CHAPTER SIX
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FIGURES

CHAPTER SIX - WATER SUPPLY STRUCTURES

6.1 INTRODUCTION

6.1.1 General

This Chapter contains some very minor changes and corrections and the addition of sections on Water Storage Tanks and Valve Chambers for Pipeline Appurtenances.

6.1.2 Common Water Supply Structures

Water supply structures are essentially hydraulic structures. Such structures are designed hydraulically and structurally to conform to flow characteristics, stability, (safety), economy and serviceability requirements.

Hydraulic structures are designed after detail surveys and data analyses• have been done, to establish some of the following parameters:

- design flood
- soundness of the geological formations (rocks etc.) scour depth
- tectonic forces (if necessary)
- silt transport
- wind velocity
- ground water level

Common water supply structures are:

- intakes
- dams, reservoirs and spillways,
- diversion weirs
- water treatment units,
- storage tanks and towers, and
- conduits: commonly pipes and chambers.

Some of these structures have been described in previous chapters.

6.2 GENERAL INVESTIGATIONS

The investigations required are broadly given here but for specific types of structure, standard books on hydraulic structures should be consulted. The main investigations include:

i) Hydrological and hydrometeorological

ii) Geotechnical studies namely:
   - overburden investigation
   - geological investigation, and
   - investigation of construction materials.

iii) Public, private or individual utilities which the structure might affect;

iv) Site topographical mapping;

v) High water levels, and minimum water levels for intakes;

vi) Land and water rights;

vii) Accessibility to site;

viii) Stability and serviceability requirements, where necessary by modelling; and

ix) Environmental impact assessment.

6.3 DESIGN CONSIDERATIONS

The aspects to be considered in designing of any hydraulic structure are many and are given in respective hand books. The standards in terms of quality and specifications to be adopted in any design shall conform as a minimum to any ISO Standard, reinforced as considered necessary by relevant British Standards, EuroNorms or their equivalent providing these are available in English translation. Where such standards do not cover the requirements then other National Standards available in English such as AWWA, or SABS, or in English translation such as DIN may be cited.

The design aspects of intake works are already covered in Chapter Two and water treatment units in general terms in Chapter Three. Their structural design details shall be obtained from standard hand books on reinforced concrete, steel, or masonry structures and manufacturers of such units. Pipe design is fully covered in Chapter Four.

For guidance, to the extent not previously covered, design consideration for dams, spillways, diversion weirs, shallow wells, tube wells, water tanks and towers, and pipeline chambers are given in the subsequent sections

6.3.1 Reservoirs, Dams and their Spillways

6.3.1.1 Reservoirs

A reservoir is required when the minimum daily design flow at the intake site plus any minimum compensation release requirement is less than the average daily demand. It is a basin constructed in a valley of the stream. For storage of water, weirs may be constructed if the difference is small but if the difference is appreciable, an earthen dam, masonry, rockfill, concrete dam may be constructed across the stream for storage

a) Site Selection:

The site for an upstream or mainstream Reservoir and its Dam should be selected such that it may command the entire area without pumping.

The following main features should be considered for selection of site of such an impounding reservoir:

i) It should be on impermeable strata, i.e. permeability coefficient should be less than 10^{-7} m/sec

ii) A narrow opening in the valley should be selected to reduce the length of the dam.

iii) Objectionable salts and minerals soluble in water should be absent from the reservoir site so that the water is of acceptable quality.

iv) The land to be submerged should be relatively unoccupied and cheap, i.e. involve least compensation and observe laws of environment conservation.

v) The land should be free of marshy layers and vegetation which could affect the colour, odour and taste of water.

vi) The slopes of the basin should be steep so to reduce the surface area per unit of volume in such a way that both undesirable shallow water and surface evaporation can be minimised.

vii) The valley of the stream in which the dam is to be constructed should be rapidly widening upstream of the dam so that it may afford the greater average volume per metre height and length of the dam.

viii) The capacity of the reservoir should be such that it will ensure the total demand of water for the town to be delivered continuously. The capacity depends upon the climatic conditions of locality and the period of dry weather

ix) The dam site should not be located over a fault line parallel to the stream bed.

x) The storage capacity in regions of dry climate, long droughts and infrequent rains will be more than that of the regions of moist climate and of frequent rains, and an initial estimate can be made using Hawksley's rule.

$$D = 1600 / \sqrt{F} \qquad 6.1$$

Where

D = the number of days for which the supply is to be stored,

F = the mean annual rainfall of three consecutive dry years expressed in cm.

xi) If the stream brings large quantities of silt, debris, etc., the storing capacity will be reduced due to considerable accumulation. It should be taken into account by providing extra storage (called dead storage) which is normally $^1/_4$- $^1/_5$ of the total storage. The actual amount of dead storage depends on the silt load and design period adopted. As far as practicable, silting should be controlled.

6.3.2 Dams

6.3.2.1 Choice of Dam

The choice of dam will depend to a large extent on the site selected for it. There are mainly three types of dams.

i) Earthen dams which include hydraulic and rock fill dams;

ii) Concrete and Masonry dams; and

iii) Sub-surface dams.

Concrete darns require the foundations of much greater bearing pressure (strength) than those on which the earthen dams can be successfully constructed.

In the case of earthen dams, the pressure exerted by their weight spreads over a much greater area by virtue of flatter embankment slopes. A slight settlement in foundation of a concrete or masonry dam may give rise to fracture whereas the same can often be accommodated in the earthen dam itself.

- ˜A Hydraulic dam is built by sluicing the earth filling into the site for the dam either through pipes or in flumes. A pond of water and mud is maintained on top of the rising dam and the excess water is drained off.
- ˜A Rockfill dam consists of an embankment made of stones of irregular sizes and shape faced either with concrete or masonry earth and clay.

- Sub-surface dams are usually constructed by excavating a trench within the sand-bed of the river during the dry season which is then filed with an impervious material.
- Concrete or masonry dams may be of three types:
  - i) Gravity dams
  - ii) Buttress dams.
  - iii) Arched dams
    - a) The stability of gravity dams is due to their weight which resists all forces.
    - b) In arch dams, the pressure of the water on the face of the dam is transmitted to the abutments. As a result, the section of the dam can be reduced to a great extent and any cracks which may occur will tend to close under this pressure.
    - c) Buttress dams are built using support down-stream. The advantages in case of buttress dams are saving in materials, and reduction of uplift pressure due to water pressure under the foundation.

6.3.2.2 Dam and Reservoir Surveys

Pre surveys are required for each of the following factors:

- Precipitation and reservoir evaporation
- Inflow of sediment from main and any the tributary river
- Planned high water level
- Watershed surroundings
- Water quality
- Water use conditions
- Choice of dam site (see also Chapter one)

6.3.2.3 Height of Dam

The height of a storage dam is governed by two factors:

i) The amount of storage that can be developed economically, and

ii) The storage volume afforded by the topography of the reservoir site

The height of the dam above the bed of the stream is determined by the level to which it is desired to raise the inflowing stream. This may however be restricted by the limitation of funds, by the cost of land which will be under water, by interference with highways railways water power development schemes, by the backwater curve effect upstream of the reservoir, by the need to relocate inhabitants in the reservoir area, or any other interests having prior rights on the land, etc.

6.3.2.4 Selection of Dam Type

The type of dam should be determined by considering the following factors

i) Topographical, geological and foundation conditions

ii) Meteorology and hydrology

iii) Materials to be used for construction

iv) Scale and layout of spillway

v) Environmental conditions and their protection

The type of dam viewed from the point of materials used can be classified into:

- Concrete dam
- Rockfill dam
- Concrete - fill dam
- Earthfill dam
- Gravity dam
- Buttress dam

i) Arch dams are influenced greatly by the topographical and geological conditions of the site, favoured with solid foundation, and in many cases built in a narrow valley with sound abutments (strong bank rocks)

ii) For gravity dams, its foundation must be relatively strong. If there are some weak points usually these must be improved by common foundation treatment technique.

iii) Rock-fill and earth-fill dams are usually built in relatively broad valley sites because large-sized machines can be operated efficiently on such sites.

Selection of dam type should be carefully made, firstly basing this on materials procurable at the dam site or in the neighbourhood, and secondly in case of fill type and where this can be found. Rain and temperature greatly affects the work period available.

A flood spillway is an indispensable part of any dam structure and therefore its size, type and the natural conditions involved in its layout often prove a governing factor in selection of dam type.

Because of the cost of spillways and the high sediment load in main watercourses, designers should always look at the possibility of off-channel storage sites on tributaries as these can often prove to be the more cost effective alternative, even though they often involve pumped storage.

6.3.2.5 Appurtenant Facilities

i) Dams must be provided with a spillway to discharge flood water. It should be designed to handle unusual flood flows.

ii) Dams should be equipped with safe maintenance and measuring equipment within the body, i.e.

~ provision for water level observation and rainfall recordings

~ warning and communication facilities

6.3.3 Spillways

a) Spillways are provided for storage and detention dams to release surplus or flood water which cannot be contained in the allocated storage space, and at dams to bypass flows exceeding those which are turned into the diversion system. Ample spillway capacity is of paramount importance for earthfill and rockfill dams, which are likely to be destroyed if overtopped, where as concrete dams may be able to withstand moderate overtopping.

b) Spillway requirements are:

- A spillway must have capacity to spill safely the excess water from the reservoir
- A spillway must be hydraulically and structurally adequate
- It must be located or provided with an energy dissipating outlet structure, such that spillway discharges will not cause downstream erosion or undermine the toe of the dam (downstream (d/s) of the dam)

c) Design consideration:

- Design flood (refer to Chapter Two)
- Sound bedrock at the bottom and sides of the channel or it may require strong protection from erosion
- Safe tail water discharge (from the spillway). This can be achieved by using an energy dissipation structures on or at the end spillway, e.g. by using a baffled or a chute ski jump.

d) Spillway components:

- A control structure to control or regulate flow into the channel
- A discharge channel to convey the flow released through the control device to a stream below the dam.
- A terminal structure which enable the spillway discharge to return into the stream without scour or erosion of the toe or downstream side of the dam.

e) Type of spillways:

- Free over-fall (straight drop)
- Ogee (over flow)
- Side channel
- Open channel (through a chute)
- Conduit
- Tunnel
- Baffled apron drop
- Culvert and apron
- Drop inlet (shelf or morning glory) [this type should not be considered except on very small dams or on off-river tributaries with very small catchments]

The design and decision on which of any of the above types of spi1lway to adopt is beyond the scope of this Manual and Designer are referred to 'the Design of Small Dams' by the US Department of the Interior, Bureau of Reclamation.

6.3.4 Diversion Weirs

6.3.4.1 General

A diversion weir is a structure which lifts up river water by means of constructing shutter gates or concrete impediments across flowing stream or river to raise the water level to ensure stable inflow to an intake structure and thus ensure the planned intake level for making a stable intake.

Effects that must however be considered are:

- Possible back-water curve effects on upstream river embankments, especially on flood plains must be taken in to consideration;

- The effect on flood water levels upstream where the natural river bed upstream is unstable and fluidised and taken into flow during flood as the weir, in obstructing this can cause not insignificant flood level increases in the vicinity upstream.

Where the above structures are of a large size, surveys on flood control, environmental impact assessment and the possible need for emergency side spillways are required.

6.3.4.2 Location of Weir

The following points should be considered in order to locate or choose a site for a weir.

i) The site should be located near the intake whereby there will be a few changes in river bed.

ii) The site should allow a stable structure at low cost.

iii) In tidal waters, the intake weir and tidal embankment should be built of reinforced concrete.

iv) In tidal waters, the intake weir and tidal embankment should be built at right angle to the direction of the river.

6.3.4.3 Height

The height of the diversion weir should be able to accommodate the designed quantity of water. It's height can be approximately determined by formula:

$$H = Hp - h - Ht - hr \qquad 6.2$$

Where,

H = height of water (m)
Hp = planned intake level (ground height) (m)
Ht = silt height of weir (m)
hr = free board of weir (m)

6.3.4.4 Apron

When the diversion weir is built on a foundation other than rock, an apron must be provided for:

i) Prevention of scouring down stream the weir by over flowing of water
ii) Coping with the uplift pressure, therefore the apron should be thick in construction.

6.3.4.5 Consolidation Work

Consolidation or protection work should be provided along the riverbed horizontally in order to prevent scouring of the bed.

6.3.4.6 Fish Passes

The diversion weir must be provided with a fish pass to allow the safe passage of fish from down to upstream of the structure and vice versa.

6.3.5 Shallow wells

A shallow well is a well of shallow depth for taking in free groundwater or subsoil water from a water bearing strata known as aquifer.

In general, these kinds of wells should only be opted for where it is known that even during an extended period of drought, the well will contain an adequate amount of water. They are of two types, namely rings wells and tube wells.

Ring wells comprise a reinforced concrete cylindrical shaped structure. These are normally cast adjacent to the well by using steel moulds and they are of two types, i.e. plain rings and perforated rings from which the collecting aperture in the walls water acts as a filter into the structure. Water is normally withdrawn by use of a hand pump.

Tube wells are drilled and fitted with casing and screen made of pipes. Again they are usually equipped with handpumps.

In order to get a good site for a shallow well the following considerations are required:

i) Selection of suitable aquifer of known reliability even during extended drought
ii) Construction of a well to suit the conditions of area adopted;
iii) Of a depth sufficient to avoid drying up during the dry season;
iv) With a reliable pumping capacity;
v) Be sufficiently far away from any sources of groundwater pollution; and
v) With a headworks that prevents localised pollution and ensures conservation of environment.

6.3.5.1 Factors for Determination of Well Sites

Factors to be considered when selecting a well site include:

1. Hydrogeological considerations
2. Method of investigation
3. Selection of equipment and how to use it
4. Preliminary investigation of water quality

6.3.5.2 Well Construction

When constructing a shallow well it is necessary to:

1. Have carried out a proper site investigation
2. Digging or augering the hole
3. Lining the well and finishing it off

Steps to be followed in order to arrive at a decision to construct a shallow well at a pool, spring or riverside or other promising site should include:

- Is the site within 1.5 km of the village?
- Is the site at a poolside, riverside or spring?
- Does the pool or spring dry out in the dry season?
- Has a survey been carried out?
- Is the nearest pollution hazard such as a cattle watering pool or latrines at least 100 m from the site?

- Is the site accessible by a lorry, or if not can it be made so?
- Has the water been analysed?
- Is electrical conductivity lower than 2000 μS/cm?
- Is the fluoride content lower than 8 mg/l?
- Is the aquifer more than 75cm thick?
- Has a pump test, preferably at the end of a dry season, proven the yield to be sufficient?
- Has one borehole with soil logging down to a depth of at least 5-10 m been sunk?

If all answers are yes, then the site is suitable for shallow well construction.

6.3.5.3 Concrete Well Rings

In Tanzania, the following types of concrete well rings are manufactured and used for lining the wells.

- Rings of 145cm dia. which are normally used.
- Rings of 40cm dia. which are used in the construction of wells with a deep lying aquifer

In both diameters two main types are manufactured with different properties.

i) Concrete lining rings of one part cement, three parts sand, and four parts gravel mix (1:3:4) mix

ii) No-fines filter rings of a similar mix but without sand (one part cement four parts gravel)

The gravel should be sieved through sieve mesh (6-18 mm), and if it contains organic or clay particles then it should be washed clean.

Sand should be obtained from a riverbed which contains over 90%silica

Each type of ring with a certain diameter and wall property should be given a number, as follows:.

1. Full height, concrete lining ring
2. Filter ring with cutting edge, to be sunk as the first ring of a well.
3 Ring with a half filter and cutting edge to be used as the first ring of a river well
4. Half height concrete lining ring.
5. Full height filter ring.
6. Small diameter filter ring
7. Small diameter filter ring
8. Small diameter half height concrete lining ring

6.3.5.4 Well Covers

Concrete well rings should be provided with a covers which are made in five types.

A: Concrete cover without hole for blind wells

B: Cover with central hole for PVC or concrete stand pipe for deep aquifer wells.

C: Cover with manhole for river wells only.

D: Cover with pump-hole complete with cast in bolts for pump stand (standard cover)

E: Cover with a manhole and a pump-hole and cast–in bolts for pump stand.

6.3.5.5 Handling of Concrete Rings

The weight of a standard ring is about 1200kg therefore special equipment is required to handle them and they should be handled with great care since they can easily be damaged.

Loading and unloading from a truck and the sinking in the well hole involves both lifting and turning over the rings, and these activities are done by using a Tripod (Shearlegs).

6.3.5.6 Tripod for Ring Lowering

A tripod is normally used for lifting the rings and consists of two standard legs each with a length of approximately 6m and a double leg of the same the length on which a winch is fastened. A cable is wound on the winch and run through a double pulley fixed in the top of the tripod and through a single pulley to which a hook is attached. A sling is provided.

For safety reasons the tripod should be located extremely carefully:

The legs should be positioned in such a way that they cannot slide away and such that the cable hangs down exactly in the middle of the tripod.

For stability, the centre of gravity of a mass hanging on the hook must always:

- Stay in between the planes formed by the three legs of the tripod.
- The legs of the tripod should be set out at the same level.
- In the case of the tripod, each of the other legs must stand at the same distance to the double leg with the winch.
- The distance between each single leg must be about 4m.
- Standing behind the winch the cable must be seen to be hanging exactly in between and parallel to the legs of the double leg

6.3.5.7 Sinking and Stacking the Rings in the Well

The tripod is first positioned in advance next to the well opening with the tackle cable hanging about 1m from the edge of the hole. The rings are rolled one by one to a position 1.5m from the well edge with its top facing the opening of the well.

The first ring to be sunk (the cutting ring) is attached to the 5 50 m sling, which is fastened around the ring somewhat higher than the middle of the ring but not higher than 30cm (1 foot) from the ring upper edge.

Next the ring is pulled slightly upwards and thus allowed to moves slowly to the edge of the well opening, hanging some how askew due to the eccentric position of the sling.

The bottom of the ring is now pressed towards the edge of the well, while at the same time the tackle is pulled away from the well and the tackle rope is pulled out. During this operation the ring must carefully be guided to prevent it from turning sideways thereby pulling the tripod down.

The well ring is then in a horizontal position, right next to the well. The position of the tripod is now changed in such away that the tackle is exactly over the centre of the hole. Then the sling is fastened around the ring again. A rope is attached to the pulley hook and by pulling the tackle cable upward at the same time pulling on the rope, the ring is carefully hoisted into a position over the well.

The ring, now hanging horizontally above the well can be lowered to the bottom of the well or stacked on top of an already placed ring, either in the well or on the surface. When lowering a cutting ring or first ring, its position must be checked with the water level after it has reached the bottom. If it is not exactly horizontal the ring can be lifted slightly, some soil removed from underneath until when fully lowered it is exactly level.

After the uppermost filter ring is in place, gravel should be introduced in the remaining annular space between the dug hole and the outside of the filter rings, and the top of this gravel pack should then be sealed with concrete.

Other rings then follow, one by one until the last lining ring which must protrude from the ground by at least 40 cm.

The annular space between the dug hole and the lining rings should be backfilled, preferably with puddle clay or with a cement grout. On the ground surface, this lining should then be extended about 2 m all around the well and sloping outwards from the well.

Finally a concrete apron should be laid on top to complete the water-tightness and pollution protection. It should be edged with a gutter to a suitable outlet point to lead both rainwater and any spillage away from the well into a ditch or soakaway.

6.3.6 Tube Wells

This type of well is fitted with wind pump; hand pump or motorized pump depending on the yield and depth.

6.3.6.1 Hand Augering Sequence

The steps to follow when auger drilling for a shallow well are as follows:-

1. Start drilling with the big riverside auger.
2. Put soil samples in rows for each metre drilled.
3. Add some water if dry material falls from auger.
4. Use the stone auger for very hard layers.
5. If too hard for the stone auger use the chisel.
6. If too hard for the chisel use a smaller auger.
7. After that ream the hole with the large auger.
8. When groundwater is reached, check its quality.
9. If quality is poor, stop further drilling.
10. If quality is good, continue drilling.
11. If the hole caves in, install casing.
12. Continue with the small auger.
13. Push casing down when lifting the auger.
14. Add water of necessary.
15. When material is washed from auger use the bailer.
16. Continue deepening till 6m below static water level.
17. Test water quality and yield of the well. A yield of more than 10 litres/minute is acceptable for a handpump
19. Place the PVC casing, plain and slotted in the well according to the lithological formation.
20. Pour in gravel, around slotted casing, diameter 2-3 mm, and pull out drilling casing simultaneously.
21. Backfill the top part with puddle clay.
22. Compact the area around well and protect as described above for ring wells.

6.3.6.2 Casing and Gravel Pack

Usually tube wells are cased to protect the hole and the pump rising main in the hole. D.I or PVC or Steel casings may be used depending on type of formation, quality of the water and available money

Blind casings are used in the impervious formation, and slotted screens are used in the aquifer formation.

Size of casing is determined by size of hole and the annular space between casing and pump.

The annular space between the hole and the filter casing is filled with graded gravel material as specified below:

1. For the gravel pack use washed rounded gravel of 2 to 3mm only.
2. It should pass the 0 4 mm sieve and be retained by the 0 1mm sieve.
3. Take the gravel from a river bed.
4. Never use crushed stones, laterite or calcrete or other parts of compacted soils.

Use a mould for pump foundation, slab and gutter.

1. Clean wet and compact the site and place and connect the moulds.
2. Check heights and slope
3. Place sufficient reinforcement
4. Use a concrete mix of 1:2:3
5. Cover the fresh concrete with wetted hessian or a plastic sheet to help cure.
6. Let it-cure for at least one week before installing the pump.

6.3.7 Service Reservoirs and Water Towers

6.3.7.1 Introduction

Water storage tanks or service reservoirs and water towers are water retaining structures and must be structurally designed according to an acceptable water retaining code of practice. They are discussed in Chapter 4 and specifically in Sections 4.6.5 and 4.20.

In summary, a service reservoir has four main functions namely:

1) To cater for fluctuations in demand in the distribution system, allowing the source to provide a steady output;
2) To provide a suitable pressure for the distribution system and to minimise pressure fluctuations in the system;
3) To provide a continuous supply of water during a failure or shutdown of a treatment plant, pumps or transmission mains supplying water to the reservoir; and
4) To provide a reserve of water to meet emergency demands including that for fire fighting.

6.3.7.2 Service Reservoir Types

Service reservoirs are normally located at or near ground level or just underground. They can be circular or rectangular in plan, the latter being better adapted to the provision of two compartments whilst the former is more economic in the amount of concrete required but also more difficult to shutter. Either arrangement is suitable for reinforced concrete although this tends to limit the storage height to maximum of about 7 m. Circular reservoirs can also be constructed as pre-stressed concrete reservoirs and be of somewhat greater water storage depth as a result.

Depths most commonly used for rectangular reinforced concrete reservoirs are 3.0-3.5 m for storage n.e. 3,500 m3, 3.5-5-0 m for storage in the range 3,500-15,000 m3 and 5.0-7.0 m for reservoirs larger than this.

The most economic plan shape for a two-compartment rectangular reservoir is usually obtained when its length at right-angles to the division wall is 1.5 times its breadth.

Flat roofed concrete reservoirs are usually covered over with earth and grassed but a gravel topping is sometimes used.

Circular, pre-stressed concrete reservoirs are usually dome roofed and historically in eastern Africa have been of the wire-wound type. However, those using buried, sheathed tendons have also been constructed. Problems have been experienced with both types. A wire wound pre-stressed concrete reservoir should not be buried so that the external wall can be routinely inspected for any slight seepage. Should this occur, the reservoir should be drained down and the seepage leak sealed on the inside for if this is not done, over time the thin pre-stressing wire will corrode through and the tank fail. The cost of remedial work which then involves the use of externally placed sheathed tendons is both specialised and often as or more costly than abandonment and replacement. If the anchoring points of buried wall tendons are not kept totally water-tight, then these tendons can also corrode through and fail and require major remedial work requiring the use of externally placed sheathed tendons.

For these reasons, pre-stressed concrete reservoirs are not recommended.

6.3.7.3 Service Reservoir Security

Special attention must be paid to ensuring service reservoirs are secure against vandalism, terrorism and theft. An impact and vulnerability assessment should be made to estimate the level of risk involved and thus the security measures that are necessary. Secure boundary fencing and padlocked gates may be sufficient to protect against vandalism but is not in itself sufficient.

Access manholes need to be well secured by both screwing down and padlocking. Roof air vents need to be well made and secure.

Where not permanently manned, reservoir sites need to be visited frequently to ensure that none of the protective measures taken have been interfered with.

6.3.7.4 Water Towers

Water towers are necessary in flat areas where there is insufficient land gradient to be able to build the service reservoir on or in the ground. They can also prove useful at the end of a primary distribution main so as to fill up at night and then help meet peak demand within the supply area during the day.

Such towers and the elevated tanks on top may be either of reinforced concrete or steel. At or near the coast, concrete structures are favoured due to the salt laden atmosphere, however inland steel towers and tanks are more often used.

When a reinforced concrete tower and tank is opted for, a cylindrical shaft some 6 m in diameter integral with the tank and with a raft base is often selected. Typical dimensions for an elevated storage tank are for storage volumes to be between 1,200-3,000 m^3, with water depths between 7-10 m and diameters between 17-22 m.

Ground level or elevated steel tanks can be for capacities between 1-15,000 m^3 and water depths of up to 6 m, and the pressed steel flanged panel tank is the most common. These comprise steel floor and wall panels, usually of 1 or 1.22 m square size and 4-6 mm thick depending on depth. They can be either hot or cold pressed but preferably the former as the heat treatment dissipates stress and avoids distortion.

They can be provided with an internal wall division and this is usually included for storage volumes in excess of 5,000 m^3 to allow for periodic emptying for maintenance.

They panels are fitted with strip jointing seals between each panel to achieve water-tightness and the steel must be adequately protected against corrosion, usually by galvanising but preferably by epoxy. Even so, an inherent weakness of such structures is in the internally placed inclined wall and horizontal corner stays and cleats which often corrode through first leading to walls bulging out and causing leakage at the joints.

It is therefore recommended for single compartment tanks in particular that the stays, cleats and their protecting bolts be of stainless steel to minimise this risk.

A typical arrangement is shown in the Figure opposite whilst their advantages include:

- Infinite range of sizes and configurations
- Excellent flexibility to adapt as storage requirements change
- Ability to be installed in areas with restricted access
- Quick and easy assembly using hand tools
- Highly economical transportation
- Inherent strength and durability of the raw material
- Excellent substrate for a wide range of finishes

The key to the numbers shown is:

1) RISING MAIN
2) FLOW CONTROL VALVE
3) OUTLET SERVICE
4) OVERFLOW
5) WASHOUT
6) DUCKFOOT BENDS
7) SUPPORT PADS

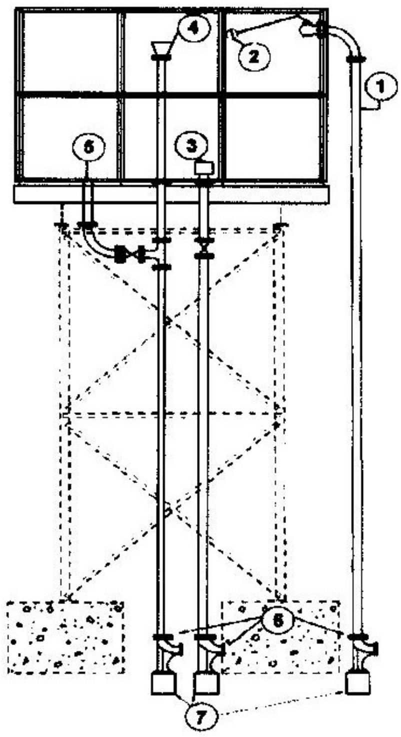

FIGURE 6.1: SECTION THROUGH A TYPICAL SMALL ELEVATED STEEL PANEL TANK

For those requiring more information, reference can be made to the website < http://www.braithwaite.co.uk/>

Because of past corrosion problems with steel panel tanks, and especially where limited or no maintenance has been undertaken a more recent alternative is to construct circular tanks where a pre-coated steel plate is sprayed by a special borosilicate glass which is then fired causing the glass slurry to fuse to produce a hard impervious finish. The tank is then formed by bolting together these curved modular plates to form a cylindrical structure and diameters of up to 17 m have been constructed without internal supports for roof panels.

Attempts to use thermoplastic plastic panels, including GRP bolted together have not proven altogether satisfactory in hot climates because the repeated flexing of plates has led to cracking near fastenings. As a result, only mould cast cylindrical thermoplastic tanks up to 10 m^3 should be considered, and even here and due to slow chemical leaching from the thermoplastic, frequent use and replenishment of the stored water is recommended.

6.3.8 Pipeline Chambers

Pipeline valve chambers are perhaps the least well considered structure in a water supply system but in some ways, because of their vulnerability amongst the most important. They can be square, rectangular or circular, pre-cast ring in plan the latter being the most economic, especially for smaller diameters, providing pressures and thrusts are not excessive.

Small chambers are often constructed of blockwork but this carries with it the risk of collapse due to external loads from the surrounding soil. It requires a top ring beam to minimise this risk and also makes more difficult the transfer of any thrust, requiring a thrust wall to be cast into one wall of the chamber or totally external to it.

Chambers and the like should never be positioned below roads but in the road verge and any road authority should always be consulted first before selecting the final position.

Where pipes are cast in to the walls of a chamber or into a separate thrust wall, it is necessary to allow for differential settlement by providing two flexible joints with a ‘rocker pipe’ at least one metre long in between.

Where the main pipeline wall material is different from that of the appurtenance and its associated fittings, it is extremely important to ensure that the joint coupling the two materials has the correct internal diameters for the two materials (such as a stepped coupling) and that it is appropriate for joining the two materials which will have different degrees of rigidity.

Thrusts occur at valved branches or when the chamber contains a line valve. The section of pipe passing through the wall should then be supplied with a thrust flange and this wall, which then transfers the thrust, will often have to be extended vertically or horizontally to allow the thrust to be taken by the surrounding soil. Appurtenances that may transmit thrust, e.g. when a line valve is closed, should have a rigid or flanged joint on the side taking the greatest thrust whilst the other joint should be a flexible coupling or other easy to disassemble joint such as a flange adapter to allow for removal of the valve for major maintenance or replacement, ands sufficient space for this must be provided. At branches, the tee should be cast onto a proper thrust carrying pad integral with or cast against the chamber floor and wall.

Unless a chamber can be made watertight there must be provision for drainage. Airvalve chambers in particular must either be well draining or the airvalve be located above any possible upper water level, otherwise the risk of drawing in polluted water occurs. Airvalve chambers must be vented to allow for the escape or return of air during operation and especially those where surge effects may cause water column separation.

The internal dimensions of a chamber must be sufficient both to allow ease of access and for the use of standard size spanners when tightening and loosening the bolts on flanges.

Attention to the design of manhole covers is also very important as there is often a risk of vandalism, including illegal valve operation and of theft, especially of water at air valves. Even lockable manhole covers, especially if the location is somewhat remote are at risk as are extra heavy concrete covers requiring two persons to remove and replace. A combination of such heavy weight covers and a lockable metal strap have proven reasonably successful in remote locations along transmission mains, provided local inhabitants are provided with a water source for their own use. Even free-water standpipes fitted with automatic closure taps and/or low-discharge orifices are better in such locations than failure to provide any water at all as the cost of dealing with vandalism and water loss far outweighs the cost of providing relatively small quantities of water to a small rural population.

It is often practice to omit chambers for valves on smaller diameter distribution pipes on account of cost and instead to backfill around the body of the valve, and to provide a sleeve between the valve spindle and a surface box to allow for tee-key operation.

In practice, this is often found to be a false economy. Unless frequently operated, the valve surface box gets covered over and forgotten, even to the extent of being concreted or tarmaced over, or the spindle sleeve gets choked with debris and then has to be re-excavated before the valve can be operated.

In all instances however, the need for frequent patrolling, preferably on foot, and inspection must not be ignored.