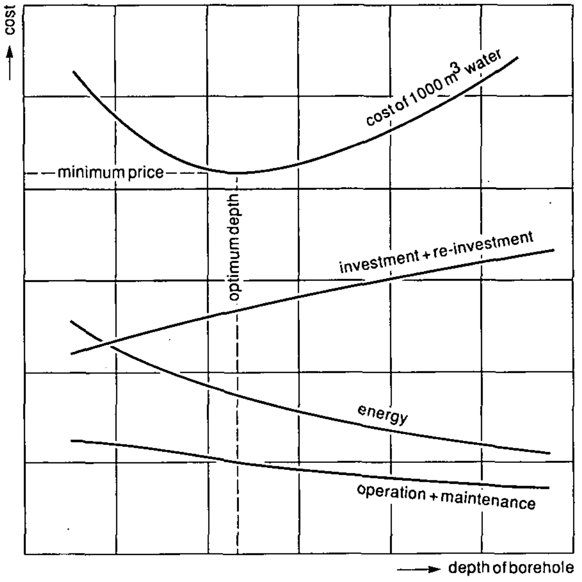

Figure 22.10 Costs of 1000 m^3 water as a function of borehole depth

lowest price. With increasing screen lengths, investment costs rise but the drawdown and the pumping costs fall. The cost per m^3 of water first decreases, owing to the decreasing head losses caused by the decreasing partial penetration of the aquifer, and consequently leads to lower pumping costs. Having reached a minimum, the price of water rises because the decreasing energy costs in the borehole no longer compensate for the higher investment costs. The calculations are repeated for different screen diameters, screen types, pump engine, and types of energy. Figure 22.10 shows the relation between the cost of water, investment and re-investment costs, energy costs, and operation and maintenance costs.

Finally, the design with the lowest costs per m^3 drainage water is selected. Obviously, the more types of screens, engines, pumps, and energy available, the better the results of the optimization procedure will be. The number of calculations required to arrive at a final result is large and complex and can best be handled by an optimum well-field-design computer program.

22.6 Maintenance

22.6.1 Borehole

The performance of a well usually declines after some years of operation, resulting in higher drawdowns and higher pumping costs. The well is in need of rehabilitation when the specific capacity of the well (i.e. the yield of the well per metre drawdown) becomes so small that the pumping costs increase or the discharge rate of the well can no longer be maintained. Before that time, the well needs to be rehabilitated.

A detailed description of the causes of well deterioration and measures for well rehabilitation will not be presented here, but can be found in literature (e.g. Driscoll 1986).

An effective well-maintenance program begins with good records being kept of the well's construction, including good records of the geological conditions, the position and types of aquifers and aquicludes, water quality, and the specific capacity of the well, determined during well testing. In an irrigation-drainage project, storage of these data in the operating agency's computer data bank is a highly recommended investment.

Every type of well requires its own maintenance program. To evaluate the performance of a well, Driscoll (1986) gives the following checklist:
- What is the static water level in the well?
- After a specified period of pumping, what is the pumping rate and the water level expressed as specific capacity, and what is the ratio of the pumping rate and the drawdown?
- What is the sand content of the pumped water?
- What is the total depth of the well?
- What was the original specific capacity of the well?

A significant decrease in specific capacity or an increase in the pumping of sand indicates that the well needs rehabilitation or restoration to its original performance. In general, rehabilitation measures are most successful when the well performance has not deteriorated too badly, or the specific capacity has not decreased too much. If the specific capacity of the well has declined by 25%, it is time to carry out a rehabilitation program.

In order to determine the right moment for well rehabilitation, periodic monitoring of well performance should be done in the term of short standard tests. Complete well records can be kept at relatively minor expense, and these are indispensable in determining the causes of well failure and selecting the maintenance and rehabilitation program.

The major causes of a reduction in well performance are:
- A reduced well yield due to chemical encrustation or clogging of the screen due to bacteriological activity;
- Plugging of the formation around the well screen by fine particles of clay and sand in the pores;
- Pumping of sand due to poor well design or corrosion of the well screen;
- Collapse of the well screen due to chemical or electrolyte corrosion of metal well screens.

Chemical and biological encrustation are major causes of well failure. Water quality and flow velocity through the screen openings determine the occurrence of encrustation. Chemical encrustation is caused by the precipitation of carbonates, mainly calcium carbonate, or iron hydroxides, which block the screen openings. Carbonate precipitation is caused by the release of carbon dioxide from the water owing to a pressure decline in the water caused by the drawdown in the well.

Iron dissolved in groundwater may precipitate from the water on the well screen because oxygen is introduced into the water when the well is pumped. Another reason for the precipitation of iron may be the presence of iron bacteria in the water.

The complete prevention of encrustation of well screens is impossible. The process can be retarded by low flow entrance velocities through the well screen openings (see Table 22.3), lower pumping rates, and longer pumping times per day.

Chemical encrustation can best be removed by treating the well with a strong acid solution that chemically dissolves the encrusting materials so that they can be removed from the well by pumping. Hydrochloric acid and sulphuric acid can be used.

Chlorine, a strong oxidizing agent, inhibits the growth of iron bacteria. The use of hypochlorite is a relatively safe and convenient alternative to chlorine gas. The occurrence of iron bacteria in wells can be prevented by disinfecting the well and the pump immediately after installation.

Physical plugging by clay and silt particles can best be prevented by proper well development after the well screen has been installed. The removal of fine particles from the formation immediately around the screen can best be achieved by washing and brushing the screen with dispersing compounds such as sodium tripolyphosphate (STP) and other types of polyphosphates.

The corrosion of well screens can severely reduce the lifetime of a well. Chemical corrosion occurs especially when metal well screens are used in aggressive and saline water loaded with gasses like hydrogen sulphide, carbon dioxide, and oxygen. Corrosion can be prevented by applying non-metal screens or, when the water is not aggressive, only metal screens of stainless steel and low-carbon steel.

22.6.2 Pump and Engine

To pump water from a tubewell in the most economic way, the sound operation of pumps and engines is a prerequisite. For pumps to operate properly under less than ideal physical and chemical conditions, and especially when pumping brackish and saline drainage water, they must be properly maintained. Pump and engine manufacturers prescribe periodical maintenance of their products. A complete analysis of pump and engine maintenance is beyond the scope of this book, so readers are referred to the maintenance procedures specified by manufacturers. Maintenance procedures depend on the pump type. They include the adjustment and replacement of impellers, bearings, stuffing boxes, and bowl assemblies.

Decreases in discharge rates are caused by the wearing of parts in the pump and by leakage in the pipes bringing the water to the surface. Only a few problems relating to deficiencies in well design will be discussed in this section. Driscoll (1986) gives the following checklist to determine the condition of the pumping unit in vertical turbine and submersible pumps:

- Do the water pressure and the discharge rate of the well deviate from the original design curve of the pump?
- Is the motor over-heating?
- Is there an unusual sound like a higher bearing-noise level?
- Is the motor using more oil?
- Is there excessive vibration?

- Is there a change in the ampere or voltage load to the pump?
- Is there any cracking or uneven settling of the floor around the pump?
- Is there sand in the pumped water?

Sand pumping causes the abrasion of pump bowls, which leads to failure of the pump. Sand pumping results from:
- Over-sized slots in screens;
- Over-sized filter pack;
- Corrosion of the well screen;
- Inadequate development of the well;
- Too high entrance velocities, causing the transport of sand from the formation towards the well.

One of the above conditions, or a combination of them, results in sand from the formation entering the well. Remedying this problem may be uneconomic. It may be better to drill a new well. The best alternative, if possible, is to replace the screen or to place an inner screen inside the original well screen.

Pumping bowls may be damaged by cavitation due to the occurrence of bubbles of water vapour in the water. This causes pitting of the impeller. To prevent the destruction of impeller vanes by cavitation, pumps should be run at flow rates close to their maximum efficiency.

The corrosion of pumps and column pipes or rising mains by chemically aggressive groundwater damages the pumps and causes pipes to leak. Choosing pumps built of materials resistant to the quality of the water they pump should prevent this corrosion problem. Other measures may be the use of galvanic cells between steel shafts and impellers.

Overload conditions that lead to over-heating of the motor and excessive vibration may be caused by poorly adjusted impellers. Bearing wear may be caused by misalignment and the improper installation of the shafts.

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