

Design Guidelines for Piped Water Networks in Refugee Settings

FOREWORD

These Design Guidelines form part of UNHCR’s series of WASH Design Guidelines for Refugee Settings which are the result of an extensive review process with WASH actors active in refugee settings. It is recognized that the Design Guidelines will require continuous review and amendment in response to changes in engineering best-practice and feedback from the field. Therefore further review will be managed by a Technical Review Committee which will meet regularly to discuss issues related to the use of the guidelines and an annual review will be reported back to the WASH community. More urgent amendments will be reported as, and when, required.

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300 SCOPE

300.1 All water supply infrastructure installed in refugee settings must meet UNHCR's minimum standards for design and construction workmanship. All design work should be conducted by qualified engineers. A package of detailed design calculations, material specifications, technical drawings, and bills of quantity should be submitted to UNHCR for verification before any medium or long-term water supply project is initiated.

301 MINIMUM DOCUMENTATION

301.1 UNHCR and WASH actors should ensure that a project design file is created for all piped water network projects for more than 5,000 persons. The project design file should contain the minimum documentation outlined below. Once the project file has been compiled by the design engineer, it should be submitted to the local UNHCR WASH Officer. The recommended minimum documentation is as follows:

- a. Project description, background, context and purpose
- b. Scope of work
- c. Map of the existing and proposed water network layout
- d. Topographic survey
- e. Daily water demand calculation
- f. Daily water availability calculation
- g. Main supply pipeline sizing calculation
- h. Pump selection calculation and justification (if required)
- i. Water treatment calculation and justification (if required)
- j. Water distribution network general layout
- k. Water distribution network peak flow calculation
- l. Water distribution network optimal pipe sizing calculation
- m. Water storage capacity calculation
- n. Locations of washouts, air valves and network isolation valves
- o. Tapstands and household connections
- p. Water system sub-component design documentation
- q. Complete system bills of quantity
- r. Plumbing schematic
- s. Construction materials and workmanship specifications
- t. Considerations for operation and maintenance (operator's manual)

Notes on each of these parts of the project design file can be found below.

- 302 PROJECT BACKGROUND, REFUGEE CONTEXT AND PURPOSE**
- 302.1 Every refugee water supply design project should include a brief paragraph explaining the humanitarian context, background and rationale for the water supply intervention. Qualitative and quantitative data (baseline data e.g. existing per capita water consumption, water quality data) should be used to present the current water supply situation where possible.
- 303 SCOPE OF WORK**
- 303.1 The project design file should include a qualitative and quantitative description of the water supply works to be carried out with a paragraph for each of the projects main elements (e.g. abstraction, treatment, storage and distribution).
- 304 MAP OF THE PROPOSED WATER NETWORK GENERAL LAYOUT**
- 304.1 If high definition maps or satellite images of the project region are available, they should be used and the proposed water system network should be superimposed onto the image using photo editing software. If maps are unavailable, an accurate scale map of the project area should be commissioned which includes all roads, paths, buildings, schools, clinics, mosques, rivers, hills valleys and all existing and proposed water system components such as spring captures, reservoirs, pipelines, valve boxes, washouts, air valves, tapstands and institutional connections.
- 305 TOPOGRAPHIC SURVEY**
- 305.1 An accurate topographic survey along the proposed pipeline routes should be commissioned to gain precise data concerning elevations and distances. Ideally this should be carried out using a surveying theodolite, either an optical or total station device capable of measuring azimuth, bearing and range. The survey must be produce no more than +/- 10mm vertical closure error per km surveyed.
- 306 DAILY WATER DEMAND CALCULATION**
- 306.1 The following design criteria should be used to estimate the total daily water demand.
- i. Current population
 - ii. Realistic population growth rate
 - iii. Water system design life
 - iv. Per capita water demand
 - v. Institutional water demand

- vi. Allowance for watering animals, construction, agriculture, brick making, and any other economic activities
- vii. Factor for wastage and leakage
- viii. Peak day factor

306.2 The daily water demand should be calculated to cater for the existing and expected future population. As the average life span of a refugee camp is 17 years it is recommended that all permanent water networks have a 20 year design life. Realistic percentage population growth rates and estimates of any potential refugee influxes should be included in the calculations.

306.3 The total daily water demand should take into account a design criteria of at least 20 litres / person / day or a higher level of supply similar to the refugee's place of origin or the host population. Per capita water consumption figures should be sufficient to cover water for all uses including drinking, cooking, washing and cleaning.

306.4 The total daily water demand calculation should also take into account consumption for every school, mosque, clinic and offices based on local consumption rates and UNHCR guidance figures (see UNHCR WASH Manual).

306.5 If there are any other potential water uses (water for animals, construction, brick making, other economic activities, local host population, etc.) these estimates should also be included in the total daily water demand calculation.

306.6 The total daily water demand figure for the population to be served should be increased by a percentage to take into account leakage and wastage (typically 10% – 30%).

306.7 Finally, the figure should be multiplied by the peak day factor (typically between 1.2 and 2.0) to takes into account increased water use during the hotter summer months.

307 DAILY WATER AVAILABILITY CALCULATION

307.1 A daily water availability calculation should be carried out to ensure the existing water source(s) are able to supply the daily water demand calculated in the previous section. If the water source(s) are unable to supply enough water to meet the demand then additional source(s) of water will need to be located.

307.2 In the case of borehole based systems the driller's long duration borehole test should clearly show a production yield that is able to provide at least three times the total daily water demand.

307.3 In the case of surface water sources the water availability should be calculated from stream gauging records.

307.4 In the case of springs, the daily water availability should be calculated using the mean spring flow rate. If no historical records exist then this should be measured in the field by timing how long it

takes to fill a large container of known volume. Local residents should be consulted to determine if the spring flow is seasonal or the source provides the same flowrate all year round. If the water supply is seasonal, a lower estimate of the flowrate should be used.

307.5 In all cases, water availability should be at least three times greater than the calculated daily water demand.

308 PUMP SELECTION CALCULATION AND JUSTIFICATION

308.1 If water pumping is required the calculations and justification for the pump selection should be clearly presented. In general, a pump should be selected on the basis that it can provide the correct duty point (the correct flowrate and pressure) where the system curve and the selected pump's pumping curve cross each other (refer to Engineering in Emergencies page 377). Note that the duty point should be as close to the pump's peak efficiency as possible.

308.2 If the pump's prime mover is naturally aspirated diesel or petrol engine then the pump curves must be de-rated for altitude, temperature, humidity and RPM effects (see the engine de-rating curves in Oxfam Water Supply for Emergencies page six).

309 WATER TREATMENT STRATEGY AND CALCULATIONS

309.1 The water system design file should provide a clear description of the raw water quality with considerations for seasonal variations. Laboratory results should be provided to show that the water is potable and fit for human consumption (refer to the UNHCR WASH Manual). If any form of treatment is required then the calculations and justification for the treatment approach should be clearly presented. In general, the simplest water treatment technology should be selected with minimal reliance on chemicals, fuel, and imported parts and expertise.

310 WATER STORAGE CAPACITY CALCULATION

310.1 A water storage capacity calculation should be included to determine how much storage is required to balance peaks in water demand with water supply from the source. Having a larger amount of storage than required can be advantageous to meet any unscheduled breaks in supply, however using a greater amount of storage than the optimized amount results in a more costly system.

310.2 The optimum storage size required should be calculated by carrying out a water balance where the optimal water storage required is given by the greatest difference in the inflows and outflows rates. A worked example of designing a water system to meet the peak hour flow can be found in Engineering in Emergencies on page 293.

311 WATER DISTRIBUTION NETWORK GENERAL LAYOUT

- 311.1 The water distribution network should be designed to convey water from the local water storage reservoir to the points of collection (either public tapstands or institutional connections). If a public water collection system is to be designed using public tapstands, these should be located in consultation with the local population at an interval of no more than one for every 250 people, taking into account population expansion and the design life of the system.
- 311.2 Where possible, tapstands should be located so that the maximum distance from any household to the nearest water point is 500 meters. These water collection points should be marked on the plan layout and then the points should be connected up to the reservoir with pipelines (by eye) trying to use the least (shortest) amount of pipes to keep costs and frictional losses to a minimum.
- 311.3 No connections (tapstands or institutions) should be connected to the main trunk lines. Connections are only permitted from service lines.
- 311.4 Depending on the geographical layout, and where possible, efforts should be made to create looped ring mains to provide alternative flow routings and improve system pressure balancing.
- 311.5 Pipelines should try and be placed along existing public rights of way (roads and paths) rather than through people's private property.

312 WATER DISTRIBUTION NETWORK PEAK FLOW CALCULATION

- 312.1 The water distribution network should be designed to meet the peak flow (typically when people wake up in the morning and perform their ablutions). If a tapstand system is being considered, the system should be designed for the morning peak scenario so that every tapstand is able to provide the design flow of 0.25 l/s at the same time.
- 312.2 If the system is being designed with individual connections, the peak flow should be calculated from knowledge of the peak hour factor - which is how much greater the peak flow is compared to the average daily demand flow (typically anything from 4 to 8). This is different for every community and culture and can only be found by observing the water usage rates at a similar existing water system. The peak hour factor can also be calculated by measuring changes in the reservoir water level and calculating water use. With this data, a typical water demand graph can be plotted. A worked example of designing a water system to meet the peak hour flow can be found in Engineering in Emergencies on page 292.

313 OPTIMAL NETWORK PIPE DIAMETER SIZING

- 313.1 The sizes of the pipe diameters in a gravity fed water system need to be very carefully optimized to provide the least cost solution that meets the peak flow. It is very easy to design a system that functions beautifully but is not optimized resulting in a vastly more expensive water network.
- 313.2 Optimization of networks is best done using professional software. These programs can be downloaded from the internet or are available from UNHCR. Secondary pressure losses from bends, junctions, reducers, valves, and taps should be calculated using the figures given in Appendix 16 of Engineering in Emergencies on page 666.
- 313.3 When sizing networks into is important to ensure that the minimum water pressure does not drop below 300 kPa (30m head) where practicable. In addition, the maximum water pressure should not exceed 800 kPa (80m head) where practicable.
- 313.4 Pipe flow velocities should be checked to ensure that they are between 0.7 m/s and 2.0 m/s. Velocities outside this range allow sedimentation of suspended particles or water hammer to occur.

314 PIPES AND FITTINGS

- 314.1 In all cases, the minimum pipe class used for water networks should be 1200 kPa (120m head) Polyethylene (PE) or Unplasticized Polyvinyl Chloride (uPVC) pipe that has been rated for potable water supply. Higher class pipes should be used if necessary to provide for the maximum working pressures in the area in which they are to be laid. PE pipes for in ground installation shall be blue in colour unless otherwise permitted. PE pipes for above ground installation should be certified with UV stabilisation. PVC pipes should not be laid above ground.
- 314.2 All pipe fitting should be rated PN16 and should be certified for drinking water supply.

315 PIPE JOINING

- 315.1 Electrofusion welding, butt fusion welding, compression fittings, uPVC cement, and ductile iron fittings are all permitted forms of pipe joining. All joints must be submitted to a network pressure test on completion (see section 322).
- 315.2 The maximum deflection at any joint should not exceed 1.5 degrees (equivalent to a 150mm offset over a 6m length of pipe).

316 PIPE DEPTHS AND BEDDING

- 316.1 Both trunk mains and service mains should be laid at least 600mm below the finished surface, except where they pass under carriageways where they should be laid at least 900mm below the road surface.
- 316.2 Blue coloured metallic detector wire should be installed within 200 - 400mm of all mains to help located pipelines for future repairs and extensions. No metallic tape is required for steel mains.
- 316.3 Pipes can be laid directly into dug trenches provided there are no sharp stones. If needed, the pipe may be protected with sieved soil or other suitable fine granular material.

317 ANCHOR OR THRUST BLOCKS

- 317.1 All pipes should be anchored with thrust blocks to resist unbalanced forces at bends, tee junctions, changes in diameter and valves. The size of the thrust blocks should be calculated according to the soil bearing strength and using standard thrust block tables (see references). Thrust blocks should be cast using in-situ concrete with a minimum compressive strength of 17.5 MPa at 28 days.

318 WASHOUTS, AIR VALVES AND ISOLATION VALVES

- 318.1 Washouts should be installed at the lowest points along any water pipelines and at the end of any branch lines to allow any sediment that collects to be routinely flushed from the system.
- 318.2 Air release valves should be installed at any high points in the system to allow trapped air bubbles to escape without causing air locks. Either certified automatic air release valves or manual valves may be used.
- 318.3 Isolation valves should be installed at any junctions so that any branch can be shut off for temporary repairs without disrupting the entire system. All isolation valves should be of resilient seat type anticlockwise closing with non-rising spindle. Butterfly valves are not permitted. A concrete pad shall be installed under all isolation valves to prevent the possibility of settlement which could cause undue stress on the adjoining pipework.

319 WATER METERS

- 319.1 Certified water supply meters should be installed on all pumping installations and at the main storage tank exit. The size of the meter installed should be the same size as the connection and the meter installation should be in accordance with manufacturer's recommendations.

319.2 In large networks it may be advantages to install water meters on separate branches to help track water use, leaks and wastage.

320 NON-RETURN VALVES AND BACKFLOW PREVENTION

320.1 Certified water supply non-return valves should be installed on all pumping installations. The size of the non-return valve should be the same size as the connection and the non-return valve should be in accordance with manufacturer's recommendations.

320.2 All tapstand and institutional connections should have one single spring, barrel type inline non-return valve installed to ensure backflow prevention. The device should be reliable, constructed from disinfected resistant (DR) brass.

321 TAPSTANDS AND INSTITUTIONAL CONNECTIONS

321.1 Tapstands and household connections must be made according to the design drawings. Every tapstand and institutional connection should have a non-return backflow prevention valve and a pressure regulating valve so that the flow can be regulated to the design flow of 0.25 l/s. This is especially important for any tapstands or public institutions situated in the lowest part of the system. Water meters are a useful (yet expensive) addition for institutions if a comprehensive cost recovery system is to be put in place.

322 PRESSURE TESTING

322.1 All water networks and pipes shall be subjected to a pressure test after laying and jointing. The section to be tested should be capped or flanged off at either end, and at any branches which it is desired to test separated. The blanked off ends and all bends, tees, crosses, etc. should be securely strutted or otherwise prevented from movement, before applying any pressure.

322.2 The pressure during the test shall be monitored by an approved pressure gauge with marked intervals of not more than 10kPa, and an accuracy of +/- 5% at the test pressure(s). The specified test pressure is to be applied to the lowest point of elevation in the section. If the pressure recording gauge is not located at the lowest point, a correction may be required if there is a significant difference in elevations.

322.3 The water network should be able to withstand a maximum pressure of 1200 kPa (120m head) measured at the lowest point of the section under test or 1.5 times the working pressure at any point in the system, whichever is the greater. In some cases additional pressure may need to be applied using an external water pump. Leakage should not exceed one litre per ten millimetres of pipe diameter per

kilometre length of pipeline per hour. The duration of the test should last no longer than one hour.

323 DISINFECTION

323.1 Before being put into service, all pipes, valves, institutional connections and other fittings shall be disinfected with chlorine. The method to be adopted should be as per the following:

- Step #1 Flush the network until the water runs clean
- Step #2 Apply 20-50mg/l chlorine solution for 24 hours
- Step #3 Test for a minimum 10mg/l chlorine residual
- Step #4 Fail = Repeat steps #1 to #3

324 WATER SYSTEM SUB-COMPONENT DESIGN DOCUMENTATION

324.1 The water system design project should contain detailed design information for each of the water system sub-components (e.g. spring boxes, boreholes, wells, pump houses, break pressure tanks, reservoirs, valve boxes, tapstands etc.). For each component there should be an individual detailed design calculations, technical drawings and a bills of quantity.

325 COMPLETE SYSTEM BILLS OF QUANTITY

325.1 The individual bills of quantity from the sub-components section should be combined to give the complete bills of quantity for the water system. The complete bills of quantity should clearly show what materials are needed for each of the sub-components in addition to the total quantities that need to be ordered (e.g. how many bags of cement are needed for each of the sub-components and also for the whole system).

326 PLUMBING SCHEMATIC

326.1 A plumbing schematic should be included showing the location and size of all plumbing components (reducers, tees, adaptors, valves, elbows etc.). This is not only to assist during the installation phase but also in ensuring that all of the correct fittings are procured at the start of the project and the work does not become delayed as a result of missing components.

327 CONSTRUCTION TECHNICAL SPECIFICATIONS

327.1 A technical specification should be included that fully explains the materials and workmanship construction standards to be followed for all construction activities (e.g. concrete curing times, sand and gravel specifications, pipe laying depths, pipe network pressure testing

specifications and pipe bedding material specifications). The UNHCR standard construction technical specifications must be followed but may be modified to suit the National Ministry of Civil Works Construction Specifications.

328 CONSIDERATIONS FOR OPERATION AND MAINTENANCE

328.1 A system operators manual should be compiled with clear maps, diagrams and full instructions explaining any daily operational procedures, the location and uses of any valves and an extensive cleaning and maintenance schedule including the recommended activities to be carried out every week, month, six months and every year including system desludging, cleaning, disinfecting, sanitary inspection, leak detection. Special instructions should be given regarding any pumping or water treatment equipment.

329 WATER SUPPLY DRAWINGS

329.1 The following drawings should be used in conjunction with these technical design guidelines

D-300/2015a	Standard Public Tapstand (with Drainage) – EMERGENCY
D-301/2015a	Standard Public Tapstand (with Drainage) – POST-EMERGENCY
D-302/2015a	Post Emergency Handpump Apron (Rectangular Concrete)
D-303/2015a	Post Emergency Hand Dug Well Apron (Circular Concrete)
D-304/2015a	Post Emergency Borehole Design (Fractured Rock Aquifer)
D-305/2015a	Post Emergency Borehole Design (Alluvial Aquifer)
D-306/2015a	Emergency Raised Water Platform (Sandbags)
D-307/2015a	Emergency Raised Water Platform (Concrete Rings)
D-308/2015a	Emergency Raised Water Platform (Corrugated Steel Rings)
D-309/2015a	Post Emergency Elevated Tower (Reinforced Concrete)

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