water consumption rates as a guide and may be used as a reference to establish various land use water demand for development projects. However, it is the sole responsibility of the consultant/developer to accurately determine the demand required with due consideration to the nature and type of the proposed development, which would later be submitted to Kahramaa for concurrence. The water demand categories have been reviewed in light of the Kahramaa Waterworks Planning and Design Manual and the revised water demand figures are presented below.

KAHRAMAA Unit Daily Water Demand (Domestic Category)		
Land Use Category	**Unit**	**Daily Water Consumption (Liters)**
Residential Building	(Per Capita)	250-400
Qatari Villas	(Per Capita)	500-800
Worker Labor Accommodation	(Per Capita)	80-150
Mixed Use Residential	(Per Capita)	250-400

KAHRAMAA Unit Daily Water Demand (Non-domestic Category)		
Land Use Category	**Unit**	**Daily Water Consumption (Liters)**
Mixed Use Commercial	(Per Capita)	60-80
Commercial Building	(Per Capita)	60-100
Mosque	(Per Capita)	10-50
Restaurant	(Per Meal)	10-20
Hotel	(Per Room)	200-300
Shop	(Per Capita)	60-80
Office	(Per Capita)	60-80
School	(Per Capita)	60-80
University	(Per Capita)	60-80
Medical	(Per Bed)	60-80
Public Amenities	(Per Capita)	20-50
Nursery	(Per Capita)	60-80
Guard House	(Per Capita)	60-80
Retail	(Per Capita)	60-80
Theatre	(Per Capita)	10-50
Stadium	(Per Capita)	15-20
Town Centre	(Per Capita)	60-80
Manufacturing	(Per Capita)	60-80
Workshop	(Per Capita)	60-80
Swimming Pool		Pool Volume plus the rate of re-filling/year
Warehouse/ Store/ Showroom	(Per Unit)	2, 889
MEW Electricity Substation	(Per Unit)	509
Clinics	(Per Unit)	26, 458
Gardens/ Parks/ Nurseries	(Per Unit)	85, 106
Car Wash	(Per Unit)	20, 991
Embassies	(Per Unit)	21, 205
Petrol Station (No Car Wash)	(Per Unit)	2, 559
Sports Stadiums	(Per Unit)	109, 712
Industry		
Heavy Water Using	(cum/hectare/day)	120
Light Water Using	(cum/hectare/day)	30
Precast Factory	(cum/hectare/day)	85
Garage for Heavy Truck	(cum/hectare/day)	30
Food Stores	(cum/hectare/day)	30
Industrial Store	(cum/hectare/day)	30

KAHRAMAA Unit Daily Water Demand (Non-domestic Category)		
Land Use Category	**Unit**	**Daily Water Consumption (Liters)**
Livestock, (liter/head/day)		
Camel	(liter/head/day)	30-55
Cow	(liter/head/day)	100-126
Sheep	(liter/head/day)	8-20
Goat	(liter/head/day)	7-12
Chicken	(liter/head/day)	13-62
Type of Crops		
Vegetables	(liter/m^2/day)	5.37
Cereals	(liter/m^2/day)	3
Fodder	(liter/m^2/day)	18
Fruits & dates	(liter/m^2/day)	8.8

1: *Sourced from Best Standard Practices from submitted Master Plans & recent Kahramaa Investigative Study.*

2: *Bulk Customer Demand to be estimated from Total Number of Persons from each Land Use Category Multiplied by the corresponding Demand Figure in Litre/Cap/Day.*

6. System Monitoring

Depending on the nature and the size of the Project Network, monitoring devices at main connection locations will be installed by Kahramaa. These devices are outlined as follows.

a) Bulk Flow Metering - is essential for measurement and flow monitoring along the distribution systems. Bulk flow meters shall be proposed at selected locations and implemented by Kahramaa.

b) Pressure Transmitters - Pressure gauges and transmitters may be required as per Kahramaa specifications to monitor pressures at locations selected by Kahramaa.

c) Pressure Regulating Valve - Pressure regulating valve will be installed in case the customer is supplied from water transmission line in order to reduce pressure at the storage facility inlet.

d) Water Quality Controls - Analyzer Stations consisting of transmitters and sensor assemblies for measuring pH, residual chlorine, conductivity and temperature shall be installed at specified locations as per Kahramaa specifications.

e) Water SCADA Requirements - Kahramaa requirements for integrating newly developed network for major projects into Kahramaa SCADA system should be discussed and agreed by Kahramaa Water Control Section and Water Planning Department.

7. Project Requirements

During the Inception and/or development stage of the project, the customer shall be required to submit to Kahramaa in full details of all the above requirement and information to facilitate in parallel the early delivery of Kahramaa services to the customer. Kahramaa requires a normal minimum lead time to deliver the required Services under the following categories as follows:

a) For direct connection to the existing mainline = 3 months minimum to 12 months maximum.

b) For connections requiring associated incidental facilities = 1 year minimum and can reach even up to 3 years from the time of initial coordination with the customer.

c) It is important that customer, developer and consultant must agree with Kahramaa for the lead time of development of the Project. It is usual to take lead time of 2 - 3 years due to planning, engineering and construction prior to commissioning but again this will entirely depend on the nature of the Project. Thus, the customer is required to submit ahead of time the project information in order for Kahramaa to deliver the required services on time.

d) In some instances, Kahramaa may decide, where it is more advantageous for customer to supply and construct under their Project, the required water facilities services that is supposed to be provided by Kahramaa, of which cost will born out fully by the customer, subject to Kahramaa approval of its design and construction.

e) Conduct regular progress review meeting with Kahramaa wherever is required.

f) Close coordination with Kahramaa during commissioning and testing phase of the project.

g) Both parties shall provide necessary advises in resolving any technical issues.

8. Applicable Documents

1. General Specification for Mainlaying Materials for Waterworks - 2005
2. General Specification for Mainlaying Contracts - June 2005
3. Regulations of Internal Water Installations and Connections Works - May 2009
4. Water Network Design Guidelines
5. Water Network Standard Drawings

9. Required Information

Developer or consultant of the customer is required to lodge the submission for assessment to Water Planning Department and shall be addressed to:

Head, Planning and Bulk Customer Section
Customer Service Department

The submission consists (as a minimum) of the following documents:

i. Complete Bulk Customer Application Form
ii. Colored hard copy of the location map and layout of the project as well as soft copy in CAD or GIS system shape file format system.
iii. Complete Master Plan study for the project.
iv. Project water demand calculation sheets, year wise phased total demand, plot / zone or phase wise demands “all calculations should be provided in MS Excel spreadsheet format including all formulas used along with supporting data files”.
v. Land use wise demand calculations including percentage of land use types and year wise percentage of occupancy envisaged by the developer.
vi. Factors used to calculate Average Demands and Peak Demands along with justifications of the same.
vii. Availability statements for plots/corridors required for the development proposal as per Kahramaa requirements.
viii. Existing and proposed site topography based on actual survey data, to support network hydraulic analysis and parameters for proposed pumping facilities.
ix. Digital as well as hard copies of internal network design indicating proposed take off points and expected pressure at each of them.
x. All hydraulic modeling file(s) developed for the network study geo-referenced to the actual coordinate system.
xi. Updated submittals for the above-mentioned documents are required in case of any changes in the demand requirements or network design.
xii. Prior to submission of proposed Internal Water Network Design, the customer will submit water demands, meter & service main location connections for concurrence.
xiii. Upon receipt and stamping of the agreed Demand Forecast and meter and service main location connections, the customer will then submit project specific & detailed drawings for Internal Water Network Design to Water Planning Department’s for approval.
xiv. Kahramaa through Water Planning Department will approve and stamp the final design drawings.

IX.2 Appendix B – Water Network Development Procedure Summary and Checklists

- Initiate project and present concept to KM for concurrence.
  - Evaluate service area limits and use categories
  - Layout pipe network and develop layout of hydraulic model with nodes and demands
  - Assign demand values and calculate flows for ADD, PDD, PHD, ADD+FF
- Proceed with Hydraulic Analysis and present to KM for review and approval (See checklist below).
- Proceed with pipe network planning with valve, hydrant, system monitoring requirements, and service location layout and present to KM for review and approval (See Transmission and Distribution Main Checklist below).

IX.2.1 Hydraulic Analysis Summary

Provide a narrative along with the hydraulic model printouts and data. The narrative should discuss low and high-pressure areas in each pressure zone, identify whether the system has adequate equalizing and firefighting storage, and propose corrective measures. If submitted as part of a water system plan, the narrative and corrective measures should be in the body of the plan. The hydraulic analysis should clearly identify how the model was developed and calibrated, and summarize the output. The following items should be in the hydraulic model discussion. These items are also in the hydraulic analysis checklist below.

- Develop a diagram showing all nodes (junctions) used and a corresponding written summary of assumed supply and demand flows for each condition that must be evaluated. Larger scale diagram sheets may be necessary to accurately show proper location and functions of all control valves and pump station facilities.
- Explain all assumptions used for the model, including friction factors for the pipes and operating conditions of sources, storage reservoirs, booster pumps, and valves. For additions to existing water systems, also provide evidence that the computer model results were compared to actual field measurements, and that the model was calibrated accordingly.
- Using a system contour map, identify the minimum pressure results found at the highest elevations and other critical areas in each pressure zone of the system under flow conditions.
- Enter pump curves for the proposed source and booster pumps into the program to indicate how the system will respond to varying flow conditions.
- Steady-state flow conditions to evaluate should include each of the following:
  - PHD in each pressure zone and throughout the water system, under conditions that deplete all equalizing storage volume and assume all sources are operating. The resulting pressures should meet the minimum requirements.
  - Highest demand firefighting flows during PHD. The engineer should evaluate the water system and each pressure zone under conditions that deplete designed firefighting volume and equalizing storage. Again, the resulting pressures must conform to Table V-3 with respect to values and locations. The

system or zone must also be evaluated with the largest capacity pump out of service.

IX.2.2 Hydraulic Analysis Checklist

A hydraulic analysis should be used to size and evaluate new or existing distribution systems. An acceptable hydraulic analysis includes:

- Description of model whether steady state, or extended period simulation.
- Assumptions are described including:
  - Allocation of demands
  - Friction coefficients, which will vary with pipe materials and age
  - Pipe network skeletonization, as appropriate
  - Operating conditions (source, storage booster pumps, valves)
- Minimum design criteria are met under all scenarios, including:
  - ADD – Average Daily Demand
  - PDD – Maximum Daily Demand
  - PHD – Peak Hourly Demand
  - ADD + FFD – Average Day Demand plus Fire Flow Demand
  - PHD + FFD with Pump Shut-down Surge Condition (When Pumping is included in design)
- Demand scenarios are described, including:
  - Current demand
  - Projected 6 year demand
  - Projected build-out demand of small water systems
- Provide copies of input and output, including:
  - Input data, (demands, elevations, friction losses, and pump curves)
  - Hydraulic profile
  - Node diagram
  - Printout of significant runs
- Summary of results, deficiencies and conclusions including:
  - Identification of deficiencies
  - Locations in distribution system where pressures do not comply with KM guidelines
  - Hydrant flow and placement on undersized mains
  - Fire flow reliability per CD guidelines

IX.2.3 Transmission and Distribution Main Design Checklist

Transmission and distribution main project reports and construction documents should include:

- Water system sizing analysis documenting availability of adequate source and storage to supply the proposed service area.
- Hydraulic analysis used to size mains and determine that required pressures can be maintained and hydraulic transient analysis for transmission mains and distribution

mains where warranted by high pressures or high velocities (see Checklist for Hydraulic)

- Analysis for additional details).
- Identification and description of proposed land use within project area.
- Service area map designating specific properties to be served.
- Distribution system map showing location of water lines, pipe sizes, type of pipe, pressure zones, easements, and location of control valves, hydrants, meters, and blow-off valves.
- Specifications for materials, construction, depth of pipe bury, pressure and leakage testing.
- Adequate separation from sewer mains, non-potable conveyance systems, and other buried utilities.
- Details for pipeline trench, service connections, air and vacuum relief valves, pressure reducing valves, thrust blocking, backflow assemblies, fire hydrants, and other system appurtenances.