CITY UTILITIES
DESIGN STANDARDS MANUAL

Book 4
Water (W)
W5 Water Main Design

September 2017

W5.01 Purpose

The purpose of this Chapter is to provide requirements on the design elements and basic hydraulic criteria necessary for the proper design of potable water distribution systems. This Chapter establishes the minimum standards and technical design criteria for all City of Fort Wayne water distribution systems. All projects that result in infrastructure that is to be owned, operated, or maintained by City Utilities shall follow these requirements. All variances from these design standards shall be approved prior to commencement of design in compliance with Chapter GR3 - Variances.

1. Basic Elements of Design
    - Horizontal alignment with consideration of separation from sanitary and storm sewers, potential sources of contamination and efficiently provide service to existing and potential water service users.
    - Vertical alignment with consideration of service depth, minimum cover, underground utility conflicts and constructability.
    - Total design flow with consideration of existing and future population served by the water main.
    - Water main size, material, bedding and construction method.
    - Necessary appurtenances and additional items required for a complete and functional water system.
2. Covered in this Chapter
    - General Improvement Location Criteria
    - Horizontal Alignment Criteria
    - Vertical Alignment Criteria
    - Pipe Bedding and Backfill
    - Pipe Materials
    - Design Flow
    - Hydraulic Design Criteria
    - Water Main Pipe Requirements
    - Joint Restraint
    - Casing Pipe
    - Infrastructure Crossings
3. Covered in Other Chapters
    - Chapter W6 - Building Services
    - Chapter W7 - Appurtenances
    - Chapter W8 - Backflow Prevention
    - Chapter W9 - Fire Services

W5.02 General Improvement Location Criteria

General improvement location criteria of proposed water main alignment to be considered shall include, but not be limited to the following:

- Use existing rights-of-way and/or easements whenever possible.
- Easements shall be required for all water main installations along proposed major corridors and non-residential streets. Consult City Utilities regarding easement acquisition for water main installation.
- Easement requirements, property values, and potential damages to all affected properties.
- Evaluate service needs of both present service area and future service area.
- Potential development and utility or street extensions and widening into adjacent areas.
- Serve entire area in best way possible.
- Existing underground and overhead utilities, roadways, and railroads.
- Proposed utilities such as sewer, stormwater, and other water facilities.
- Environmentally sensitive areas including creeks, rivers, wetlands, trees, protected habitats, etc.
- 100-year flood elevations and regulatory floodways.
- Continuity with adjacent design segments.
- Maintenance of traffic during construction.
- Availability of materials.
- Foundation conditions.
- Construction costs.
- Subsurface conditions: soils and ground water.
- Access for maintenance and repair.

W5.03 Horizontal Alignment Criteria

In general, water mains shall be located on the opposite side of the street from the sanitary sewer. Water mains are generally located on the north and west sides of the public right of way. Every effort shall be made to locate the water main outside of the pavement, but within existing or proposed right-of-way or easements. Refer to Chapter GR7 - Easements for further guidelines regarding water main easements.

1. Placement in Existing Right-of-Way
   A. For water mains located within existing or proposed street right-of-way, the preferred placement shall be as generally defined in Exhibit W5-1 Recommended Utility Placement in Public Right-of-Way.
   B. Allowances for future sidewalk shall be made.
   C. The location of the roadway, curb and gutter, sidewalk and other utilities shall be taken into account.
2. Placement Outside of Existing Right-of-Way
   A. Where water mains cannot be placed within right-of-way, easements shall be procured.

B. Easements adjacent to the right-of-way shall be required for all water main installations along major arterial corridors and non-residential streets.
C. Refer to Figure GR7.1 Minimum Easement Widths in Chapter GR7 - Easements for minimum easement widths required for water main installation.

3. Minimum Horizontal Separation from Sewers

A. A ten (10) foot horizontal distance edge to edge shall be maintained between water main and any existing or proposed gravity or pressurized sewer line or structure per Title 327 IAC 8-3.2-9.
B. The crossing must maintain a minimum angle of intersection of 45 degrees (45^{o}) measured from the centerlines of the water main and sewer line. This angle of intersection shall be maintained for a minimum distance of 10 feet (10') from either side of the water main.
C. If it is not possible to maintain the ten (10) foot horizontal separation, the following design criteria shall apply:

- Installation of the water main closer to the sewer may be approved, provided that the water main is in a separate trench or on an undisturbed earth shelf located on one side of the sewer and at an elevation such that the bottom of the water main is at least 18 inches (18") above the top of the sewer.
- The sewer shall be constructed of water main grade pipe material from manhole to manhole with pressure rated joints complying with Title 327 IAC 8-3.2-8. All water main grade pipe material requirements are defined in Chapter MA7 - Water Materials and Testing Requirements.
- Either the water main or sewer shall be encased in a watertight casing pipe which extends for a minimum distance of 10 feet (10') from either side of the water main or sewer as measured from the outside edge of the water main to the outside edge of the sewer.

4. Minimum Distance from Buildings

A. Water mains (not service lines) shall be located a minimum of 10 feet (10') horizontally from any part of a building structure or its foundation.

5. Minimum Distance from Storage Tanks

A. The following shall apply when storage tanks are in the vicinity of the proposed water main:

- Storage Tanks Containing Hazardous Materials: Water mains shall be separated from existing and proposed above ground or underground storage tanks and their local distribution devices (pumps) containing or potentially containing hazardous materials, petroleum products, or waste materials by a distance

of 25 feet (25') horizontally measured from the outside edge of the water main to the outside edge of the tank or distribution device and shall not cross such tanks or local distribution devices.

- Other Storage Tanks: Water mains shall be separated from all other below ground storage tanks not defined above (excluding potable water storage tanks) by 10 feet (10') measured horizontally from the outside edge of the water main to the outside edge of the storage tank.

6. Minimum Distance from Liquid Petroleum and High Pressure Piping

   A. Liquid Petroleum and any high pressure piping shall be separated from water mains in the same manner as sanitary and storm sewer lines and related structures or the respective owner's specifications. In the event of conflicting specifications, the more stringent shall apply.

7. Minimum Distances from Utilities Other than Sewers

   A. When practical, all utility lines not addressed in other sections (electric, cable, telephone) shall be separated a minimum of 3 feet (3') or per the respective owner's specifications. In the event of conflicting specifications, the more stringent shall apply.
   B. Large electrical transmission line foundations shall be a minimum 10 feet (10') away from water mains.
   C. All drawings shall show the location of both underground and overhead utilities.
   D. Utility locations shall be derived from the most reliable and up-to-date information.
   E. Each utility shall receive a set of drawings prior to final submittal. On these drawings, they shall note changes or addition to utility information.
   F. Separation distance of water main from other utilities shall be determined by the representative of other utilities and the applicant.
   G. Any necessary relocation shall be closely coordinated with the respective utility representative.

8. Minimum Distance from Potential Contamination Sources

   A. The following shall apply when potential contamination sources are in the vicinity of the proposed water main:

      - Sewage or Septic Areas: Water mains shall be separated from sewage or septic treatment equipment and septic tank absorption field trenches and lift stations by 10 feet (10') measured horizontally from the outside edge of the water main to the outside edge of the defined structure.
      - Grave Sites: Water mains shall be separated from grave sites by 10 feet (10') measured horizontally from the outside edge of the water main to the outside edge of the grave site.

- Landfills: Water mains shall be separated from existing or proposed landfills by 50 feet (50') measured horizontally from the water main to the outside edge of the waste boundary of an existing or proposed landfill. In addition, water mains within 300 feet (300') of the outside edge of the waste boundary of an existing or proposed landfill shall be constructed of non-permeable materials. Water mains shall not cross or pass through the waste boundary of an existing or proposed landfill.
- Organic Compounds: Where distribution systems are installed in areas of groundwater contaminated by organic compounds, pipes and joint materials which are not subject to permeation of the organic compounds shall be used. The non-permeable materials shall be used for all portions of the system including the water main, service connections, and hydrant leads

9. Location in Relation to Streams and Waterways

   A. Water mains located along existing or proposed streams or waterways shall be located outside of the stream bed or edge of the water line and sufficiently separated to allow for future improvements to the stream or waterway channel.
   B. Water mains shall be separated from existing or proposed water bodies by a minimum of 10 feet (10') horizontally measured from the outside edge of the water main to the outside edge of the typical water line or ditch outside edge if the stream is intermittent.
   C. If bridge structure wingwalls are present at the stream or waterway crossing, a minimum distance of three (3) feet horizontal must be maintained between the outer edge of the wingwall and the outer edge of the water main pipe.

10. Allowable Horizontal Pipe Deflection

   A. When it is necessary to deflect pipe horizontally from a straight line, the amount of joint deflection for PVC pipe shall not exceed 50-percent of the manufacturer recommended deflection. Consult the manufacturer's literature for allowable joint deflections for allowable pipe deflections.
   B. The allowable joint deflection for ductile iron pipe shall be as shown in Exhibit W5-2, Maximum Ductile Iron Joint Deflections. For design purposes, deflection shall be limited to 80 percent (80%) of the values shown.
   C. If the manufacturer's specified deflection allowance is greater than that described above and in Exhibit W5-2, City Utilities can be consulted to allow such deflections.

11. Angle of Intersection

   A. Water mains are preferred to cross other utility conduits, highways, and railroads at 90 degree (90^{o}) angles.

W5.04 Vertical Alignment Criteria

1. Minimum Depth of Cover
   - Minimum depth of cover for water main pipes located within the right of way of arterial streets shall be 6 feet as measured from the proposed surface elevation to the top of the water main pipe.
   - Minimum depth of cover for all water main pipes outside of an arterial street right of way shall be 5 feet as measured from the proposed surface elevation to the top of the water main pipe.
   - Minimum depth of cover for service lines shall be 5 feet.
2. Minimum Vertical Separation from Sewers
   - A minimum vertical separation of 18 inches (18”) measured vertically from the outside edge of the water main to the outside edge of any existing or proposed gravity or pressurized sewer line or structure shall be maintained per 327 IAC 8-3.2-9.
   - When crossing a sewer the 18 inches (18”) vertical separation shall be maintained for a minimum distance of 10 feet (10’) from either side of the water main as measured from the outside edge of the water main to the outside edge of the sewer line.
   - If it is not possible to maintain the 18 inch (18”) vertical separation, the following criteria shall apply:
     A. The sewer shall be constructed of water main grade pipe material from manhole to manhole with pressure rated joints complying with 327 IAC 8-3.2-8. All water main grade pipe material requirements are defined in Chapter MA7 - Water Materials and Testing Requirements.
     B. Either the water main or sewer shall be encased in a watertight casing pipe which extends for a minimum distance of 10 feet (10’) from either side of the water main or sewer as measured from the outside edge of the water main to the outside edge of the sewer.
3. Air Release Structures
   - Air Release Valves or similar shall be installed in locations where the vertical alignment of the water main results in a high point in the elevation.
   - Refer to Chapter W7 - Appurtenances for air release structure requirements.
4. Stream and Waterway Crossings
   - Water mains located above streams, waterways or any water bodies are not allowed.
   - Water mains located under existing or proposed streams, waterways or water bodies less than 15 feet (15’) in width at the crossing point shall be covered with a minimum of 60 inches (60”) of cover and constructed with watertight, flexible joints.
   - Water mains crossing under existing or proposed streams, waterways or water bodies greater than 15 feet (15’) in width at the

crossing point shall be covered with a minimum of 60 inches (60") of cover, constructed with watertight, flexible joints, have valves placed at both ends of the surface water body. The valves shall be easily accessible, not subject to flooding, and have the valve closest to the supply source located in a manhole structure. It is desirable to have permanent taps made on each side of the valve within the manhole to allow insertion of a small meter to determine leakage and for sampling purposes.

5. Allowable Vertical Pipe Deflection

   - When it is necessary to deflect pipe horizontally from a straight line, the amount of joint deflection for PVC pipe shall not exceed 50-percent of the manufacturer recommendation for deflection. Consult the manufacturer's literature for allowable joint deflections and for allowable pipe deflections.
   - The allowable joint deflection for ductile iron pipe shall be as shown in Exhibit W5-2 Maximum Ductile Iron Joint Deflections. For design purposes, deflection shall be limited to 80 percent (80%) of the values shown.
   - If the manufacturer's specified deflection allowance is greater than that described above and in Exhibit W5-2, City Utilities can be consulted to allow such deflections

W5.05 Pipe Bedding and Backfill

1. See Standard Drawing BS-4 General Rigid Pipe Bedding Detail.
2. See Standard Drawing BS-5 General Flexible Pipe Bedding Detail.
3. All backfill for valves, fire hydrants and curb stops shall be INDOT No. 8 or INDOT No. 53/73 stone. Refer to Chapter MA7 - Water Materials and Testing Requirements.
4. Refer to Chapter MA4 - Common Materials for bedding and backfill specifications.

W5.06 Pipe Materials

Refer to Chapter MA7 - Water Materials and Testing Requirements for approved water main pipe materials.

W5.07 Design Flow

In general, water mains shall be designed to provide for the Design Demand in accordance with the criteria established below.

1. Design Demand

   The Design Demand is the combination of maximum daily demand plus fire flow demand as follows:

   DD = (Max day) + FF

   where:

DD = Design Demand (gpm)

Max day = Maximum daily demand (gpm)

FF = Fire flow demand (gpm)

Each of the above demands is described in the following sections. Please note that this section presents the minimum values and rates. Higher or more conservative values and rates can be utilized. Exhibit W5-3 Design Demand Determination Worksheet provides a guideline to aid in determining Design Demand.

2. Maximum Daily Demand

Maximum Daily Demand is the summation of all domestic, processing, indirect and unknown demands with applied peaking factors (PF) as follows:

Max day = (Dom + Proc + Indirect + Unk) x PF

where:

Max day = Maximum daily demand (gpm)

Dom = domestic demands (gpm)

Proc = process demands (gpm)

Indirect = indirect demands (gpm)

Unk = unknown water demands (gpm)

PF = peaking factor (note that peaking factors can be applicable only to a specific water demand)

- Domestic Demand

Domestic demand (Dom) is the amount of water needed for household and sanitary purposes. This includes water needed at home or at work for drinking, washing, bathing, cooking, flushing, and other purposes. Domestic demand shall be determined as follows:

Dom = residential domestic demand + commercial domestic demand + industrial domestic demand

A. Residential Domestic Demand

The residential domestic demand shall be determined using one of the two following methods:

- Method A – General Average

The residential domestic demand shall be determined by using the proposed number of residential units and the following general average:

0.35 gallons/residential unit/minute

This rate shall be multiplied by the proposed number of residential units to determine the residential domestic

demand of the development. A residential unit represents a single family home, apartment unit, mobile home lot, or a single portion of a multiple family dwelling unit.

- Method B – Determined Average

  The residential domestic demand may be determined using the proposed number of residential units and the determined average (using data provided by City Utilities). The determined average shall be as follows:

  (ADCD10) / (SC10)

  where:

  ADCD10 = the average daily customer demand as reported by City Utilities over the previous ten (10) years

  SC10 = number of service connections at the time of ADCD10

  This rate shall be multiplied by the proposed number of residential units to determine the residential domestic demand of the development. A residential unit represents a single family home, apartment unit, mobile home lot, or a single portion of a multiple family dwelling unit.

- Commercial and Industrial Domestic Demand

  The commercial and industrial domestic demand shall be determined using the proposed number of people at building capacity, the proposed number of operating shifts (1, 2, or 3), and the following general average:

  0.07 gallons / capita / shift / minute

- Process Demand

  Process demand (Proc) is the amount of water needed for commercial and industrial processing such as cooling water or that used for processes such as canning or bottling. Process water demand shall be evaluated on a case-by-case basis. Justification and documentation shall be submitted for each processing water demand in accordance with Chapter W4 - Drawings and Submittals.

- Indirect Demand

  Indirect demand (indirect) is the amount of water set aside for future off-site extensions of the water main such as additional sections of subdivisions. Indirect demand is usually comprised of the types of demand (dom, proc) that are estimated (or set aside) for future anticipated demand. This demand must be stated as zero (0) if no considerations are being made for indirect demands.

- Unknown Demand

Unknown demand (unk) is the amount of water set aside for the on-site development of the proposed project if the project occupants are unknown (i.e. spec buildings or industrial development park). Unknown demand can either be assumed or intentionally determined to maximize the water demand capacity of the proposed development. Note that assumed unknown demands that are too low may limit the eventual build out of the proposed development while assumed unknown demands that are too high may increase construction costs. This demand must be stated as zero (0) if no considerations are being made for unknown demands.

- Peaking Factors

  Peaking factors are used to recognize that water demand is not always constant. Demand throughout the day, week, season, or by weather can cause fluctuations from average values.

  A. The following minimum peaking factors shall apply:

     - Domestic demand 2.5*
     - Process demand 1.6
     - Indirect demand (unless domestic)1.6
     - Unknown demand 1.6

     **Domestic demand peaking factors shall apply to indirect demands that are domestic in nature.*

  B. An alternative method of determining the domestic demand may be determined using data provided by City Utilities as follows:

     PF* = MDD10 / 10YADD

     where:

     PF* = alternative domestic demand peaking factor

     MDD10 = the maximum single day demand as reported by City Utilities over the previous 10 years

     10YADD = the 10 year average daily demand as reported by City Utilities

3. Fire Flow

   Fire flow (FF) is the fire protection demand based upon the type of construction, size, number of floors, type of occupancy and exposure of the structures.

   - Residential

     In the case of residential areas, water mains shall be designed to provide a minimum fire flow demand of 1,000 gpm at the most remote fire hydrant in the project area.

   - Commercial and Industrial

Commercial and industrial demand rates will be dependent on the type of facility constructed. These flows will need to be evaluated on a case-by-case basis taking specific facility activity into account. Information from the I.S.O. "Guide for Determination of Required Fire Flow" can provide guidance. Generally, commercial areas range from 1,500-2,500 gpm and industrial areas range from 2,000-3,500 gpm. In the absence of other information, the high end of the above ranges shall be utilized.

Above typical fire flow rates desired by individual facilities may not be possible without private, on-site fire hydrants, water storage tanks, and fire pumping facilities. City Utilities shall be consulted in accordance with Chapter W9 - Fire Services.

W5.08 Hydraulic Design Criteria

Sound engineering judgment shall be employed when designing water distribution systems. The following sections outline specific design requirements and considerations.

1. Pressure and Flow Rate

   All potable water distribution system projects shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in the distribution system under maximum daily demand plus fire flow demand. In addition, all distribution systems shall be designed to maintain a minimum static (no flow) pressure of 35 psi.

2. Velocity

   Velocity in a water main shall be determined as follows:

   $$V = 0.409\ Q/D^2$$

   where:

   V = velocity, ft/sec

   Q = flow rate (referred to as design demand, see above), gpm

   D = nominal diameter of pipe, inches

   The maximum velocity of water within a proposed water main under maximum daily demand plus fire flow demand (Design Demand) shall be per Figure W5.1 as follows:

Figure W5.1 – Maximum Velocity

Pipe Diameter (inches)	Maximum Velocity (ft/sec)	Corresponding Design Demand (gpm)
6	12.22	1075
8	7.36	1150
12	4.68	1650
16	4.23	2650
>16	Consult City Utilities	

3. Data Requirements

- Topographic

Topographic data including proposed ground contours and surface features will be required for water main design. The general improvement location criteria shall be referenced for determining required topographic information.

- Soils Testing (Survey)

Upon approval by the City Utilities for the use of ductile iron water main a Soil Survey Report Form shall be completed. The presence of corrosive soils along the proposed path of the water main shall be investigated in accordance with AWWA C105/A21.5. All areas not investigated shall be assumed to be corrosive. A formal soil survey report or statement of assumed corrosive soils shall be submitted to City Utilities during project design. Exhibit W5-4 Soil Survey Report Form shall be used for submitting a soil survey report or statement of assumed corrosive soils. All ductile iron pipe water main installed within corrosive soils or assumed to be corrosive soils shall be wrapped with polyethylene wrap. Refer to Chapter MA7 - Water Materials and Testing Requirements for information on polyethylene encasement material.

- Flow Testing

Flow testing results, provided by City Utilities, representative to each of the points of connection to the proposed project are required for design basis of the proposed project and determine the adequacy of the system to handle anticipated demands.

4. Hydraulic Calculations

Hydraulic calculations that demonstrate the adequacy of design must be submitted with each proposed project. The calculations must be consistent with the requirements for calculations and shall address the existing conditions and translation of the flow test results as well as the determination of the changes in these conditions along existing water mains. The calculations must demonstrate that the proposed design

meets the required design flow criteria in Section W5.07 at all most remote points in the proposed potable water distribution system.

- Hydraulic calculations completed for distribution system design must be reproducible using the Hazen-Williams equation.
    - h_f = Piping friction losses, psi
      Piping friction losses shall be calculated using the following Hazen Williams formula for friction loss:

$$h_f = [10.44L\frac{Q^{1.85}}{C^{1.85} * D^{4.8655}}]/2.31$$

Where:

D = inside pipe diameter, inches

Q = flow rate, gpm

C = pipe roughness coefficient (100, 110, 120)

L = main length, feet

- Commercial programs may be utilized to compute distribution system hydraulic calculations but if requested by City Utilities must be reproduced utilizing Hazen-Williams related equations.
- General Hydraulic Calculation Requirements

A. Roughness Coefficients

Proposed projects must address design life expectancy of water mains. The roughness coefficients to be used for existing pipe and proposed pipe are shown in Figure W5.2.

Figure W5.2 – Roughness Coefficients

C Factor	Age of Pipe
120	New and Existing HDPE Pipe
120	New and Existing PVC Pipe
120	New Ductile Iron Pipe (24" or larger)
120	All Existing Pipe (Less than 20 years)
110	All Existing Pipe (20 to 40 years)
100	All Existing Pipe (Greater than 40 years)

Theoretical methods using constants other than C factors to demonstrate pipe roughness must provide a demonstration of equivalent assumptions. Site specific C factors shall be used for existing pipe in lieu of the C factors presented in this subsection.

B. Minor Losses

Minor losses shall be determined when the length of the proposed project is less than 1,500 times the diameter of the included pipe. This determination to include minor losses must be included with the calculations. Refer to Exhibit W5-5 and

Exhibit W5-6 for the Minor Losses Worksheets 1 and 2 as an aid in this determination.

C. Friction Losses

Friction losses along a water main due to pipe roughness shall be determined when evaluating the adequacy of design. These friction losses can be determined using Hazen-Williams theories. Refer to Exhibit W5-7 Friction Losses, Unidirectional Dead End Segment Worksheet for guidance in determining unidirectional, dead end friction losses. Hardy-Cross theories can be utilized to determine friction losses in loops of water mains. Exhibit W5-8 Friction Losses, Unidirectional Single Loop Worksheet presents a worksheet for determining friction losses over a loop of water mains.

D. Changes Due to Elevation

Hydraulic calculations shall be completed to evaluate static head. The flow test data is applicable to the elevation of the pressure hydrant and its relationship to and translation to the proposed design is necessary.

5. Translation of Flow Test Results

The flow test results prepared by City Utilities present current performance capacity in the proposed project area. Using the static pressure, residual pressure, and measured flow rate data from the flow test and the design demand for the proposed project, the following translation of the residual pressure shall be completed:

$$RP_{DD} = ST_{FT} - [(ST_{FT} - RP_{FT})^{1/0.54} * Q_{DD}/Q_{FT}]^{0.54}$$

where:

RP_{DD} = residual pressure at pressure hydrant location at design demand

ST_{FT} = static pressure at pressure hydrant location

RP_{FT} = residual pressure at pressure hydrant location at flow test measured flow rate

Q_{DD} = flow rate, design demand

Q_{FT} = flow rate, flow test measured

For larger development projects or main extensions that have significant impact on the distribution system, City Utilities shall be consulted to determine the need to review the proposed project utilizing the City's water model.

Exhibit W5-9 Translation of Flow Test Results presents a worksheet to aid in the calculation of flow test results.

6. Existing Water Main Conditions

The flow test pressure hydrant will likely not be the point of connection for the proposed water main. As such, the effect of the existing water

mains between the pressure hydrant and the proposed point of connection must be determined. These effects are calculated by minor losses (if required), friction losses, and changes in elevation. Requirement of the calculation of minor losses is determined with the aid of Exhibit W5-5 and Exhibit W5-6. Friction losses can be determined with the aid of Exhibit W5-7 and Exhibit W5-8. Changes in elevation must address both the elevation of the pressure hydrant and the point(s) of connection.

7. Most Remote Tests

   Once the point of connection conditions are established, the adequacy of the proposed water main design must be demonstrated by determining if the performance criteria is fulfilled throughout. This shall be accomplished by the use of "most remote tests".

   Most remote tests include the calculation of all performance criteria at all "plausible" most remote locations in the proposed design. This would include but not be limited to all end points to the proposed distribution system, all areas of higher relative elevation, all points of significant point demand, and all points furthest from a point of connection (regardless if end point). Other plausible most remote points may exist and must be investigated.

   Each most remote test will include the effects of minor losses (if required), friction losses, and changes due to elevation. Requirements for the calculation of minor losses can be determined with the aid of Exhibit W5-5 and Exhibit W5-6. Friction losses can be determined with the aid of Exhibit W5-7 and Exhibit W5-8. Changes in elevation must be relative to the pressure hydrant of the respective flow test.

   All remote points must be investigated or stated why a location was not investigated (i.e. redundant). Exhibit W5-10, Most Remote Test Results provides worksheets for use in providing the results of the most remote testing.

8. Water Main Over-sizing

   City Utilities shall be consulted to determine the need for water main over-sizing to accommodate anticipated future demands.

W5.09 Water Main Pipe Requirements

Water main pipe requirements are as follows:

1. PVC or HDPE pipe shall be used for all new water mains with nominal pipe diameters of 6-inches thru 16-inches. Consult City Utilities Engineering for approval of any other pipe material.
2. All pipe materials shall be per Chapter MA7 - Water Materials and Testing Requirements.
3. All water mains shall be constructed and tested per Chapter MA7 - Water Materials and Testing Requirements.

W5.10 Joint Restraint

Adequate precautions must be taken to prevent the separation of joints at crosses, tees, elbows, hydrants, valves, reducers and plugged ends. This shall be done by the use of restrained joints. Concrete blocking only is not acceptable.

1. Restrained Joint Location Requirements

   Joint restraint devices are required at the following locations and as directed by the Engineer or Inspector:

   - Bends
   - Crosses
   - Tees
   - Fire hydrants
   - Reducers (both sides)
   - In-line valves
   - Plugs or caps
   - Pipe inside casings

2. Restrained Joint Calculations

   Joint restraint lengths vary depending on multiple factors such as; the type of fitting, surrounding soil conditions, pipe material, pipe diameter, test pressure, depth of bury, restrained length encroachment etc. The Ductile Iron Pipe Research Association (DIPRA) manual contains detailed information on determining the required joint restraint lengths. Exhibit W5-11, Exhibit W5-12 and Exhibit W5-13 lists minimum restrained joint lengths calculated based on the DIPRA manual and typical site conditions experienced in Fort Wayne. Each exhibit lists the assumptions used to calculate the restraint length. If actual project conditions differ recalculate the required restraint joint lengths. These exhibits are not applicable when fittings are in close proximity and the calculated restraint lengths overlap (encroach), refer to the DIPRA Manual for encroachment calculations.

3. Restrained Joint Materials
   - Refer to Chapter MA7 - Water Materials and Testing Requirements for acceptable types of Joint Restraint.
   - The extent of the restraint shall be in accordance with the following Standard Drawings: W-44, W-45, W-46, and W-47.

W5.11 Casing Pipe

In cases where the water main shall be installed inside a casing the following criteria shall apply.

1. Casing Pipe Requirements

   Casing pipe shall be bare wall steel pipe with a minimum yield strength of 35,000 psi. The inside diameter of the casing pipe shall be a minimum of six inches (6”) greater than the outside diameter of the

carrier pipe joints or couplings. The casing pipe shall have a minimum wall thickness as required by Figure W5.3 below:

Figure W5.3

Casing Outside Diameter (inches)	Casing Wall Thickness Highway Crossings (inches)	Casing Wall Thickness Railroad Crossings (inches)
16	0.250	0.281
18	0.250	0.312
20	0.250	0.344
24	0.250	0.406
30	0.375	0.469
36	0.375	0.532

Minimum depth of cover of the casing pipe shall be 54 inches (54”) or as required by the affected highway, railroad, etc.

City Utilities reserves the right to require larger diameter carrier pipes to accommodate additional proposed or future utility lines.

Refer to Standard Drawing W-48 Typical Jacked and Bored Casing Pipe.

2. Casing End Seals

The casing pipe shall have end seals between the casing pipe and the carrier pipe to prevent the entrance of foreign material.

Refer to Standard Drawing W-50 Casing End Seals.

3. Casing Spacers

The casing pipe and carrier pipe shall be separated by insulators, spacers or skids. The insulators, spacers or skids shall be installed to support the weight of the pipe and its contents. At a minimum, they shall be placed a maximum of one foot (1’) from each side of a joint and at maximum five foot (5’) intervals.

Refer to Standard Drawing W-49 Casing Spacers.

W5.12 Infrastructure Crossings

1. Railroad Crossings

When any railroad is crossed, the specifications and precautionary measures required by the respective railroad officials shall be followed. A copy of the railroad crossing application and proof of approval from the respective railroad entity shall be submitted to City Utilties. In the absence of specific railroad requirements, the following general criteria shall apply:

A. Criteria

The following criteria shall apply to instances in which water main construction affects railroad rights-of-way and facilities. In certain instances, the requirements of the specific railroad company may be more stringent than these standards. In those instances, the more stringent standard shall apply.

- Water main shall cross tracks at an angle as close as possible to 90 degrees (90°).
- Water mains crossing beneath railroad tracks shall be constructed in bored and jacked casings.
- Casing pipe under railroad tracks and across railroad rights-of-way shall extend to a point a minimum distance of 25 feet (25') from the centerline of the outside track or the right-of-way line, whichever occurs first and a minimum of 5 feet (5') beyond the top of ditch bank within the railroad right-of-way.
- Water mains laid longitudinally along railroad rights-of-way shall be located as far as practical from the tracks. If the water main is located within 25 feet (25') of the centerline of any track, the water main shall be encased or shall be of a special design as approved by City Utilities Engineering.
- Casings under tracks and across railroad rights-of-way shall be a minimum of 54 inches (54") deep as measured from the bottom of the track rail to the top of the casing pipe.

B. Railroad Crossing Drawings

A railroad crossing drawing shall be prepared and address the following:

- Both a plan and profile view shall be provided**.** .
- The following items shall be included on the drawing: relationship between the proposed water and the railroad, angle of crossing, location of utilities, original survey station of the railroad (when available), right-of-way lines, limits of boring or casing liner, topography, and general layout. The profile shall clearly show the water main in relation to both the tracks and existing ground elevations.

The crossing drawing and project drawings shall be submitted to both City Utilities Engineering and the appropriate railroad company for review and approval.

2. Highway Crossings

When any highway is crossed, the specifications and precautionary measures required by the respective highway officials shall be followed. A copy of the highway crossing application or Right-of-Way permit and proof of approval from the respective highway entity shall be submitted. In the absence of specific highway requirements, the following general criteria shall apply:

A. Criteria

The following criteria shall apply to instances in which water main construction affects highway rights-of-way and facilities. In certain instances, the requirements of the highway department may be more stringent than these standards. In those instances, the more stringent standard shall apply.

- Water mains shall cross the roadway at an angle as close as possible to 90 degrees (90°).
- Water Mains shall not be placed under roadway bridges where the possibility of restricting the required waterway area or where a possibility of compromising the structural integrity of bridge foundations exists.
- Pipes crossing beneath highways shall be installed by jack and bore method with a casing pipe, tunneling method or micro-tunneling method.
- Borings under highways shall have a minimum depth of cover of 54 inches (54”) as measured from the surface elevation to the top of the casing. The top of the casing shall have a minimum of 48 inches (48”) of cover below the invert of existing or proposed ditches.
- Borings under highways shall extend a minimum of 10 feet (10’) (measured perpendicularly) outside the outer edge of existing pavement or to the toe of slope when the roadway is on fill and the toe of slope exceeds the 10 feet (10’) outside of pavement requirement.
- Water mains laid longitudinally along highway rights-of-way shall be located a sufficient distance outside of the existing edge of pavement to ensure worker and motorist safety during construction.