EXPERIMENTAL ARTIFICIAL RECHARGE PONDS,

ALICE SPRINGS

GROUNDWATER BASIN - 1967.R5

G. PIDE

June, 1967.
SYNOPSIS

A summary of the design and use of artificial recharge facilities and the factors effecting their design and operation is presented in the following report. The status of the Alice Springs Town Basin in relation to recharge is briefly discussed.

Recommendations are made for the construction of ten experimental recharge ponds. Their proposed designs are presented in the appendices.
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INTRODUCTION

Artificial recharge may be defined as the augmenting of natural infiltration of precipitation or surface water into underground formations by some method of construction, spreading of water or by artificially changing natural conditions. Throughout this report, artificial recharge will be referred to as recharge. Methods of artificial recharge discussed in this report include the use of basins, pits, recharge wells, trenches and flooding.

Artificial recharge has applications in many situations including:

(a) the increasing of available water supply from groundwater basins
(b) the disposal of excess water
(c) the prevention of salt water intrusion

In order to evaluate recharge, it is necessary to understand principles of the flow of water in soils and the factors affecting recharge. Design of recharge facilities must be compatible with these factors as applied to specific regions. It is this aspect alone that can be termed experimental.

Although there are only a few facilities in Australia, in other places in the world artificial recharge is being used extensively; many facilities having been in operation prior to the 1920's. The ever increasing demand for water by expanding populations and the consequent overdraft of a large number of groundwater basins, has been responsible for the rapid advance of recharge technology in the last few years.

If artificial recharge can be successfully applied in the Alice Springs district, it will increase substantially the available yield from the Alice Springs Town Basin with a consequent decrease in the cost of water to the consumer.
TYPES OF RECHARGE FACILITIES

A considerable number and variety of recharge facilities have been constructed throughout the world. They may be classified into two (2) major types, those that spread water onto the land surface and those which inject water underground. Spreading techniques cover flooding tracts of unused land, use of excess water in irrigation and use of basins formed by dykes. Injection methods involve the removal of soil to expose coarse or aquifer material. Some methods used are basins, trenches, pits, bores and wells.

BASINS.

Based on Californian experience, surface recharge basins are the most popular type of recharge facility. Basins consist of shallow

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<tr>
<td>2 Coyote</td>
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<td>55.0 *</td>
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<td>3 Ford Road</td>
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* Confirmed by actual operation.

Table 1: Recharge Basins - Santa Clara Valley

trench of depth between one (1) and ten (10) feet, of area from half an acre to several hundred acres. Some basins continuously recharge in the order of three hundred (300) acre feet per day.

The Santa Clara Valley County Authority in California is at present constructing sixteen (16) ponds with a total area of four hundred and ninety (490) acres. These ponds will be used in conjunction with sixty-five (65) acres of natural stream bed, to recharge one hundred and twenty thousand (120,000) acre feet of water per annum. The area and percolation rate at each of these basins is shown in Table I.

**PITS.**

When the depth of a basin is greater than ten (10) feet it is called a pit. With pits, the major portion of recharge is through the walls.

Disused quarries have been successfully used in many places. Their advantage lies in the size of surface storage available allowing greater hydraulic heads and their direct contact with aquifers.

Grill Pit in Santa Ana, California, covers an area of sixty-four (64) acres and has an average percolation rate of three (3) vertical feet per day. Over an eighteen month period, twenty-five thousand (25,000) acre feet was recharged, the depth of water in the pit ranging between twenty (20) and fifty (50) feet.

**WELLS AND BORES.**

When the base of a pit extends below the water table the pit becomes a well. Bore are small diameter wells.

Theoretically recharge by injection into wells and bores should be highly successful however, this has not been borne out in actual practice. Many field measurements indicate that recharge rates are substantially lower than discharge rates for the same well. There is a tendency to consider that a recharge well is a production well in reverse. This is an incorrect assumption. A large number of projects have failed since they have used 'production' wells instead of correctly constructed injection wells. The main factors controlling the effectiveness of recharge wells and bores, are the suspended solids content of

2. J. Toups - Spreading for Groundwater Recharge in the Orange county Water District.
the recharge water and the rate at which the formation will safely accept water. Wells and borings require a recharge water practically free from suspended solids. If these are present the facility will clog in a short period.

A successful project utilizing nine (9) bores in the Ventura County, California, has recharged fifteen hundred (1,500) more feet of water over ten (10) months. The average injection rate was 0.75 cusecs, the maximum rate being three (3) cusecs when the water table was low.

MODIFIED STREAM BED.

One cheap method of recharge is to increase the percolation in river channels. A common technique is to spread the river flow over as much of the surface of a stream bed as is possible. This may be achieved using level crested weirs extending across the channel spaced at selected intervals. In the case of ephemeral streams, grassing and scarifying have also been used successfully.

The Santa Ana River spreading grounds in California consist of six (6) miles of river channel varying in width from five hundred (500) to one thousand (1,000) feet with a slope of approximately seventeen (17) feet per mile. A series of low weirs were constructed at half mile intervals to spread the stream flow across the full width of the channel. Spreading in the river has been as high as twenty thousand (20,000) acre feet per month.

TRENCHES AND DITCHES.

A basin which is less than ten (10) feet wide is described as a trench. A ditch is merely a shallow trench.

Large quantities of water in relation to the size of the facility may be recharged using trenches and ditches. As capital and maintenance costs are high, this method is generally only used with small projects. The facility may consist of an open trench excavated in a stream bed or other highly permeable areas or a trench with a refined filter intake system. On the high Plains in Texas, a trench six hundred (600) feet long with a 0.1 foot grade per one hundred (100) feet was excavated in the bed of a channel and a fifteen (15) inch steel shelter screen, five hundred and four (504) feet long was placed in

1. M. Price - Groundwater Recharge Activities in the United Water Conservation District of Ventura County, California.
2. J. Toups - Spreading for Groundwater Recharge in the Orange County Water District.
the trench on top of a six (6) inch layer of gravel. A thirty (30) inch thick filter consisting of pea gravel varying from 1/16" to ¼" in diameter was placed over a layer of large sized gravel. This trench was capable of recharging eight (8) acre feet per day.

FLOODING

This method can be successfully used when large quantities of water and a considerable land area is available. Evapo-transpiration losses are generally high. It is desirable that the quality of the recharge water is good, otherwise salt deposition can be a major problem. Excessive irrigation of croplands with surplus surface water has been carried out in many areas.

1. L. Schift - Groundwater Recharge Methods based on Site Characteristics and on Sediment in Floodwater.
FLOW OF WATER IN SOILS

Before we discuss the movement of water through a soil our terminology must be defined.

SOILS.

Soil consists of three (3) materials: solids, liquids and air. The physical characteristics of each of these materials directly affects the flow of water into and through soils. In some cases, their chemical characteristics also affect the movement through soils.

TEXTURE.

The primary soil particles are designated by textural groups, these being gravel, sand, silt and clay. Texture is the classification of particle size and average particle size.

STRUCTURE.

Soil structure refers to the degree to which individual soil particles are grouped together to form aggregates.

VOID WATER.

The volume of a soil occupied by the liquid and air phases is called the void space. Water in the void space is called pore water. A soil may be classified as dry, saturated or partially saturated according to air-water ratio. When a soil is 'dry' the voids are filled with air only. This is an unusual state which rarely occurs. Soils which are normally described as dry, generally contain some water. These soils are partially saturated. A saturated soil is one in which the voids are completely filled with water.

CAPILLARY WATER.

Water rises in a small diameter tube to a height where the weight of the liquid balances the differences in attraction between the adhesive force (liquid and tube material) and the cohesive force (the force between two of the liquid molecules). Similarly water rises in the void space by the same mechanism and is called capillary water.

CAPILLARY FRINGE.

Capillary fringe water is that water rising above the saturation zone by capillary forces. The amount of water in storage in the capillary fringe depends on the height of the fringe and porosity of the soil.
Capillary rise is higher in the case of falling water table than in the case of a rising water table due to large irregularity in the size of the soil openings (voids). The capillary fringe ranges in thickness from a few inches in coarse sands to several hundred feet in loams. Fringe flow occurs as vertical capillary flow and vertical gravity flow.

WATER TABLE:

The water table is the level at which the water pressure is at atmospheric. Under equilibrium conditions, above the water table water is maintained in place against the force of gravity, by capillary attraction and surface tension. Below the water table, pore water is under normal hydrostatic head, the pressure increasing with depth, as in free-standing water.

LAMINAR FLOW:

As the velocity of water particles is usually extremely low and the passageways are small, subsurface flow is nearly always laminar.

VISCOOSITY:

The viscosity of a fluid is its internal fluid friction. Viscosity varies with temperature, an increase in temperature lowers the viscosity of liquids but raises it for gases.

INFILTRATION:

Infiltration is the entry of water into a soil. It occurs by gravity and capillary absorption. Infiltration rate is the rate at which surface infiltration actually occurs in a given time and has the dimensions vol/unit time/unit area. The infiltration rate may be limited by any restriction to the flow of water through the soil profile. Although such restrictions often occur at the soil surface, it may occur at some point in the lower zones of the profile. The rate depends on the water availability and may be any value up to the infiltration capacity.

INFILTRATION CAPACITY:

Infiltration capacity is the maximum rate at which infiltration can occur at the land surface at a given time. Field capacity is the amount of water that soil subjected to excess infiltration, will retain against the pull of gravity. Water will not flow through a zone until the field capacity has been satisfied.
HYDRAULIC CONDUCTIVITY.

The ability of a soil to transmit water is referred to as the porosity rate or hydraulic conductivity. The hydraulic conductivity of a soil depends on its texture, structure and the density and viscosity of the fluid. The particle size of soils (its texture) may be fine, medium or coarse. Structure is the shape and arrangement of the individual soil particles. Structure is good or poor depending on whether the structure lends itself to the rapid water movement.

FLOW OF WATER IN UNSATURATED SOIL.

Soil moisture moves under the influence of the gravitational force and the force resulting from difference in capillary potential.

As the top soil becomes wet from infiltration, soil moisture will move downwards under the combined influence of the capillary and gravitational force.

Moisture advances downward in a "wetting zone" in which the capillary potential gradient is very steep. This wetting zone will extend twelve to thirty inches below the ground surface, depending upon the type of soil, before the surface soil will attain a moisture content as great as the field capacity. As the wetting zone continues downwards, the layer of top soil which has attained field capacity gradually increases in thickness.
FACTORS EFFECTING RECHARGE

The three main factors effecting recharge are: available storage, percolation rate and infiltration rate. These three factors are mainly controlled by the characteristics of the soil and recharging water.

AVAILABLE STORAGE.

A major consideration with recharge is the storage capacity of a groundwater basin and the extraction from the basin in the short term and long term views. If there is storage space available then the groundwater basin has a capacity to be recharged. An empty basin will accept recharge at a greater rate than a partially full basin.

Highly porous formations surrounding a recharge facility will enable large quantities of water to be recharged by virtue of its storage capacity if the water table is low. For example, consider an area of one hundred (100) acres, with an average infiltration rate of five (5) feet per day for twenty (20) days. Based on a specific yield of ten per cent (10%) one thousand (1,000) acre feet could be recharged if the alluvium was one hundred (100) feet thick.

PERCOLATION.

As discussed earlier, the percolation rate through a void depends on the texture and structure of the soil and the density and viscosity of the recharging water. Water flows slower through a clay loam than it does through a sandy loam because the pore through which water moves in clay soils is much smaller than in sandy soil. It is also apparent that the shape, and stability of the arrangement, will have a marked effect on the permeability of a soil.

GROUNDWATER MOUNDS.

When the percolation rate of a substratum is less than the infiltration rate a 'mound' will develop and can restrict the infiltration rate when continuity of flow to the surface exists. The mound is a zone of saturated soil hence the surface of the mound defines a water table.

Figures 1a, 1b and 1c show the development of a mound moving upward and laterally as the recharging water reaches an impeding surface. If lateral flow is not great enough, the mound will build up and contact the short saturated column extending down from the surface. When this occurs, the infiltration rate declines and is controlled largely by the
A. PRIOR TO RECHARGE

B. DEVELOPMENT OF MOUND

C. MOUND DEVELOPED
SEDIMENT CLOGGING.

A major problem that confronts any recharge programme is the suspended sediment load in the recharge water. With highly turbid water, percolation beds can be effectively sealed in a short time after commencement of operations. Even with water with a small suspended sediment load there is a gradual accumulation of silt on the percolation beds with a corresponding loss in the rate of infiltration. A skin \( \frac{1}{2} \)" thick will effectively seal a basin.

The effect of the sediment load on the infiltration rate depends

- on amount of sediment load
- depth or deposition

Sediment deposition will either form a thin skin or clog the pore space of soil depending on the strata. Considerably more sediment is required to fill the pore space of a soil in comparison with the amount required to form a thin skin.

CHEMICAL CLOGGING.

Salts may frequently be precipitated on or near the soil surface. In recharge operations it is the slightly soluble salts such as calcium and magnesium that tend to precipitate. These salts precipitate due to evapo-transpiration and indirectly due to the resulting increase in soluble sodium, exchangeable sodium, and solutes pH. Salts which have precipitated on or in a soil reduce permeability by mechanical clogging of soil pores.

The permeability of silts and clays can be appreciably influenced by base exchange chemistry whereas sands and gravels are practically unaffected. If the sodium level absorbed on dry surface is high the clays and the aggregates become unstable and permeability is reduced. Clay, when partially sodium-saturated is highly dispersible in the absence of flocculating salts and tends to move downward and accumulates at lower levels in the soil. Where the clay accumulates, the soil develops a dense layer of low permeability.

BACTERIAL CLOGGING.

Organic material in recharge water will enable bacteria to thrive. Bacterial secretions can clog soil pores reducing permeability.
Permeability can be maintained when the interference between the soil and water is stabilised such that the soil particles are prevented from moving. Organic residue incorporated in the soil is decomposed by bacteria with subsequent reduction in the infiltration rate during the early stages of decomposition. However, with complete decomposition, the enlarged pores and dried secretions will improve soil structure and stability of structure thus, the infiltration rate will increase above the original level.

Bacterial activity generally only effects the first few feet of soil permeability.

**Vegetation.**

Vegetation particularly grasses increase the infiltration rate since they provide an excellent stable transition zone at the soil surface and the decomposition of roots provide small scale wells with high infiltration rates. Vegetation maintains an open, friable surface-soil with waters with a suspended load up to 550 parts per million.

**Entrapped Air.**

When infiltration occurs at near uniform rates over a large area, the air in the soil pores may be trapped temporarily. The downward movement of the sheet of water entering the soil compresses the air. There is evidence that air is not pushed out by the pressure of the infiltrating water but is gradually absorbed by the water. Entrapped air restricts flow by reducing the void volume that can be filled by the infiltrating water. As the air is absorbed, the infiltration rate will increase.

**Temperature.**

A rise in temperature will reduce the viscosity of the infiltration water, however, the rise in temperature will be accompanied by increased micro-organism activity and swelling of clays. It is possible that the nett effect of a rise in temperature is negligible.

**Inwash Materials.**

When soil is very dry the surface often contains many fine particles. When infiltration commences, these fine particles can be carried into the soil being deposited in the interstitial spaces.
DESIGN OF RECHARGE BASINS

Many factors which are detrimental to recharge can be minimized by good design of the recharge facility. To effect good design, the characteristics of the potential recharge site, the characteristics of the basin being recharged and the recharging water characteristics must be known in advance.

SITE SELECTION.

Recharge basins should be located over zones of high permeability where they will quickly transmit water to storage. Availability of suitable land is often a key factor in selection of sites.

SIZE AND SHAPE.

The size and shape of a basin is determined principally by three (3) factors: Infiltration rate, volume of water to be recharged and lateral flow characteristics. A shape with maximum surface area for the smallest embankment and least excavation is usually dictated by costs.

Generally there is only limited storage beneath a basin hence most recharge water must be dissipated in lateral flow.

Consider the case of a basin constructed over a reasonably uniform coarse textured soil and substratum materials which is sixty (60) feet thick overlying an impermeable bedrock. It would require twenty (20) acres of basins on such soil, taking water at four (4) feet per day over two months to achieve four thousand eight hundred (4,800) acre feet of recharge. Based on a specific yield of ten (10) percent, approximately ten (10) acre feet of water could be stored below the twenty (20) acres of basins between a depth of ten (10) and sixty (60) feet. The other four thousand seven hundred and ninety (4,790) acre feet would have to move laterally under adjacent areas.

Plan Shape:

Based on a ratio of perimeters, more lateral flow will occur if a number of spreading areas are used rather than one large area.

If in the case sited, ten, two (2) acre basins are used instead of one large basin, then more lateral flow will occur since the total perimeter of small basins will be considerably greater than the
perimeter of a single basin with the same area. Further, the lateral flow can be increased if the area is a rectangle rather than a square.

Section Shape:

Laboratory experiments have shown that higher recharge rates can be achieved using wedge-shaped rather than rectangular or trapezoidal shaped basins. This can probably be attributed to greater horizontal than vertical permeability, causing the side area of the pits to permit infiltration at a higher rate than the bottom. Also, silt which effects the entire bottom of a rectangular pit will only effect the apex of a moderately steep-sided wedge-shaped pit.

Side Slope -
Gentle sloping sides and fluctuating water levels are conducive to mosquito breeding, hence steep slopes in the order of 45° are desirable.

Depth -
High surface beds will increase the hydraulic gradient and consequently increase percolation. Ponding of water will cause suspended sediment to settle, thus a balance must be made between deposition of sediment and the increase in percolation rate with head.

FILTERS.

Sand and gravel filters have been successfully used in many basins. In some cases, filters have more than doubled the long term infiltration rates. The ratio of filter material to aquifer material in size appears to be a major factor in increasing the infiltration rate.

There are no fixed rules in selecting filter materials. It has been found that filters which are successful in some areas are not suitable in similar areas. The most suitable type for a particular area must be selected by experiment.

As indicated earlier, the deposition of suspended sediment load is a major problem with most recharge projects. Filters which allow the deposition of fine materials through a depth rather than in a thin plane can be constructed. However, the depth of sedimentation should be such as to permit economical cleaning by scraping or suction. Methods which cause the sediment to remain in suspension have also been used successfully. In one case, filtration rates were twice as great as

1. J. Lehr - Relation of Shape of Artificial Recharge Pits to Infiltration Rate.
when water flowed over a filter as when ponded on a filter. Raking the filter to a depth of half an inch (½") caused deposited fines to go into suspension and be carried away by the flowing water in another case.

DIVERSIONS, INTAKES AND OUTLETS.

Diversion facilities are of many types - temporary levees, slotted channels with automatic gates, radial gates, slide gates and permanent dams. Interbasin flow is generally controlled by slide gates or flashboard weir structures.

Intake structures should have a shut-off at the point where surface streams are diverted, as it may be desirable to prevent inflow during periods of extreme turbidity, rapid algae growth, undesirable water temperatures or when maintenance of the basin is being undertaken.

It is desirable that influent to a recharge basin enters near the bottom to prevent erosion of the sides. When this is not practical and flow enters above the water level, then the inflow channel should be paved or otherwise protected.

SCREENS.

If the water source carries floating or submerged coarse materials, screening of basin inflow is desirable. Self cleaning screens are best however, are not always economical thus simple trash racks are generally used.

FLOW MEASUREMENT.

It is essential that the quantity and quality of recharge water be continuously measured. The infiltration rate in all basins deteriorates with time. If a basin is to operate at optimum efficiency, then the characteristics of the basin must first be determined by analysing inflow and recharge data. The inflow can then be varied to maximise recharge.

Metering devices for measuring basin inflow may be weirs, parshall flumes, venturi meters, or any type of meter suited to the quality of the water and the hydraulics of the particular situation. The metering device should be equipped with recorders or totalizers.

DESILTING BASINS.

With most projects where potential recharge water has a high suspended sediment load stream stabilization measures are carried out, to reduce the sediment load at its source.
With recharge projects, a suspended sediment load in excess of five hundred (500) parts per million is considered high. Suspended sediment load can be reduced in a detention or desilting basin where the water is ponded for a short period.

Desilting basins are generally designed with a dual purpose. Firstly to settle out a large proportion of the suspended sediment load and secondly to act as a minor recharge basin. These basins are generally grassed to maintain an open friable surface soil even with high sediment loads. In some cases, water is routed through the basin prior to spreading to remove deposited silt.

They should be constructed with a slight up-slope from the entrance to the discharge end. This slope facilitates ponding, allows control of detention time and permits grasses such as bermuda grass to grow if a major portion of the plant remains above water.

**FLOCCULATION.**

In some cases chemical treatment to coagulate and settle the suspended solids in recharge water can be carried out economically. The flocculation chemical is generally discharged into a turbulent section of streams with sufficient length such that the chemical is thoroughly mixed with the turbid water by the time it reaches a settling basin. The flocculated silt particles are then allowed to settle out in the settling basin for periods in the order of one hour before the clarified water is discharged into a percolation pond. In the Santa Clara Valley turbid waters were salvaged for about $2.50 per acre-foot using a flocculant called Malco 600.¹

**CHEMICAL TREATMENT OF SOIL AND WATER.**

Treatments of soil and water are designed to enlarge soil pores, develop stable aggregates and promote continuity of large pores through less pervious soil layers and prevent chemical dispersion of soil particles.

Outstanding increases in infiltration rates have been obtained with a layer of cotton gin trash in the surface layer at the base of percolation pits.² The benefits are due to microbial decomposition of

the cotton gin trash following wetting and drying.

Where sodium is a major problem, benefits may be expected through the use of gypsum. Note that soil conditions are only effective for short periods.

**AUXILIARY FACILITIES.**

Auxiliary facilities may include fencing, landscaping of ground, laboratory facilities and test wells to check the effectiveness of the recharge operations and for taking groundwater samples.

**CONSTRUCTION.**

The construction procedure specified in the building of recharge basins should accord with the need to maintain the permeability of the proposed wetted area. Compaction of material below the water line should be avoided. It is desirable to dig recharge basins from the center outward, so that no equipment has to roll over finished surfaces. Clays or silts should not be deposited on the permeable areas.
THEORY OF RECHARGE.

Our definition of a recharge well is that it is a recharge facility which injects recharge water directly into the saturated zone. With surface recharge facilities, recharge occurs by infiltration into an unsaturated zone, thus the mechanics of recharge flow in bore or well is completely different.

Recharge wells have their own idiosyncrasies and characteristics quite distinct from those of production wells. Two production well characteristics, namely equilibrium at certain constant extraction rates and critical depth do not apply to a recharge well in a horizontal aquifer. For a steady rate of recharge in an unconfined aquifer the shape of the cone of impression does not remain constant but undergoes continuous flattening of its slopes as the mound it envelopes expands. Figure 2 shows this characteristic schematically. If the head in the recharge well is limited by the ground surface as is usually the case, then recharge will stop when the slope of the cone of impression is zero.

The groundwater mound created through recharge of an open horizontal aquifer moves away from the centre of recharge radially in the form of a wave. The velocity of this wave may greatly exceed the velocity of the groundwater particles. An observation well, quite remote from the recharge well may register a rise in the water table long before any part of the recharge water has reached the observation well.

With an inclined aquifer a recharge well can attain equilibrium. A point of stagnation will be established upstream from the recharge well and a stream will emanate on the downstream side.

The operation of a water well in an unconfined aquifer is always governed by atmospheric pressure however, a recharge well can be operated under any arbitrary pressure so long as the flow from the well remains laminar.
DESIGN OF RECHARGE WELLS

As previously indicated, a recharge well cannot be considered to be a pumped bore in reverse. This factor and the critical requirement that the recharging water be virtually free from suspended solids, have resulted in the failure of a considerable number of recharge projects using injection wells.

Well recharging is practicable where deep confined aquifers must be recharged, or where economy of space, such as in urban areas, is an important consideration.

Since there has only been limited success with injection wells, their use has mainly been limited to specific problems such as the restriction of salt water intrusion and the recirculation of water drawn from underground sources. However, in areas where optimum requirements can be satisfied, correctly designed recharge wells could be used in a much wider range of recharge projects.

LOCATION

Where the primary aim of a recharge well is to increase the available water in a groundwater basin, then the recharge well should be sited similarly to that for a production bore, that is, where there are zones of high permeability and transmissibility. Where recharge wells are used for specific purposes such as salt water intrusion, a series of wells may be required in order to form a fresh water barrier.

SPACING

The wells should not be spaced less than 2W (see Fig. 2) otherwise there will be an undesirable constriction of the native groundwater flow with a subsequent "back-up" effect. After fulfilling this requirement, spacing of wells is generally governed by the economics of the project.

DEPTH

Where possible, recharge wells should be constructed to penetrate the complete thickness of the major aquifers present at any location, otherwise partial penetration effects will reduce the volume of water which may be recharged. One limitation of the depth of a recharge well is the maximum injection pressure a formation can withstand. In most cases, formations can withstand reasonably high injection pressures which result in reduced frequency of well development and hence lower maintenance costs.

In special cases, dry wells which consist of a perforated
FIG II

Ground Surface

Standing water level

Drawdown cone stabilising with constant rate of withdrawal

impermeable layer

PRODUCTION WELL

Ground Surface

Standing water level

Cone of impression

Native water

Recharge water

Native water

RECHARGE WELL

DIFFERENCES BETWEEN PRODUCTION & RECHARGE WELLS
cased hole above the water table, may be constructed. A dry well permits some heat dissipation of returned water before it reaches the water table and because of the shallower depth, is generally cheaper to construct. However, excessive clogging and the problems associated with the development of dry wells are important disadvantages and in general the wet type of well is regarded as the more successful.

**DIAMETER.**

The considerations for choosing a well size for an injection well are quite similar to those used for pumping wells. The larger the diameter of the well, the better are the hydraulic characteristics in the adjacent formations. The casing must be large enough to accept the special injection equipment required in recharge wells.

**CASING.**

Black bore casing is not normally used in injection wells due to the highly corrosive environment which is caused by chlorination and the high dissolved oxygen content of injection water. To minimise corrosion problems, recharge wells are generally cased with such non-corrosive materials as asbestos cement, plastic pipe, fibre-glass tubing or concrete pipe.

**PERFORATIONS.**

The size of perforations is related to the size of the gravel pack or the natural formation. Total area of perforations should be large enough to reduce flow velocity to reasonable levels at the expected injection rate. If the thickness of the formation allows, considerable additional perforated areas should be provided to minimise well-clogging effects.

**GRAVEL PACKING.**

Depending on the nature of the formation, recharge wells are of the gravel pack or the non-gravel pack type. The gradation of the gravel pack is chosen to control the migration of fines from the formation during development and pumping.

Gravel packed wells commonly have a 3-9 inch gravel layer introduced into the annulus between the casing and the wall of the hole.

**CONDUCTOR PIPE.**

An essential feature of an injection well is the conductor pipe required to carry the injected water into the well beneath the
water surface inside the well casing. This pipe is required so that the injected water will not plunge into the well casing and cause turbulence that may entrain air bubbles and carry them into the gravel packing of the well and the aquifer formation beyond.

A full flow in the conductor pipe can be achieved by selecting the size of the pipe so that friction loss is comparable to the distance the water must drop. This procedure, however, limits the range of flows that may be used. Alternatively a back pressure valve is installed at the bottom of the conductor pipe.

CONSTRUCTION.

Any technique which produces a clean hole is suitable for the construction of recharge wells. Economics and local conditions should be considered in the selection of the method of construction.

DEVELOPMENT.

A recharge bore must be 'developed' specifically for injection purposes. To develop a recharge well, water should be recharged at a low velocity initially, the rate increasing each day between pumping periods until 85 percent of the pumping capacity is reached. Many wells will take considerably more water than they will pump. The maximum rate at which the formation will accept water is dependent upon the formation material. A rock and gravel formation will accept much more water than a tight sand, even though they might both pump similar quantities. Since there is no constant movement of water into the developed area during recharge, development may take several recharge periods to completely clear the area of sand.

WATER TREATMENT.

Recharge water used in injection wells must satisfy certain chemical and physical standards if clogging of the aquifer and a consequent decrease in recharge rates is to be prevented.

The suspended sediment load must be less than 20 p.p.m. and the water must be chemically and bacterially non-reactive with the formation. It is preferable that the chemical quality of the recharge water is similar to that of the natural water in the formation.

Should analysis reveal that a hazard exists, the water must be treated before injection. Normal treatment plants utilise flocculation, ponding and filtering as required.
CHLORINATION.

Short-term high chlorination is required to prevent the growth of subsurface bacteria native to the underground formation which may be activated by the introduction of an oxygen source in the injected water.

FLOW MEASUREMENTS.

It is essential that the quality of recharge water is continuously measured. To operate the bore or well at optimum efficiency the quantity of recharge water may need to be varied to suit the well characteristics.

Metering devices for measuring well inflow may include weirs, flumes, venturi meters or any type of recorder suited to the quantity of water and the hydraulics of the particular situation. The metering device should be equipped with recorders or totalizers.

AUXILIARY FACILITIES.

These may include fencing, laboratory facilities and monitoring wells to check the effectiveness of the recharge operation.
OPERATION AND MAINTENANCE OF RECHARGE WELLS

Strict operational and maintenance procedures must be adhered to when using injection wells in a recharge project.

INJECTION RATE.

It is desirable that the injection rate be maintained at the maximum rate allowed during initial development. Wells require less injection head for a given injection rate after a reduction in rate or shut down for a period of a few days, followed by a return to the original injection rate. Reducing the rate may postpone, for a short period the need for redevelopment, however, there are other detrimental effects. A better technique for maintaining injection rates is to pump the well for a short period each day (say 2 hours).

REDEVELOPMENT.

When the injection head reaches the limit of available water pressure, some type of redevelopment is necessary so that the well may remain in service at the desired injection rate. Well redevelopment may be achieved by one of several methods -

(1) bailing and surging with a cable tool
(2) jet pumping and surging with an air lift
(3) pumping and surging with a deep well turbine pump

DUAL PURPOSE WELLS.

Many recharge wells are also used as pumping wells.
The Alice Springs Town Basin is a small alluvial groundwater basin which is located beneath the township of Alice Springs. The safe yield of the basin is 150 million gallons. Natural recharge is derived almost solely from flood flows in the Todd River. Since the water requirement for the township of Alice Springs is in excess of 200 million gallons the town basin cannot naturally supply all the water required. At present all water required for town supply is being supplied from the Mereenie Basin, seven (7) miles South of the Town.

Groundwater from the Mereenie Basin is of better quality, however, at present it costs at least twice as much as the Town Basin water due to extra pumping costs. It may be possible to construct and operate recharge facilities which increase the available supply of cheap water from the town basin.

A proposal for a recharge dam to be constructed on the Todd River has been made. It is intended that such a dam would recharge the Town Basin. A method for recharging the basin with water from the dam must be selected.

It may be possible to economically increase the recharge to the town basin without the construction of a dam using recharge ponds or other methods which will increase the infiltration rate during river flows.
RECOMMENDATIONS

1. Experimental recharge basins should be constructed in areas of high permeability in the Town Basin as defined by Eggington to enable the most suitable design and operating procedure to be selected.

2. The following effects should be investigated:
   (a) Use of wedge shaped pits as opposed to trapezoidal sections
   (b) Infiltration rates on natural filtered surfaces and ground surfaces
   (c) Varying thickness of filters
   (d) Various types of filters
   (e) Various surface heads
   (f) Effect of suspended solids content of water
   (g) Effect of water temperature
   (h) Effect of organisms
   (i) Groundwater movements

3. Having selected a suitable type or types carry out an economical analyses of recharge.

4. Postulate a groundwater management scheme for Town Basin to utilize available water supply.

NOTE:
Appendix 1 presents a suitable design for the proposed 10 experimental recharge ponds
Appendix 2 examines which parameters should be measured
Appendix 3 lists material required for the 10 proposed experimental recharge ponds

1. Eggington - Proposal for artificial improvement to the Alice Springs Town Basin.
High permeability zones

FIG. III

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EXPERIMENTAL ARTIFICIAL RECLAMATION ZONES
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APPENDIX 1

LOCATION AND DESIGN OF PROPOSED EXPERIMENTAL RECHARGE PONDS.

Many of the areas defined by Eggington¹ as areas of high permeability in the Town Basin are now occupied. Each area was visited and the following areas were selected as suitable for construction of experimental recharge ponds:

1. Todd Well
2. Colacag
3. Memorial
4. Bent Tree
5. Traeger East

The location of these areas is shown in Plate II.

With experimental basins, it is desirable to construct the largest area as is possible, to simulate full size basins. There are so many varied factors which affect recharge that it is difficult to calculate and adjust measurements for model effects. The limiting factor determining the area of the experimental basins is the availability of recharge water. The recharge water for the proposed experimental basins can be obtained from fire hydrants, the water being extracted either from the Mesa Verde Groundwater Basin or bores in the Town Basin distant from the recharge ponds. It has been established that the supply from fire hydrants in the vicinity of the proposed sites is twenty thousand (20,000) gallons per hour.

Considering this supply, the infiltration rates expected and the storage required to maintain head above the surface of the ponds, one twentieth (1/20) of an acre was selected as a suitable size for an experimental recharge pond.

TODD WELL RECHARGE BASIN.

The aim of this basin is to determine the infiltration rate of the stream bed in this area.

1. Eggington - Proposal for Artificial Improvement of Recharge to the Alice Springs Town Basin.
COLACAG RECHARGE BASIN.

Three (3) basins are to be constructed on the flood bank of the river adjacent to Colacag Park. The basins will be of three (3) different types -

- grassed
- filtered
- wedge shape

It is proposed to conduct recharge experiments on the grassed basin before grassing. Similarly with the filtered basin, recharge experiments will be conducted before the sand filter is constructed. Experiments with the grassed and filtered basins will include the addition of sediment into the recharge water to simulate water in the Todd River.

MEMORIAL RECHARGE BASIN.

This area (adjacent to the Memorial Club) is the best natural recharge area to the Town Basin. Three basins are to be constructed in this area -

- grassed
- filtered
- natural

BENT TREE.

This area is near the two production bores, Bent Tree Well 1 and 2. One filtered basin will be constructed here.

TUBARIB EAST.

Two basins are to be constructed in this area. One basin is to be filtered, the recharge water being supplied from flows in the Todd River. The other will be a natural basin.
APPENDIX 2

1. WATER LEVEL.

Water level observation borws are to be constructed around each recharge pond. The variations in groundwater level are to be continuously monitored preferably using recorders. The number of recorders used depends on the availability of recorders; megger readings are to be taken in borws without recorders. The surface head in the ponds must also be measured.

2. WATER DISCHARGE.

The intake water to each basin is to be measured using water meters and or weirs combined with water level recorders. Excess water is to be measured using weirs combined with water level recorders. The water level recorders should be preferably digital Fischer and Porter recorders.

3. WATER QUALITY.

The chemical quality of the recharge water and the groundwater is to be monitored by conductivity measurements from one litre water samples. A complete chemical analysis is to be carried out on selected samples. The turbidity of the water is to be measured. The stubble bottle sampling technique is to be used for sampling.

4. WATER TEMPERATURE.

The temperature of the recharging water is to be measured at selected intervals. If electric logging equipment is available, the varying temperature gradient of the Groundwater is to be measured using the temperature probe.

5. METEOROLOGICAL MEASUREMENTS.

The following measurements to be taken daily -
- Air temperature (maximum and minimum)
- Wind velocity and direction
- Evaporation

6. DEPTH OF SEDIMENTATION.

At selected intervals the depth of sedimentation is to be observed by using shallow, narrow trenches.
7. **STRATA.**

The particle size distribution of the aquifers beneath the recharge ponds is to be determined by sieve analysis.

8. **COMPACTION, DENSITY, MOISTURE CONTENT.**

At the completion of construction of each pond, the compaction of the bed of the ponds is to be measured using a proctor needle, the density using sand density apparatus and the moisture content measured using the speedy moisture content apparatus.