CHAPTER 2

2.Planning, Investigations, Design and Implementation

CHAPTER 2: PLANNING, INVESTIGATIONS, DESIGN AND IMPLEMENTATION

2.1 Introduction

Planning is defined as "defining objectives for a given period, designing various courses of action to achieve them and selecting the most practicable alternative from the various alternatives". In water supply systems, it is required to achieve the Service Level Benchmarks (SLBs) as set out by the Ministry of Housing and Urban Affairs (MoHUA), Government of India (GoI).

GoI launched Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0 in Oct, 2021 with a vision to make all cities' water secure and provide safe and adequate drinking water to all urban areas. Though GoI, State Governments, and Urban Local Bodies (ULBs) are making huge investments for providing safe and reliable water supply in urban areas, ULBs could not achieve the above said SLBs due to various reasons as discussed below. Water supplied at the household level is not meeting BIS (IS 10500:2012) and therefore, households adopt coping mechanism for improving water quality by using RO devices that may not be advisable as the water is devoid of essential minerals.

As per the earlier Manual on Water Supply and Treatment published by the Ministry of Housing and Urban Affairs in 1999, all projects were planned, designed and implemented to achieve 24×7 pressurised water supply to supply safe and potable drinking water in adequate quantity, conveniently and as economically as possible. However, after implementation, the water supply systems were switched over to intermittent supply mode due to various reasons such as inadequate water resources, improper zoning, haphazard laying and tapping of pipes which are in unserved area and are not part of the design, low residual nodal pressure and lack of water meters etc.

Even though the earlier manual stated that the residual pressures should have been 7 m for a single storey building, 12 m for two storeys, 17 m for three storeys and 22 m for four storeys, most of the projects were designed with the residual pressure of 7 m or 12 m and operated in intermittent mode which results into contamination of water due to entry of dirty water into the pipeline during non-supply hours, high NRW and inequitable water supply.

Drinking water quality is one of the biggest challenges in water sector of India. National Institution for Transforming India (NITI) Aayog in its Composite Water Management Index (2019) stated that eight million children (< age of 14) in urban India are at risk due to poor water supply. Infant mortality is the death of an infant before his or her first birthday. The infant mortality rate is the number of infant deaths for every 1,000 live births. The infant mortality rate for India (https://www.macrotrends.net/countries/IND/India/infant-mortality-rate) in 2022 was 27.695 deaths per 1000 live births.

Article 21 in 'The Constitution of India', 1949 states "Protection of life and personal liberty: No person shall be deprived of his life or personal liberty except according to procedure established by law". Thus, the right to access to drinking water is fundamental to life and it is is a duty of the State, under Article 21, to provide clean drinking water to its citizens.

India is a party to the resolution of the UNO passed during the United Nations Water Conference in 1977: "All people, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantum and of a quality equal to their basic needs."

2.2 Essentials of 24×7 Pressurised Water Supply System

The city water supply scheme comprises of components such as collection at the source, a conveyance system in the form of a pumping main or gravity main for raw water and units for treatment, purification and transmission mains for treated water to the distribution system. A typical city water supply scheme is shown in Figure 2.1.

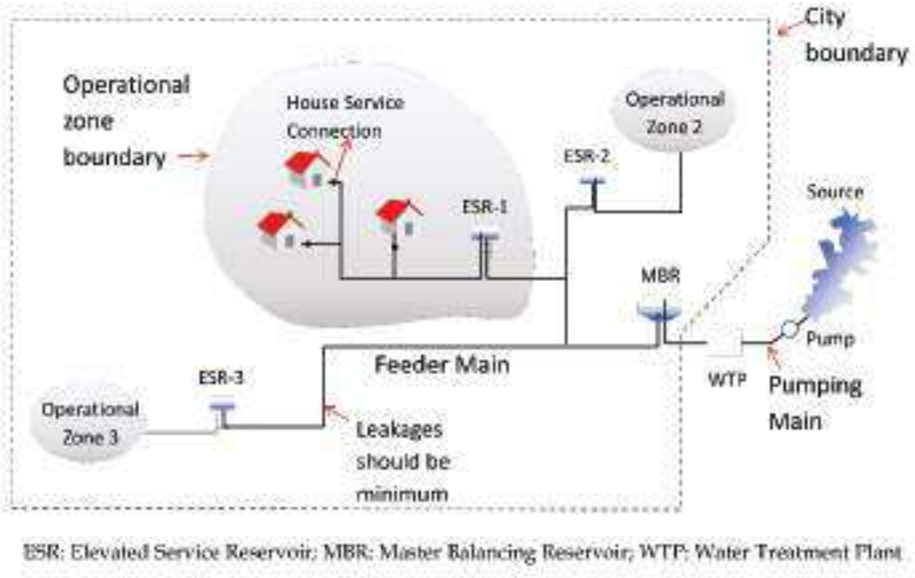

Figure 2.1: A typical city water supply scheme

Essentials of water supply scheme include adequate source which should be at least 95% reliable and dependable. 95% reliability and dependability mean that the source will cater the needs of a city for at least 95% confidence intervals.

A proper water supply system consists of the following:

- The source of water should be free from contaminants
- Highly efficient transmission system for raw water
- Well maintained WTP
- Service reservoirs that do not get empty or overflowing
- Properly designed distribution system with well-established district metered areas (DMAs) to monitor and control NRW and ensure equitable water supply
- 100% metering with differential volumetric tariff

It is necessary to investigate, carry out survey, plan and design before execution of the scheme. Proper planning ensures that the scheme is implemented, commissioned operated and maintained within the scheduled time. The main steps involved in the implementation of the water supply project are shown in Figure 2.2.

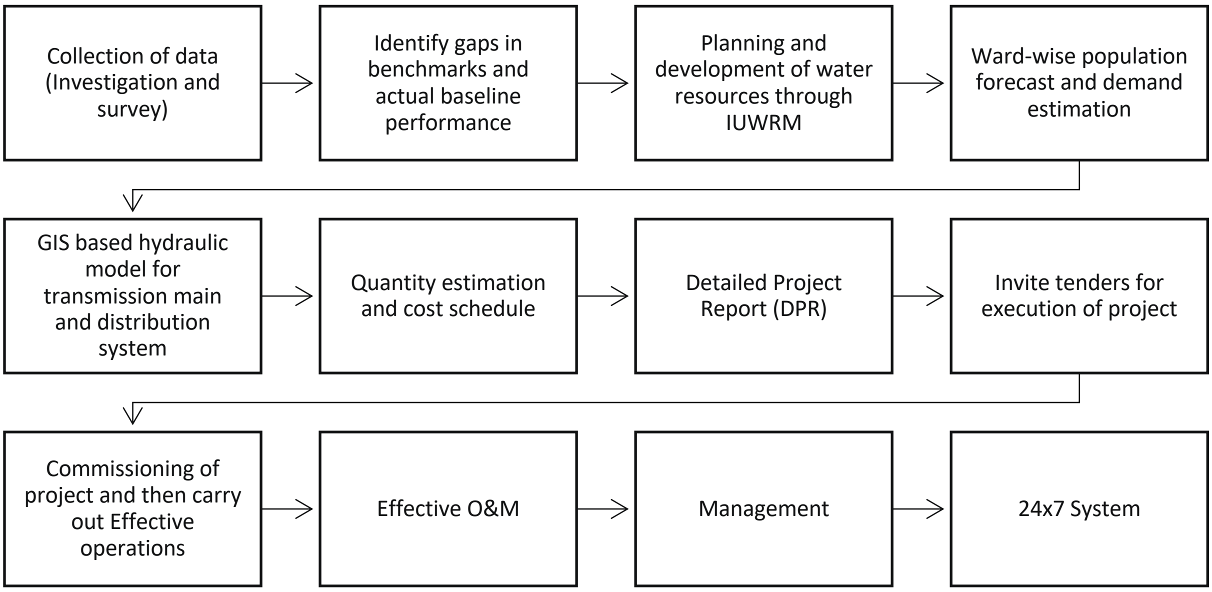

Figure 2.2: Main steps involved in the implementation of water supply project

Planning water supply involves the process of determining how water is proposed to be delivered to the consumers. Planning also requires assessment of any issues relating to water supply including protection of the sources. It also concerns the consideration of the water scarcity conditions and disaster management (emergency planning and response). Disasters can be natural (flood and drought), or human-made (chemical spill and sabotage). The city administration would respond to such conditions.

2.3 Vision, Goal and Objective

2.3.1 Vision

"All urban citizens and other user categories especially the poor and vulnerable should have access to adequate, safe and affordable "Drink From Tap" (DFT) facilities to meet personal hygiene and economic uses leading to sustained improvements in public health, well-being and economic productivity of urban areas through gradual conversion of intermittent water supply to a continuous 24×7 pressurised water supply and also covering uncovered areas in a phased manner in all cities and towns by 2047."

2.3.2 Goal

Gradual conversion and operationalisation of intermittent water supply to continuous 24×7 pressurised water supply and covering uncovered areas through a scientific and rigorous planning and implementation process to provide a safe and affordable water supply services to 100% urban citizens including poor and vulnerable by 2047.

2.3.3 Objective

Main objectives of city water supply system are: (a) to supply safe and potable water to the consumers as per drinking water quality as stipulated by BIS (IS 10500:2012); (b) to supply water in adequate quantity; and (c) to ensure equitable access with adequate pressure as equitable water supply brings affordability.

2.4 Proposed planning approach through DMA concept

DMAs are the building blocks of the 24×7 pressurised water supply scheme. Before the advent of DMA, identification of leaks in the distribution system was a difficult task. In early 1980s, DMA concept was first initiated in UK. With DMA, the problem of prioritisation of leaks was simplified. Since then, DMA methodology is being practised throughout the world. Bureau of Indian Standards code IS 17482: 2020 emphasises to adopt DMA concept to achieve 24×7 pressurised water supply system (PWSS with DFT). Thus, DMAs in distribution systems should be planned and designed for every city. The concept of DMA is prevalent in the developed countries and also in some of the developing African and Southeast Asian countries.

In India, the concept of DMA has been propagated by CPHEEO, MoHUA by organising various international, national, regional and state level conferences/ workshops. The Ministry also published an Advisory on “Guidelines for Planning, Design and Implementation of 24x7 Water Supply Systems” in December 2021.

So far, the practice of DMA has been practised only in some states in India such as Karnataka, Odisha, Maharashtra, Tamil Nadu, Andhra Pradesh etc. Now, the awareness is being developed in many states and cities to adopt DMA concept. More than 600 cities and towns from about 27 States have reported that they are in process of formulation and implementation of projects based on DMA concept.

Cities such as Puri, Malkapur, Alnawar, Kundagola, and Thirthahalli have converted their intermittent system to 24×7 pressurised water systems for the entire city. Government of Odisha has also embarked DFT in 23 towns. Also, Nagpur, Coimbatore and Vishakhapatnam commissioned 24×7 PWSS with DFT partly. Other cities in Karnataka such as Hubli-Dharwad, Belgaum and Kalburgi have partly commissioned their water supply to 24×7 pressurised system and have planned for full achievement.

The case studies of 24×7 water supply systems commissioned in case of Puri, Malkapur, Alnawar, Belagavi, Kalaburagi, Hubballi-Dharwad, Coimbatore, Pune, Nagpur, Visakhapatnam, Indi, Thirthahalli, and Shirpur cities is enclosed at **Annexure 2.1**.

The various ULBs mentioned above and few more ULBs who have implemented and are in the process of scaling up of 24×7 PWSS with DFT for pan city. They have achieved 24×7 supply by creation of DMAs, rehabilitation of existing water supply components, 100% replacement of the HSCs with a per capita cost in the range of Rs. 800 to Rs. 27,000 which largely depends on the condition of the existing system, type of meters used and the cost of other water supply scheme components. The status of the 24×7 water supply projects and the details of the components can be referred to in the table at **Annexure 2.1**.

This manual strongly recommends planning and design of distribution system based on using the GIS and hydraulic modelling tools.

2.5 Reduction of NRW strategy

Non-revenue water (NRW) is defined as the difference of the quantity of water supplied and water billed. It comprises of the physical loss and the commercial loss. Physical losses are due to leakages in pipeline, inaccuracy of meters and overflow whereas commercial losses are due to theft, illegal connections, etc.

Many cities in India have NRW of more than 50%. Average NRW in Indian cities is 31%. This manual recommends NRW to be reduced to 15% for the overall system and 10% for distribution system at DMA level. So, the strategy to reduce NRW is of paramount importance. The first step is to prepare GIS maps of the existing pipelines in the city and then prepare a hydraulic model. The boundaries of operational zones (OZs) and DMAs should be created on a hydraulic model and the same maybe established by using isolation valves. The sub-DMA shall also be ascertained using isolation valves for monitoring NRW in case the DMA is not 100% metered.

When consumer metering is not done (which may be the case in most of the ULBs), the top-down approach of water audit should be adopted. Till 100% metering is achieved, the top-down water audit shall be carried out wherein quantum of water coming in the city can be known from the available pump registers and from the water billing data, the water consumption can be computed and thus, the difference of water coming in and water consumed gives up an approximate value of NRW.

The bottom-up water audit should be carried out when metering is done 100%. The bulk meter is installed at the entry point of the DMA. Every consumer should be metered and geo-tagged. The difference between the inflow of water coming in DMA and the quantity of water consumed in DMA gives the value of NRW of that DMA. Computation of NRW of all the DMAs should be carried out and the DMA with most leaking DMA should be tackled for leak identification and repair.

In case the metering is partially done, then water audit can be carried out in sub-DMAs. In this method, at least 10% of the customers in the sub-DMA should be metered. The flow in that sub-DMA can be measured by regular meter or by portable flow meter. This gives a sample value from which the NRW for the entire DMA can be extrapolated using statistical methods.

There are technologies that may identify the leakage areas when the values of flow and pressures (measured by pressure gauge at key locations) are fed to them. Other leakage methods such as noise co-relators can then be used to pinpoint the exact leakage spot. If the ULB desires to make quick leak identification of the pipelines, then some methods like helium gas, etc., can be used.

Replacing existing old leaking pipes and HSC shall result in substantial NRW reduction after formation of DMAs.

Advantage of NRW reduction programme is that once leaks are identified and repaired, water is saved and the saved water then leads to increased supply hours and in this way, NRW may be decreased to less than 15%.

2.6 Planning Objectives

The planning of water supply scheme aims at creating holistic/ comprehensive approach that help in effective water resource planning through Integrated Urban Water Resource Management (IUWRM) so as to achieve goal of converting existing water supply to 24×7 PWSS and covering uncovered areas to supply 24×7 pressurised water to every household meeting water quality standard as per provisions of IS 10500:2012.

The aforesaid objectives can be met by planning and designing of the water supply system by using DMA approach only to achieve 24×7 pressurised water supply. The planning based on DMAs concept has been standardised by Clause 8.5.2 of BIS 17482: 2020. Henceforth, ULBs shall plan and design urban water supply projects based on DMA approach which will enable them to improve the service delivery, control NRW from the present service levels and achieve 24×7 pressurised water supply. The Phase wise conversion of 24×7 PWSS is shown in Figure 2.3.

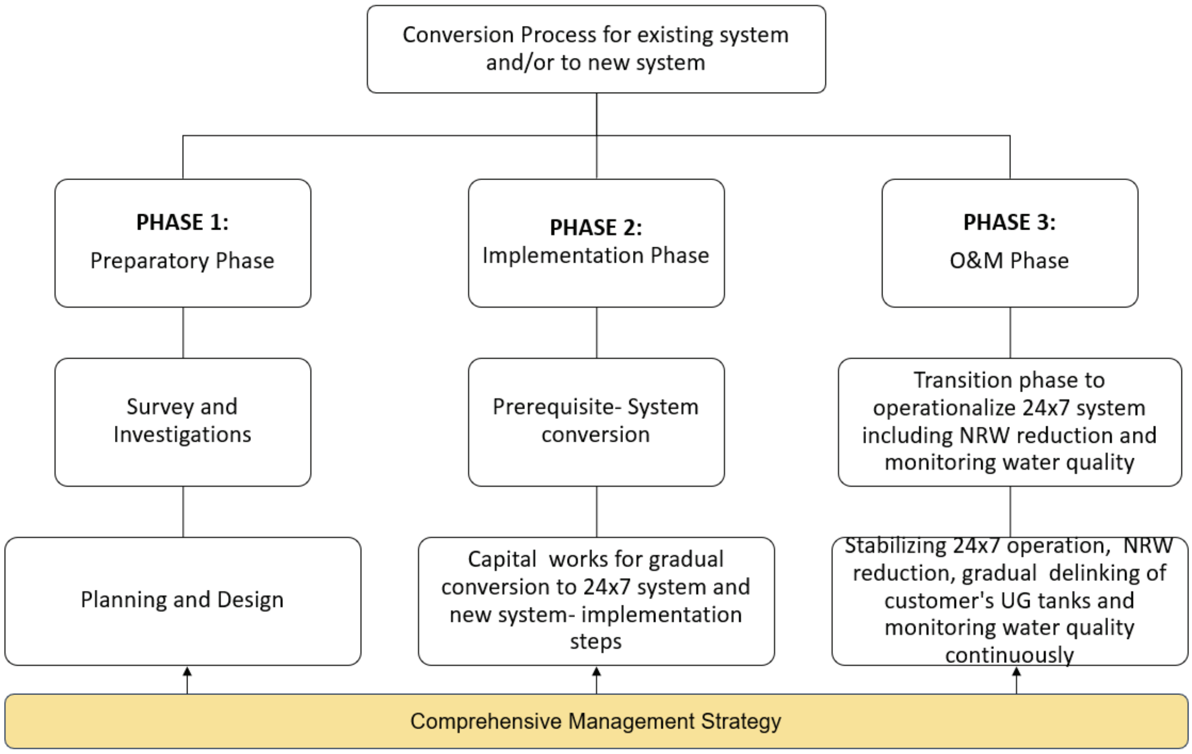

Figure 2.3: Conversion process of existing system to new system

2.7 Preparatory phase (Phase 1)

Preparatory phase includes of survey & investigation and planning & design of water supply schemes.

2.7.1 Preparatory Phase – Survey & Investigation

2.7.1.1 Survey for Elevations

A physical survey for elevation may not be required if the validated contours are generated using a 3D stereo-paired high-resolution satellite image. However, those cities who prefer to have a 2D satellite image shall carry out total station survey by taking levels along the city roads at 30 m chainage. GIS contours can be generated by the following methods.

a) Total station survey: Modern instrument consists of a theodolite with a built-in distance meter. Hence, it can measure angles and distances at the same time. It consists of a built-in emitter capable of emitting microwaves and infrared signals. Using the wavelength of these emitted waves, distance is calculated. Distance is calculated by multiplying the time taken to cover a certain distance by velocity.
b) GIS co-ordinates: Total station can measure the co-ordinates like X, Y, and Z or GIS northing, easting, and elevation of surveyed points.
c) In water supply projects, a surveyor conducts a survey along the city roads. With total station, generally, it records X, Y, and Z co-ordinates. Here, the city engineer should give directives to

record the northings and eastings along with the elevation of surveyed points along the road. These readings of northings, eastings and elevations in excel sheets are then used in GIS software to generate the shapefile of the points, which is then used to generate the GIS-based contours.

d) LIDAR: An elevation survey can also be conducted using Light Detection and Ranging (LIDAR) technology, which is a remote sensing method that uses light in the form of a pulsed laser.
e) Drones: Drones are also used to generate contours. Drones are used when the roads are not seen on the satellite images. Drones provide high-quality images. The drone flies along the flight path, and while passing, it takes precision images at two overlapping angles. Hundreds of high-resolution quality images are obtained and then processed by the appropriate software, which gives the Digital Elevation Model (DEM). DEM is then processed in GIS software to generate the contours. The contours thus formed should be validated by a Differential GPS (DGPS) survey.
f) DGPS-RTK: Differential Global Positioning System (DGPS) with real-time kinematics (RTK) can be used to make survey. All along the roads in city the ground elevations shall be recorded using DGPS. Using ground elevations GIS based contours are generated.
g) CORS: Recently, a Continuously Operating Reference Station (CORS) system is being used in the survey work of water supply of large cities. CORS is a network of RTK base stations that broadcast data usually over an Internet connection. A CORS comprises a GPS receiver operating continuously and antenna set up in a stable manner at a safe location (higher place like building top) with a reliable power supply for continuously streaming raw data. The centralised CORS station is usually connected to the multiple receivers (rovers) up to a distance of about 100 km. The levels recorded ensure uniformity which is suitable for large cities. The elevation and latitude and longitude co-ordinates are computed to an accuracy of 5-15 mm on the earth’s surface.

2.7.1.2 Open Street Map

Open Street Map is a freeware tool using which we can get road edges, footprints of properties, railway tracks, water bodies, etc. However, Open Street Map is not used to generate contours.

2.7.1.3 Survey of Consumers

A consumer survey should be carried out to map the consumers in the distribution system. This survey should be planned for getting (a) requirement of consumer meters associated with various pipe diameter and type of use, e.g., residential, commercial, etc., (b) listing of suspected illegal connections and (c) connections from mainline which are to be shifted to lines designed for giving connections. Consumer survey provides information of consumer category, status of meters and current meter readings for billing purposes. GIS-based consumer geocoding provides information on the number of connections in each OZ of the service tanks, which determines the number of DMAs in the OZ. Information collected from this survey can be transferred to a GIS-based map. Geocoding with GIS co-ordinates of all the consumer meters is preferred.

The procedure for consumer survey is discussed in **Annexure 2.2**.

2.7.2 Investigations

Identifying Existing Pipelines and Condition Assessment

Identification of existing pipes is the necessary and most important activity both for augmentation and retrofitting in the existing system or a brand-new scheme.

For creation of hydraulic model, existing pipelines need to be identified and documented. Emphasis should be given to use existing pipe network in the model. It is extremely difficult to identify the existing pipeline as they are buried in ground and in most of the cities, database and maps of such pipelines are not available. There are five methods of detecting underground pipelines. These are (a) Manual digging pit, (b) Acoustic Detection Method, (c) Electromagnetic Induction Method, (d) Location of valves and (e) Ground Penetration Radar Method.

All these methods of identifying existing pipelines are discussed in **Annexure 2.3**.

Various methods of condition assessment including that of robotics are as follows:

1) Robotic Pipeline Inspection
2) Inline Tethered Pipeline Inspection
3) External Non-Destructive Test (NDT) Techniques

All these methods of condition assessment are discussed in **Annexure 2.4**

2.8 Preparatory Phase - Planning & Design

2.8.1 Planning

Planning is required at various jurisdictional levels, i.e., for the urban areas of the country as a whole, the state level, regional level and community level. Though the responsibility of the various organisations in-charge of the planning of water supply systems can be different, they must function within the priorities mandated by the National and State Governments.

The water supply projects formulated by the various state authorities and local government agencies at present may not contain all the essential elements viz GIS maps, hydraulic modelling, equitable pressure, Supervisory Control and Data Acquisition (SCADA), etc. Also, different guidelines and norms are adopted by the States and ULBs; for example, population forecast, assumptions regarding per capita water supply, design period, size of zoning etc. Therefore, there is a need to specify appropriate norms for planning and designing to avoid the different approaches and maintain uniformity throughout the country.

The following aspects need to be considered in the planning and designing of water supply projects.

2.8.1.1 Achieving Benchmarks

The targeted SLBs for water supply notified by MoHUA in 2008 are shown in the Table 2.1

Table 2.1: Targeted service level benchmarks for water supply services

S. No.	Performance indicator	Targeted Benchmark
1	Coverage of water supply connections	100%
2	Per capita supply of water	135 LPCD
3	Extent of metering of water connections	100%
4	Extent of NRW	15%
5	Continuity of water supply	24 hours
6	Quality of water supplied	100%

S. No.	Performance indicator	Targeted Benchmark
7	Efficiency in redressal of customer complaints	80%
8	Cost recovery in water supply services	100%
9	Efficiency in collection of water supply-related charges	90%

While planning the water supply scheme, the ULB shall carry out the survey of its city/town and find out the baseline parameters of the performance indicators. The gaps between the benchmarks and the baseline parameters shall be worked out and the detailed project report (DPR) shall be prepared to bridge the gaps so that the benchmarks, as shown in Table 2.1, shall be attained. Some of the SLBs such as 24×7 water supply, 100% metering, control of NRW and quality of water supply shall be considered as Key Performance Indicators (KPIs) in the tender document. In addition to the above, residual nodal pressure shall be included in the tender document as KPI.

All water supply projects should be implemented with the objective to achieve the aforesaid SLBs and monitor the same throughout the design period.

2.8.1.2 Planning Considerations

Planning long-term requirement for sustainable water supply in India is a big challenge due to the complexity of the system and rapid growth in population and water demand. The challenge further increases as the city water sources are becoming distant due to the non-availability of nearby reliable and adequate water sources, thus increasing the project's cost. Engineering decisions are required to specify the area and population to be served, the design period, per capita rate of water supply, other water needs in the area, the nature and location of facilities to be provided, the utilisation of centralised or decentralised treatment facilities and points of water supply intake and wastewater disposal. Projects have to be identified and prepared in adequate detail in order to enable timely and proper implementation.

A detailed long-term planning is needed to decide the number of phases and phase-wise expansion of the water works synchronising with the expansion of the urban area. Working capital cost required, interest charges, period of loan repayment and water tax should be given due consideration.

2.8.1.3 Planning and Development of Water Sources

Integrated Water Resource Management (IWRM) is defined as a technique that encourages co-ordinated land and water development and management in order to maximise economic and social welfare in an equitable manner and is needed for comprehensive planning of river sub basin and groundwater sources. In a river sub basin, there are number of cities dwelling on the bank of the same river. State Water Resource Departments/Irrigation Departments need to compute the water balance for entire river sub basin including groundwater sources in consultation with State Groundwater Board/Department which will give an available balance of water for planning of water resources for various consumptive/non-consumptive uses. ULB need to carry out the study of IUWRM for a city which is a subset of IWRM. IUWRM needs the water availability, input variable and various demands in a city as an output variable based on the water demand for population and other non-domestic needs and availability of water from surface and groundwater sources, recycled water, rainwater harvesting, sea water, etc. Thus, using IUWRM, ULBs need to prepare city water balance for sustainable planning of the city water supply to ensure 95% dependability and reliability of water sources for a design period of 30 years as per requirement for water supply project. The outcome of IUWRM tells us whether the city has enough water or is in deficit for catering its water needs. If the water balance is in deficit, the city has to comprehensively plan for addressing the deficit/ gap in water by recycling of water, rainwater harvesting, etc. Details of IWRM and IUWRM including City Water Balance Plan are discussed in section 4.13 & 4.14 of Part A Manual.

City engineers to ensure that the city has a perennial sustainable water source with 95% dependability. This includes evaporation losses for the projected population of the ultimate stage with designed per capita supply. Water resources department make planning of dams and the city can take this information from them.

Dedicated express feeder with standby arrangement for electric substations at pumping stations at headworks and at Water Treatment Plant is mandatory. The work of electric lines shall be done from the corresponding electricity board. Electricity board shall ensure that they do not give electric connections to other consumers from this dedicated express feeder. The cost of the express feeder should be included in the project cost.

2.8.1.4 Water Security

Urban water security does not merely mean developing water sources and supply water at every household in urban areas, but it is globally defined as the dynamic capacity of the water system and water stakeholders to safeguard sustainable and equitable access to adequate quantities and acceptable quality of water that is continuously, physically, and legally available at an affordable cost for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against waterborne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.

2.8.1.5 Water Quality and Quantity

The objective of Water Works Management is to ensure that the water supplied is free from pathogenic organisms, clear, palatable and free from undesirable taste and odour, of reasonable temperature, neither corrosive nor scale forming and free from minerals that could produce undesirable physiological effects. The establishment of minimum quality standards for public water supply is of fundamental importance in achieving this objective. The water to be handled may vary both in quantity and quality and the degree of treatment required changes seasonally, monthly, daily and sometimes, even hourly. The public health engineer may use his ingenuity to mitigate the variations in quantity by the provision of storage, which may be drawn upon during peak demand. Variations in quality can be managed by provision for the introduction of suitable process adjustments in the WTP.

It is the responsibility of the ULB/Water Boards/PHED to supply water with adequate quantity and required pressure and acceptable quality by meeting drinking water supply standards at every household as per the Tables 1 to 5 of the BIS code IS 10500:2012 which are shown in **Annexure 2.5**.

2.8.1.6 Strategy for Improvement of Drinking Water Quality

Following strategy shall be adopted for improvement of drinking water quality:

i. **Contamination of drinking water in pipeline during non-supply hours:** It occurs during non-supply hours in intermittent water supply system when the pipeline is empty which attracts outside contaminants, thus contaminating water. The strategy is to provide continuous water supply with adequate pressure so that the entry of outside contaminants is prevented.
ii. **Contamination of drinking water in customer underground tanks:** Customers construct underground (UG) storage tanks due to interrupted supply prevalent in the distribution

system. In the past, the UG tanks were constructed with brick masonry where the joints in bricks are porous. Thus, not only does the water leaks but it also allows outside contaminants to enter. Therefore, consumer UG tanks should be discouraged for the buildings up to the three storeys. The strategy is to provide continuous potable water supply with residual pressures of 17-21 m in case of Class I and II cities and 12-15 m for other and then subsequently remove UG tanks gradually. However, for high rise buildings, waterproof UG RCC/HDPE tanks are recommended with annual cleaning using chlorine.

iii. **Contamination of water in pipelines through ferrule points of HSCs**: As per various studies conducted, about 70-80% leakages occur at ferrule points and they become the point of contamination. This manual emphasises the use of standard quality ferrules and pipes in addition to employing the services of licensed skilled plumbers for giving HSCs.

iv. **Contamination of raw water sources due to discharge of untreated wastewater**: Progressively over the past, the wastewater (partially treated or untreated) has been discharged into the water bodies. As the wastewater effluent and the pesticides leached from the agricultural fields discharged into the water bodies contain various contaminants including micro-pollutants, Endocrine Disrupting Chemicals etc., it is important to adopt high degree of treatment to protect the public health. Therefore, the conventional water treatment processes are ineffective to treat such variety of contaminants. The degree of treatment for raw water sources may be required to be enhanced with a judicious combination of appropriate treatment technologies by making additional investments. The suggested line of treatment options for contaminated surface water sources have been provided in Chapter 8.

2.8.1.7 Water Conservation

Rising demand for water in urban communities due to population increase, commercial and industrial development and improvement in living standards is putting enormous stress on the water resources. Not only the quantity of extractable freshwater resources is being depleted but also the quality is deteriorating. The problem is further aggravated due to the over-abstraction of ground waters and/or indiscriminate use of surface water bodies for the discharge of municipal and industrial untreated wastewaters. It has, therefore, become essential to initiate measures for an effective and integrated approach to water conservation.

2.8.1.8 Increasing the Water Availability, Supply & Demand Management

The measures required to increase the water availability involve augmentation of water resources by storing rainwater on the surface or below the surface. Surface storage is usually contemplated either in natural ponds, reservoirs, and lakes or artificially created depressions, ponds, impounding reservoirs, or tanks. Subsurface storage of water is affected by constructing subsurface dykes, artificial recharge wells, etc. For storing subsurface water in rocky areas, several techniques have been developed indigenously like Jack Well Technique, Bore Blast Techniques and Fracture Seal Cementation. These techniques have been deployed to improve porosity, storage volume as well as interconnectivity between fractures/fissures and other types of pores. Artificial recharge of ground water may be considered in areas that are suitable for such purpose.

Water supply management aims to improve the supply by minimising losses and wastage and reducing NRW in the transmission mains and distribution system. A robust performance monitoring system should be planned to secure the quantity and quality of water including reduction of NRW by adopting the methodology of water balance suggested by International Water Association (IWA.) The NRW can constitute a significant fraction of total water supplied in poorly constructed and managed water transmission and distribution systems. Measures like detection, control and prevention of leakage, metering of water supply, installation of properly designed water efficient taps and prompt action to repair and maintain distribution system components should be adopted.

Water demand management involves measures that aim at reducing water demand by optimal utilisation of water supplies for all essential and desirable needs. It can also be done by enforcing differential tariff based on the volumetric consumption. It focuses on the identification of all practices and uses of water more than the functional requirement. The appropriate use of plumbing fixtures, such as low volume and dual flushing tanks in place of conventional cisterns that conserve water should be encouraged. Practices like the recycling and reuse of treated wastewater should be promoted as mandated under AMRUT 2.0 to conserve fresh water sources. In many cities, apartments are mandated to treat wastewater and reuse in their premises.

2.8.1.9 Planning of OZs and DMAs

The city should be divided into pressure zones based on the GIS based contours of the city within the jurisdiction of each WTP. The city should be further divided into Operational Zones (OZs) within a pressure zone based on the contours with each OZ defining the minimum and maximum pressure. There shall be at least one OZ for each service tank. After determining the optimum boundaries of OZs of all existing service tanks, new service tanks should be planned in the unserved areas. Care shall be taken to see that the maximum ultimate population of each OZ shall not exceed about 50,000 or 10,000 connections in plain areas and for hilly areas, maximum population per OZ should be about 30,000 or 6,000 connections. Each OZ shall be divided into sub zones which are called as DMAs. Each OZ shall have not more than four DMAs. Each DMA shall have the number of connections in the range of 500 to 3000 in plain areas and 300 to 1500 in hilly areas and all DMAs shall be hydraulically discrete (isolated) for which zero pressure test (Refer Section 12.12.2) shall be planned. Each DMA shall be connected to its respective service reservoir by a common branch pipe connected to the outlet of service reservoir. On the branch pipe connecting to each DMA an arrangement comprising of isolation valve, bulk meter and flow control valve (FCV) should be made. The bulk meter and the FCV shall be connected to the SCADA through the Remote Terminal Unit (RTU).

In some cases, land for construction of service tanks may not be available and very few service tanks but larger capacity has to be planned, in such cases the number of District Metering Areas (DMAs) may be more than 4 as per the terrain conditions. This may be also applicable in the area where population is saturated.

In saturated/high density population areas, where land is a constraint, construction of service reservoir for catering OZ with 50,000 population, the norm of 50,000 population per OZ shall be relaxed and ultimate population up to 75,000 to 100,000 shall be considered in OZ with proper justification. However, maximum no. of household connections shall be restricted to 3000 by increasing the suitable no. of DMAs.

The design of various components of OZs under DMAs are provided under preparatory phase design mentioned in Clause 2.7.2.2.

2.8.1.10 Location of Water Supply System Components

Though the distribution layout and the sources of supply and their development methods are important in placing the different units like headworks, transmission mains, WTP, overhead or underground storage tank, pumping stations, pressure reducing valves, flow control valves, etc. for optimal and economical utilisation, factors like topography, soil conditions and physical hazards should also be taken into consideration. Hillside construction may have an advantage in accommodating the head loss in the plant without excessive excavation. Wet sites must be dewatered and structures may have to be designed considering the hydrostatic uplift. On the soils having low bearing capacities, structures may need to be placed on piles or rafts. Rocky sites may require costly excavation.

Flooding is a common hazard for the treatment plants and pumping stations located near rivers and other surface water bodies. The highest flood level observed at the site should be taken into account and the treatment plant and pumping station structures shall be built at least two feet above the high-water mark. Irrigation and Flood Control Department should be contacted for the flood warning system.

2.8.1.11 Automation

Mechanisation, instrumentation and automation are becoming more and more common in water works and distribution network and this should also be considered in planning the system, subject to local availability and maintenance facilities.

Automation replaces and serves the functions that cannot be performed efficiently by manual operations, such as the removal of the sludge from sedimentation tanks etc. Instrumentation involves the installation of various kinds of devices and gauges for monitoring and recording plant flows and performance. Automation combines instrumentation and mechanisation are required to monitor water quality parameters, levels, pressures and flow etc., in headworks, WTP, service reservoirs and distribution network.

2.8.1.12 Service Building

Considerable attention is to be given to the service building required at treatment works and pumping stations such as houses, offices and laboratories, storerooms, chemical house, pump house, etc. In moderate climates, only operating units need to be protected against rain and sun, while in adverse climates, complete protection of all the units is advisable.

2.8.1.13 Other Utilities

Provision needs to be made for facilities such as electricity, water supply, drainage, roadways, parking areas, walkways, fencing, telephone facilities and other welfare services such as housing for operation and maintenance personnel.

2.8.1.14 All Season Roads

Headworks, WTP, sumps, Balancing Reservoir and Elevated Service Reservoirs (ESRs) should be accessible in all seasons by road. All pipelines of principal transmission main feeding MBR and sump should be laid along all-season road and transmission mains from MBR should be preferably laid along all season road or at least those cart tracks which are accessible even during monsoon.

2.8.1.15 Planning of Big Zones (group of several OZs)

Large cities have generally more than one WTPs. Each such WTP has its own jurisdiction or supply area and each of them contains several service reservoirs and thus a number of OZs. The following considerations shall be given to holistically plan such big zones.

(i) Demarcate each every WTP on the GIS map of the city.

(ii) Create a base map of jurisdiction of each WTP. The base map comprises of road edges, footprint of each property, water bodies, land use polygons of residential, commercial, industrial areas, etc.

(iii) Carryout elevation survey along the roads and create GIS contours in the area under consideration.

(iv) Create pressure zones using contours/elevation points. Pressure zones visualise high altitude areas and low-lying areas of the city in different colour codes. Pressure zones help in designing the OZs and its feeder mains.
(v) Carryout consumer survey of domestic and commercial customers.
(vi) Show existing pipelines after identifying them also show existing service reservoirs.
(vii) Create network of the existing pipelines using GIS based hydraulic model.
(viii) Assign ground elevations and demands to all the nodes of the existing pipelines.
(ix) Determine optimum boundary of each of the existing service reservoirs and mark unserved areas.
(x) There should be one location both for existing and proposed new service reservoir (in phases depending on design) for one OZ.
(xi) Plan new service reservoirs in the unserved areas.
(xii) Plan new pipelines in unserved areas to achieve 100% coverage.
(xiii) Assign demand to the nodes of new pipelines.
(xiv) Design transmission mains from clear water sump of WTP to each service reservoirs (both existing and new).
(xv) The Manual recommends 30yrs. design period for service reservoirs. If in case two service reservoirs are planned (one for 15 years and another for next 15 years) due to land constraints then the transmission main shall also be connected to such tanks.
(xvi) Design distribution system network using hydraulic model.

In this way, big command areas of WTP shall be planned. Detailed flow chart for planning OZs/DMAs of the command areas is provided in Figure 2.6.

2.8.1.16 Planning of Existing Large Size Service Reservoir

Sometimes, the large-sized service tanks are constructed in difficult terrain where the land for construction is not available. In such situations, the number of DMAs may be more than four. However, size of DMA shall by maximum 3000 connections. A separate pipe shall be branched from the common outlet of the service tank leading to each DMA. Necessary isolation valve, bulk meter and FCV shall be installed at the entry point of each DMA.

If some of the DMAs are located at lower ground elevations, necessary pressure reducing valve (PRV) shall be installed to regulate the nodal pressure in such DMAs.

If the large-sized service tank is located at high altitude, then nodal pressures would be higher. Suitable pipes in the distribution shall be planned to sustain higher nodal pressures.

However, if the larger sized service tank is located at flat terrain (which should be discouraged) and if the residual nodal pressures are less, then VFD pump may be planned to increase nodal pressures.

2.8.1.17 Planning of Ground Water Schemes

In many urban areas which depend on ground water sources, water from tube wells is directly pumped into distribution system. This practice of pumping water from a number of tube wells directly into distribution system shall be discouraged as it has following demerits:

- Interruption of water supply during power failure or any breakdown.
- Direct chlorination in the pipeline will provide less contact time and the households near tube well will get pungent smell due to high concentration of chlorine which may also affect their health.

- Wear and tear of pumps due to back pressure when many pumps are directly connected to the distribution system. In certain cases, the flow may be from multiple directions as water is pumped from multiple tube wells.
- Heavy leakage from pipes due to high pumping head.

Therefore, it is recommended to pump the water from tube well into ca ommon clear water reservoir (CWR) and then to the service reservoir. Capacity of the clear water sump may be considered as 25% of the capacity of ESR planned. From the service reservoir, water is supplied to the distribution network. Total NRW in ground water sources is 11%, out of which 10% may be allowed in the distribution system.

It must be ensured that the water quality of every tube well should meet the physical and chemical parameters stipulated in BIS IS 10500:2012. If not, appropriate treatment for removal of hot spot parameters such as salinity, iron, fluoride, arsenic, etc., shall be given and then taken to CWR.

2.8.1.18 Data Required in Planning Phase

(i) General data

General data required are as follows:

a) census population data for the last three to five decades;
b) daily per capita supply in litres at the consumer end (LPCD);
c) supply hours for the design of pipelines up to ESRs, i.e., for rising/transmission mains;
d) capacity and staging height for ESR and side water depth (SWD) (difference between maximum water elevation and minimum water elevation in the tank);
e) residual nodal head;
f) demand management by consumer meters;
g) water tariff - a tool for demand management;
h) losses in the system;
i) valves and meters;
j) land required for planning.

(ii) **Collection of Available Data for both Existing and New Schemes**

The implementing Agency/ULB should collect the necessary information/data which is required to prepare the DPR. DPR should contain background of the project, population projection, water demand, DMA formation, design of various water supply components, standards and specifications, bill of quantity, etc. Agency/ULB is required to collect all relevant data and prepare the DPR, if required, the same may be outsourced. The following information is required:

1) Details of all sources and their 95% reliability and dependability
2) Ward boundaries with ward-wise population of the latest census year and population of the census year
3) Base maps: GIS based shape files of road edges, streams, property footprints, GIS based contours, etc.
4) Details of existing distribution system and other water supply components including WTP etc.
5) Existing valves and its location (If valves are corroded and defunct, they should be either removed or replaced)

6) Pumping station details, including principal mechanical and electrical plant infrastructure specifications, i.e., details of pumps, motors, starters, transformers, etc. of their actual duty details, age and status
7) Details of reservoirs such as ESR, Ground Service Reservoir (GSR), and Master Balancing Reservoir (MBR), including capacity and validated operating levels, including staging height, present life and repair details
8) Details of bulk supply of water
9) Status of the statutory clearances
10) Permission of land availability
11) Arrangement of financial resources

2.8.1.19 Land Required for Water Supply Infrastructure

Even though the water treatment units are designed and initially made functional for an intermediate stage of 15 years, land should be kept available for the ultimate stage (30 years after base year) and future expansion.

The land for elevated service reservoirs shall be earmarked for 30 yrs. In case sufficient land is not available for service reservoir, then direct pumping to distribution system using VFD pumps may be considered to reduce the footprint area where adequate standby power backup.

City planners should earmark the land required for water supply infrastructure and its expansion in the ultimate stage in the master plan of the city for a minimum of the next 30 years. As cities are planning for DMAs/OZs, necessary land may be earmarked as per the requirement by the ULBs.

The city planner should consult and ascertain land requirement for water infrastructure and incorporate the same in the City Development Plan (CDP)/ Master Plan and ULB should amend the bylaws accordingly.

When the land for water supply infrastructure is not available, the city planners should allow development of water infrastructure over or below recreational amenities or parks, stadiums, etc. Such planning is shown in **Annexure 2.6**. The authorities may have to amend the planning rules/ by laws to implement such arrangement.

2.8.1.20 Base Maps

Creating base maps using GIS includes the following:

(i) Satellite Image

A satellite image of the city with 0.5 m resolution should be obtained. The satellite image has two formats - 2D satellite image and 3D stereo paired image. Those cities whose terrain is relatively flat can go for procuring 3D stereo paired images so that they generate seamless contours of 1 m intervals for the entire city.

It is observed that most cities carry out surveys by different agencies with different benchmarks. Thus, when one tries to integrate the contours, they are not seamless. This difficulty can be overcome by procuring a 3D stereo paired satellite image. The city administration can obtain this image from National Remote Sensing Agency (NRSA). After obtaining the image, the contours can be generated with appropriate photogrammetric software. The contours generated shall be validated by carrying out DGPS survey. DGPS is attached to several satellites and gives accurate level of the spot. Normally, one reading per square kilometre is taken to validate the contours.

If a satellite image is not procured, then the designer can use the online service of the GIS software, which makes online satellite images available.

(ii) Digitisation of Features

Digitisation is the process of converting information into a digital format. When the image is scanned the scanner converts it to an image file, such as a JPG or bitmap. On digitisation, information is obtained, which makes it easier to preserve, access and share. Digitisation is required for the base maps as it is used as background drawing in network software. Digitisation of properties in a city is used to map the consumers in GIS.

There are some examples of freeware like Open Street Map which provide digitised shape files of road centreline, footprints of house properties, water bodies, etc.

(iii) Landmarks

Landmarks can be created from the satellite images, Google Earth etc.

(iv) Existing Water Infrastructure

Transmission and distribution pipelines, tanks, etc., are created by several ways, as mentioned in the Advisory on "GIS Mapping of Water Supply and Sewerage Infrastructure" published by MoHUA in 2020.

(v) Mapping of existing pipe network

Existing pipe network including isolation valves, air valves, flowmeters, stand posts, etc., should be mapped on the GIS base maps of the city.

a. The existing pipeline can be known from the "as-built" completion drawing of an existing scheme. As-built drawings are the completion drawings of an existing scheme when the scheme is commissioned. During handing over of the scheme to ULB, these as built drawings are also handed over.
b. The existing pipelines can be made known by interacting with the group of residents, mechanic, plumbers, retired operators, valve operators, meter readers, etc., along with them the utility engineer can interact with the local people to enquire about the location of alignment of pipeline and approximate year of laying.
c. Pipe locators can be used to assess the pipe alignment wherever required. This work has been successfully carried out in Coimbatore city.
d. In some cities, the existing pipeline is identified by ground penetrating radar (GPR). Wherever possible, this method can be used.
e. Wherever possible, in cities, the adequate number of trial pits can be taken to identify the attributes of the existing pipe network.
f. Existing pipe can be considered in the design or in hydraulic model only if their location on map, material, diameter and year of laying is known. Otherwise, the hydraulic model should be created using the data of existing pipes whichever is available at least to complete the model. This is a continuous process and cannot be done 100% at the initial stage. To begin with, the hydraulic model should be prepared using above and it should be continuously updated after knowing the additional data.

The methods of identifying existing pipelines are discussed above in Section 2.7.2.

2.8.1.21 Contour

Contours should be generated by conducting a survey.

2.8.1.22 Planning Tool

A Geographic Information System (GIS) is the most effective tool used in planning water supply schemes. GIS is defined as "a system designed to capture, store, manipulate, analyse, manage, and present or display spatial or geographically referenced information, i.e., data identified according to their locations". GIS information required is elaborated in the Advisory on, "GIS Mapping of Water Supply and Sewerage Infrastructure," which is available on Govt. of India's web site https://mohua.gov.in/ pdf. GIS can put information on maps. Here, information means things in the real world that are organised into layers. For example, to comprehensively depict its distribution system, a city requires various pieces of information like street data, building data, pipes data, and contours data which are organised in layers. Integrated data is displayed as a combined map.

Box-1: What is Shape file?

A shape file is a simple, non-topological (shared boundary is stored once for each polygon) format for storing the geometric location and attribute information of geographic features. Geographic features in a shape file can be represented by the primitive geometric shape of points, lines, or polygons (areas).

Why Shape files?

Shape file stores non-topological data and attribute information for spatial features. Feature's geometry is stored as a shape having vector co-ordinates like latitude and longitude.

Since, processing of the topological data structures is avoided, the shape files are supposed to be efficient for rendering and requires less memory space and easy to read and write.

2.8.1.23 Creation of Land Use Map of City

Land use maps of a city comprise of the spatial information/data of the various physical land uses like the residential area, areas of commercial activity, transportation, parks and gardens, forest land, etc. These land use coverages are generally provided in City Development Plans (CDP). Normally, Town and Country Planning Department creates such CDP maps, which are in GIS format. ULB must get such maps in consultation with Town and Country Planning Department. The map of CDP, if available in hard copy, should be collected and georeferenced. After the process of geo-referencing, the polylines of roads, buildings, etc., are exported to form the shape file of the different types of the land use.

2.8.1.24 Population Density using GIS Maps

Following steps may be followed:

(i) **Determining Population Density of Wards:** A GIS ward map of all the wards of a city is prepared. The polygons of different wards are digitised and a shape file of the boundary of all the wards of the city is created.

(ii) **Ward-Wise Land Use Area**: Though the map showing all types of land uses for the entire town is available, it is necessary to find out different types of land use areas for each individual ward. To divide the different type of land use areas for each ward, the 'split' command from the GIS software can be used. Two overlapping shape files - (i) land use map and (ii) wards are used to form overlapping layers. After executing the split command, shape files of each ward with corresponding land use areas are obtained. Information from these shape files after the split command is collected.

(iii) **Projected ward-wise population by Equivalent Area Method:** Objective is not only the total population of the city, but its ward-wise distribution and computation is required for allotment of the present and future water demands to the nodes of the distribution network. In the large pipe network of the distribution system of water supply, future demand needs to be assigned to hundreds of the nodes. Manual exercise of this demand allocation to nodes is prone to error. In most of the softwares, the demand is given using the population density map which is based on the land use maps. Therefore, land use maps are required prior to the creation of population density maps.

Since the population density of each ward with respect to land use is to be discovered, it is required to find out the equivalent area of each ward. While determining equivalent area, the general factors - such as 100% for residential, 25% for public and 10% for industries and agriculture must be used.

An illustrative example of the projected ward-wise population by the equivalent area method is incorporated in **Annexure 2.7**.

2.8.2 Design

The comprehensive planning and design norms are discussed in the following paragraphs and summarised in Table 2.7. Sustainable O&M practices of continuous (24×7) PWSS are summarised in Table 2.8.

2.8.2.1 Design Period

The design period of the water supply scheme depends on the life of the components sharing a significant proportion of the cost as well as the difficulty in augmenting them. The projects must be designed normally to meet the requirements over a 30-year period (Handbook on Water Supply and Drainage (SP 35: 1987) of Bureau of Indian Standards) after their completion and commissioning. The time lag between design and completion of the project should also be considered, which should not exceed two years for small and medium size projects and five years for large size projects. The 30-year period may, however, be modified regarding certain components of the project and depending on their useful life, the facility for carrying out extensions when required and the rate of interest so that excessive expenditure in due course of time is avoided. Necessary land for future expansion should be acquired in the beginning of the project. Where large tunnels and aqueducts are involved entailing significant capital outlay for expansion, they may be designed for ultimate project requirements. Where there is a possibility of failure such as the collapse of steel pipes under vacuum which may put the pipeline out of commission for a long time or the pipe location presents hazards such as floods, ice, mining, etc., duplicate lines may be necessary.

Redundancy should be factored into the design plan and included in cost-benefit analysis to evaluate trade-off of system failures.

Stages in design period: Stages involved are defined as follows:

- Base year: means the proposed date of completion of the scheme.
- Intermediate stage: is computed as base year + 15 years.
- Ultimate stage: is computed as base year + 30 years.

However, different components of the water supply system are designed to work satisfactorily for different periods, as shown in Table 2.2.

This manual suggests consideration of using existing infrastructure which is in good condition while designing the proposed scheme. Rehabilitation could extend some of the items listed in Table 2.2. They should be considered in the design of the system. For example, when WTP is to be planned for 15 years, civil structures of the existing WTP, after assessing their useful condition, must be considered. So, usefulness of existing structures would not be jeopardised.

Table 2.2: Design period in years

S. No.	Items	Design period in years
1	Storage by impounding reservoirs/dams/barrage/weir	50
2	Headworks (intake, jack well or canal intake)	
	(a) Pump house (civil works)	50!
	(b) Electric motors and pumps	15
3	Groundwater source (tube wells/bore well/dug wells)	
	Tube wells, bore well	15
	Life of pumps and for ground water	15
	Life of pumping main for ground water	30
4	Water treatment units	15*
5	Channels and pipe connection to several treatment units in WTP	15**
6	Raw water, clear water conveying mains and Pipes in Distribution system	30!!
7	Clearwater reservoirs at the WTP, balancing tanks	15*
8	Service reservoirs (overhead or ground level)	30#
9	Civil work of pump house for direct pumping	30
10	Pumping machinery for direct pumping	15

! The spaces in the pump pit and pump house need to be designed for all working + standby pumps for both stages.

* Land allocation to be made for 30 years.

** The pipe sizes shall be computed considering the 20% overloading in the WTP, i.e., over and above the intermediate demand. However, since, Aeration fountain, Inlet channel including parshall flume, flash mixer and flow distribution box to clarifiers are common for the present and future stages above components athough constructed in the present stage need to be designed for flow of ultimate stage.

!! WTP after 15 years should be located in the same premises. However, if it is located at a different place which is away from the existing one, then the pipeline shall be designed for the capacity of the respective WTP.

The ESR is recommended to be designed for 30 years for the following reasons:

- It should be ensured that each OZ should be served by one ESR.
- In most projects, it is observed that initially one ESR is designed and constructed for initial 15 years as per previous guidelines and another ESR was to be designed for the next 15 years. However, in almost all the projects, additional ESR is not constructed and only one initial ESR

with 15 years demand capacity is serving the OZ of 30 years demand. This situation has vitiated the hydraulics and the nodal pressures dropped thus forcing the system to be resorted to an intermittent water supply scheme.

- Although two ESRs are proposed for intermediate and ultimate stages, the pipe network has been designed initially for the ultimate demand is now to be reorganised after 15 years when the second ESR is to be constructed. Changing network after 15 years is virtually difficult task and not practised at all in the field.
- The capacity of ESR will be one-third of the ultimate stage demand and will ensure 24×7 continuous water supply throughout the design period of 30 years.

2.8.2.2 Population Projections

The first step in the water supply scheme planning process is to quantify current and future population projection first and then the corresponding water demand.

General considerations: The design population will have to be estimated with due regard to all the factors governing the future growth and development of the project area in the industrial, commercial, educational, social and administrative spheres.

Any underestimated value will make the water supply system inadequate for the purpose intended; similarly, the overestimated value will make it costly. Special factors causing sudden emigration or influx of population should also be foreseen to the extent possible. As change in the population of the city over the years occurs, the system should be designed considering the population at the end of the design period. Factors affecting changes in population are:

- increase due to births
- decrease due to deaths
- increase/decrease due to migration
- increase due to annexation

The present and past population records for the city can be obtained from the census population records. After collecting these population figures, the population at the end of the design period is predicted using various methods suitable for that city considering the growth pattern followed by the city.

- Demographic Method
- Arithmetical Increase Method
- Incremental Increase Method
- Geometrical Increase Method
- Decreasing Rate of Growth Method
- Graphical Method
- Logistic method
- Method of Density
- Curvilinear method

Various methods of population forecast are discussed in **Annexure 2.8**.

However, the ULB/ parastatals should finalise total population for immediate and ultimate stage in consultation with Town and Country Planning Department before preparation of DPR of the water supply project. Total population thus arrived shall be judiciously distributed ward wise by ascertaining trend of growth, i.e., ward wise population density for immediate and ultimate stage for designing the distribution network as detailed in section 2.8.1.24 of Part A Manual.

2.8.2.3 Per Capita Supply

Piped water supplies for communities should provide adequately for the following as applicable:

a) domestic needs such as drinking, cooking, bathing, washing, flushing of toilets, gardening and individual air conditioning
b) institutional needs
c) industrial and commercial uses, including central air conditioning
d) firefighting
e) requirement for livestock
f) minimum permissible NRW

2.8.2.4 Factors Affecting Consumption

The following factors affect water consumption:

a) Size of City: Water demand increases with an increase in the size of the town or city. The water demand increases in terms of water use, road cleaning, maintaining parks, etc.
b) Characteristics of Population and Standard of Living: The water demand depends directly upon the habits and economic status of the consumer. A big city with higher living facilities will have higher water demand than a town with lower living facilities. Slum areas of large cities have low per capita consumption. A person staying in an independent bungalow consumes more water compared to a person staying in a flat. The person's habits also affects consumption; the type of bath, i.e., tub bath or otherwise and material used for washing, etc., also affect per capita consumption.
c) Industries and Commerce: Industrial and commercial activities increase water demand in the area. The type and number of different industries also affect consumption. The water consumption in the industry or commerce varies considerably depending on the processes included and the size of the industry.
d) Climatic Conditions: With a rising temperature and uneven rainfall, the water demand will also get affected. In hot weather, the consumption of water is more compared to that during cold weather. The issue of climate change is to be considered while developing a water demand forecast model to achieve sustainable water supply management.
e) Metering: The consumption of water is less when supply is measured by the water meters compared to that when the water charges are on a flat rate basis.
f) Variation in water demand: The hourly variation takes place on a day when the water demand is at its peak while it drops down in other hours of the day. Mornings and evenings are associated with higher residential use because consumers are getting ready in the mornings and returning home in the evenings.

2.8.2.5 Recommendations

In the Code of Basic Requirements of Water Supply, Drainage and Sanitation (IS: 1172-1993, Reaffirmed 2007), a minimum of 135 LPCD has been recommended for all residences provided with a flushing system for excreta disposal. The breakup of water requirements is shown in Table 2.3.

Table 2.3: Average water use per person per day in urban area

S. No.	Purpose	Quantity (LPCD)
1	Drinking	5

S. No.	Purpose	Quantity (LPCD)
2	Cooking	5
3	Bathing	50
4	Toilet flushing	30
5	Washing utensils	15
6	Washing the house	10
7	Washing of clothes	20
	Total	135

It is well recognised that the minimum water requirements for domestic and other essential beneficial uses should be met through the public water supply systems which are defined in the following paragraphs. Other needs for water, including industries, etc., may have to be supplemented from other systems depending upon the constraints imposed by the availability of capital finances and the proximity of water sources having adequate quantities of acceptable quality which can be economically utilised for municipal water supplies.

Based on the objectives of full coverage of urban communities with easy access to potable drinking water to meet the domestic and other essential non-domestic needs, the following recommendations are made:

(i) Recommended per capita Water Supply Levels

The earlier manual (1999) suggested to adopt 150 LPCD for all metro and mega cities, 135 LPCD for cities/towns that have sewerage system or are contemplating to have such system and 70 LPCD for the towns that do not have sewerage system. This manual recommends LPCD values as shown in Table 2.4. The Class I & II cities and towns should plan for water supply projects considering a per capita water supply of 150 and 135 LPCD as proposed below (Table 2.4) and should take up underground sewerage systems within three years of commissioning of water supply schemes.

The other towns which are planning for water supply projects and considering 135 LPCD should also take up underground sewerage system within three years from the commissioning of water supply projects. In case of towns which have source constraints and are not contemplating sewerage system within the next 5 years, they can restrict per capita water supply to 100 LPCD for water supply projects and plan for decentralised sewerage facilities/ on-site system with reuse facilities as recommended in the Sewerage Manual.

Table 2.4: Recommended per capita water supply levels for designing schemes

S. No.	Classification of towns/cities	Recommended Maximum Water Supply Levels (LPCD)
1	Cities/ towns with a population of less than 10 lakhs (0.1 million)	135
2	Metro and Mega cities having a population of 10 lakh (1 million) or more	150

Note:

- Supply should be at the consumer end. This means 15% system losses shall be added to the demand.

- The domestic demand does not include bulk requirements of water for semi-commercial, commercial, institutional and industrial purposes. Demands due to commercial (malls, hotels etc), institutional and industrial purposes must be assessed separately through consumer survey and duly extrapolated for different stages.
- Such demands should be assigned to the nearest pipe/nodes of the pipe network in the distribution system.
- Semi-commercial demands include micro industries, market, shops, vegetable market, traders, hawkers, non-residential tourists, picnic spots, religious places, etc.
- In the absence of consumer survey, the present demand due to semi-commercial to the tune of about 5-10% of intermediate demand (domestic) may be considered depending on the nature of the town. The semi-commercial demand for intermediate and ultimate stages may be calculated considering an increase of 1% per year on the initial semi-commercial demand.
- Fire demand should be added to domestic demand proportionately.

(ii) Requirement of Floating Population

The rate of supply for the floating population should be as follows (Table 2.5):

Table 2.5: Rate of supply for floating population

S. No.	Facility	Litres per capita per day (LPCD)
1	Bathing facilities provided	45
2	Bathing facilities not provided	25
3	Floating population using only public facilities (such as market traders, hawkers, non-residential tourists, picnickers, religious tourists, etc.)	15

The data on floating population/ tourists shall be obtained from the tourism department of the State Government.

In the absence of such data, floating population may be considered as percentage of ultimate stage (30 years) population as below:

- Class I cities: 2-5%
- District HQ: 2-3%
- Hill Stations: 5-10%
- Seaside cities:5-10%
- Small towns: 1-3%

However, ULB can increase/ decrease floating population with proper justification on case-to-case basis.

(iii) Institutional Needs

The water requirements for institutions should be provided in addition to the provisions indicated in Table 2.6, where required, if they are of considerable magnitude and not covered in the provisions already made. The individual requirements are as shown in Table 2.6.

Table 2.6: Requirement of water for institutions

Sl. No.	Institutions	Litres per head per day
1	Hospital (including laundry)	
	(a) No. of beds exceeding 100	450 (per bed)
	(b) No. of beds not exceeding 100	340 (per bed)
2	Hotels	180 (per bed)
3	Hostels	135
4	Nurses' homes and medical quarters	135
5	Boarding schools / colleges	135
6	Restaurants	70 (per seat)
7	Airports and seaports	70
8	Junction Stations and intermediate stations where mail or express stoppage (both railways and bus stations) is presided	70
9	Terminal stations	45
10	Intermediate stations (excluding mail and express stops)	45 (could be reduced to 25 where bathing facilities are not provided)
11	Day schools / colleges	45
12	Offices	45
13	Factories	45 (could be reduced to 30 where no bathrooms are provided)
14	Cinema, concert halls, and theatre	15

(iv) Fire Fighting Demand

Prior to computation of fire requirements of OZ, it is necessary to compute the fire requirements for the entire city using following formula:

Fire requirement for entire city = $100\sqrt{P}$ (m^3/day)

Where P is the population of the intermediate stage (15 years) of the entire city in thousands.

$$\text{Fire Requirement of OZ} = \left(\frac{\text{Intermediate population of OZ}}{\text{Intermediate population of the entire city}}\right)(\text{Fire requirement of the entire city}) \quad \text{... Eq 2.1}$$

In case the service reservoir is designed for ultimate stage the word "intermediate" shall be replaced by "Ultimate".

It is desirable that one-third of the firefighting requirements of each OZ form part of the service storage. For this purpose, the outlet of the tank supplying water for normal operation should be kept just above this storage so that the capacity provided for mitigating fire is always available. There should be a fire outlet at the bottom of the tank that can be opened when an instance of fire occurs as well as at the time of cleaning the tank.

The balance requirements may be met out from secondary sources. The high-rise buildings should be provided with adequate fire storage from the protected water supply distribution. Also, there is a remote possibility that the fire occurs at multiple places, hence nearby ESRs can also be used for firefighting requirement.

The location of fire hydrants should be decided in consultation with the Fire Department. However, arrangements for filling vehicles from the fire brigade should be provided at each ESR. The pressure required for firefighting would have to be boosted by the fire engines.

(v) Total demand

In addition to domestic demand, fire demand, commercial demands (hotels, lodges, hospitals, markets, etc.) and institutional demand (schools, colleges, offices, theatres, etc.) duly extrapolated for different stages (base year, immediate and ultimate) should be added as point loads to the respective nodes in the distribution system.

Total demand should be computed by adding the following losses:

Total losses in the system (surface water) should not exceed 15%. The indicative break-up of losses is shown in Figure 2.4.

Figure 2.4: Indicative break-up of losses

a) Headworks to the inlet of WTP should not be more than 1%.
b) In WTP, losses should not be more than 3%.
c) Outlet of WTP to Various ESRs losses should not be more than 1%.
d) Sometimes, the location of WTP is close to headworks and sometimes it is close to the city boundary. Hence, (a) and (c) above put together shall not be more than 2%. However, if (a) and (c) together is more than 20 km, then total loss should be considered at the rate of 1% per 10 km, instead of 2%.
e) In a distribution system, losses should not be more than 10%. (With 24×7 Water Supply project with 100% metering, NRW is expected to be reduced. Hence losses should not be > 10%).

For ground water where water is directly supplied to distribution system and WTP is not part of the system, the total loss should not exceed 11%.

2.8.2.6 Pressure requirement

Pressure requirements are discussed in Table 2.7 of design norms. Piped water supplies should be designed on a continuous 24 hours basis to distribute water to consumers at adequate pressure at all points. Intermittent supplies are neither desirable from the public health point of view nor economical.

2.8.2.7 Formation of OZ and DMAs Based on Pressure Zones

A pressure zone is defined (www.usbr.gov/gp) as “the area bounded by both a lower and upper elevation, all of which receives water from a given hydraulic grade line (HGL) or pressure from a set water surface.”

Objective of providing pressure zones is to provide water to customers in adequate quantity in an efficient manner. By forming pressure zones high and low elevation zones are separated, hence cost of pumping and O&M cost can be lowered. Pressure zones are formed using GIS techniques as follows:

a) Add shape file of city boundary on the online satellite image. Online image is available on GIS software.
b) Add shape file of GIS contours.
c) Using GIS tool, form the land polygons called as “Topo-to-Raster”
d) Alternatively, if the survey is carried out along the roads by taking levels at fixed chainages, say 30m, then these points can be mapped on the online GIS data layer. Using GIS tool Inverse Distance Weighted (IDW), surface/polygons shall be formed and different elevation polygons shall be demarcated with colour code in GIS.
e) Elevation range is marked.

The resulting image is shown in Figure 2.5. Pressure zones are shown in different colours.

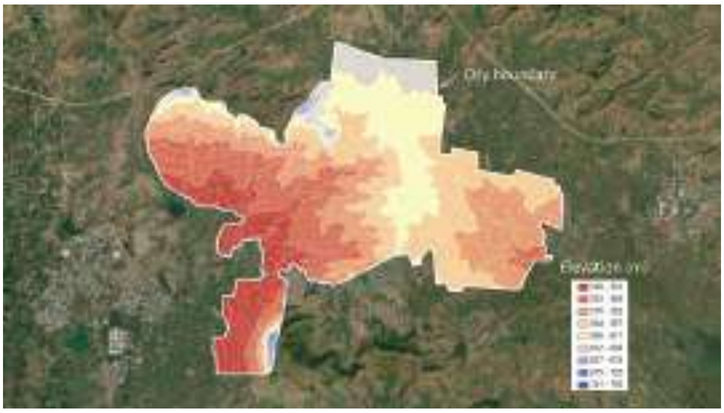

Figure 2.5: Pressure zones

2.9 Logical Flow Diagram for Switching Over Process

Switching over process from intermittent supply of existing system to 24×7 water supply requires reengineering and refurbishing water system considering aspects of DMA for their optimal utilisation. The process can be referred by the concerned levels.

(a) Broad Summary (for administrators and senior level engineers)
Broad Summary of planning and implementation stages are shown in Figure 2.6. This table should be referred by the administrators and senior level engineers.

(b) Detailed Steps (for consultants and junior level engineers)
Detailed Steps of planning and implementation stages are shown in Figure 2.7 (a) to (h). This table should be referred by the consultants and junior level engineers.

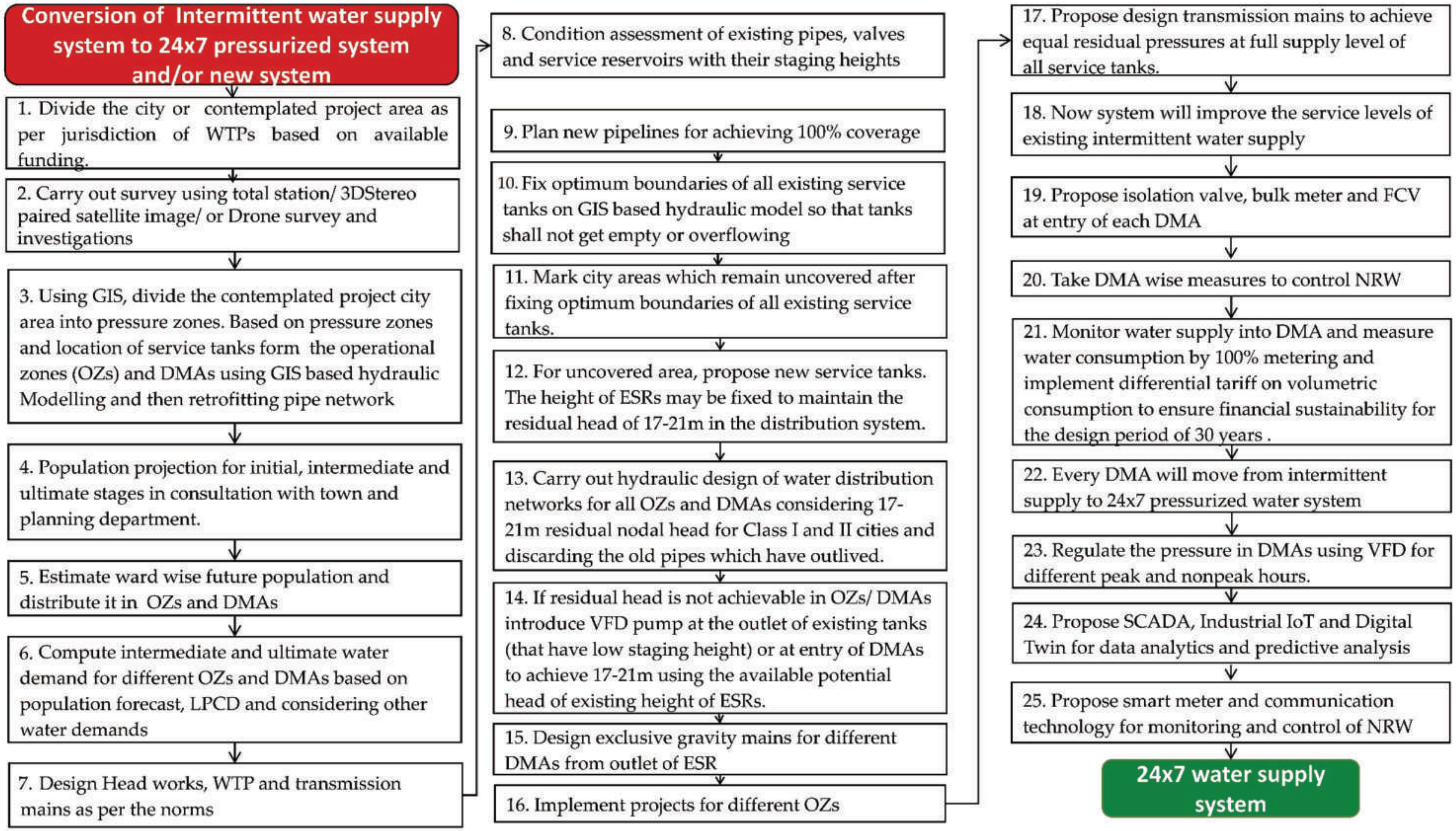

Figure 2.6: Summary of conversion of intermittent water supply to 24×7 pressurised water supply and/or new system for administrators and senior level engineers, they should refer Tables 2.7 and 2.8

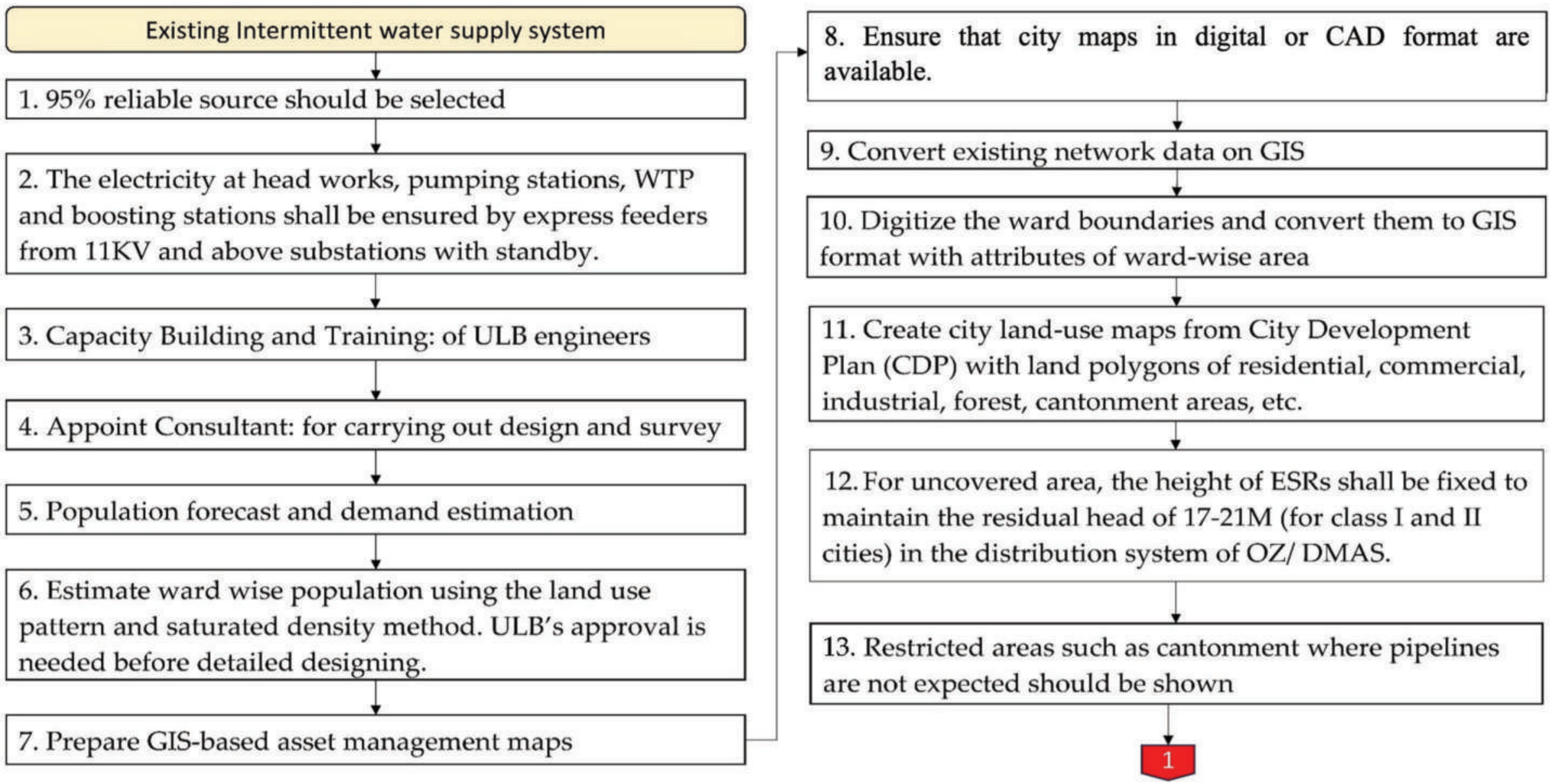

Figure 2.7 (a): Planning and design of conversion of intermittent water supply to 24×7 pressurised systems for consultants and junior level engineers, they should refer to Tables 2.7 and 2.8.

Note: Figure 2.7 consists of Figures 2.7 (a) to (h) which are connected by the connectors shown in red pentagons.

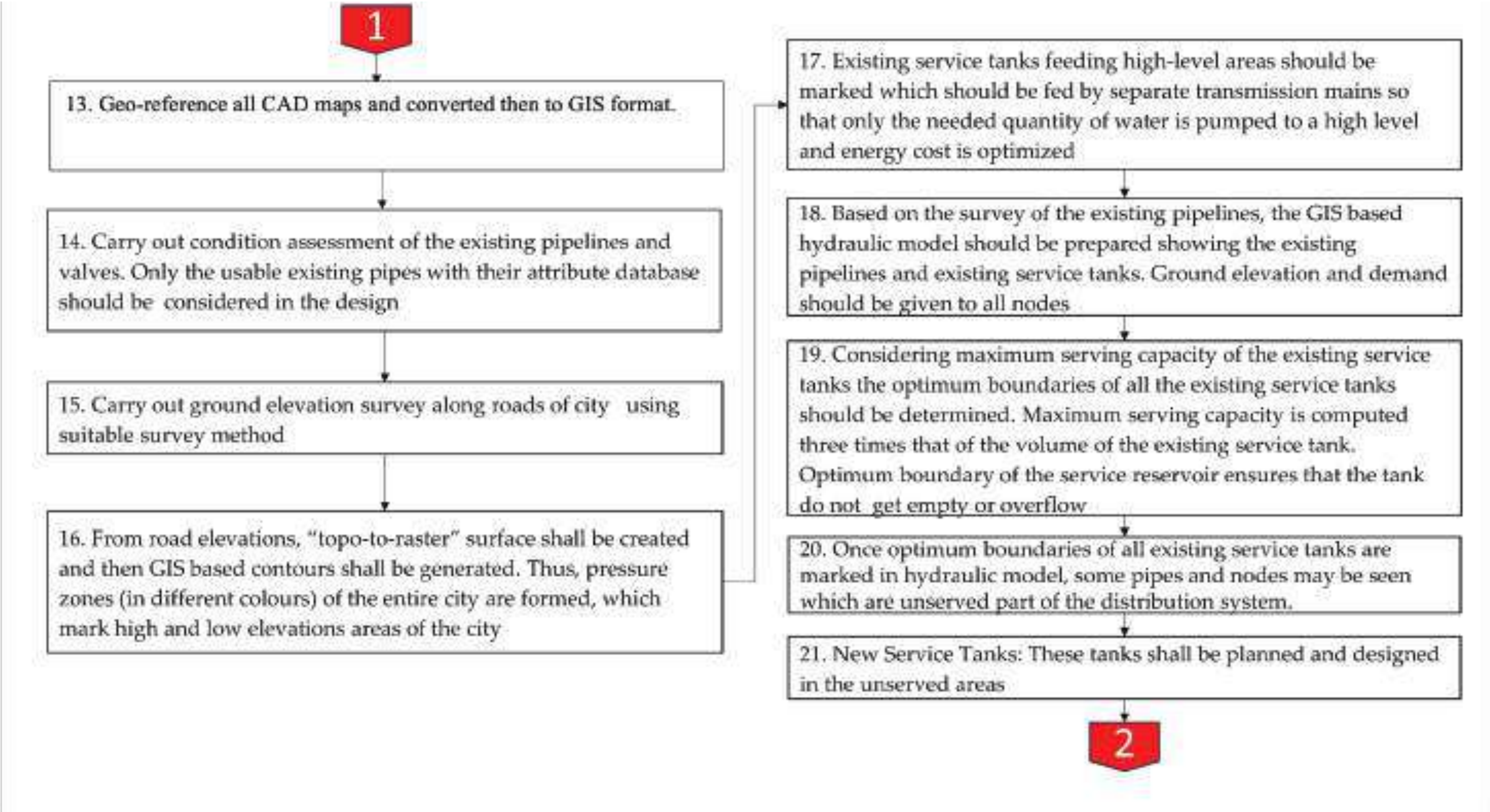

Figure 2.7 (b): Continued

2

22. Proposed new pipelines shall be designed in the OZs of existing and new service tanks. Existing and proposed service reservoirs (in unserved areas) should also be considered in the hydraulic model

23. Only two GIS-based hydraulic models are prepared for the entire city- (i) for the entire distribution system and (ii) for raw/treated transmission mains. If the city is exceptionally large and is divided into excessively big zones as per jurisdiction of each WTP, then the two models can be prepared each jurisdiction of WTP (one for transmission mains and another for distribution system).

24. In Distribution System:

a. The operational zones, one per service tank should be planned. DMAs should be planned as sub zones of each operational zones.

b. The installation of the DMAs should be included as an item in the DPR.

c. Adequate provision of items under retrofitting of existing pipelines (such as cutting of the pipes, providing dead ends, replacing pipes etc.) should be made.

d. 100% consumer metering should be ensured with differential tariff based on the volumetric consumption.

e. Leakage occurs at joints of municipal pipe with house service connection (HSC) if ferrule connection is not made. Hence, at such places, ferrule connections must be made by the skilled plumber of the municipality. For this purpose, an item of replacing HSC should be incorporated in the DPR.

25. Operational Zone: Only one operational zone (OZ) should be planned for each service reservoir. One operational zone may have maximum of 4 district metered areas (DMAs), except in the terrain where service reservoirs are difficult to construct due to non-availability of land. OZ shall be designed to cater the ultimate stage population up to 50,000 or 10,000 connections in plain areas. For hilly areas OZ may be designed for ultimate stage population up to 20,000 or 4,000 connections. Number of connections in one DMA should preferably be in the range of 500 to 3000 in plain areas and 500-1500 in hilly areas.

26. All the DMAs are hydraulically discrete (isolated)

27. For forming the boundaries of OZ and DMAs, natural boundaries like nalla/ roads/river/ railway line be used. Proper retrofitting of existing pipe network is required.

28. The distribution pipe network is for existing as well as newly proposed pipes. 100% coverage shall be ensured.

3

Figure 2.7 (c): Continued

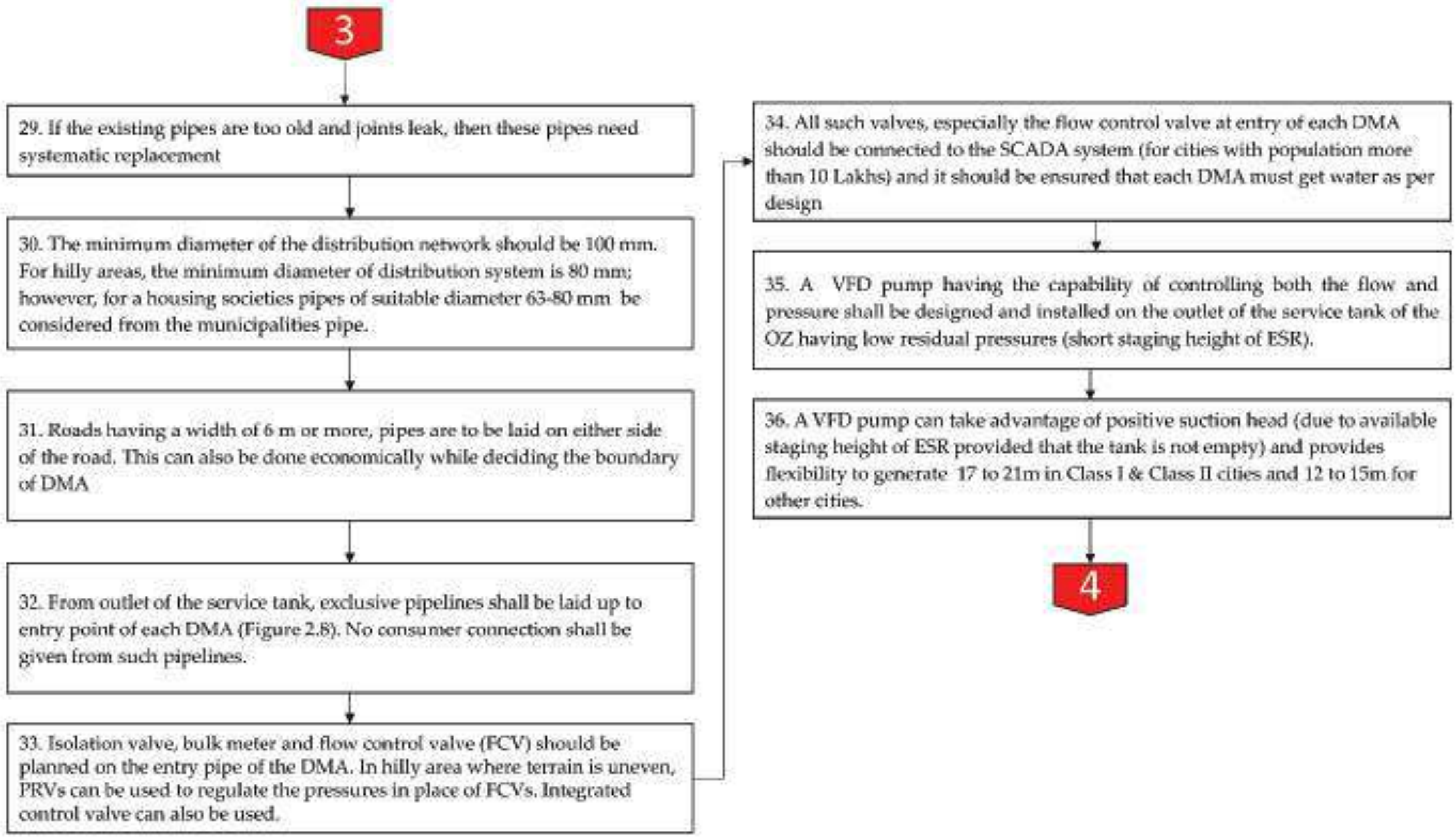

Figure 2.7(d): Continued

4

37. After running the hydraulic model for the OZ, the nodal pressures are checked for required heads (17-21m for Class I & Class II cities and 12-15m for other cities). The velocity of flow in pipes shall not be more than 2.5m/s. In hilly regions, as well as the pipeline joining ESR with main pipeline the velocity may be as high as 4.3 m/s. The reasons for adopting the pressures in the range of 17-21m are as follows:

a. In most of the developed countries during maximum hourly demand, minimum nodal pressures have been adopted in the range of 21m to 35m and the maximum pressures are in the range of 56 to 70m. Of course, they provided water by direct pumping.
b. In earlier manual 17m nodal pressure has been recommended for building with 3 storeys and 22m up to 4th floor.
c. In order to get rid of consumer's leaking and contaminated underground storage tanks, water should reach up to 3rd floor.
d. When 21m nodal head is achieved, there may be some leakages in the old network. This may be due to old pipes and improper joints. During this transition period there will be drop in pressures owing to the leakages and the pressure may come down to about 17m.
e. The drop in pressures may be observed as reduced water level (standing water depth) in service tanks during peak hours.
f. Considering above Sr. (d) and (e), about 4m drop in pressures occurs and effective nodal pressures may come down from 21m to 17m. To account for this, design nodal pressure should be 21m.

38. The maximum allowable pressure at any ferrule points other than the critical nodes in an operational zone in the existing distribution network shall be the field test pressure of the existing pipes.

39. All items with item rates required for making OZ and DMAs hydraulically discrete should be incorporated in the cost estimate of DPR. The items should include retrofitting existing pipelines {such as cutting the pipes, providing dead ends (should be discouraged as far as possible), replacing pipes, etc.}. This is necessary for the installation of the DMAs

40. After retrofitting, the road needs reinstatement for which a separate item should be included in the DPR

41. House service connections for individual consumers should not be given on the pipes in distribution network having more than 200 mm internal diameter. For this purpose, additional rider pipes may be shown (but not compulsory) and included in the design of the distribution system

5

Figure 2.7 (e): Continued

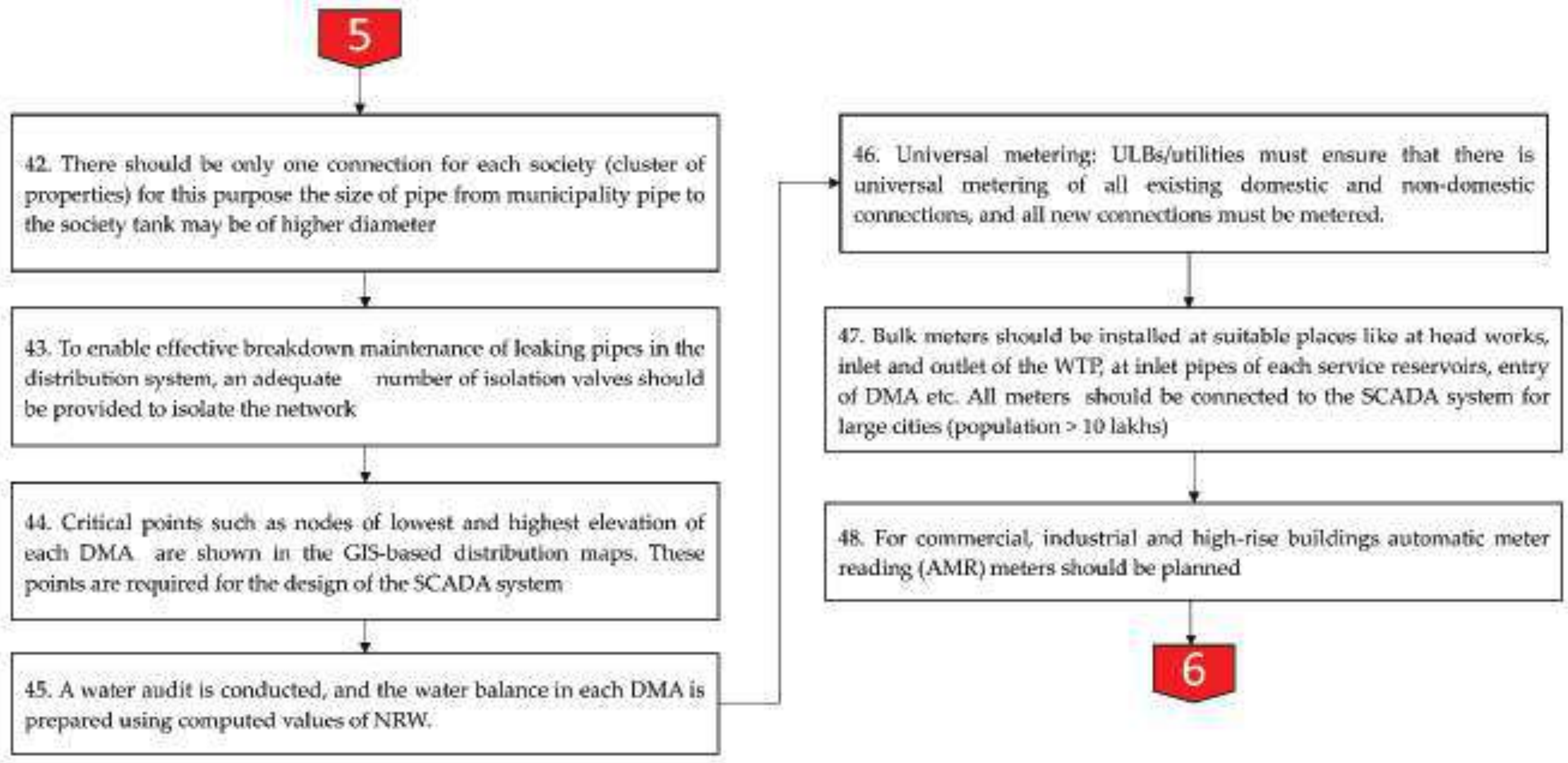

Figure 2.7 (f): Continued

6

49. Connections: City engineer to observe that- in most of the developed countries during maximum hourly demand, minimum nodal pressures have been adopted in the range of 21m to 35m and the maximum pressures are in the range of 56 to 70m. Of course, they provided water by direct pumping.

(a) City bylaws should be amended to meet the requirements as follows.

(b) As every family is to be supplied water through house connection, no new stand post should be given.

(c) Existing stand posts should be removed and converted to connections to households with the meter by formulating an operational zone-wise time-bound program by the ULB.

(d) If the distribution pipes are non-metallic and valves are rusted, a systematic plan of replacing them is prepared. Adequate budget provision is made for this purpose. Replacement of these existing old non-metallic pipes should be planned by running the GIS-based hydraulic model.

(e) Leakage occurs, in most of the cases, at the joint of municipality pipe with house service connection (HSC) made of substandard material and the connection is made by the non-skilled plumber. Hence, at such places, ferrule connections shall be made using quality products and materials by the skilled plumber of the municipality. For this purpose, an item for replacing HSC should be incorporated in the DPR.

(f) Clause 9.5 of the IS 2065: 1983 reaffirmed 2022 states that the ownership of consumer meters shall rest with ULB.

(g) All consumers shall be metered, and the estimated cost of meters should be provided in the DPR.

50. Valves: City engineer to observe that-

a) Required control valves (FCVs/ PRVs for hilly areas) are planned for the designed distribution of water.

b) All such valves, especially the flow control valve at the entry of each DMA, are connected to the SCADA system (wherever possible), and it is to be ensured that each DMA gets water as per design.

51. Disaster management: system should be designed for each city. For this purpose, the GIS based hydraulic model should be prepared and interlinking of the various water works within the city should be planned

52. Miscellaneous: City engineer to observe that-

a) WTP, MBRs, ESRs, and pumping stations are located on all-season roads, and the necessary roads are provided in DPR along with the cost so that pipelines up to the city boundary are laid on all-season roads.

b) Wherever possible, Break Pressure Tank (BPT) should be planned. The inlet and outlet of BPT/ MBR should be placed at the same level.

c) Energy audit of pumps should be carried out.

d) Cities having population of more than 1 lakh should have their own meter repair and calibration cell and adequate spare part should be stocked.

7

Figure 2.7 (g): Continued

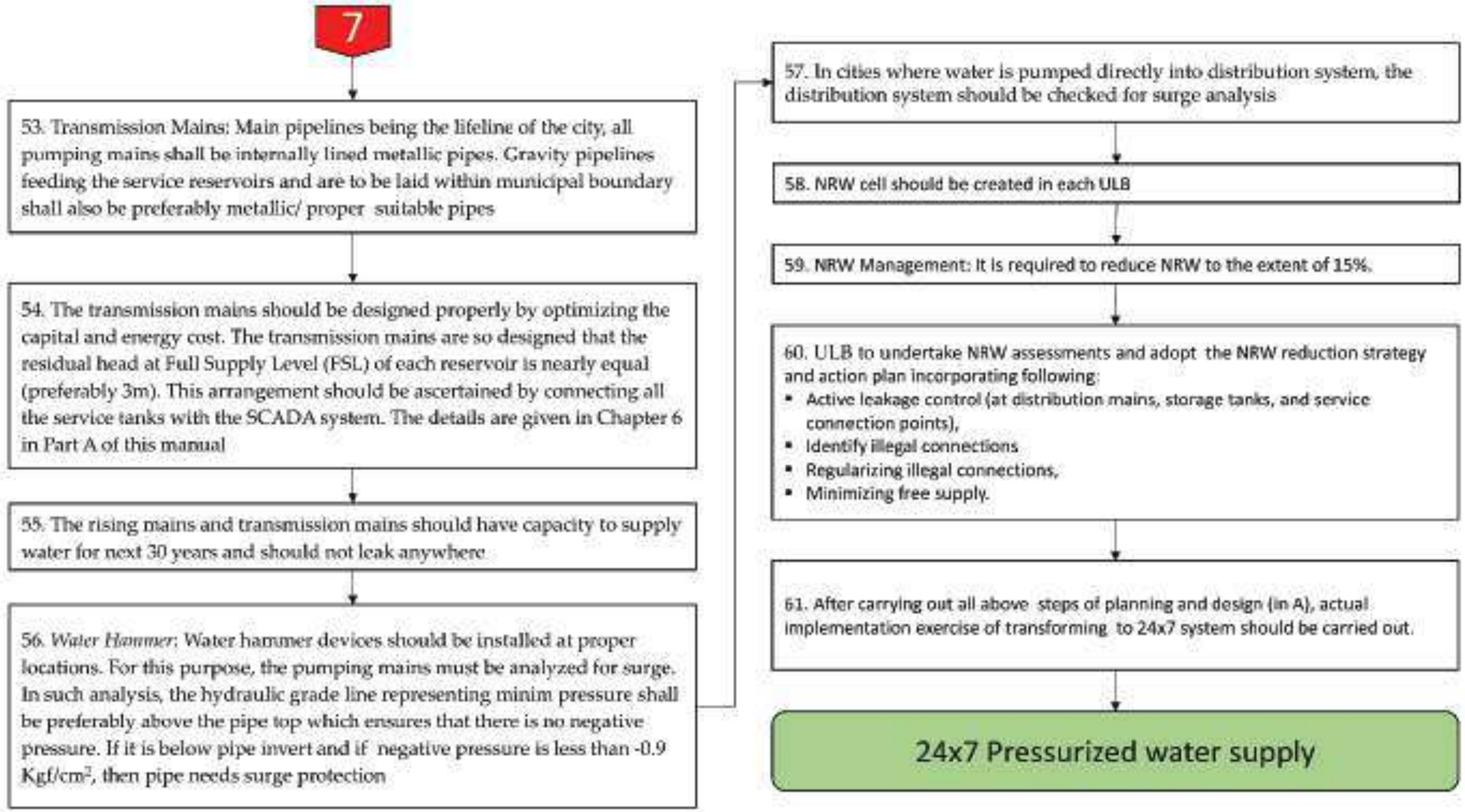

Figure 2.7 (h) - End of Figure 2.7

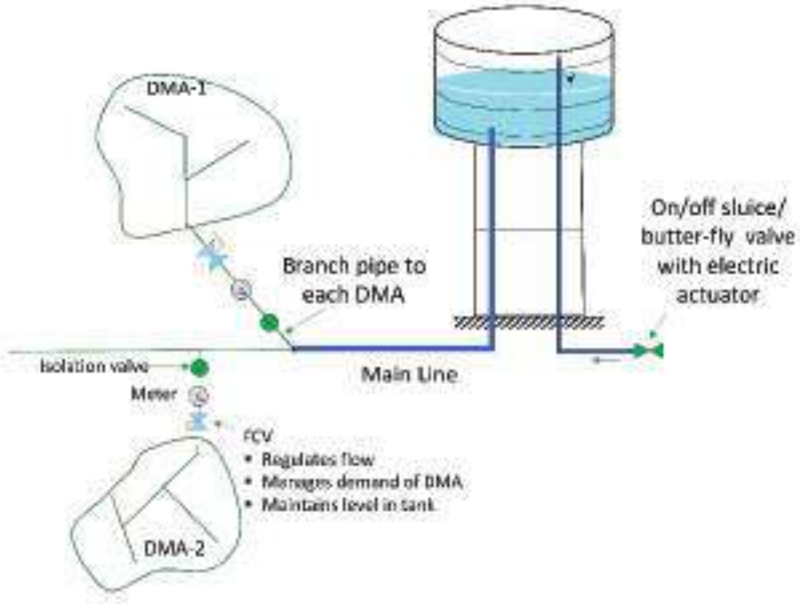

Figure 2.8: Separate branch pipe to each DMA

2.10 Implementation phase (Phase 2)

2.10.1 Prerequisite

2.10.1.1 System Conversion

(i) Removing Public Stand Posts

Stand posts are provided for supply of water to low-income groups who cannot afford an independent connection. However, a lot of water wastages have been observed at stand posts as supply through stand posts are free and no-one is accountable for wastage at such locations. Therefore, the stand posts are required to be converted/eliminated to and individual connections to be with metered supply by providing subsidy.

(ii) Replacement of Faulty Consumer Meters, Faulty Service Connections

Metering is essential to levy consumers based on the quantity of water utilised. If the existing mode of charging is based on flat rate, then it should be changed, and consumers should be charged based on quantity of water utilised. Therefore, new meters should be installed.

A survey should be carried out to check the status of each meter, connection through ferrule and status of service line up to meter. Service lines are normally of galvanised iron (GI). GI pipe gets rusted fast when it is buried underground. Studies have shown considerable water loss at service connection and in-service lines. Leaky lines should be repaired or replaced depending upon the status of pipeline. Consumers should also be advised to check the pipeline beyond meter and get leak repaired if any.

(iii) Regularisation of Illegal Connections

Illegal connections are one of the major causes for high NRW. Their identification is difficult and once identified the present process of regularisation is a big task because it involves penalties for illegal use for the period for which water has been used illegally. A proper strategy is needed for regularisation of illegal connections. First, it is necessary to identify the suspected connections. During consumer survey, the survey team may follow the steps shown in Figure 2.9 to roughly identify the suspected illegal connections. If any family is identified as suspected of an illegal connection, meter reader should regularly make physical verification of that suspected consumer and try to bring him into the billing cycle.

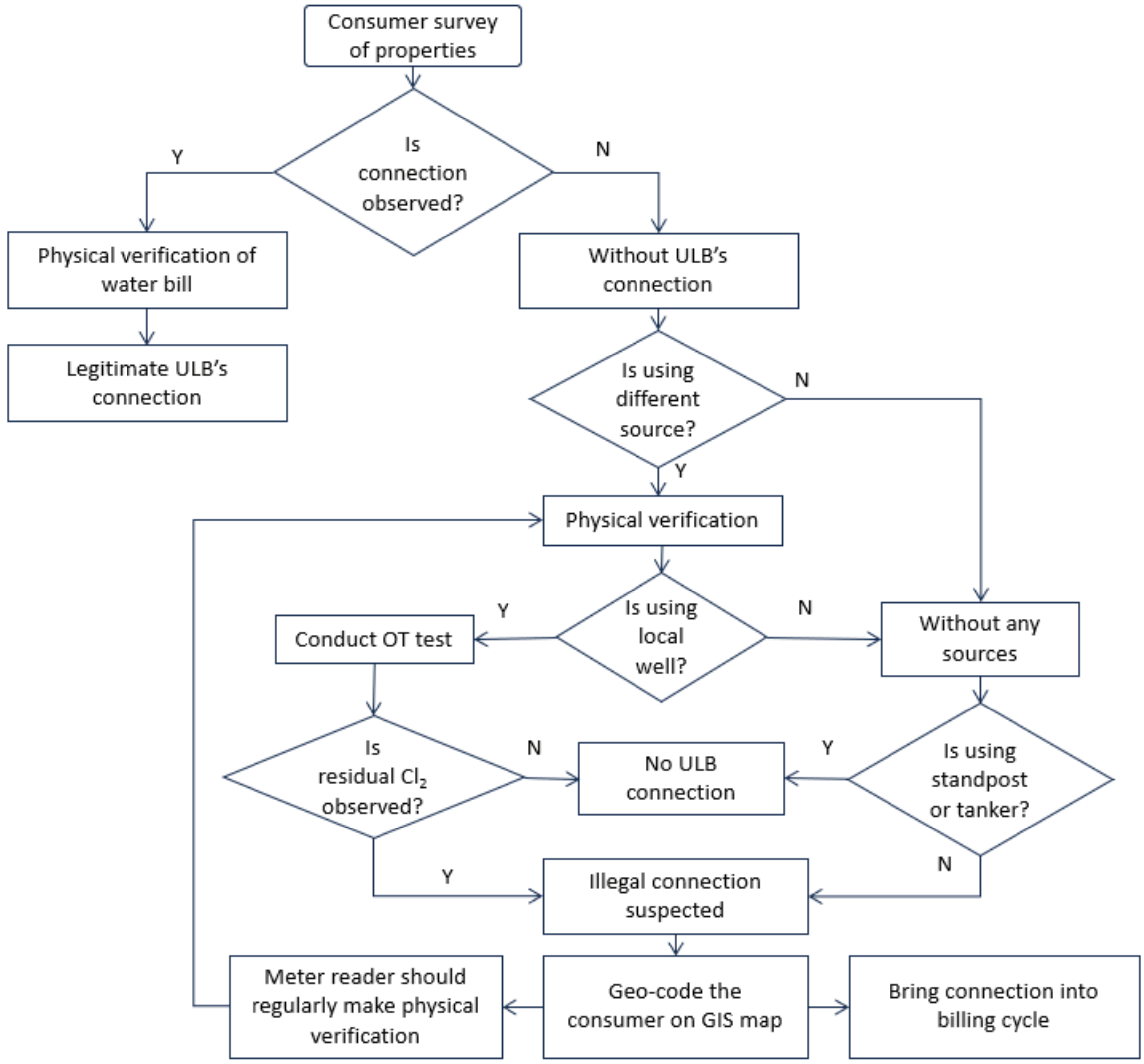

Figure 2.9: Steps of identifying suspected illegal connections

(iv) Replacing Old Pipes

While carrying out reconfiguration of a network to isolate DMAs, replacement of heavy leaking old pipes should be carried out. Old pipes having a previous record of number of repairs should be replaced. For each main line there is an economic range in which it is cost effective to carry out replacement. The process is explained in DMA management in section 12.16 of Part A Manual.

(v) GIS Mapping

GIS mapping is necessary and is discussed at length in the Guidelines of "GIS Mapping of Water Supply and Sewerage Infrastructure", released by the MoHUA in April 2020.

(vi) Customer's Underground (UG) Tank/ Sump

The UG tanks/ sumps are leaky and contaminated as per the study carried out at Nagpur by NEERI and VNIT, Nagpur by CPHEEO. Therefore, it is recommended that, for buildings up to three storeys, there should be no underground tank/ sump at the customer's house to prevent seepage and contamination. If it exists, then after stabilisation of 24×7 pressurised supply, such tanks/ sumps shall be removed gradually in a phased manner. However, a building with more than three storeys can have watertight RCC underground tank with lining/ PE tank (with a maximum of two days storage at 135 LPCD). ULB's to develop a protocol (bylaws) for regular cleaning of such underground tanks.

The ULB shall monitor the monthly consumption of water for all households and check the households whose consumption is abnormal which may be due to leakage of water through seepage. The ULB should give warning to such households to repair/ replace their sumps either with RCC or PE tank. Till the 24x7 water supply is stabilised, all existing UG sumps which are constructed with brickwork have to be either plastered or converted to RCC or PE tank with storage capacity of two days. Once the 24x7 water supply is stabilised the UG tank may be delinked (for building up to three storey) gradually in a phased manner. If any household desires to create storage capacity even after getting 24x7 water supply to ensure water supply storage for emergency situation, it is recommended that households shall preferably create storage on the rooftop of their buildings with a capacity of 50% of their daily requirement as the distribution system is designed for residual pressures of 17 – 21 m and 12 -15 m as the case may be.

(vii) Strategy for increasing supply hours to 24 hours

The basic principle of conversion is to increase the supply hours of the existing system by saving water. This can be done by 100% consumer metering and management of demand by enforcing a telescopic (differential) tariff based on volumetric consumption. This means the higher the consumption, the higher is the tariff slab. Water can be saved by arresting the leakages in the system. Strategy of increasing supply hours to 24 hours is shown in Figure 2.10.

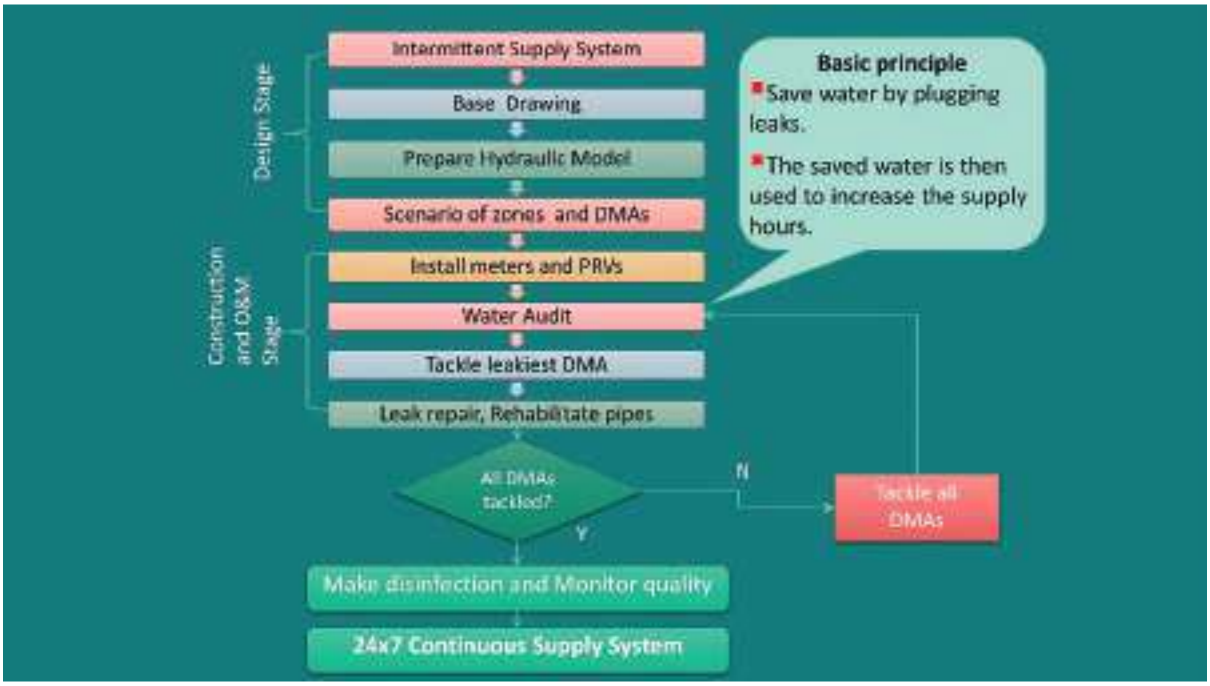

Figure 2.10: Strategy of increasing supply hours to 24 hours

(viii) Strategy for sustainable 24×7 pressurised system

Apart from the technical measures, a tariff strategy is required to save water by discontinuation of flat rates and charging on a volumetric basis by adopting telescopic tariff. Other measures such as organisational, commercial, policy, and budget are equally important. A summary of strategy for sustainable 24×7 pressurised system is shown in Figure 2.11.

All the above measures should be taken into consideration. If technical measures alone are taken, then the goal of conversion to 24×7 would not be achieved.

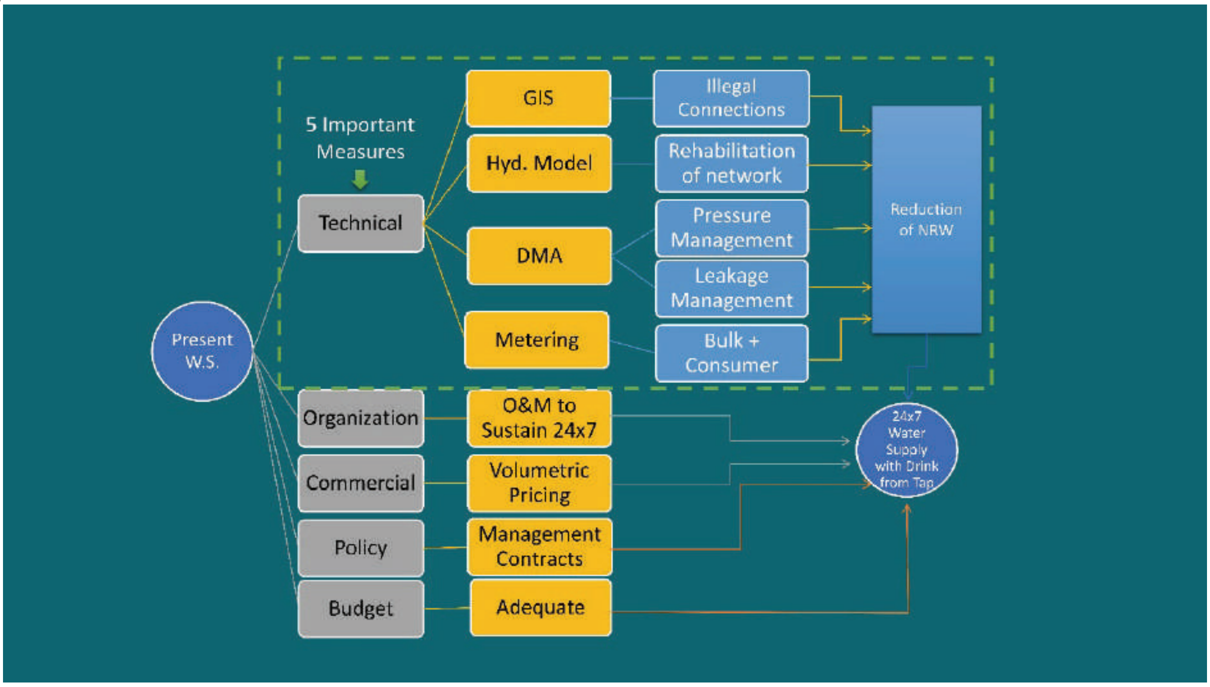

Figure 2.11: Strategy for sustainable 24×7 pressurised system

(ix) Disaster Management

Source and system failure in water supply can occur during disasters. When a source fails it takes a longer period for restoration of water supply. Therefore, there is a need for the preparation of action plans to mitigate disasters in the water supply systems.

Providing water supply in a disaster period is an important task for water supply authorities. There is a great risk of an outburst of epidemics if the water supply is not restored within a few hours of the onset of disaster. As disasters to water infrastructure cannot be clearly comprehended, it is very necessary to have perfect knowledge of the system.

If one source of the city is hampered, the system must ensure that it receives water from an alternate source to maintain a continuous water supply. The alternate source can be an unaffected source supplying water either to some other part of the same city or to other cities. Modelling the failure system is a critical part of designing and operating water networks so that the water system serves the community reliably, safely, and efficiently in the crisis period. Disaster management consists of the following phases:

Emergency Phases: General information on emergencies should be obtained. In routine operations of the water supply of the city, there may be some signs/indications seen before the actual outbreak of disasters. For example, during monsoon season, daily rainfall data and river levels can give such warnings.

Apart from flood and loss of supply, contamination by chemical spills is also possible. Alerts based on change in water quality should be made available using appropriate technology. If water pollution is detected at an early stage, suitable measures can be taken so that critical situations can be averted. This can be done by doing water quality examination in real-time. Such smart solutions for monitoring of water quality are very important with advancement in sensors, communication, and Internet of Things (IoT) technology.

These measures will provide sufficient time to warn the consumers and implement mitigation measures designated to reduce loss of life and proper damage.

Some emergencies occur with little or no advance warning; for example, during the disaster of 26th July 2005, the heavy floods washed away the gates of the Badlapur barrage, which is a source for Ambernath and Badlapur cities, in District Thane. On the eventful day, there was historical heavy rains (940 mm in 24 hours). The gates were designed for earlier Highest Flood Level (HFL). However, on that day, HGL was also changed and increased by 5 m. So, the gates were subjected with horizontal thrust of the flood water and were washed away. Pumping machineries were inundated. Rise in level was so rapid that 25 workers were trapped in the pump house.

Such type of incidents require immediate activation of the emergency operations plan. All employees must be prepared to respond promptly and effectively to any probable emergency. Emergency management activities require the following phases:

Preparedness Phase: This phase involves activities taken in advance of an emergency. The hydraulic model simulating the operation of transmission mains and action plans should be prepared. Standard Operating Procedures (SOPs) should be prepared to respond to a disaster. This phase also involves a checklist mentioning staff assignments, notifications, procedures and resource lists. The maps of important valves should be shown on GIS maps and kept for display in the office of the city engineer and the building of WTP. The water works staff should be familiar with these SOPs and they should be trained accordingly. Apart from knowing where they are, they should be exercised on a regular basis so they can function during emergency situations.

Mitigation Phase: In this phase, besides the valve operations, actions should be taken to make regular water supply. For example, when the water level in the barrage is decreased due to the washing away of the gates, some pumps may be required to supply water during a crisis. Mitigation should be thought of as taking actions to strengthen facilities and reduce the potential damage to structures.

A case study of source failure of water supply in the Mumbai metropolitan area is presented in **Annexure 2.9**.

(x) Activity Chart for Change of Mode from intermittent to 24×7 water supply

Common activities necessary for the adoption of the 24×7 water supply which may be considered by the ULBs which are shown in Figure 2.12.

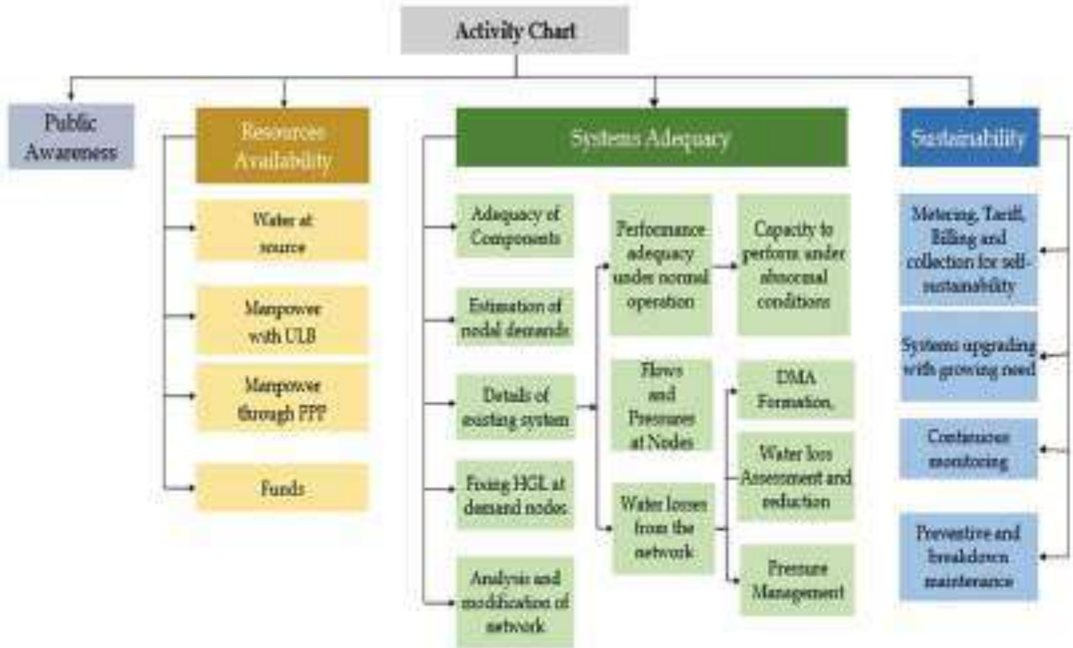

Figure 2.12: Activity chart showing a road map for change of mode

2.10.2 Implementation Steps for Gradual Conversion to 24×7 System

Detailed steps for gradual conversion through planning and implementation phases are as follows:

While planning the conversion process from existing intermittent system, it must be ensured that the residual nodal pressures in the existing OZ/DMAs shall be 17-21 m for Class I and II cities and 12-15 m for other cities. In reality, however, it may be observed that the residual pressures are far less than 17-21 m as the projects in the past were designed with low residual pressures in the distribution system.

Hence, the first task is to achieve the recommended residual pressures in a gradual manner. The biggest challenge is that in most of the cities, the staging height of the service reservoirs is not enough and, as a result the required residual pressures of 17-21 m could not be achieved. Hence, in the preparatory phase of planning and design, a strategy has to be developed for achieving the required residual pressure. The detailed implementation steps for operationalisation of 24×7 system for the senior, middle and junior level engineers and the consultants are shown in Figure 2.13. Figure 2.13 is expanded in Figures 2.13 (a), (b).

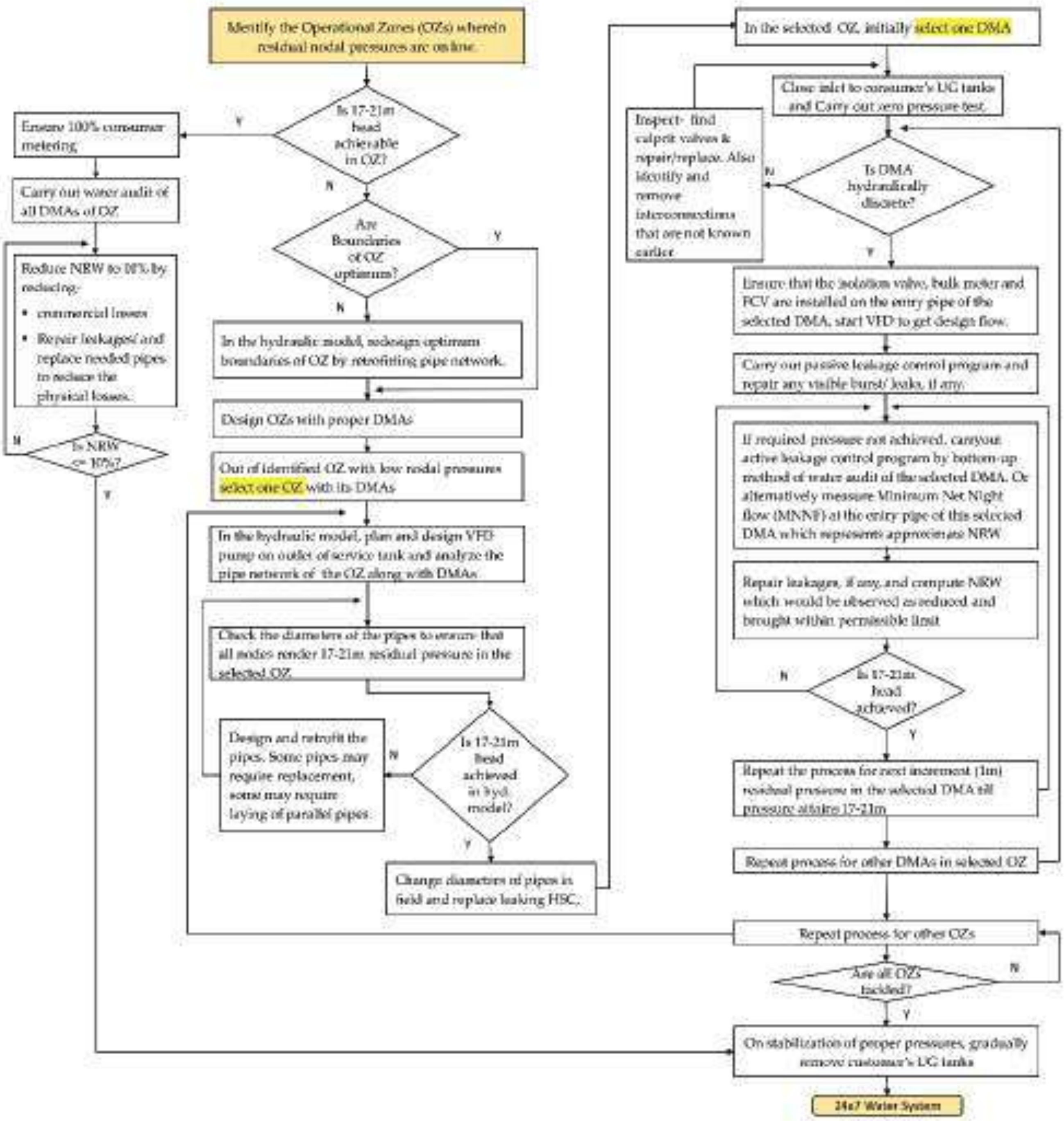

Figure 2.13: Detailed implementation steps for operationalisation of 24×7 Pressurised Water Supply System for the senior, middle, and junior level engineers and consultants.

[Parts of this figure are enlarged in Figures 2.13 (a) and (b)]

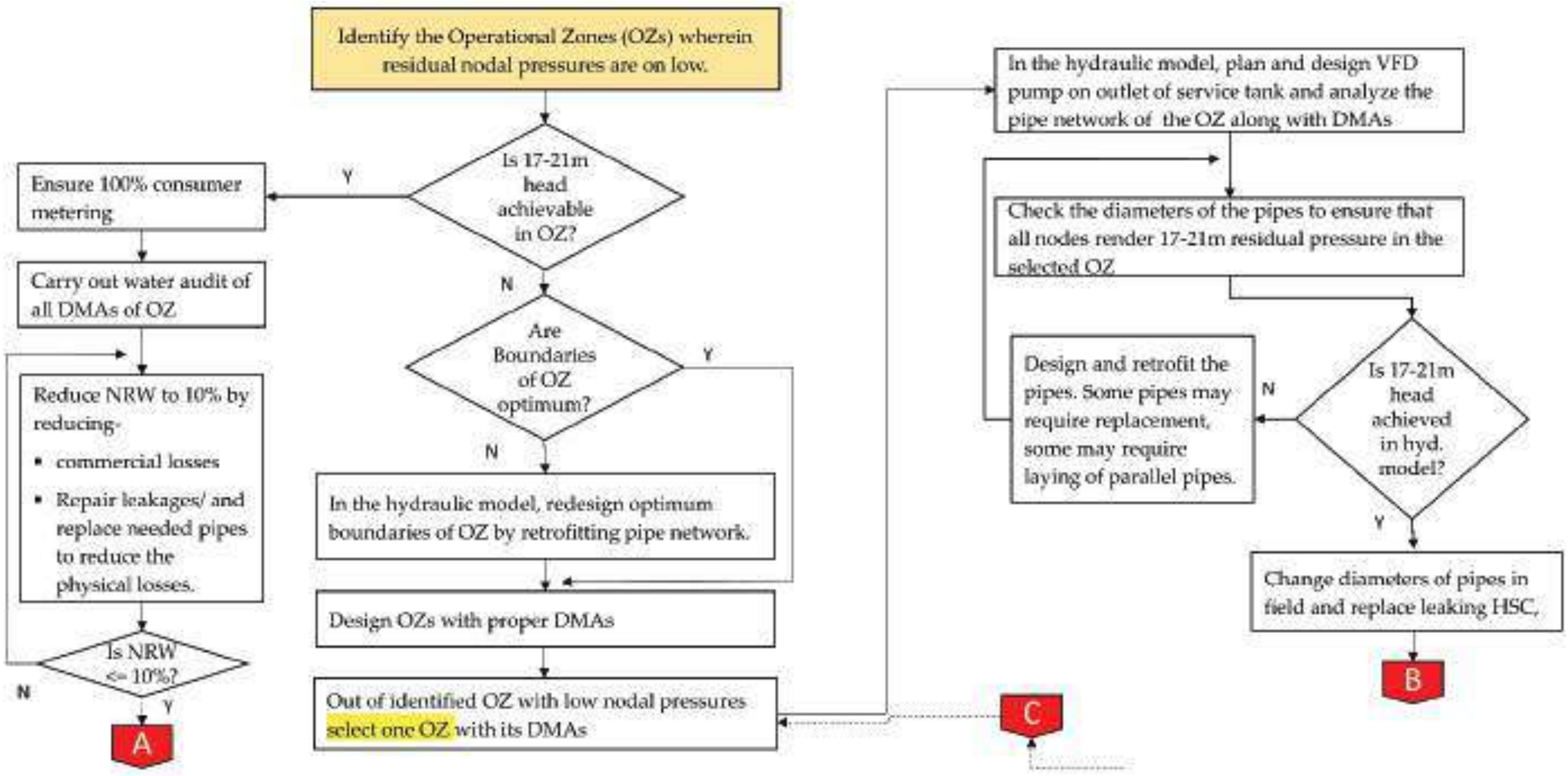
Identify the Operational Zones (OZs) wherein residual nodal pressures are on low.
Is 17-21m head achievable in OZ?
Y
N
Ensure 100% consumer metering
Carry out water audit of all DMAs of OZ
Reduce NRW to 10% by reducing-
• commercial losses
• Repair leakages/ and replace needed pipes to reduce the physical losses.
Is NRW <= 10%?
N
Y
A
Are Boundaries of OZ optimum?
Y
N
In the hydraulic model, redesign optimum boundaries of OZ by retrofitting pipe network.
Design OZs with proper DMAs
Out of identified OZ with low nodal pressures select one OZ with its DMAs
C
In the hydraulic model, plan and design VFD pump on outlet of service tank and analyze the pipe network of the OZ along with DMAs
Check the diameters of the pipes to ensure that all nodes render 17-21m residual pressure in the selected OZ
Is 17-21m head achieved in hyd. model?
N
Y
Design and retrofit the pipes. Some pipes may require replacement, some may require laying of parallel pipes.
Change diameters of pipes in field and replace leaking HSC,
B

Figure 2.13(a)

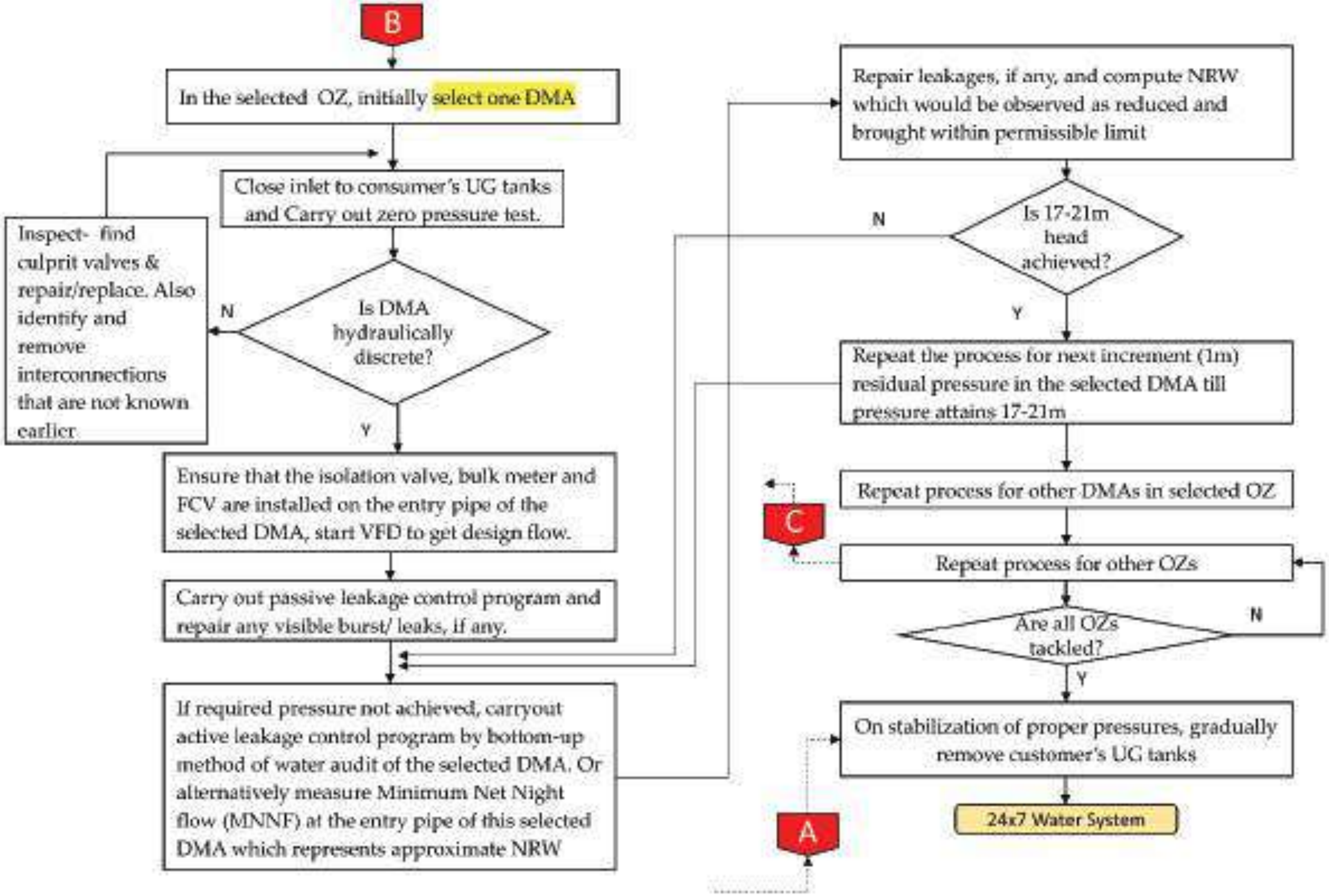
B
In the selected OZ, initially select one DMA
Close inlet to consumer's UG tanks and Carry out zero pressure test.
Inspect- find culprit valves & repair/replace. Also identify and remove interconnections that are not known earlier
N
Is DMA hydraulically discrete?
Y
Ensure that the isolation valve, bulk meter and FCV are installed on the entry pipe of the selected DMA, start VFD to get design flow.
Carry out passive leakage control program and repair any visible burst/ leaks, if any.
If required pressure not achieved, carryout active leakage control program by bottom-up method of water audit of the selected DMA. Or alternatively measure Minimum Net Night flow (MNNF) at the entry pipe of this selected DMA which represents approximate NRW
Repair leakages, if any, and compute NRW which would be observed as reduced and brought within permissible limit
N
Is 17-21m head achieved?
Y
Repeat the process for next increment (1m) residual pressure in the selected DMA till pressure attains 17-21m
Repeat process for other DMAs in selected OZ
C
Repeat process for other OZs
Are all OZs tackled?
N
Y
On stabilization of proper pressures, gradually remove customer's UG tanks
A
24x7 Water System

Figure 2.13(b)

Detailed steps in Figure 2.13 are explained as below:

(1) Dedicated NRW cell is required in each ULB which can take stock of the situation and continuously monitor and reduce the NRW levels.

(2) Water quality cell is needed to continuously monitor and control the water quality.

(3) Identify the OZs in the GIS based hydraulic model wherein residual nodal measured pressures are low due to insufficient staging height of the ESRs.

(4) The residual nodal pressures are to be checked whether 17-21 m (or 12-15 m as the case) are being obtained or not. Henceforth, the required nodal pressures will be denoted by 17-21 m.

(5) If such pressures are obtainable as per hydraulic model, then ensure that DMA is made hydraulically discrete by closing boundary valves, then the 100% consumer metering should be done and DMA-wise, water audit in the OZ should be carried out. The NRW should be less than or equal to 10% in the DMA. If not, then we need to reduce NRW by taking NRW reduction programme. Once the required NRW is achieved, then after stabilisation of the nodal pressures to 17-21 m, consumer UG tanks shall be gradually delinked. In this manner, 24×7 pressurised supply can be achieved.

(6) However, as mentioned above in Sr. no. 4, if nodal pressure is less than 17-21 m, then the existing service tanks shall be studied to ascertain whether they have optimum boundaries (proper allocation of command areas to ESR) or not. If not, the exercise of making optimum boundaries should be taken up in hand with the help of hydraulic model. This can be done by re-engineering and retrofitting the pipe network using the hydraulic model.

(7) On optimising boundary of the existing service tank, out of the OZs with optimised boundary, select one OZ with the lowest nodal pressure.

(8) In the hydraulic model, plan and design the VFD pump on the outlet of the service tank and analyse the pipe network of the selected OZ along with DMAs for diameters of the pipes to ensure that all nodes would render 17-21 m residual pressure.

(9) Before checking the actual required field pressure of 17-21 m in the OZ, the capability of the OZ should be checked to see whether it is capable of creating and sustaining 17-21 m at the nodes. This should be checked using the hydraulic model. If the network is incapable to sustain the pressure, then design and propose retrofitting of the pipes using hydraulic model. Some pipes may require replacement with slightly higher diameters, some may require laying of parallel pipes.

(10) It is observed that about 70%-80% of the total leakages occur at ferrule point which is a start point of the HSC. In implementation stage such HSC shall be replaced.

(11) The change in network should be implemented on field and the nodal pressures shall be measured at the highest elevation of the DMA in the field. On achieving the required nodal pressure of 17-21 m, in the selected OZ, initially select one DMA.

(12) Carryout the zero-pressure test to ensure that the selected DMA is hydraulically discrete. Before conducting this test, ensure that the inflow to consumer underground (UG) tanks is closed by closing isolation valve, precaution shall be taken to see that the float is in good condition.

(13) If the test is negative (there is leakage), then inspect the circumferential boundary of DMAs where the isolation valves (if dead ends are not planned) are installed. Identify the culprit valves that are leaking. Either repair them or replace them. Also identify any interconnections between the adjoining DMAs that are not known earlier and plug them.

(14) On doing these actions again carry out the zero-pressure test. It should indicate that the DMA is 100% discrete (isolated).

(15) Ensure that the isolation valve, bulk meter and FCV are installed on the entry pipe of the selected DMA.

(16) Now that the arrangement is ready for performance observation, the flow in the DMA should be started slowly (up to design flow) by the installed designed VFD. The average observed nodal pressure shall be measured.

(17) Carry out passive leakage control programme. In passive leakage control programme, the visible burst/leaks are to be repaired. On removing such visible leaks/bursts, the residual nodal pressures are expected to increase.

(18) Still, if the required nodal pressures are not seen, the active leakage programme should be taken up in the selected DMA which is in the selected OZ. The active leakage programme can be carried out in three ways:

  (a) If 100% consumer metering is done in the entire DMA along with isolation on the HSC, the procedure followed is to carryout leakage programme through bottom-up method of water audit (detailed in Part B Chapter 11: Water Audit and Leakage Control), in which the quantum of water coming in the DMA is measured by the bulk meter installed at the entry point of DMA and the total water consumption in DMA is measured by the consumer's meters. The difference of water coming in the DMA and water consumed in DMA gives the value of NRW.

  (b) If 100% metering is not done in entire DMA, then the sub-DMAs are to be formed. At least 10% of the customers in the sub-DMA are to be metered. The inflow to the sub-DMA shall be measured by the portable flowmeter and the consumption shall be measured by meters in the sub-DMA.

  (c) However, during the process of increasing nodal pressures to 17-21 m, quick determination of value of NRW is required. In the absence of formation of sub-DMAs and household meters, NRW can be approximately and quickly computed by measuring the minimum net night flow (MNNF) at the entry pipe of this selected DMA which represents approximate NRW. For this purpose, reading of the minimum night flow (MNF) should be taken from the bulk meter installed. Determine the legitimate night consumption such as consumption in hospitals etc. After deducting the legitimate night consumption from MNF, value of the net minimum night flow is measured, which indicates the approximate NRW in the network of the selected DMA.

(19) Identify the leakage spots while carrying out steps (a), (b), or (c) in the selected DMA and repair leakages, if any, and compute NRW which would be observed as reduced and brought within permissible limit.

(20) Repeat the process for the next increment of 1 m which is added to the average observed nodal pressure in the field at the highest node till the required residual pressures of 17-21 m are obtained in the selected DMA.

(21) Now repeat the above steps for all DMAs in the selected OZ. The NRW values in this selected OZ are expected to be reduced and the nodal pressures to the extent of 17-21 m are also expected.

(22) Repeat the above steps for the rest of the OZs.

(23) On stabilisation of pressures 17-21 m in all the OZs, the system is gradually converted into 24×7 pressurised water supply scheme.

(24) Now gradually delink consumer UG tanks by closing the valve leading to the UG tank and opening the valve on bypass arrangement for direct connection up to the third floor. The delinking of UG tanks should be done through wider publicity.

(25) The water quality of all the OZs and DMAs should be sampled and monitored. If the required standard quality (as per BIS code IS10500:2012) is not met, then the corrective measures in WTP such as disinfectant's dose should be monitored. To assess quality in the distribution network, Orthotolidine (OT) test should be taken regularly, one sample for every 10,000 population once in a month. In addition to this, regular sampling and monitoring online or offline of pH and residual chlorine at the farthest node of each DMA should be carried out and recorded for taking corrective measures if any.

2.10.3 Gradual increase in nodal pressure for cities

In the past, many water supply systems were designed for 7m or 12m residual head but operated with less than 7m or 12m due to field conditions and other reasons. In such a situation, if the staging height of service tank is sufficient enough to maintain the required pressure the following procedure shall be adopted.

Generally, isolation valve is installed on the outlet of service tank. This valve shall be opened very slowly with an increment of one thread at a time and then the residual nodal pressures in the OZ shall be checked. For this purpose, the pressure logger shall be installed at the critical nodes (highest elevation node). After opening the successive thread of isolation valve, the pressure at the critical node is expected to increase. The NRW cell should inspect to check if there is any leakage in the OZ. After repairing such leak next operation of opening of the successive thread of the isolation valve shall be carried slowly and the process is repeated till we get required pressure at the critical node.

2.11 O&M phase (Phase 3)

2.11.1 Transition phase to operationalise 24×7 system

Even after implementation of the project, during the operational stage, the value of NRW may increase continuously due to gradual increase of pressure during operation of VFD till the desired pressure is achieved. Therefore, the NRW control measure shall be continued while increasing the residual pressure to achieve the target residual nodal pressure of 17-21 m and reducing NRW to 10%. During this process water quality monitoring shall be continued to supply drinking water to every household free from biological contamination and meeting the drinking water quality standards of BIS (IS 10500:2012).

The continuous monitoring can be achieved by installing the SCADA/IoT system. The SCADA system generates a lot of data which is helpful. The generated data analytics and the predictive analysis are required and the same can be produced using digital twin technology.

2.11.2 Stabilising 24×7 Operation, NRW reduction and delinking of UG tanks

When 24×7 PWSS is commissioned, the residual nodal pressures are stabilised in all the nodes in the distribution network. With availability of 17-21 m, buildings up to three storeys need not have underground (UG) storage tanks as these tanks leak and are contaminated due to entry of outside contaminants into it. This makes water non-potable. Therefore, after implementation of 24×7 pressurised system, the consumer's UG tanks should be gradually delinked. Initially, the consumers may not agree to do so. But when the 24×7 system is stabilised, the consumers shall get water continuously and they shall have confidence induced in the system. However, vigorous information, education, and communication (IEC) programme should be carried out by forming women's self-help group (Jalsathi's) like in Puri, Odisha.

House service connection pipe can be directly connected to the internal plumbing system so that can water can reach up to 3rd floor.

In case of high-rise buildings, the society (group of residence) may have the watertight UG tank constructed in RCC/PE. The water in UG tank may be pumped to their common overhead tank.

The UG tanks need timely cleaning operation at least once in six months. ULB's NRW cell can monitor this activity by conducting regular surveys.

2.12 Comprehensive Management Strategy

The management of water supply systems is the process of planning, developing and managing entire system from its source to consumer's tap so that the consumer gets adequate quantity of potable water. The management includes financial planning and management, monitoring and implementation of the project, structuring and implementation of differential water tariff to ensure sustainability, creation of enabling environment for Public-Private Partnership (PPP), capacity building, preparation of metering policy, asset management, stakeholder's engagement, MIS, O&M of water supply system implemented to achieve 24×7 pressurised system, monitoring of the SLBs, monitoring key performance indicators, continuous monitoring and reduction of NRW and the water quality monitoring and surveillance throughout the design period as detailed in different chapters of Part C of this manual.

The three phases, viz., Phase 1: Preparatory Phase, Phase 2: Implementation Phase, and Phase 3: O&M Phase, need a very strong comprehensive management strategy from day one for successfully achieving and sustaining a 24×7 PWSS.

A comprehensive management strategy is very important and crucial for implementing the 24×7 PWSS and the phase-wise key management strategies are explained below:

THE STRATEGY

Phase 1: Preparatory Phase:

Survey and Investigations: Survey activities are the crucial building blocks for planning, designing, implementation and O&M of the existing and new systems. The survey involves various activities which needs complete involvement of the authorities in facilitating the survey. This needs various permissions and information from different departments, e.g., ULBs water department, roads department, water resources department, forest department, railways and various government and private agencies. The condition assessment needs permissions to use various wireless instruments as well as digging the roads and diverting traffic with stopping water supply of certain section of network or facility. The survey may need use of drones which requires permission from the respective departments.

The consumer survey, preferably in local language, is a very sensitive activity and needs an elaborated questionnaire with access to visit the consumer premises. This will have to be facilitated by ULB officials with complete co-operation from the elected members for getting accurate consumer data for preparing an accurate network model as well as billing database. The accuracy of this data will be critical for successful implementation of 24x7 water supply projects to make the system financially attractive for any PPP Operator.

Once survey and investigation activities are over, the comprehensive data base should be prepared, maintained and uploaded in the ULB's web site so that it is made available to all the stakeholders.

Preparatory Phase - Planning and Design: The water supply systems are planned for a design period of 30 yrs. with 95% dependability. A sustainable source availability is critical and the ULB authorities have to work with water resources department authorities/groundwater development authorities to identify, survey, investigate and get permission for extraction of water at source. To develop the source from dams/reservoirs, permission and water reservation/allocation are needed from water resource department as well as forest department for construction of the intake structures as they generally fall under protected forest. The water lifting also needs approval and reservation/allocation with respect to the yearly quantity of raw water to be lifted.

Land is needed for all the components/structures of the water supply system, including, intake, approach roads, WTPs, pumping stations, ESRs and office premises. These permissions generally need serious interventions from all authorities and political fraternity at local, state and even national level for certain interstate sources. Sometimes the lands are owned by national organisations, defence or private owners which needs a clear land acquisition/transfer policy at all levels.

To supply affordable drinking water to every household as per BIS IS 10500:2012, it must be ensured that the selection of raw water source should not be contaminated with the discharge of industrial waste, hazardous waste, toxic waste and domestic sewage. It must also be ensured that the cities and towns receiving surface water in the downstream should take up with ULBs which are on the upstream and discharging municipal sewage and also other industries to adhere to the pollution control norms of the state and central authorities. The respective ULBs on the downstream side may resolve these issues by referring them to the respective state pollution board and also state government board. The state pollution control board and the industry departments will have to be taken into confidence.

Many times, the pipe alignments fall in the national/state highways/roads right of way or through forest areas and may need to cross railway lines also. These permissions need elaborated documentation and is time-consuming.

The city water balance plan has to be prepared by the ULB based on the concept of IUWRM to ensure water security throughout the design period as explained in section 4.13.

The population forecasting involves various departments e.g., Town and Country Planning Department, Statistics Department and Tourism Department (for floating population). While designing the project, the land use pattern, population growth pattern, population projection for a design period of 30 years shall be finalised in consultation with Town and Country Planning Department of State Government, wherever necessary.

The states must have a legal and institutional framework (as discussed in Chapter 2 of the Part C of the manual) in place at state and ULB level, which forms various policies, issues advisories, initiate various investment programmes as well as data and information transfer initiatives in the sector. There is also a strong need for regulation in the urban water sector. The water policies, including tariff setting, have to be framed and implemented by State/ULB at the planning stage itself for implementing 24×7 PWSS which is technically and financial sustainable. These issues have been discussed and addressed in various chapters of Part C - Management, of this Manual.

Phase 2: Implementation Phase:

Prerequisite: During the implementation phase, various activities like removing public stand posts, identification and replacement of faulty HSC, old pipes, pumping machinery, regularisation of Illegal connections, identification and planning of the construction of new WTPs and ESRs, SCADA, instrumentation, establishment of water quality laboratories, etc., will have to be carried with the legal framework, institutional staff arrangements and stakeholders engagement with active involvement of the ULBs. NRW cell and water quality monitoring cell shall be established in ULB.

ULBs should initiate action to formulate their own metering policy, tariff policy and connection policy as per the respective model policies provided in Chapter 13 of Part A of this manual.

Capital works for Gradual Conversion to 24×7 PWSS and New System - Implementation Steps: The conversion to a 24×7 project involves preparation of DPR, which includes all the capital works, O&M costs, project development costs along with the land acquisition. The costs for power supply and environmental, social and gender safeguards should also be included. The funding of the project will need strong financial systems in place and efficient billing and collection. Funding from state, central and multilateral agencies will have to be studied and a funding strategy has to be put in place. The cash flow to maintain the funds for execution of works has to be embedded in the budget of the ULBs. ULBs should ensure that 100% consumer metering with an incremental differential (telescopic) tariff including subsidy for urban poor based on volumetric consumption for 30 years to sustain O&M cost. PPP option has to be explored with a detailed study of the suitability of the PPP model so as to attract private agencies. All of the above including the PPP part is covered in Part C, Chapter 8 - Public Private Partnership of this Manual. This is explained in Part C, Chapter 4 - Financial Management of this Manual.

In the Guidelines for AMRUT 2.0, it is mentioned that projects on 24x7 pressurised water supply system with drink from tap facility may be taken up.

However, in order to ensure speedy implementation of 24x7 PWSS project, the city needs to prioritise the implementation of various project components in a phased manner. In this regard, it is recommended that the cities should initially implement water distribution network in the project area or the whole city by considering OZs and DMAs with inlet and outlet arrangements (bulk flow meters, isolation valves, pressure valves, HSC up to boundary of the premises etc.) to facilitate better utilization of the capital investment available under time bound missions like AMRUT 2.0 or State Funds. Immediately after the formation of all OZs and DMAs, the cities shall initiate action to connect the house service connections with houses along with water meters for gradually achieving 24x7 PWSS in one after another DMA and upscale to project area or entire city in a phased manner as clubbing the laying of main distribution network and providing house service connection with meters simultaneously will delay the commissioning of the overall project.

After completing the replacement of pipelines and HSCs in DMAs, ULB should initiate action to undertake NRW reduction programme and monitor the same using various modern metering and communication methods suiting to respective cities and towns as discussed in Chapters 13 and 14 of Part A of the manual.

It must be ensured that water quality monitoring and surveillance should be undertaken as per the guidelines given in Chapter 8 in Part B of this manual.

Considering the climate change impact on water availability, utmost care must be taken to design the component of works which are climate resilient. This aspect has been discussed in Chapter 9 - Building Resilience for Climate Change and Disaster Management in Part C of this Manual.

Phase 3: O&M Phase:

It is necessary to make timely daily operation of various components of the water supply system such as headworks, treatment plant, machinery and equipment, transmission mains, service reservoirs and distribution system, etc. The operation of 24×7 PWSS should be done in an efficient and economically way, so that the aim of supplying safe and clean water in an equitable manner to the consumers is achieved.

It is needed to maintain water supply system efficiently. Maintenance is an art of keeping the structures, plants, machinery and equipment and other facilities in an optimum working order to attain proper functioning without any interruption. Maintenance is of two types - preventive maintenance and corrective maintenance. All aspects of O&M are discussed in Part B of this manual.

Transition Phase to Operationalise 24×7 Pressurised Water Supply System Including NRW Reduction and Monitoring Water Quality: During the transition phase to operationalise the 24×7 system, more emphasis will have to be given to the DMA management and data collection. The stakeholder’s engagement is going to play a crucial role in making people accept metering, their willingness to pay for good services and good water quality by implementing 24×7 PWSS with DFT. The assets installed, e.g., pipes, meters, etc., have to be managed by good asset management systems so as to monitor the transition activities. Institutional strengthening is essential to have trained and efficient staff to carry out all the transition activities and operate 24×7 PWSS. The self-help group, for example, Jalsathi’s in Puri, NGOs, residential welfare associations, etc., will play an active role in this phase. These issues have been discussed and addressed in Chapter 3: Institutional Strengthening and Capacity Building of Part C Manual.

Stabilising 24×7 Operation, NRW Reduction and Gradual Delinking of Customer's UG Tanks and Monitoring Water Quality Continuously: Stabilisation of the system will increase the confidence of the people in the water supply system and the ULBs will be in a position to delink the underground (UG) tanks through vide publicity and achieve consumer satisfaction. This will also increase the revenue of the ULB/PPP operator, thus achieving financial sustainability, which ultimately will increase the quality of life of the people. Continuous monitoring via. MIS and regular stakeholder engagements will make the system efficient and robust. Efficient O&M with strict Water Quality Monitoring will be the key for sustaining the success of the project with DFT mission. The O&M activities, including Water Quality Monitoring and Surveillance has been explained in Part B - O&M, of this Manual. The Management Practices can be referred in Part C - Management of this Manual.

Capacity Building

Capacity building is paramount important to operate and maintain the 24×7 PWSS throughout the design period as ULB requires skilled manpower. It must be ensured that the engineers of ULBs and that of the state departments should be trained through various central and state government PHE training programmes as discussed in Chapter 3 of the Part C of this manual.

Since many ULBs lack technical capacity to plan, design, implement and operate maintain and sustain 24×7 PWSS, ULBs are encouraged to implement, operate and maintain water supply system through PPP mode on a long term basis as discussed in Chapter 8 of the Part C of the manual.

Reforms in Governance for O&M of Water Supply Systems

Urban Local Governments were empowered through the 74th Constitutional Amendment Act (CAA) in 1992 to undertake 18 functions including water supply and sanitation services as per the 12th Schedule in the Constitution which contains the power, authority and responsibilities of Municipalities. However, despite three decades of empowering ULBs through 74th Amendment to the Indian Constitution, India's Local Government still requires many administrative and financial reforms apart from technological and capacity building reforms.

As per the constitutional amendment, ULBs are mandated to oversee the planning, implementation and O&M of water supply systems. Still, the current practice of project implementation is done by the State PHE Department, Boards etc. and ULBS are responsible for O&M of the completed project through ownership transfer from State PHEDs to ULBs. This practice has not been yielding the desired optimum management of service delivery system. This issue needs to be addressed so that agency who is implementing the project shall also operate and maintain the system.

Henceforth, future water supply projects are to be planned, designed, implemented, operated and maintained to provide 24×7 PWSS with an objective to supply water up to consumer end as per BIS (IS 10500:2012). It is of utmost importance that the scheme implemented by the State PHEDs and Water Boards should be operated and maintained by the same agency in order to ensure successful operation of 24×7 PWSS as envisaged during project planning and sustain the services throughout the design period by undertaking various measures including monitoring of NRW reduction, water quality and the service levels. Therefore, following reform measures are needed in all the States and UTs for effective planning, design, implementation and O&M of 24×7 pressurised water supply projects in a sustainable manner:

i. PHE Departments, individually headed by Pr. Secretary and the Municipal Administration Departments headed by Pr. Secretary, be brought under one umbrella of administration headed by the Additional Chief Secretary level officer.
ii. Intertwining the implementation and operation of water supply and sanitation project to share the knowledge of infrastructure design, implementation and their operational management aspects.
iii. Ownership building at different levels of operational training by bridging the gap between a silo approach of construction and operational activities with no system transfer at any level and instead, a common pool of officers (like state public health engineering services) at all required levels drawn from both the streams without losing their own cadre, be engaged and made jointly responsible for effective water supply and sanitation service delivery system as encompassed under the 74th CAA 1992.

2.13 Summary of Planning and design norms

The design norms for the capital works and for sustainable O&M of a continuous (24×7) water supply systems are summarised in Table 2.7 and Table 2.8. respectively.

2.14 Dual Water Distribution System (DWDS) in Coastal Cities

Dual water supply systems consist of two independent pipe networks with separate treatment, pumping and storage system to supply different grades of water to consumers for potable and non-potable applications. DWDS may be planned and designed in the following two cases:

2.14.1 Case 1: Coastal Cities and Towns

Most of the coastal cities & towns face the problems of saline water intrusion, thereby increasing the TDS in ground water not rendering the water for domestic consumption. Further, fresh water from either the surface water or distant ground water sources is available in limited quantity. In such cases, the coastal cities are forced to adopt desalination plants to meet their fresh water demands. The capital and O&M cost of desalination plants with raw water source either from sea water or brackish water is very high; therefore such cities/towns shall explore the possibility of adopting dual water distribution system, where one pipe will convey limited quantity of potable water/desalinated product water, with say a minimum of 40 LPCD with peak factor of 2 for potable uses like drinking, cooking and bathing as piped water supply below this rate may have operation problems; and another pipe will carry water with high TDS saline ground water (not sea water) that is acceptable by community for toilet flushing and other uses with peak factor of 2.5. This option may be economical as compared to desalination plants and shall be considered by coastal cities/towns. The existing distribution system shall be retained to supply water for other purposes.

It must be ensured that the first pipe should carry 40 LPCD of water with low TDS, preferably less than acceptable limit of 500 mg/L or relaxed TDS value as decided by the competent authority as per the field conditions, i.e., Chief Engineer of the State/UT Govts. and another pipe should carry water with TDS not more than permissible value of 2000 mg/L for other uses such as toilet flushing, washing of cloths etc. High TDS water affects the metallic pipes and plumbing fixtures and reduces their lifespans. Therefore, HDPE and O-PVC pipes are more suitable for conveyance of high TDS water.

The city should carry out the techno-economic feasibility to adopt DWDS for supply of dual quality water *vis-à-vis* desalination treatment plant to meet the additional water requirement with conventional a single pipe system.

The Dual pipeline carrying 40 LPCD should be designed and operated with 24x7 pressurised water supply system to prevent entry of outside dirt/wastewater in the pipeline during non-supply hours. Operationalising 24x7 pressurised system with 40 LPCD will be great challenge and it requires skilled manpower. However, the decision whether to adopt dual piping system or Desalination plant (to meet partial or full demand) is completely left with State Govt/ULBs/Parastatals.

The rationing of potable water is essential to ensure equitable distribution of water to all households, various commercial establishments and institutions and the required quantity of water can be restricted by installing flow meter with solenoid valve.

2.14.2 Case 2: Water Scarce Areas

Recycling and reuse of tertiary treated water in residential, commercial and industrial complexes at local level are being practiced in many cities to reduce the freshwater requirement. For example, Nagpur Municipal Corporation (NMC) is supplying 200 MLD of tertiary treated water to one of the power plants; Bangalore Water Supply and Sewerage Board (BWSSB) is supplying 4 MLD tertiary treated water to Vidhana Soudha, Raj Bhavan, Legislators home, Cubbon park and other important areas in central Bangalore from last 10 years for non-potable use; Nada Prabhu Kempe Gowda Layout (NPKGL) developed by Bangalore Development Authority (BDA) has planned and implementing to supply tertiary treated waste water for non-potable purposes with a dual water supply network. IISc Bangalore campus is supplying 1 MLD (whose requirement of fresh water is around 4 MLD) of tertiary treated water using MBR technology for gardening, cooling, toilet flushing etc. with a dual water supply system from last 7 years. However, Dual Water Distribution System need not be used in the part of cities and towns where water supply is already provided and because the households may not be willing to convert their plumbing system to dual plumbing system to supply potable water for drinking & bathing from one pipe and tertiary treated water for toilet flushing from another. Therefore, dual water distribution systems are recommended only in new layouts particularly in water scarcity towns so that one pipe will carry potable water for potable use and another will carry tertiary treated water for non-potable use such as toilet flushing etc. subject to the condition that the households in the new layout agree to adopt dual plumbing system in their respective houses/flats.

In the dual water supply system - two separate pipelines are to be provided clearly demarcated with different colour coding - one for potable water supply distribution to consumers ferrule through *blue colour* lining on pipe and other for supply of recycled treated wastewater to house flushing through *brown colour* lining on pipe. Accordingly, the consumers will be required to have dual plumbing system network within the households/premises with blue and brown colours lining on two separate piping system - one for potable water supply faucets/taps and other for flushing system.

"National Framework on safe Reuse of treated water in urban India" published in November 2022 by Namami Gange may be referred. The norms provided by CPHEEO for recycling and reuse of water for various specific purposes including toilet may be referred to at the Ministry website (https://mohua.gov.in/). Also, the BIS (IS 17663: 2021) which provides guidelines for water reuse safety evaluation- assessment parameters and methods for water reuse in urban areas may be followed for regular quality monitoring.

States and ULBs shall also encourage recycling of wastewater for non-potable applications within the premises of the large size residential apartments/Individual Households and commercial establishment to conserve fresh water.

A minimum diameter of 63 mm is recommended for dual piping system in case 1 and 2. However, the minimum diameter may be relaxed as per the field conditions. The city should carry out the techno-economic feasibility to adopt DWSS for supplying fresh water as well as tertiary treated water in coastal areas and water scarce areas.

Table 2.7: Recommended norms for planning, design and implementation- Capital works

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
1	**Design period (refer table 2.2)**	(a) Headwork should be designed for 50 years. (b) Units for Intermediate Stage: Tube wells/ bore wells, WTPs, CWRs and pumping machinery should be designed for intermediate stage and land should be kept available for ultimate stage and for future expansion. (c) Ultimate stage: ESRs and all pipelines including raw and treated water transmission mains, distribution pipes, pump house.	Base year: means proposed date of completion of the scheme. Intermediate: is computed as base year +15 years. Ultimate stage: is computed as base year +30 years.
2	**Land required for water supply infrastructure**	City planners should earmark the land required for water supply infrastructure and its expansion of ultimate stage in the master plan of the city for next 30 years or more.	Land is required for WTPs, sumps, ESRs, etc. When land for water supply infrastructure and its expansion is not available, the city planners may earmark in recreational amenities or parks, stadium, etc.
3	**Population forecast: Ward-wise forecast of population and population density**	Not only total population of city but its ward-wise distribution and computation of ward-wise future population density based on equivalent area is necessary.	This (nodal demand by future population density) has been discussed in **Annexure 2.7** along with the case study.

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
4	**Per capita supply of domestic/non-domestic for design (refer table 2.4)**	Cities/ towns with population less than 10 lakhs should be 135 LPCD Larger cities having population of 10 lakh or more should be designed for 150 LPCD. Non-domestic demand, bulk supply, etc., should be assessed as per the actual consumer survey. The non-domestic demand should be assigned to the respective nearby nodes. Fire demand should be added to domestic demand proportionately.	Supply should be at the consumer end. This means physical losses should be added to the demand. 1. The Metro and Mega cities should plan for water supply projects considering a per capita water supply of 150 LPCD and should take up underground sewerage systems within three years of commissioning of water supply scheme. 2. The other towns which are planning for water supply projects considering 135 LPCD should also take up undergoing sewerage system within three years from the commissioning of water supply scheme. 3. In case towns are facing water scarcity and are not contemplating sewerage system in the next 5 years, they can restrict per capita water supply to 100 LPCD for water supply projects and plan for decentralised sewerage facilities with on-site

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
			system as recommended in Sewerage Manual.
5	**Floating population**	Rate of supply for floating population should be as follows: i) Bathing facilities provided: 45 LPCD ii) Bathing facilities not provided: 25 LPCD iii) Floating population using only public facilities (such as market traders, hawkers, non-residential tourists, picnic spots, religious tourists etc.): 15 LPCD.	Figures should be got certified by ULB/ Tourism Department/ Statistical Department.
6	**Total demand**	The domestic demand does not include bulk requirements of water for semi-commercial, commercial, institutional, and industrial. Demands due to commercial, institutional, and industrial must be assessed separately through consumer survey and duly extrapolated for different stages. In the absence of consumer survey, the present demand due to semi-commercial to the tune of about 5%-10% of intermediate demand (domestic) may be considered depending on the nature of the town. The semi-commercial demand for intermediate and ultimate stages may be calculated considering an	Consumer survey of the city is mandatory for commercial, institutional, and industrial establishments (such locations can be easily identified using Google Earth). Consumer survey helps to ascertain requirement of consumer meters, identifying suspected illegal connections and for shifting of connections from main line. After deciding these values of demands, hydraulic modelling

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		increase of 1% per year on the initial semi-commercial demand. Fire demand should be added to domestic demand proportionately. Total demand should not exceed 15% and should be computed by adding following indicative losses: • Headwork to the inlet of WTP should not be more than 1% • In WTP, losses should not be more than 3% • Outlet of WTP to Various ESRs losses should not be more than 1% Sometimes, the location of WTP is close to headwork, and sometimes it is close to the city boundary. Hence, (a) and (c) above put together shall not be more than 2%. However, if (a) and (c) together is more than 20 km, then total loss should be considered at the rate of 1% per 10 km, instead of 2%. In a distribution system, losses should not be more than 10%. (With 24×7 project with 100 % metering NRW is expected to be reduced. Hence total losses in the distribution shall not be > 10%).	(design of distribution system) should be taken up.

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		For ground water (with appropriate treatment) where water is directly supplied to distribution system and WTP is not part of the system, the total loss should not exceed 11%.	
7	**Supply Hours and Peak Factor**	(a) The transmission system for both raw water and treated water including all pipelines up to ESRs should be designed for 22 hours of supply. (b) Water distribution networks of urban schemes: Peak factor should be designed for a peak factor of 2.5 irrespective of population. (c) Water distribution networks of rural part of urban-rural schemes: A peak factor of 3 irrespective of population should be adopted in rural areas.	On stabilisation of the water supply systems, peak factor may reach to the optimum value, based on the internationally established 24×7 water supply system.
8	**Minimum Diameter of Pipe for water distribution**	Minimum of 100 mm for all primary pipes in all the cities (for new pipes). In case the existing pipe is 80mm, the same may be retained in the system. In hilly terrain, 80 mm can be considered as the minimum size of pipe (for new pipes) for primary pipes. In case the existing pipe is 63 mm, the same may be retained in the system. For secondary pipes in small lanes of hilly areas for facilitating with the HSC pipes, the diameter shall be between 32-63 mm as per the local conditions.	

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
9	**Public stand post**	No new stand post should be given. Existing stand posts should be removed and converted to house connections with meter by formulating OZ-wise time bound programme by ULB.	Metered tap connections to all households are necessary.
10	**Minimum residual head at ferrule**	The residual nodal pressures at ferrule at highest node shall be 17-21 m for Class I and II cities and 12-15 m for other cities. **For existing ESRs:** In case staging height of existing ESR is not sufficient to develop designed residual pressure of 17-21 m or 12-15m as the case may be, the size of OZ shall be restricted based on the capacity of ESR (ultimate stage population). The VFD shall be designed taking into account the positive suction head (potential energy due to staging height). However, it is to be ensured that water level in the service tank should be maintained and the VFD pump shall automatically stop with dry running condition. If necessary, bypass arrangement may be made between inlet pipe and outlet pipe. The operation of the VFD pump shall be regulated through smart solutions by installing sensors at critical node of the OZ/DMA.	Though earlier manual (1999) recommended 7 m for single storey, 12 m for two storeys, 17 m for three storeys, and 22 m for four storeys, in practice, most of the cities have designed and implemented their projects with residual pressure of 7 m or 12 m irrespective of whether the cities have two or three-storeyed buildings. Because of this, water supply systems have to resort to the consumer's underground tanks. In a recent study conducted by CPHEEO through VNIT and NEERI, Nagpur on water quality deterioration and water quantity loss through seepages from consumer's underground sumps in the DMA of Nagpur city where 24×7 water supply is provided, it was observed that:

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		New ESRs: All new ESRs has to be constructed to maintain residual pressure of 17-21 m or 12-15 m as the case may be.	a) 42% of samples (25 number of sumps out of 60 total number of samples) had presence of indicator bacteria E-Coli/Thermotolerant Coliforms in the sumps. However, only 5% samples at inlet to the sumps were having presence of E-Coli. It means that the underground tanks are contaminated by seepages from outside contaminants. b) Number of samples from sumps having free chlorine less than 0.2 mg/L were 35%, while the samples from inlet having free chlorine less than the 0.2 mg/L were 10% only. c) 12% of the consumer sumps were observed leaking significantly. The quantity of water loss was observed varying from 13.20% of total household demand to as high as 223% as that of total household demand with an average of 98.27% of total consumer demand. Thus, the total water loss was 15.95 KL as against the total supply of 29.45 KL

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
			calculated based on 150 LPCD from seven households. In old areas of city, despite pipe material being metallic, many times the joints are weak due to aging specials of jointing of pipes. Even in such situations, pressure should not be relaxed. A systematic pipe replacement programme may be carried out stage wise in such cases.
11	**Maximum staging height of ESR**	Maximum staging height may be proposed to meet the residual head of 17- 21m.	To achieve above minimum head of 21 m and to have optimum velocity to achieve economical design of all pipelines in distribution, the staging height of the new service reservoirs should be appropriately chosen.
12	**Capacity of ESRs/ GSRs**	Balancing capacity of the service reservoir shall be calculated by: (i) mass balance, or (ii) 33% of the total demand of ultimate stage (30 years from the base year) of the OZ of that ESR. In any case, the minimum capacity shall not be less than 33% of the demand as above.	In case the VFD pumps are adopted for direct feeding the network, the sump acts as a service reservoir and provision of capacity mentioned in Col. 3 applies to this as well. Side Water Depth (SWD) if excessively chosen then the ESRs do

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		However, for rural areas the service tank may be designed for 50% of the ultimate demand.	not work efficiently. The maximum SWD should be as under: • For ESR capacity up to 1 Lakh litres: 3 m • For ESR capacity up to 10 Lakh litres: 4 m • For ESR capacity > 10 Lakh litres: 5 m
13	**Fire demand**	Prior to computation of fire requirements of OZ, it is necessary to compute the fire requirements for the entire city using following formula: For cities with population more than 50,000: $\text{Fire requirement for entire city} = 100\sqrt{P}$ (m^3/day) Where P is the intermediate stage (15 years) population of the entire city in thousands. $\textit{Fire requirement of OZ} = \left(\frac{\textit{Intermediate population of OZ}}{\textit{Intermediate population of the entire city}}\right) \times (\textit{Fire requirement of the entire city.})$	It is desirable that one-third of the firefighting requirements of each OZ form part of the service storage. For this purpose, the outlet of the tank supplying water for normal operation should be kept just above this storage so that the capacity provided for mitigating fire is always available. There should be fire outlet at the bottom of the tank that can be opened when an instance of fire occurs as well as at the time of cleaning the tank. The balance requirements maybe met out from secondary sources. The high-rise buildings should be

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		In case the service reservoir is designed for ultimate stage the word "intermediate" shall be replaced by Ultimate in above formula. For cities with population less than 50,000: Fire demand of OZ shall be computed initially for 50,000 and then proportionately decreased accordingly.	provided with adequate fire storage from the protected water supply distribution. Also, there is a remote possibility that the fire occurs at multiple places, hence nearby ESRs can also be used for firefighting requirement. The location of fire hydrants should be decided in consultation with fire department. However, arrangements for filling vehicles of fire brigade should be provided at each ESR. The pressure required for firefighting would have to be boosted by the fire engines.
14	**GIS Mapping**	GIS mapping of all the existing, proposed and executed infrastructure is required. GIS maps of ward boundary should be adopted for estimating demand by future ward-wise population density method. Training courses on GIS should be organised for capacity building of ULB's engineers and planners.	

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
15	**Consumer meters**	Distributing water with 100% consumer metering is most essential. Hence, consumer metering is necessary. Details of metering policy are mentioned in section 13.2 of Part A of this manual.	Demand management is not possible in case of unmetered water supply at flat rate. Therefore, policy should be adopted for 100% house metered connection by the ULBs. Geo coding with GIS coordinates of all the consumer and bulk meters is mandatory.
16	**Water tariff**	Volumetric telescopic tariff structure is mandatory. This method, will help to supply water to urban poor at affordable price, encourage consumers to decrease their consumption and penalise for their excessive consumption.	It is required for controlling demand and hence it is an important tool for demand management. 100% household are to be supplied water through house metered connection (without public stand posts), first slab of telescopic tariff structure should be such designed that the urban poor can get drinking water at affordable price. Quantum of subsequent slab should be so designed that the middle-class persons get incentive for decreasing their consumption. At the same time, this slab should not be too costly to poor to maintain minimum hygiene

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
			standards. Quantum of subsequent slab/slabs for higher consumption shall be such priced that it becomes penalty for excessive consumption.
17	**Hydraulic Modelling**	Hydraulic modelling is required for planning and designing OZs and DMAs required for 24×7 water supply system. GIS based hydraulic model should be adopted which is effective in O&M. Values of elevations and demands must be given to each node using GIS and the software tools. Only two hydraulic models should be prepared for entire city - (i) for entire distribution system and (ii) for raw/treated transmission mains. If the city is exceptionally large and is divided into big zones, then the two models as above should be prepared each for the respective very big zone.	Hydraulic model should not be prepared in pieces. If it is done in pieces, the contours will not be seamless. In such case proper elevations should be assigned to the nodes. And the nodes will have incorrect elevations, and this will vitiate the hydraulics of the network. The water demand on nodes shall also be rationally distributed. The assignment of ground elevations and nodal demands to all the nodes in city should be given, i.e., to follow "whole to the part" method and not by the "part to the whole" method. Hydraulic modelling can be done using various software including freeware available in public domain.
18	**Creation of OZ**	The main principle of decentralised planning is that each service reservoir should have one OZ. These	OZ boundary is determined with help of natural features like the roads,

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		OZs are further sub divided in DMAs. Each OZ and each DMA should be hydraulically discrete. Such OZs should be created for entire city by following proposed hydraulic parameters of residual head and the respective peak factor.	railway line, nalla etc. and slope within OZ area. Normally in non-hilly area the slope within OZ should be up to 5 m. In case of direct pumping, pressure zones shall be formed using the GIS technology and then the number of OZs shall be computed. The transmission/feeder mains shall be so designed that all the OZs should be brought on a co-ordinated sharing in case of a massive disruption in one OZ, it should be possible to make up the restoration from other zones.
19	**Optimised boundaries of OZs**	If the extent of OZ is not sized, designed, and maintained properly, it leads to malfunctioning of storage reservoirs like emptying and overflowing. Hence, boundaries of OZs should be optimised.	In the current (existing) systems, optimum boundaries of OZ are not designed scientifically hence this exercise should be made as described in section 12.11 in Part A of this manual.
20	**Maximum size of OZ**	The size of OZ for new service tank should not be more than 50,000 population or 10,000 connections.	Oversize OZ will be difficult to operate and maintain, i.e., to provide

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		For hilly areas, maximum ultimate population per OZ should be 30,000 or 6,000 connections. For size of OZ for existing service tank should be based on capacity of the existing service tank which will meet the demand of ultimate stage. In saturated/high density population areas where land is a constraint construction of service reservoir for catering OZ with 50,000 population, the norm of 50,000 population per OZ shall be relaxed and ultimate population up to 75,000 to 100,000 shall be considered in OZ with proper justification. However, maximum no. of household connections shall be restricted to 3000 by increasing the suitable no. of DMAs.	equitable distribution of water and designed residual head and, hence, its size be limited.
21	**Design of DMA, its boundary, and Maximum size**	Number of DMAs in one OZ should not be more than four but preferably two or three and each DMA should be hydraulically discrete. Each DMA should have HSCs in the range of 500 to 3000 in plain areas and 300-1500 in hilly areas for ultimate stage. The size of an individual DMA may vary, depending on number of local factors and system characteristics. All DMAs should be fed by common pipe from outlet of ESR in OZ with branches and from these pipelines,	OZ and DMA boundary is determined with help of natural features like the roads, railway line, water bodies, nalla etc. and slope within OZ area. For newly proposed tank, there should be separate outlets from the tank for each DMA.

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		consumer connections should not be given. Each DMA should have only one inlet. By this arrangement and by limiting the size and boundary of DMAs, equitable distribution of water as per designed nodal demands with designed residual head can be achieved.	
22	**Transmission mains**	Design methodology for achieving economy in capital/pumping cost and equalisation of residual head at FSLs of ESRs is mentioned in detail in Chapter 6. By this method, velocities in pipes are increased to optimum level, diameters are reduced, pumping head is optimised and every ESR gets just designed quantity of water.	This methodology uses the tool of velocity (m/s) and head loss gradient (should not exceed 10m/km) prudently. The value of head loss gradient can be exceeded in hilly areas, however, the velocity should not exceed the permissible value of 2.5 m/s.
23	**Design of distribution system**	Design methodology in details is given in Chapters 12. Velocities in pipes need to be increased to optimum level and diameters can be reduced. Minimum and maximum velocity criteria are specified in section 6.6 in Part A of this manual.	Strategic points such as maximum and minimum ground elevation and the farthest point should be marked on the drawings of OZs/DMA.
24	**Bulk metering**	Bulk meters shall be installed at head work, inlet, and outlet of WTP and at entry of each DMA.	By observing minimum net night flow through bulk meter at inlet of DMA, Non-Revenue Water (NRW) can be effectively monitored.

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
25	**Automatic Meter Reading (AMR) meters**	It is recommended that bulk supply connection should have AMR meter installed for conducting water audit. Commercial establishment having connection size greater than 50mm and society of colony of high-rise buildings are encouraged to install AMR meters from the revenue generation perspective.	AMR facility is optional.
26	**Control valves** **PRVs** **FCVs**	PRVs are needed in hilly cities/areas. PRVs are also needed when some of the DMAs are situated on lower elevations. FCVs with dual Solenoid at entry of DMA are proposed. They should be set for peak hour design demand.	Control valves such as PRV and FCV are vital for equitable distribution of water and equal terminal pressures. FCV at entry of DMA helps in maintaining water level in the tank.
27	**Preparation of contract documents and speedy implementation**	Contract document for capital works need to be clear, unambiguously worded for avoiding litigation/arbitration/unrequired payment and speedy execution. This is achieved by formulating standardised (model) DTP and this avoids repetitive and erroneous work.	
28	**Break Pressure Tank (BPT)**	Design methodology of computing volume along with depth required is mentioned in section 6.14 in Part A of this manual.	Inlet and outlets should be kept at same elevation for BPT and MBR to

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
			optimise head on pumps and save electricity.
29	**Master Balancing Reservoir (MBR) & Zonal Balancing Reservoir (ZBR)**	The storage capacity of MBR for Urban area shall be designed for three hours of ultimate demand & for combined Urban & Rural as well as for Rural the storage capacity shall be three hours of ultimate demand. However, ULBs are free to carry out the capacity of MBR based on the mass curve. The storage capacity of zonal balancing reservoir in rural areas shall be designed for 2 hours capacity of the ultimate demand of the service tanks under its command area.	The capacity should be more than the downstream system volume (service tanks + pipelines) to run the system continuously.
30	**Sub-DMAs/Isolation valves**	For enabling effective break down maintenance of leaky pipes in distribution system, adequate number of isolation valves should be provided to isolate the network. Sub-DMA also helps to conduct water audit. Isolation valves should be such located that a segment of not exceeding 50 connections in hilly areas and 50 to 250 connections in other areas gets isolated for the purpose of repairs and rest of the connections remains unaffected. Optimisation of number of isolation valves is possible and	The drawing showing these locations of isolation valves should be readily available with maintenance staff. Modern softwares have facility of carrying out Criticality Analysis of the pipe network. Using this facility, optimum number of isolation valves can be determined. Formation of sub-DMAs with isolation valves are required in carrying out the STEP test.

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		recommended to operate the scheme on continuous supply basis.	
31	**Capacity of raw/clear water sump**	The capacity should be more than the downstream system volume (service tanks + pipelines) to run the system continuously. When WTP needs augmentation after 15 years, extra inlet from future Chlorine Contact Tank (CCT) to the clear water sump is required, which should be planned in the present WTP.	Two hours of the capacity of the WTP.
32	**Pipe material**	Distribution system – Provide metallic and/ or non-metallic pipes as per the site and service conditions. Raw/treated water pumping mains, transmission mains and feeder mains to DMAs - These are the arteries of water supply projects and preferably be laid with metallic pipe having internal lining. If non-metallic pipes are proposed, they shall be duly justified. Gravity transmission mains - Inside and outside city areas - pipes should be based on economical size of the gravity mains. The metallic pipes shall be preferred. If non-metallic pipes are proposed, they shall be duly justified.	

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
33	**Laying of pipelines**	Minimum cover of 0.9m is recommended, however cover should be provided as per respective BIS code for different pipe materials & suiting to the local field conditions Laying, jointing and alignment should be made as per the IS code. In the terrain where ambient temperature goes below 0 degree Celsius, pipes may be protected with proper insulation.	More than 25 mm size connection should be avoided to be given from small diameter such as 80 or 100 mm. Service connections must not be given from raw, pure water pumping mains, transmission mains, and mains feeding DMAs.
34	**Pipelines on both sides of roads having width 6 m and more**	In planning and design of new schemes, the roads having width 6 m or more, pipes are to be laid on either side of the road. This can also be done economically while deciding boundary of DMA.	It is necessary to lay pipelines on either side of the road so that while giving house connection, the road is not required to be cut/damaged. The method for roads having a width of more than 6 m is to insert the ducts intermittently in the body of the roads so that service connection pipes can be laid through it.
35	**Consumer underground tank**	For the buildings up to three floors, underground tank should not be encouraged at the customer's house. If such tank exists, then after stabilisation of 24×7 pressurised supply, such tanks shall be gradually removed/abandoned.	This manual recommends considering 17-21 m residual head for Class I and Class II cities/towns and 12-15 m for other cities. For the buildings up to three storeys,

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
			underground tank is not recommended at customer's house. If it is there, then after stabilisation of 24×7 pressurised supply, such tanks shall be removed/abandoned subsequently. However, for buildings with more than three storeys, they can have underground tank RCC/ PE with waterproof treatment to avoid outward seepage and inward contamination. The cleaning of such tanks is mandatory with frequency of once in six months and it should be strictly monitored by the agency responsible for O&M.
36	**Head loss computation**	Head loss can be computed using Hazen-Williams method or Darcy-Weisbach method.	
37	**Drinking water quality**	It shall be as per IS 10500:2012.	Drinking water criteria in Tables 1 to 6 from IS 10500:2012 are enclosed in **Annexure 2.5** of Part A Manual. The same is available along **with the latest amendments in Chapter 7** of Part A Manual.

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
38	**Express feeder for electric substations**	Express feeder for electric substations at pumping stations at headworks and at WTP as detailed in Chapter 16 at Sr no. 16.15 is mandatory to ensure continuous water supply in the city. The work of electric lines shall be got done from corresponding electricity board. Electricity Board shall not give electric connections to other customers from the express feeder. The cost of express feeder should be included in the project cost.	Express feeders from 11KV and above substation are necessary for uninterrupted electricity required for pumping water in 24×7 projects. The standby arrangement preferably from national power grid shall be provided. Standby in the form of generators may be provided for small BHP pumps up to 50 BHP.
39	**Consumer Survey**	Door-to-door consumer survey should be carried out. The consumer meters should be geo-tagged with GIS co-ordinates and shown on GIS maps of DMAs.	The city shall be divided into grid of suitable size. Survey team should visit all properties in an element of grid. During survey, illegal connections shall be identified.
40	**Physical Survey for generating Contours**	Ground elevations all along the roads in the city should be found out by total station method. The instrument should have capability of recording GIS co-ordinates. The elevation points shall be mapped in GIS and GIS-based contours shall be generated. If city terrain is not undulating, the contours can be generated using 3D stereo satellite method.	GIS based contours are necessary to assign the ground elevations to the nodes.

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
		In hilly areas when roads are not seen, "Drones" or other suitable methods may be used to generate contours.	
41	**Identifying Existing Pipelines and Condition Assessment**	Existing laid pipelines shall be identified by pipe alignment survey. Details are shown in Section 2.7.2 of this Chapter.	A change management team shall be formed comprising of ULB engineer, agency's engineer, valve operators etc. They should identify existing pipes by interacting with local people.
42	**City Water Balance**	A city water balance considering IUWRM may be computed.	Refer Section 4.14 of Part A Manual
43	**Design of buried pipelines in seismic active areas**	The design shall be as per provisions of "IITK-GSDMA Guidelines For Seismic Design of Buried Pipelines Provisions with Commentary and Explanatory Examples", which is available at http://www.iitk.ac.in/nicee/IITK-GSDMA/EQ28.pdf In seismic prone areas, MS pipes may be used for water supply projects as mild steel is flexible. DI pipes, being semi-rigid, can also be used with restraint joints.	The seismic hazards which are directly related to pipeline failure can be classified as: Permanent ground deformation related to soil failures Longitudinal permanent ground deformation Transverse permanent ground deformation Landslide Buoyancy due to liquefaction

S. No.	Parameter	Conversion from Present Intermittent Supply to 24×7 Pressurised Water Supply System	Remarks
1	2	3	4
			Permanent ground deformation related to faulting Seismic wave propagation
44	**Branch roads to WTP, Head works, MBR, BPT, ZBR**	All pipelines should be laid along all season roads; missing links and branch roads should be provided to important structures at project cost.	Pipelines should not be laid along cross country for saving lengths.

Table 2.8: Recommended norms for O&M works

S. No.	Parameter	Conversion from present intermittent supply to 24×7 pressurised water supply system	Remarks
1	2	3	4
1	**NRW monitoring and control measures (leakage programme)**	Since bulk meters at the entry of DMAs and 100% consumer meters are to be installed, and active leakage management programme is essential, the NRW values can be computed by (a) knowing the quantity of water entering DMA and consumption in DMA); (b) conducting step tests; (c) NRW of the entire system should be brought down to 15% or less; (d) NRW monitoring measure using water meter and communication technology are provided in Chapter 14 of Part A of this manual.	In the passive leakage programme, only visible leaks are attended and repaired. For leakage identification, modern methods such as detection using inert gas techniques can be used, which can be conducted in a shorter time compared to the conventional methods.
2	**Creation of NRW cell**	Mandatory for all the cities and towns along with quick response teams with vehicles equipped with necessary tools/equipment.	Dedicated NRW cell is required which can take stock of situation and continuously monitor NRW levels.
3	**Creation of calibration/repair workshop for domestic consumer meters**	ULB should promote the creation of a calibration/repair workshop for domestic consumer meters for 15 mm to 50 mm diameters with bench testing facility on the lines of the electricity board. Adequate stock of common spare parts should be ensured for making them commercially viable.	ULB should promote the creation of a meter repair workshop with a testing facility.
4	**Water audit**	Due to the provision of bulk meter at the entry of DMA, NRW of the OZ can be computed as all consumer connections are equipped with meters. Water audit of rising mains, transmission mains, OZ, and DMAs is essential.	In a 24×7 system, a water audit is a continuous activity. There is an 'economic level' of reducing NRW to 10% in the distribution systems at DMA level.
5	**Energy audit**	Energy audit is essential as per IS 17482:2020.	In many ULBs, pumps are not replaced even after 15 years.

S. No.	Parameter	Conversion from present intermittent supply to 24×7 pressurised water supply system	Remarks
1	2	3	4
			Hence, low efficiency is observed, and ULB has to pay more electricity bills.
6	**Eradication of illegal connections**	It is certainly possible to eliminate all illegal connections by enlisting suspected connections in a house-to-house survey to be undertaken. Step by step, illegal connections can be eliminated.	Identification of illegal connections should be made during customer surveys and mapped on GIS.
7	**Water quality**	Water quality should be monitored as per IS 17482:2020.	Water quality testing facilities should be created.
8	**SCADA**	SCADA system is recommended for cities (preferably population more than 10 Lakhs) to monitor the flow and functioning of the water supply systems, including night flow and leakages.	All the level controls of tanks, pumps, Bulk meters, FCVs, and PRVs should be connected to the SCADA. Softwares compatible to SCADA may be used to monitor real-time values of concentration of residual chlorine in any pipe at any point of time.
9	**Digital twin**	Digital twin technology may be adopted which uses real-time data generated by SCADA. With data analytics, digital twin makes predictive analysis. Thus, digital twin can help ULB to mitigate any urgencies such as pump failure, pipe burst, fire outbreak, low pressures, or the failure of ageing assets.	"Digital twin" is a virtual representation of ULB's water supply system. Digital twin brings SCADA, GIS, hydraulic modelling, and consumer information into a connected data environment, delivering cost-effective operations strategies in real time.
10	**Consumer billing and complaint redressal**	Consumer billing and complaint redressal system is essential. Computerised billing systems should be encouraged.	With SCADA/MIS, it is possible to show the redressal of complaints online for compliance of complaints. Complaint redressal cell should be set up.

S. No.	Parameter	Conversion from present intermittent supply to 24×7 pressurised water supply system	Remarks
1	2	3	4
11	**Special Purpose Vehicle (SPV)**	SPV may be preferred by the city to implement 24x7 water supply project alongwith long-term O&M.	Details are given in Part C of the Manual.
12	**PPP/O&M Through Contractor**	AMRUT 2.0 recommends planning and implementation of projects in PPP mode in water sector in cities with population more than 10 lakhs. It is recommended to develop standardised tender documents for various sub-works of O&M of headworks, pipelines, WTP and pumping machinery, etc.	Some of the components like WTP, pumping machinery with transformer, major pipeline, distribution system, etc., may be undertaken using separate O&M contracts.
13	**Training and Capacity Building**	Various training modules as discussed in the advisory on "GIS Mapping of Water Supply and Sewerage Infrastructure", as well as the PHE training program conducted by CPHEEO, may be referred to.	