Guidelines for Alberta Brine Storage Reservoirs

March 1978

Effective March 29, 2014, the Alberta Energy Regulator (AER) has taken over jurisdictional responsibility for water and the environment with respect to energy resource activities in Alberta from Alberta Environment and Sustainable Resource Development.

As part of this jurisdictional transfer, the title page of this guide now carries the AER logo. However, no other changes have been made.

For more information, contact the AER Customer Contact Centre at 1-855-297-8311 or inquiries@aer.ca.

guidelines for alberta brine storage reservoirs

Alberta
ENVIRONMENT

ADDENDUM TO GUIDELINES FOR ALBERTA BRINE STORAGE RESERVOIRS

TO WHOM IT MAY CONCERN:

RE: Guidelines for Alberta Brine Storage Reservoirs, March 1, 1978

The above-mentioned guidelines are not up to date with respect to liner requirements. The following is an abridged summary of requirements for brine storage reservoirs. These are required to be implemented through the permits and licences under the Clean Water Act.

1. New facilities, and existing facilities when upgrading is necessary, shall have two synthetic liners with an early leak detection system/collection system in between the two liners. If the applicant can guarantee that upon leak detection the pond liner would be immediately repaired, a single synthetic liner with an early leak detection/collection system and a secondary clay liner may be accepted.

2. Leakage collected by the leak collection system shall be returned to the brine storage reservior. The quality (pH, conductivity, chloride) shall be measured once per month, and total volume returned to the reservoir each month shall be recorded.

3. Those facilities which collect surface runoff from the vicinity of reservoirs, in the leak collection sump, must develop a means of estimating actual leakage flow each month.

If the reader has any questions concerning any of the above, please contact staff of the Water Quality Branch at 427-5888.

Yours truly,

Alberta Environment
August 6, 1991

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In accordance with Part 1, Section 6 of the Clean Water (General) Regulations being Alberta Statute 216/73, Alberta Environment hereby issues

GUIDELINES FOR ALBERTA BRINE STORAGE RESERVOIRS

Prepared By:
Water Quality Branch
Standards and Approvals Division
and
Soils Branch
Earth Sciences and Licensing Division
Environmental Protection Service
Alberta Environment

March 1, 1978

FOREWORD

The guidelines presented herein have been developed and reviewed jointly by the Standards and Approvals Division and the Earth Sciences and Licensing Division of Alberta Environment, the industrial sector which operate facilities associated with the underground storage of hydrocarbons, and the Energy Resources Conservation Board. They are intended to define acceptable levels of control and performance of brine storage reservoirs. Alternative control technology may be implemented provided the environmental protection objectives of these guidelines are achieved.

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1. INFORMATION REQUIRED FOR A PERMIT OR LICENSE APPLICATION

1. Size and location of the brine storage reservoir.

2. Maximum anticipated volume of the brine solution that will be stored, measured in imperial gallons and cubic metres.

3. Detailed design criteria for the reservoir including design drawings, expected seepage losses from the reservoir, thickness of the clay liner, permeability of the clay liner, and any other information pertinent to reservoir construction.

4. Details concerning the groundwater observation wells including location, well depth, lithologic log, completion details, etc. for each well.

5. Plan view showing the relative locations of reservoir, observation wells, disposal wells, pump house, roadways, and any other surface improvements associated with the hydrocarbon storage facilities in the immediate vicinity of the reservoir.

6. Topographic map (1 to 50,000) showing the location of all surface bodies of water, water wells, and other pertinent data within a three-mile radius of the reservoir. A photo copy of an up-to-date 1 to 50,000 National Topographic System (NTS) map is acceptable for this purpose.

7. Hydrogeologic information including the following:

   a. Depths to the water table at the time of reservoir construction;

   b. Direction of the groundwater flow (horizontal and vertical components);

   c. Approximate groundwater velocity;

   d. Background chemistry of the shallow groundwater system;

   e. Estimated permeability and porosity of the aquifers within the zone of potential contamination;

   f. Location, construction details, and water levels of all groundwater wells within a three-mile radius of the proposed site; furthermore, it is recommended that the sodium, calcium, magnesium, and chloride concentrations be determined in all water wells within a three-mile radius of the proposed site.

   g. Detailed lithologic log of a least one test hole to a depth of 50 feet or 15 feet into the bedrock, whichever is lesser. (At the completion of the hydrogeologic investigation phase, all test holes that are likely to transmit brine seepage vertically to aquifers or sand lenses beneath the site should be sealed from bottom to top; of the sealants, cement is recommended as the most effective against concentrated brine solutions.)

2. CONSTRUCTION AND REPAIR REQUIREMENTS

1. In order to promote a uniformly compacted liner, reduce clay lumps to an appropriate size prior to compaction as specified by the design consultant.

2. Construct the clay liner with clay demonstrated in laboratory tests to have a permeability not exceeding 1×10^{-9} centimetres per second (cm/sec).

3. It is recommended that the clay liner forming the floor of the reservoir be at least three feet thick while the liner on the inner walls of the reservoir dykes be at least four feet thick.

4. Adequate compaction cannot be achieved with frozen materials; therefore it is not recommended that the construction of compacted clay liners proceed from November to April inclusive. It is recognized that abnormally warm winters do occur upon occasion; the construction of clay liners may proceed under such conditions if neither the material being compacted nor the clay base are frozen.

5. It is recommended that the brine pond designs include measures to minimize seepage from the reservoir floor. An example of such a design is a double clay liner separated by a permeable sand or gravel zone from which brine seepage may be effectively collected. A second example of an effective seepage control measure is use of an artificial membrane to line the entire reservoir. Alternative seepage control measures may be satisfactory providing they are acceptable to the Director of Standards and Approvals Division.

3. MAINTENANCE, MONITORING, AND REPORTING REQUIREMENTS

3.1 MAINTENANCE

a. The walls of the reservoir dyke should be inspected by the operator on a regular basis and recompacted where necessary to maintain the clay liner at the designed permeability. The operator may, from time to time, be requested to perform tests on the clay liner to ensure compliance with the designed permeability.

b. Log booms, rip rap or some other means of protection should be installed to minimize the adverse effects of wave action on the clay liner.

c. Internal dyke drains for the purpose of seepage control should be designed for possible connection to a closed collection system which discharges back to the brine pond. Such a seepage collection system may be required should the volume of seepage through the dykes be considered excessive by the Director of Standards and Approvals.

3.2 MONITORING

a. A minimum of five observation wells shall be installed so as to monitor the quality of the groundwater moving away from the reservoir. It is recommended that the observation wells be constructed in accordance with the procedures outlined in Appendix 5.

b. Groundwater samples shall be collected from the observation wells on a regular basis and analyzed. In order to ensure that the monitoring is serving a useful purpose, it is recommended that samples be obtained from each observation well once per calendar month and analyzed for the following parameters during the first three months of operation:

1. Chloride (Cl^-)
2. pH
3. Calcium (Ca^{2+})
4. Magnesium (Mg^{2+})
5. Sodium (Na^+)
6. Total dissolved solids
7. Alkalinity
8. Potassium (K^+)
9. Iron (total dissolved)
10. Sulphate (SO_4^{2-})
11. Conductivity
12. Nitrate (NO_3^-)
13. Carbonate (CO_3^{2-})
14. Bicarbonate (HCO_3^-)

A less rigorous testing schedule can commence beginning the fourth month of operation as follows:

1. Chloride (Cl^-)
2. Conductivity
3. Calcium (Ca^{2+})
4. Magnesium (Mg^{2+})
5. Sodium (Na^+)

c. The depth to the water level should be determined at the sâme time as each groundwater sample is obtained.

d. In order to ensure that the results of monitoring will be of value groundwater samples should be obtained and analyzed in accordance with the procedures outlined in Appendix 6.

3.3 REPORTING

a. A quarterly report of the monthly tests prescribed in Section 3.2 shall be submitted to the Director of Pollution Control, Alberta Environment.

b. Should the monthly analyses indicate chloride concentrations in excess of 1,000 milligrams per litre (mg/l) in any one observation well, the company shall inform the Director of Pollution Control, Alberta Environment, immediately.

APPENDIX 1. INTRODUCTION

Surface brine storage reservoirs are used in conjunction with underground salt caverns for storing liquified petroleum gases (LPG), such as propane, butane, and ethane.

During the underground cavern-forming operations, fresh water is injected into a salt formation and a brine solution is returned to the surface. Once the storage cavern is completed, saturated brine solution is retained in a surface reservoir and used for displacing the product (LPG) from the salt cavern when product recovery is desired. To avoid enlargement of the underground salt cavern, saturated brine must be used as the displacement fluid.

It is common practice in Alberta to use clay liners in brine storage reservoirs to retard subsurface infiltration and subsequent groundwater contamination. Brine storage reservoirs lined with clay are not impervious and a finite amount of brine seepage into surface and groundwater systems will occur. The amount of seepage depends upon the permeability and thickness of the clay liner, the degree of saturation, the electrolyte concentration, and the depth of brine solution in the reservoir.

Problems with salt water seepage from clay-lined reservoirs have been experienced in the past. In all instances the seepage problem has been related to faulty liners.

APPENDIX 2. PROBLEMS ENCOUNTERED

The single, most significant problem in the operation and maintenance of brine storage reservoirs is the seepage of brine solution and subsequent contamination of soil, groundwater, and vegetation in the surrounding area. Chloride concentrations are difficult to reduce in the natural environment because the chloride ion is not absorbed by soil particles or exchanged for other ions at exchange sites on clay minerals. In addition, the chloride ion does not enter into equilibrium reactions with insoluble minerals at temperatures and pressures typical of surface water and/or shallow groundwater systems. The only mechanism for reducing the chloride concentration in the natural environment is dilution and dispersion within the water system. Large volumes of water moving under turbulent flow offer the best mechanism for rapidly diluting excessive chloride concentrations. Groundwater flow is usually laminar rather than turbulent, and contaminants (including chloride ion) tend to move as a concentrated plume within the groundwater system. Because the velocity of groundwater is low, the time necessary for an aquifer to cleanse itself by dilution and dispersion is usually measured in decades and removal of contaminants from the groundwater reservoir by artifical means is an almost impossible task.

The flow of water through soil is partially a function of permeability, pressure head, and distance to be travelled. The controlling factors that contribute to seepage are related to permeability and can be identified as follows:

a. Incomplete compaction of the clay liner;

b. Freeze/thaw effects on the exposed clay liner;

c. Inadequate thickness of the clay liner;

d. Improper construction of the reservoir dyke;

e. Damage to the clay liner by construction equipment; and

f. Inadequate maintenance over the operating life of the reservoir.

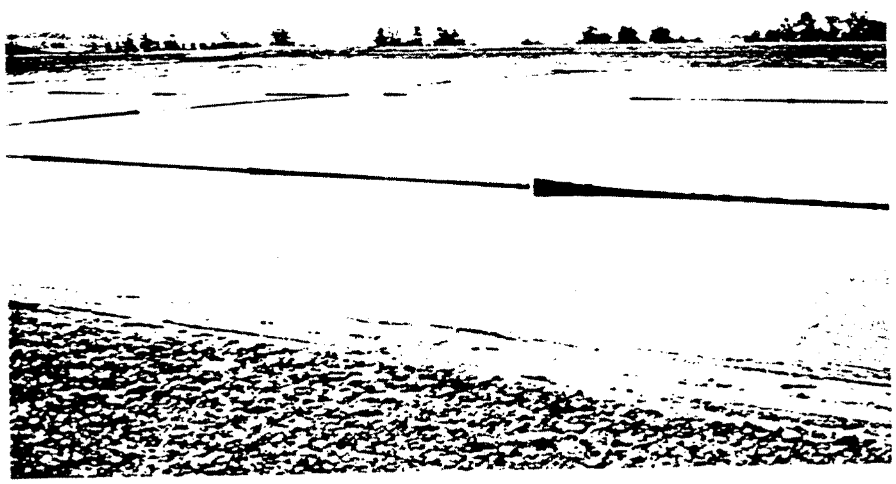


Fig. 1 A typical brine storage reservoir with log booms to minimize wave action.

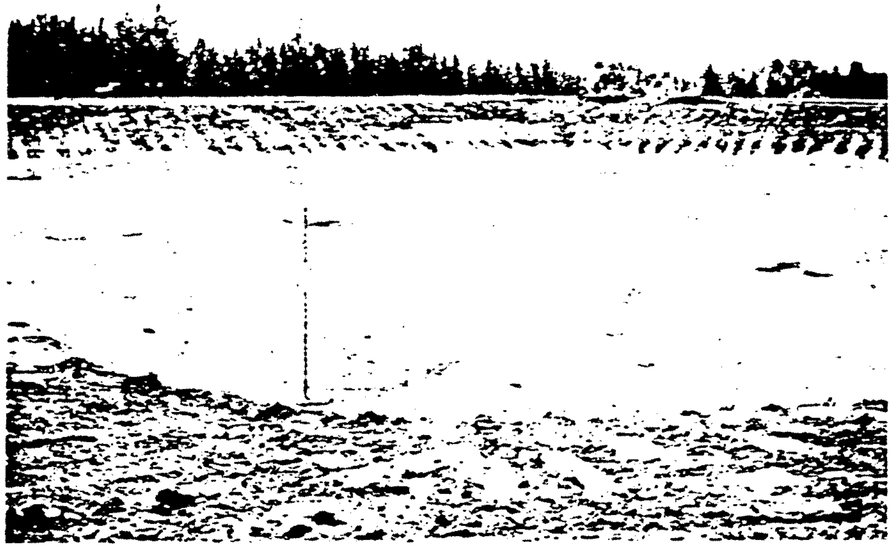


Fig. 2 A brine storage reservoir with seepage problem under repair.

Fig. 3 An observation well (near fence) easy to locate because of external structure.

APPENDIX 3. CORRECTIVE MEASURES

3.1 COMPACTION OF THE CLAY LINER

Proper compaction of the clay liner is essential to reduce seepage losses, but may be difficult to achieve in some cases. Clay deposits that have been over-consolidated by glacial over-riding are often excavated in lumps which are difficult to break down and compact. In order to construct a uniformly compacted liner, these clay lumps must be reduced to an appropriate size prior to compaction, as specified by the design consultant. Appropriate compaction is not possible when the compacted base or the material being compacted is frozen; therefore, it is not considered practical to attempt construction of compacted clay liners from November to April inclusive. It is recognized that if abnormally warm temperatures occur during this interval, construction may logically proceed.

To ensure compaction of the clay liner to the designed permeability over the entire reservoir, it is essential to exercise rigid quality control and it is recommended that construction proceed only under constant supervision of responsible personnel.

3.2 FREEZE/THAW EFFECT

Freeze/thaw cycles contribute to the degradation of compacted clay liners by producing secondary structures (fractures, fissures) through desiccation. It is necessary, therefore, to provide an adequate thickness of clay liner.

3.3 THICKNESS OF CLAY LINER

To effectively retard seepage, an adequate thickness of clay liner is essential. It is recommended that the clay liner forming the floor of the reservoir be at least three feet thick while the liner on the inner walls of the reservoir dykes be at least four feet thick.

3.4 MAINTENANCE

Good environmental housekeeping should include regular inspection and maintenance of the reservoir. In particular, the inner walls of the reservoir dyke are susceptible to damage through wave action, however small the waves may be. It is also inevitable that the liquid level will fluctuate as the brine solution is pumped back and forth to the underground caverns; this leads to further deterioration of the walls by cycles of wetting and drying or freezing and thawing. Heavy rainfall on the exposed dyke walls can also be a factor in damaging the clay liner. Hence, to maintain the clay liner at the designed permeability, the clay liner must be inspected by the operator and recompacted as necessary. The effects of wave action can be minimized by placing log booms on the surface of the brine solution, rip rap on the inside dykes or any other acceptable method.

To maintain the dykes of the reservoir, internal drains are recommended to intercept any seepage. Such drains should be designed for possible connection to a closed collection system which discharges back to the brine reservoir. This type of "closed-circuit" seepage collection system will not completely eliminate the loss of brine solution to the environment, but the volume loss will be reduced and dyke stabilization will be increased. Both procedures will enhance clay-lined reservoirs as a more acceptable method of storing brine on the surface.

APPENDIX 4. SITE SELECTION

Hydrogeologic criteria that affect the siting of brine storage reservoirs include the following:

(1) Soil type – fine-textured sediments such as lacustrine, glaciolacustrine, and glacial till consisting predominantly of clay and silt are ordinarily favourable materials in which to construct brine storage reservoirs. Such deposits characteristically have a low inter-granular hydraulic conductivity which results in reduced groundwater velocity. Brine seepage into such materials may result in locally high concentrations of chloride ion, but contaminant migration from the area should be exceedingly slow due to reduced permeability. The existence of more permeable zones such as sand layers beneath any potential brine storage site should be determined as these will provide avenues for more rapid movement of brine from the area.

(2) Groundwater regime – Brine storage reservoirs should not be located in groundwater recharge areas, because a large volume of groundwater will be exposed to contamination should excessive brine seepage occur. Areas in which groundwater flow is horizontal, or toward the surface (discharge area), are more favourable locations for brine pond sites as potential contamination of the deep groundwater system is avoided. A reasonably short groundwater flow path between the point of contamination (brine storage reservoir) and the point of groundwater discharge to the surface water system is also advisable. In case of dyke failure, or excessive seepage, the extent of groundwater contamination would be limited to the area between the storage reservoir and the point of discharge. A maximum flow path length of one mile is suggested when considering potential locations for brine storage reservoirs.

APPENDIX 5. INSTALLATION OF OBSERVATION WELLS

5.1 GROUNDWATER MONITORING SYSTEMS

A number of factors must be considered prior to installing an observation well system. The hydrogeological aspects of the site must be investigated via a test drilling program complemented by a review of published and unpublished data prior to installation of any monitoring wells. After the hydrogeology of the site is adequately defined, the number and position of piezometers and/or standpipes to be placed within the system to be monitored can be determined.

Observation wells are installed in the vicinity of the facility (brine storage reservoir) in order to monitor the quality of groundwater moving away from such sites. Contaminant movement cannot be properly detected unless observation wells are properly located and constructed within the groundwater flow system. For this reason, observation wells should be designed and installed under the direction of a hydrogeologist.

5.2 TYPES OF OBSERVATION WELLS

Observation wells are classified as either piezometers or water-table wells depending on the method of construction. Piezometers are used to:

1. Isolate a specific zone of higher permeability to enable sampling of groundwater within that zone (see Figure 1a); and
2. Measure the hydraulic potential at a specific point within the lithologic sequence to determine the direction of groundwater movement. Short sections of screen are placed opposite the zone to be monitored and all water-bearing horizons above and below the screen are sealed off. Piezometers are usually placed in pairs or groups to monitor groundwater quality within two or more permeable strata underlying the storage facility.

Water-table wells or standpipes are observation wells which contain long sections of screen allowing the entry of groundwater along most of the well depth. Standpipes are used where no apparent water-bearing strata are present in homogeneous materials. The water sample obtained from a standpipe is theoretically representative of a column of groundwater between the water table and the bottom of the well (see Figure 1b). This is not truly the case, however, as groundwater is probably being transmitted along permeable zones or fractures which have not been detected. Standpipes should not extend large distances below the water table if the exact depth to the water table is required. Should the standpipe extend to a confined permeable zone below the water table, the actual water level in the observation well may reflect the hydraulic potential of the more permeable zone.

5.3 CONSTRUCTION MATERIALS

Metal pipe should be used in installations greater than 50 feet below the surface to prevent structural damage of the casing. Schedule 80 plastic pipe is recommended in shallow installations that are subject to settlement deformation, such as adjacent to reservoir walls.

The diameter of casing used in observation wells is not a critical factor. Large diameter wells (4-6 inches) are easier to bail or pump, but the installation and materials cost is considerably greater than for smaller diameter wells. Casing with an inside diameter ranging from 1 1/2 inches to 6 inches is acceptable for the construction of observation wells.

5.4 PIEZOMETER SCREENS

A wide variety of piezometer screens (metal and plastic) is available from commercial sources. The type of screen chosen depends on the purpose of monitoring as the screen material may contribute contaminants to the groundwater. Commercially-slotted screens with large open areas are recommended for piezometers. The increased open area will reduce the amount of drawdown due to 'well losses' while pumping or bailing the well. The full length of screen must be backfilled with sand of suitable grain size. The sand should be coarse enough to prevent entry through the screen but fine enough to filter out silt and clay-sized particles.

5.5 STANDPIPE SCREENS

Standpipes are usually screened along much of their length as indicated previously. In order to reduce costs, standpipes are usually constructed by perforating the well casing with a hacksaw. Well losses are increased with this type of construction, but standpipes are usually installed in poorly-permeable soils where no apparent permeable strata are present. Well efficiency probably cannot be improved by using commercial screens under these conditions. The entire perforated section is to be backfilled with sand.

5.6 ANNULUS SEALS

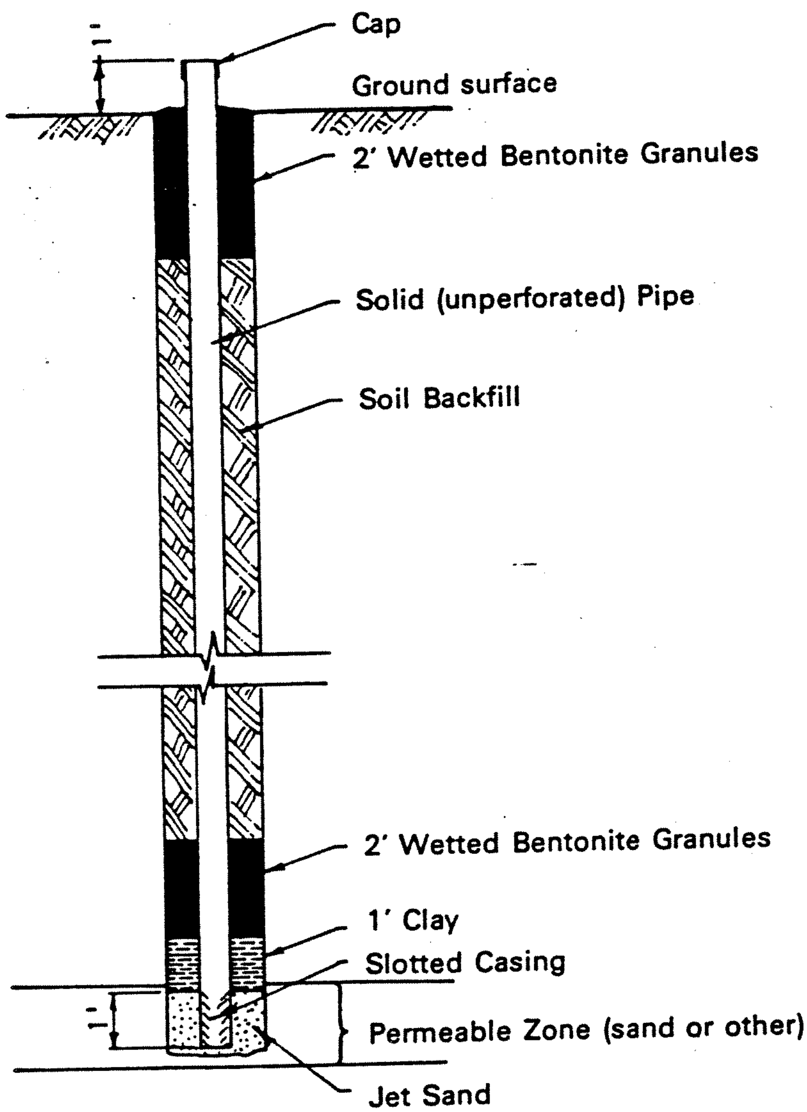
The annular space between the casing and the test hole must be sealed immediately above the piezometer screens to prevent hydraulic communication between the permeable horizons and also to prevent the influx of surface water. Bentonite is probably the most effective material for use as an annular seal. Bentonite swells when wet to form a tight seal, but it may also contribute lead and sodium ions to groundwater in the observation well. In order to reduce this contribution, the bentonite seal should be isolated from the sand pack surrounding the piezometer screen by a 6 to 8 inch layer of clay cuttings (material removed from the hole during drilling). A 6 to 8 inch layer of bentonite can then be placed on top of the cuttings either as a slurry or wetted granules, and the remaining annular space filled with cuttings. A bentonite seal should be placed at the surface to prevent influx of surface water in both piezometers and water table wells.

A commercial piezometer seal known as "PiezoSeal" is currently available on the market. This product can be used for metal casing only, as its heat of hydration is apparently in the realm of 400°F which will destroy plastic casing and screens.

Cement should not normally be used as an annulus seal due to shrinkage upon setting which opens the annulus to water-bearing horizons above the screen, and also allows entry of surface water. In the case of exposure to saline waters, however, cement may provide a more effective piezometer seal than bentonite, in spite of its limitations.

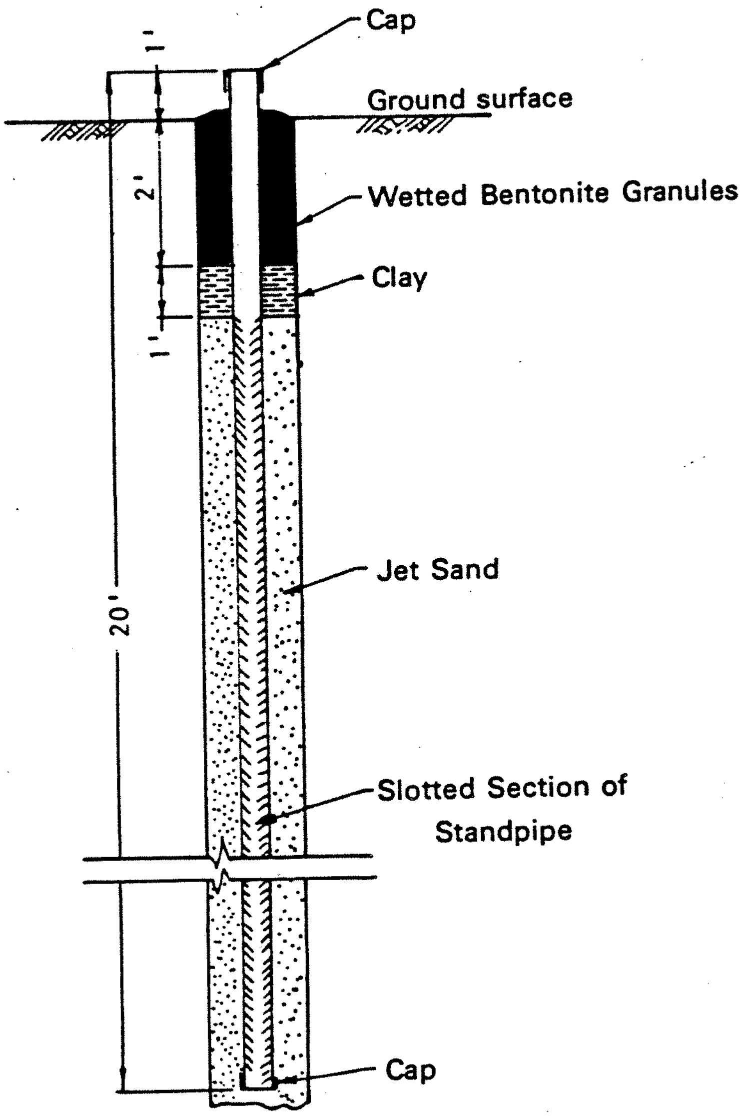
5.7 WELL DEVELOPMENT

After the construction of observation wells, well development must be effected by bailing, flushing or pumping. However, care must be taken to minimize the internal casing pressure to avoid annulus seal damage.



PIEZOMETER CONSTRUCTION DETAILS

Figure 1a



STANDPIPE CONSTRUCTION DETAILS

Figure 1b

APPENDIX 6. SAMPLING AND ANALYSIS TECHNIQUE

A large number of factors may affect the natural chemistry of the groundwater withdrawn from an observation well. Changes in temperature and pressure occur within a water sample during and after removal and chemical changes are to be expected. The objective of a proper sampling technique is to minimize such changes so that laboratory results approximate as closely as possible the actual chemistry of the groundwater.

The following sampling procedure is recommended:

1. Remove at least two well casing volumes of water from the well prior to sampling;
2. Obtain the water sample from the well by bailing, pumping or air injection;
3. Transport the sample in a sealed container (glass or polyethylene), shielded from direct sunlight, and maintained at or near groundwater temperature;
4. Analyze the sample within 24 hours (present information suggests that CO_2 diffusion through the wall of a polyethylene bottle is significant after 24 hours).

The background water quality should always be established in all observation wells before the brine storage reservoir is operational. This will identify anomalous groundwater chemistry conditions which might otherwise be attributed to contamination from the brine storage reservoir. The background chemical analyses should always include constituents and parameters that are commonly found and determined in Alberta groundwater (see Section 3.2 (b)).

All observation wells would ideally be constructed at least one year prior to operation of the facility. Four background samples could then be obtained on a quarterly basis and seasonal variations of the background water chemistry determined. In actual practice, however, observation wells are usually installed shortly before the facility becomes operational. In this case, all wells should be sampled at least three times (sampling dates separated by one month) and the background water chemistry assumed as the average of the three values. It is important that the background water chemistry be established before the facility is operational.

Analysis of the groundwater sample shall be conducted:

i. In a manner described in the publication "Standard Methods for the Examination of Water and Wastewater", 14th edition (1975) or the most recent edition, published jointly by the American Public Health Association, American Water Works Association and the Water Pollution Control Federation; or

ii. In a manner described in the "Methods Manual for Chemical Analysis of Water and Wastes" published by Alberta Environment; or

iii. By any other equivalent method, approved in writing by the Director of Standards and Approvals, the results of which can be confirmed by the methods referred to in sub-section (i) above.