SUSTAINABLE CIVIL, MECHANICAL AND ELECTRICAL EQUIPMENT IN WATER SUPPLY PROJECTS

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Contents

Summary

In this review of the topic of sustainable water supply projects, emphasis is placed on functional equipment of the mechanical and electrical kind in association with structures for water supply and control. Sound design philosophy is based on assured water supply and well designed structures. In considering typical applications for community water supply, first groundwater, then pipelines, weirs and canals are discussed. Water quality specifications are dealt with next, also the role of reservoirs and elevated tanks, distribution networks, control systems and power supplies.

Finally, the need for fiscal management, monitoring the performance of a project, its operation and maintenance, is dealt with. In the concluding section a brief introduction to the articles following under this topic is given.

In the appendixes some details are given regarding the wide variety of equipment used in both permanent as well as temporary capacity. Permanent works are first discussed with structures such as intakes and operating equipment: valves, pumps and motors. In the construction phase materials have to be excavated, provided, conveyed and placed, needing a variety of equipment. Finally therefore, a survey is made of temporary works and equipment necessary for constructing a water supply projects, that may include weirs, dams, tunnels, pipelines and structures such as pump stations.

1. Introduction

The functioning of hydraulic structures in water projects is totally dependent on equipment of the civil, mechanical and electrical kind. To deliver water all reservoirs and dams need to have outlet works with controllable valves and screened intakes. To convey water to higher lying areas, pumping stations equipped with pumped motor sets are needed.

To develop hydro-electric power turbines and generators are necessary. Power transmission lines connect these stations to electricity supply grids and transformers and switch gear convert voltages from high to low tension and back as required. System pressures are maintained by booster pumps and flow rates are controlled by valves. Flow rates and water levels have to be recorded and data transmitted.

Not only in the execution of their functions are hydraulic structures dependent on sophisticated mechanical and electrical equipment, but also in their construction in the first place. For a large waterworks construction such as a dam, a power house, a pumping station, tunnels, canals and pipelines a wide variety of temporary construction plant, highly mechanized and electrified, is necessary. This requires expertise in the gathering, handling, transporting, processing of materials such as rock, sand, clay, concrete, timber, plastics, steel, etc.

Excavating, crushing and compacting equipment, screening, batching, and mixing plant, transportation and placing apparatus are required, besides the variety of supporting equipment of temporary nature such as washing and cooling plants for conditioning aggregates, dredges and pumps, construction with water supply and treatment, craneage, belt conveyors workshops and stores.

To perform duties both these temporary as well as permanent installations require the resources of trained professional personnel; mechanical and electrical engineers, office personnel, service staff such as workshop foremen, artisans and labourers. A closely integrated "systems-approach" is needed to perform these duties timeously, economically and safely, through all stages of planning, design, implementation, service and maintenance.

A review of these items by categorizing them will be given in the following sections, considering it from the point of view of a *community water supply project*, emphasising the importance and function of each category of mechanical and electrical piece of equipment. To logically develop the scenario, the presentation given in the appendixes commences with describing the permanently installed equipment and concludes with reviewing the antecedent construction phase and the use and re-use of temporary equipment.

2. Design Philosophy

Sound design involves both the creation of hydraulic structures capable of performing the necessary storage and controlling functions, as well as ensuring that the water supply will be adequate to provide for the needs of the community. In the following will be discussed the elements of project design, water resource estimation, ground water extraction by means of bored water wells, dams and weirs, water quality, pumping station and equipment, pipelines, storage reservoirs and elevated tanks.

2.1. Project Design

Projects should be designed for simplicity of operation, affordability, upgradability, maintainability, robustness, and for sustainability. The project design is intended to allow for expansion, to include other communities at a later date to be supplied from the same source. In addition, this will mean that if there is a request for a higher level of service, then only the pipes additional to those already provided for the minimal standpipe service need to be supplied. The additional costs should then be affordable to the community, since expenditure on upgrading the existing basic infrastructure would not be required.

- *Service Providers*. The water service providers must be identified, and their ability assessed before going on to design. Other important factors to be considered when designing a water project is the availability of trained staff to operate, maintain, and administer it. Many community water supply schemes, especially those funded through reconstruction and development programs, are in rural areas and are going to be operated by emerging local authorities with little technical capacity.

- *Design Lifetimes and Capacities*. Projects should be designed to minimize the life-cycle cost. For this reason pipelines and reticulations are designed for 60 litres per capita per day (lcd) for a ten year design horizon at a 2.5 percent growth rate per annum, whilst pumps, reservoirs and treatment works are also designed for 60 lcd (but based on a design horizon of five to ten years at 2.5 percent per annum growth rate). The difference in design water usage between the two forms of infrastructure allows for the fact that, whereas pumps, reservoirs and treatment works can be upgraded easily, pipelines and reticulations cannot, and hence the higher standard, allowing for a longer lifetime for the latter.

Exceptions. Exceptions apply for projects supplied by groundwater, where a minimum standard using 25 lcd for a ten year design period is acceptable for the bored water-well pumps, pumping mains and storage only. The reticulation is, however, still designed for 60 lcd (ten-year design horizon). The design criteria are not applicable to township or village developments where complete house connections are to be provided at the outset. Notwithstanding the guidelines given in this document, the professional responsibility remains with the consulting engineer in regard to the choice of design criteria.

2.2. Water Resource Estimation

A common cause of project failure is the overestimation of the availability of water. Care must be taken that the underlying assumptions of the water supply availability estimates are proven, especially in the cases of ground water and where river abstraction is not controlled by a significant amount of upstream storage.

Raw water should be available 98 percent of the time. There should not be interruptions of more than seven days in a year, and these seven days must not be consecutive.

- *Project Layout*. It is an important consideration for each project that all apparently technically viable alternative layouts, that can meet the project needs in terms of supply be identified. Two or three alternative layouts should be evaluated in terms of their cost, technical feasibility, economic viability, social and biophysical impacts.

Before preliminary design is proceeded with, the proposed project layout for the ultimate choice should be approved by all decision-making parties, before proceeding with the detailed design. In general, gravity schemes are preferred to pumping schemes for community water supply on the grounds of dependability and lower overhead and running costs.

3. Ground Water Extraction by Means of Bored Water-wells

For smaller scale projects, especially in semi-arid regions where surface water may be scarce, or too costly to gather and store, recourse is generally made to underground water extraction of which there usually is an adequate supply (see *Ground Water Data Acquisition Methods and the Siting of Water Supply Wells*).

3.1. General Considerations

A minimum of two equipped bored water-wells are to be provided for a village water supply. This means that if a village requires only one bored water-well to meet the demand, then a standby bored water-well must still be provided. The equipment of the standby bored water-well can be a pump station or hand operated pump, as appropriate.

For domestic consumption the water quality from a bored water-well must be tested by an approved laboratory for the key parameters as given below. The following key parameters are the main indicators for groundwater acceptability:

Nitrates, NO_3 as N	6mg/l	to	10 mg/l
Fluorides, F	1.0 mg/l	to	1.5 mg/l
Chlorides, Cl	100 mg/l	to	200 mg/l
Total dissolved Salts (TDS)	450 mg/l	to	1000 mg/l
Faecal coliforms (FC)	0 count/100ml	to	1 count/100ml

3.2. Ground-level Storage

If a *ground level storage* can be located close to the village and could provide the required residual head for the reticulation, then 36 hours to 48 hours storage at 60 lcd should be provided, according to the number of bored water-wells utilized.

However, if achieving the minimum residual pressure requires an *elevated tank*, then it is recommended that the ground level storage be omitted. The elevated tank should only be sized for 16 to 24 hours at 25 lcd supply (ten years design horizon), and the bored water-well pumps will then have to pump directly into the tank. An elevated tank so sized will be adequate in the short term and will be a suitable investment for use as an elevated tank in conjunction with added ground level storage at some future date (see *Ground Level Reservoirs and Elevated Storage Tanks*).

3.3. Groundwater Investigations

The provision of potable water to communities relies substantially on the successful development of groundwater resources to the required minimum standards. Since groundwater is a hidden resource not amenable to direct observation, some level of exploration or assessment is usually necessary for the establishment of an extraction system (single bored water-well or well-field). The scope and detail of an investigation depends upon its objectives, the size of the study area, prevailing groundwater potential, and the *record and standard of previous exploration and development programs* (see *Ground Water Data Acquisition Methods and the Siting of Water Supply Wells*).

Poor standards of workmanship, of assessments of groundwater potential and inadequate record-keeping in previous exploration and development programs, in addition to poor operation and maintenance practices, are often the main causes for the failure of groundwater extraction systems as sustainable sources for community water supply. Following prescribed guidelines as presented elsewhere may be a step towards rectifying and preventing the repetition or errors made in the past (see *Guidelines for Sustainable Community Water Supply and Sanitation Projects*).

The establishment of potable groundwater sources for community water supply, entails hydrogeological investigations and the drilling and test-pumping of existing and new bored water-wells. All these actions are to be executed in close liaison with local authorities and communities as well as social development agencies and civil engineering services.

It is imperative that the establishment of potable groundwater sources be executed by experts and be placed under the controlled supervision of qualified and experienced hydrogeologists, (geologists, geophysicists and hydrogeological technicians). The general project flow diagram and responsibilities of the hydrogeologist are presented in the guidelines referred to previously.

Identification and recommendation of source development programs are required, with regard to the evaluation and/or rehabilitation of existing bored water-wells and the establishment of new groundwater sources. In addition, it is required to document the preliminary condition and the required refurbishment of engineering works. The hydrogeologist is responsible for ensuring that project funds are utilized in the most cost-effective manner to establish a sustainable water supply.

Prior to the establishment of new ground-based water supply sources (siting, drilling and testing of bored water-wells) it is essential that the prevailing groundwater potential, water quality, and the construction and safe yield of existing bored water-wells be confirmed. This may require test-pumping of existing bored water-wells, rehabilitation, reaming or re-drilling of bored water-wells and chemical analysis of water samples, regarding the condition of existing bored water-wells. Establishment of the reliability and availability of documentation, with regard to potability and sustained delivery rate, is essential.

3.4. Groundwater Quality Assessment

The hydrogeologist is responsible for the health-related water quality assessment of all groundwater sources intended for domestic use. A health-related water quality assessment guide was developed by the Institute of Water Quality Studies.

These guidelines recognise four classes of groundwater quality for domestic use, identified as classes 0, 1, 2 and 3. These classes apply to untreated water, which represents the quality of water obtained directly from a bored water-well. In qualitative terms, class 0 represents an ideal quality of water, class 1 a good quality of water, class 2, water which is safe for short term use only, and class 3, an unacceptable quality of water.

3.5. Bored Water-well Siting

Bored water-well sites are located in, nearby or at a distance from the user. The hydrogeologist has to ensure that appropriate, scientifically based methods (in relation to prevailing hydrogeological conditions) are applied to identify drilling targets for exploratory drilling. These are needed to establish production bored water-wells and/or to provide for aquifer monitoring facilities. In addition to hydrogeological aspects, bored water-well sites are selected in accordance with and observance of the existence of artificial structures (roads, pipelines, cemeteries, sewage plants, overhead power lines, buildings) to ensure safe working conditions, and to limit the risk of pollution entering the groundwater abstraction facility. Bored water-wells should be sited a minimum distance of 15m from any power line.

3.6. Supervision of Drilling and Administration of Drilling Contracts

The hydrogeologist is responsible for ensuring that bored water-wells are drilled, designed and constructed and equipped to the required standards by controlled and on-site supervision of the drilling rigs. One supervisor has to supervise at least two drilling rigs, up to a maximum of three. On-site supervision by the hydrogeologist of all drilling operations is required during:

- Set-up of rig on drilling site.
- Installation of casing (plain or perforated).
- Bored water-well construction, besides written on-site instructions by the supervising hydrogeologist.
- Bored water-well development on completion of its construction.

Measurement and recording of the following statistics are necessary:

- Final air-lift yield (measured after at least 30 minutes air-lift testing.
- Final bored water-well depth (measured after final air-lift test.
- Measurement of installed steel casing depth utilising a suitable-casing detector.
- Taking of water-samples for limited chemical analysis (pH, TDS, NO_3 and F).
- Capping and numbering of bored water-well.
- Auditing of bored water-well construction, by geophysical bored water-well logging or video inspection (bored water-wells not meeting required standards will have to be re-drilled or reconstructed at the contractor's expense).

4. Dams and Weirs

Where a dam is built for bulk water storage, and the water is released down river, it may be necessary to construct a weir at the point of abstraction. The purpose of the weir is to provide limited balancing storage for the bulk releases from the dam. Weirs can also be constructed to store limited amounts of runoff, or, by allowing the basin to be filled with alluvial material, to create a reservoir from within the alluvial sand of which water can be abstracted.

In the case of weirs, siltation is a far greater problem than in the case of large- or medium-sized dams. This problem needs to be recognised, and the outlet works and abstraction points need to be kept free of silt.

Weirs, generally being of a limited height and capacity, will be over-topped by large floods. They will therefore need to be constructed of concrete or other non-erodible material. An ideal site for a weir is one where both the river bed and the abutments consist of good quality rock.

More usually the weir is founded on rock in the river section and one or both of the abutments will be situated on soft river-bank materials, In that case special measures are required to prevent the outflanking of the structure by floods. The design of weirs should be undertaken and supervised, by competent engineers who are conversant with the particular problems associated with these structures.

4.1. Outlet Pipe Systems

The design of dam outlet-pipe systems varies depending on the set volumes of water demand to be supplied from the dam or weir, thus determining the outlet pipe diameters and outlet configuration. It is, however, important to provide dual-system outlets in order to ensure a continuous outlet from such water sources, the reason being that a back-up system should be available, when repair or maintenance of the main supply pipeline is required.

At the most upstream point of the outlet-pipe system, emergency closure by means of underwater wall-type spindle-driven sluice gates (operated by manual actuators) may be employed, but only if the size of the outlets is in excess of 600 mm in diameter. Water directly drawn from the dam to the water treatment works should come from the upper 1.2 m layer of the reservoir.

Depending on the size of the outlet pipe systems, the option of specifying high-density polyethylene (HDPE) pipe-work is acceptable for small dams, provided that these are of an approved standard and pressure rating, and only subject to the approval by the Engineer. For small dams and weir applications, reducers and pipe-work directly adjacent to valves, shall be fabricated in steel.

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Biographical Sketches

Ron Chantler holds the degrees B.Sc.(Hons.) Mechanical Engineering (Manchester) and Electrical Engineering (University of the Witwatersrand, Johannesburg) and is a Chartered Engineer (UK) and Professional Engineer (RSA). His professional experience includes five years as Design Engineer on Nuclear Power Plants in the UK and thirty five years as Professional Engineer (Mechanical and Electrical) with the Department of Water Affairs, South Africa. Publications include the proceedings of a Conference on Early Flood Warning Measures, Reports on Flow Metering and Guidelines for Equipping Dams with Flood Gates.

Jan Jordaan was born in Cape Town and raised in Bloemfontein and Pretoria, South Africa. He obtained his B.Sc. Eng. Civil at the University of the Witwatersrand, Johannesburg in 1952, and joined the Irrigation Department of South Africa, now known as the Department of Water Affairs and Forestry. While on study leave from 1953 to 1958, he obtained the SM Degree at the University of Wisconsin, USA and the CE and Sc.D. Degrees at the Massachusetts Institute of Technology, USA. After completing his post-graduate studies, he returned to South Africa, resuming work with the Department of Water Affairs in Pretoria until 1959. He then joined the South African Council for Scientific and Industrial Research as a Research Officer until 1963, being involved with mainly coastal engineering research and applications.

Subsequently, he worked for the US Naval Civil Engineering Laboratory, Port Hueneme, California, until mid 1965 as a Senior Research Engineer on ocean wave research. There after he joined the University of Hawaii as an Associate Professor in civil engineering and tsunami research, from 1965 to 1968. He occupied the same position at the University of Delaware from 1968 to 1969. He thereupon resumed employment with the Department of Water Affairs, Pretoria where he was active in hydraulic engineering design for the major part of 28 years until his retirement in 1997, as Chief Engineer Design Services. During this period he was assigned to the P.K. le Roux Dam and Van der Kloof Canals Construction Project for two years; and for seven years in the Namibia (former South West Africa) Branch of the same Department as Chief Engineer Investigations, dealing with water resources, hydrology and construction.

In 1985 and 1987 he was temporarily seconded to the Department of Foreign Affairs, and acted as Technical Assessor in Bolivia for the Misicuni Hydroelectric and Water Supply Project for Cochabamba Department. He was also sent on foreign duty in Grenoble, France in connection with their model studies of the Lesotho Highlands Water and Power Project. He also visited Britain, Spain, Portugal, Germany, Norway, The Netherlands, Hungary, Egypt and the Sudan, China and Taiwan in connection with official duties.

He is a registered Professional Engineer in South Africa, a Fellow of the South African Institution of Civil Engineers, Member of the American Society of Civil Engineers and Member of the International Association of Hydraulic Research. From 1989 until 1998 he was part-time Professor of Hydraulic Engineering in the Department of Civil Engineering of the University of Pretoria. His major publications include a chapter in "Advances in Hydroscience", 1970, Academic Press, USA, on laboratory experiments with impulsively generated water waves; co-authorship of "Water in our Common Future", COWAR, UNESCO, 1993; editorship of the SANCOLD volume "Large Dams and Water Systems in South Africa", 1994; co-authorship with D. Batuca of "Silting and Desilting of Reservoirs", 2000, Balkema Publishers, The Netherlands.