SITE VISIT - FOX-M
FRESH WATER RESERVOIR - REPORT

PURPOSE

Reports received from Fox-M states that water is seeping through the berms of the Fresh Water Reservoir. On July 21, 1993, Mansukh Shah traveled to Fox-M to examine the condition of the Reservoir, prepare a report and provide recommendations for remedial measures.

BACKGROUND

The potable/fresh water reservoir is located West of the main site. From the data available, approximately 35 years ago an earth dam was built in the middle of the existing lake and berms constructed along the perimeter of the banks forming the present Reservoir. No data is available as to the type of material, sealing compound or adhesive used during the construction of the Reservoir. The Reservoir is the prime source of fresh water supply for both the site and the community of Hall Beach.

According to FSC in Virginia, water seepage had been noticed in 1981. Bentonite was sprayed on the surface of the Reservoir in 1985 to seal the leaks. Reports are unavailable as to the extent of water seepage experienced in 1981 and the results of repairs.

The reservoir does not indicate the presence of Aquatic life and it is difficult to confirm whether the Aquatic Life has ever existed in the Reservoir or the lake. Fish may be extinct, as a result of spraying, (i.e. sedimentation method), Bentonite in 1985.

There is no possibility of hauling water from other sources in Winter. There are no lakes or ponds, within the vicinity of 20 km. of the site, deep enough to provide potable water during Winter.

LAKES IN THE ARCTIC

Generally the lakes in the Arctic are shallow and freeze to the bottom during Winter. Increasing the depth of the lake by blasting, dredging, excavation or construction of gravel berms results in disturbance of the permafrost in the Arctic.

FRESH WATER RESERVOIR

The reservoir is approximately 550 to 500 meters long by 400 to 350 meters wide. Depth of water in the reservoir varies from 1.2 meters along the perimeter to 4.2 meters in the middle and along the dam.

The catchment area, West of the reservoir, is the water supply source. The land around the catchment area and along the Western edge of the reservoir is at a higher elevation than that found East of the reservoir.

The water gravity feeds through the catchment area via a channel and into the reservoir . A sluice gate at the South-East corner controls the flow of water in the reservoir. An overflow culvert at the North- West corner regulates the water level. The excess water flows, via the culvert, along the North edge of the dam and into the lake.

The excess water from the catchment area has two run-off paths; the first being along the South side of channel and reservoir and into the ocean, the second being along the West edge of the reservoir, into the lake and subsequently into the ocean.

WATER CONSUMPTION & MAINTENANCE

The Hamlet of Hall Beach consumed approximately 16 million liters of water during the period from April 1992 to March 1993. The population is approximately 550 persons. During the same period, the North Warning Site consumed 7 million liters of water, population average being 70 persons per day.

The roads leading to the Reservoir and surrounding areas and the Reservoir are maintained by the NWS. Neither The Hamlet or the Government of the Northwest Territories contribute toward the maintenance costs of these facilities.

OBSERVATIONS

The following are observations made during examination of the Reservoir, the Dam and the Berms :

1. The depth of water in the reservoir varies from 1.2 meters along the periphery of the berms to a maximum of 4.2 meters in the center of the reservoir and along the length of the dam. No turbulence or other activity was observed in the areas of seepage through the berms.

2. Deposits of Bentonite and silt are evident at the bottom of the reservoir

3. At several location the sides of the Dam show severe erosion.

4. There is no evidence of water seepage through the Dam structure.

5. The Dam is made of well consolidated gravel fill. The fill consists of aggregates mixed with silt but no binding material is evident.

6.. Water is seeping through approximately about 70% of berm along the East side of the reservoir. At several locations the seepage is severe. The Site has tried unsuccessfully to seal the leaks with gravel.

7. The Berm along the South side of the reservoir is leaking along it's length. Seepage is severe in several locations.

8. The East and South side berms are severely eroded in several places. Wash out of silt/clay material is also evident.

9. Water is also seeping at locations along West side berm. This seepage is not serious, as the differential water level in the reservoir and outside the reservoir is approximately 200 mm. Head loss by water seepage on the West side of the reservoir will not have significant impact on reservoir's capacity.

10. The West side berm is severely eroded at several locations.

11. The East, West and South side berms, consisting of the same material as the Dam, are well consolidated.

12. It seems the reservoir has been leaking over the past few years. These leaks have progressed over years and become severe.

OPTIONS - TECHNICAL

1. The reservoir was built about 35 years ago. It is reasonable to assume that the settlement of the ground and the disturbance of the permafrost along the Dam and the berms has subsided by now. The permafrost should have penetrated into the Dam and the berms forming a natural barrier against water seepage, however this may not be the case. In Winter water freezes to a depth of approximately 1.8 meters. The water below ice is above the freezing point and may prevent the penetration of permafrost into the upper layer of the berms and the Dam. Blasting the bottom of the reservoir and making use of the natural permafrost ground as barrier against seepage is an option. This is costly and may disturb the stability of the Dam and the berms.

2. The reservoir presently holds approximately 600 million liters of water. In Winter water freezes upto a depth of 1.8 meters. Water from the bottom 450 mm depth cannot be used. This leaves approximately 245 million liters, (2 meters head), of potable water for winter use. Leaving the reservoir in its present condition may result in serious reduction of holding capacity and ultimately the unavailability of water.

3. Construction of berms with impermeable liners adjacent to the existing berms along the East and South sides. Protect berms with gabions. Spray bentonite over other areas of the reservoir to seal minor leaks.

4. Emptying the reservoir, grading the East and South side berms and installing impermeable liners or suitable materials. Protecting berms with gabions. Spraying bentonite over other areas of the reservoir to seal of minor leaks.

5a. Spraying Bentonite over entire lake and monitoring the results. Protecting berms with gabions.

5b. Spraying Bentonite along the East and South side berms and monitoring the results. Protecting berms with gabions.

6. Drilling holes and injecting impermeable expandable grout into the East and South side berms. Protecting berms with gabions. Spraying bentonite over other areas of the reservoir to seal of minor leaks.

Continuous leaks through the berms are undermining these earthen structures. Failure of these structures will result in the creation of health and safety hazards at Hall Beach.

RECENT REPORT FROM SITE

Report received from site recently indicates the water level in the reservoir has dropped by 300 mm. After accounting for water used by the site and the Hamlet and loss due to evaporation, this drop amounts to approximately 35 million liters of water loss due to leaks.

DESIGN AND LOGISTICS CONSTRAINTS

Unavailability of geotechnical information, past record of the Reservoir, the logistical difficulties in mobilizing equipment and material, short Arctic Summer construction season and the unpredictable Arctic weather makes it is difficult to estimate costs of various options within reasonable parameters.

For the present, the problems which contribute to water seepage are understood to be as follows -

a. The earth berms lack binding or sealing material
b. The earth berms were constructed on top of the tundra and the compressed tundra beneath the berms remains permeable.
c. Seasonal thawing and freezing disturbs the berms and the tundra resulting in increased water seepage.

In order to understand the above problems and to arrive at a reasonable permanent solution, it is advisable to carry-out a geotechnical investigation prior to the final design.

RECOMMENDATIONS - TECHNICAL

Option 1, blasting the bottom of the reservoir is not advisable. This may destabilize the Dam and the Berms.

Option 2, taking no action is not advisable. The Site and the Hamlet may loose their only water supply source.

Option 3, is expensive but is probably the best long term permanent solution. Will require a geotechnical investigation prior to final design. Should the implementation of the project be spread over two construction seasons, the Site and the Hamlet will have water for Winter use.

Option 4, is expensive and not advisable as the reservoir is the water resource. Reservoir will have to be emptied, sides and bottom dredged, sides will have to be sloped and gravel will have to be processed to protect the liner. All this activity will result in project being spread over two years and as such the Site and the Hamlet will lose their Winter water source for one season.

Option 5a, is not a guaranteed solution. The seepage along East and South sides is severe and there is a risk of bentonite of being washed out through these highly permeable areas of the dyke. However Option 5b could be implemented.

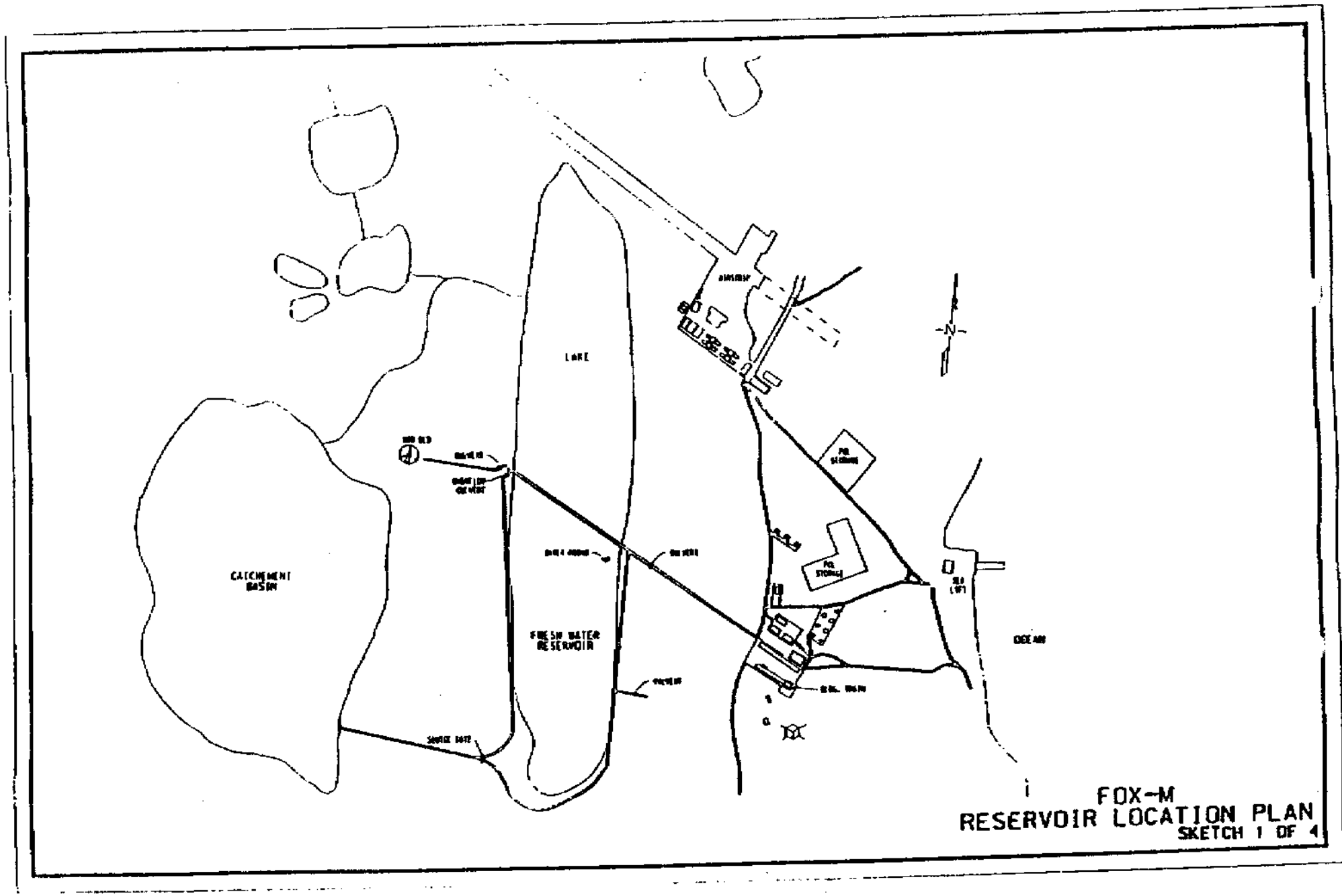
Option 5b, is inexpensive and can be implemented in a short period of time. But this solution is not guaranteed. If due to the logistic problems, the selected Option or other solution cannot be implemented next construction season, it is advisable to implement Option 5b as temporary remedial measure.

Option 6, to inject impermeable expandable grout will require a thorough geotechnical investigation. May result in extra cost if additional holes are required other than those anticipated in the design.

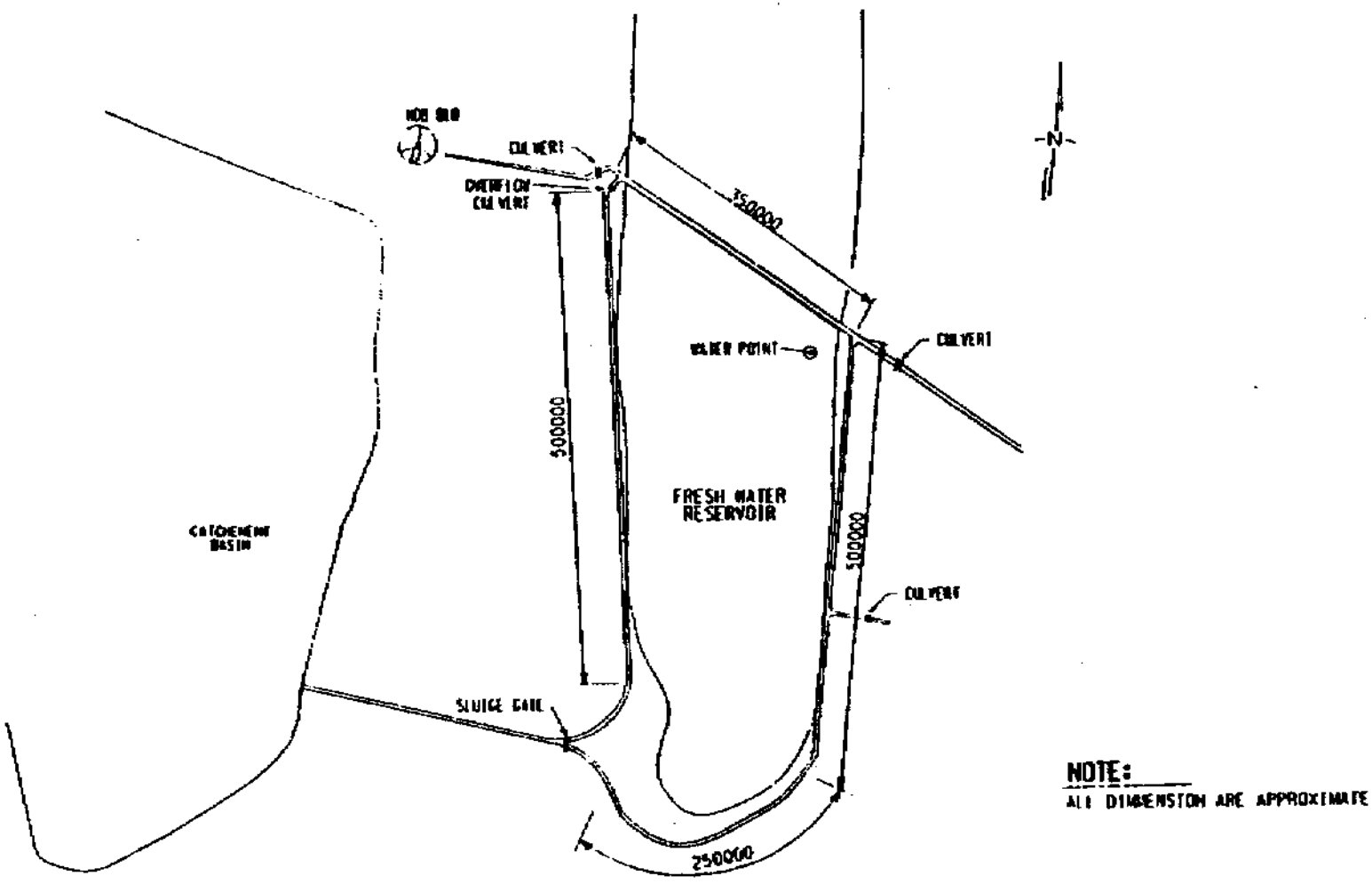
ENVIRONMENTAL ISSUES

Adoption of any solution should incorporate all environmental issues, at each design stage. Selection of material with regards to pollution and protection of surroundings as far as possible should be considered carefully.

DIAGRAMS



d:\dgn\tom\fox-m.dgn Aug. 13, 1993 11:04:56

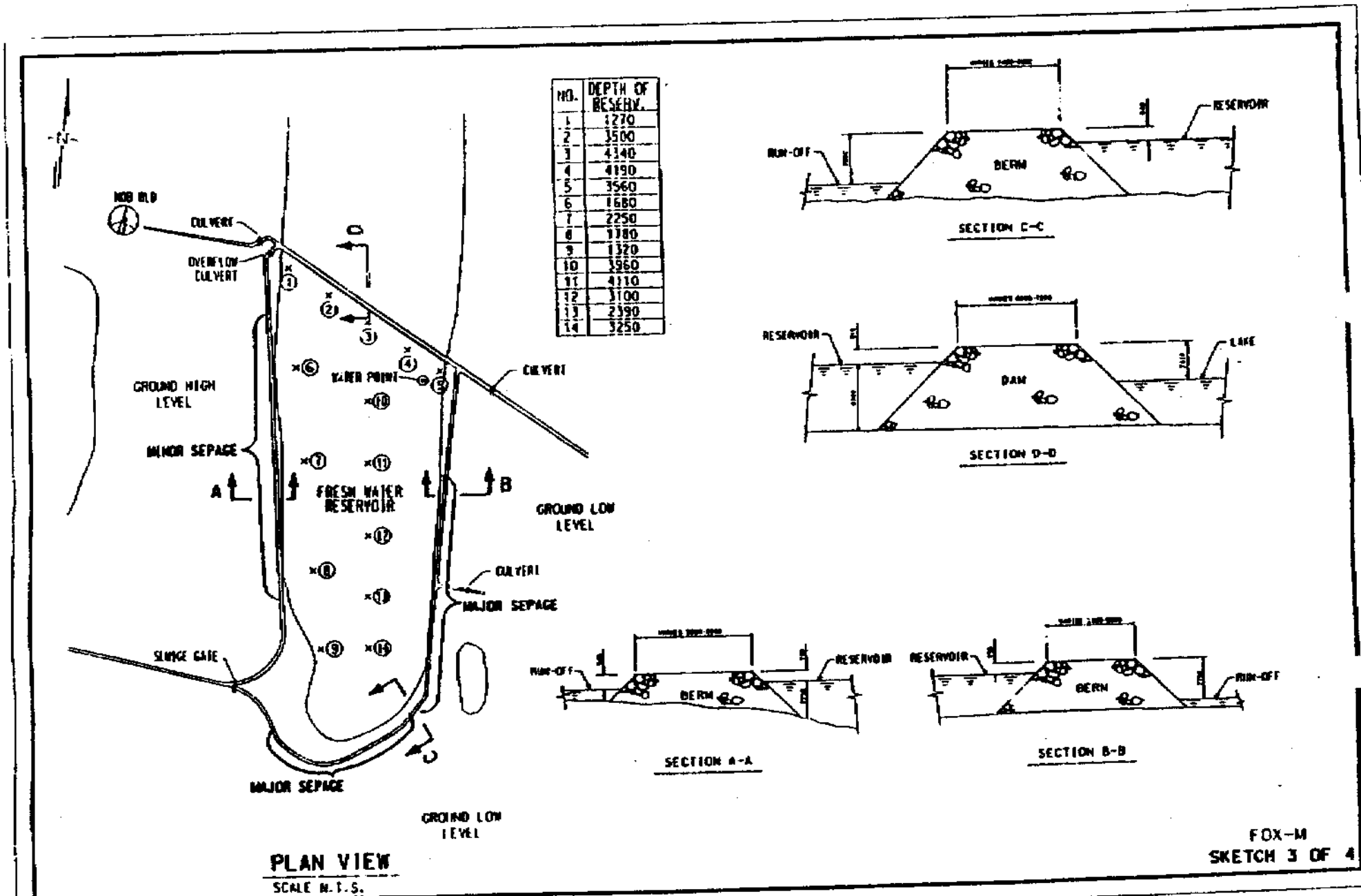


NOTE:
ALL DIMENSION ARE APPROXIMATE

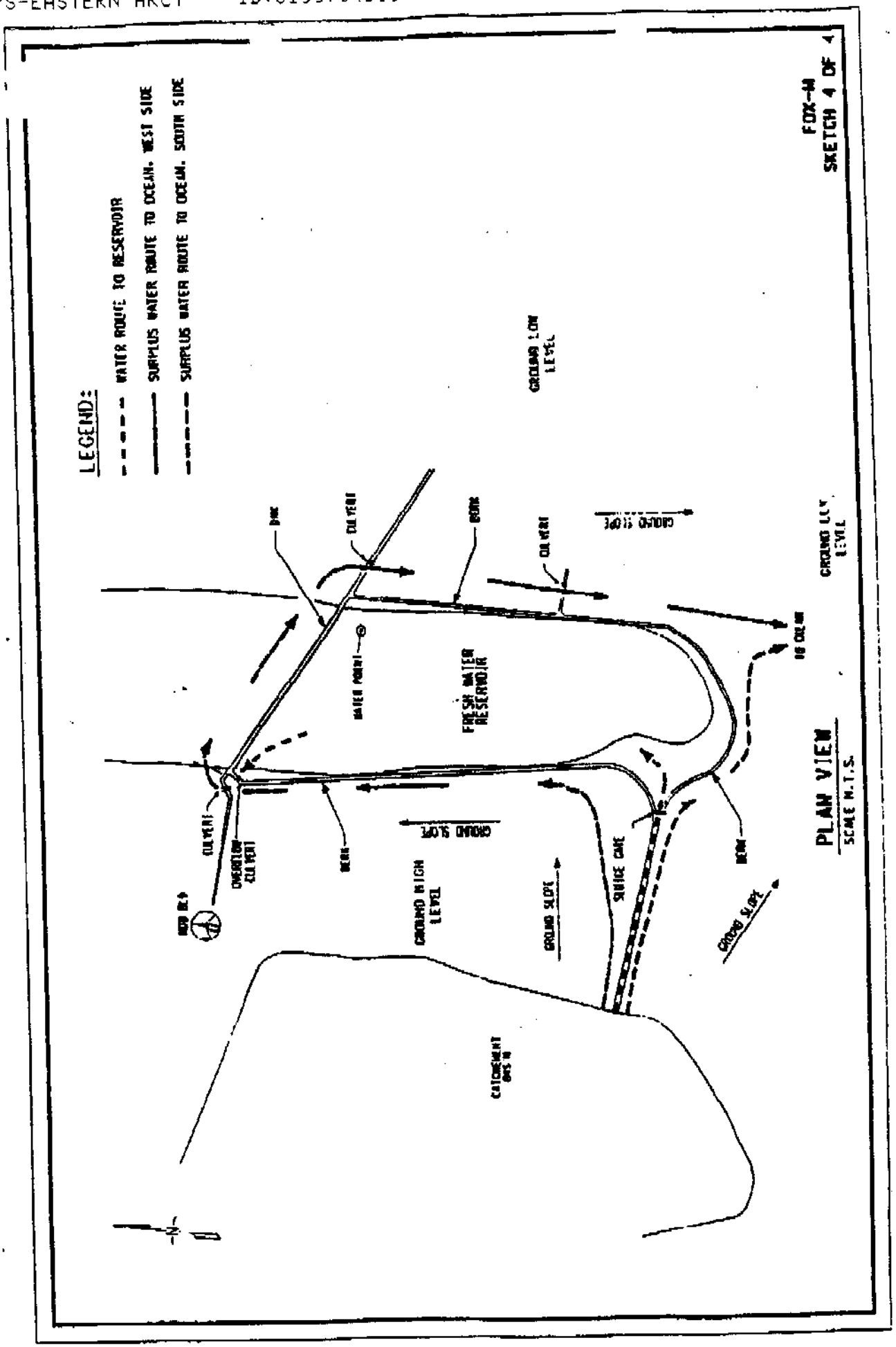
PLAN VIEW
SCALE N.T.S.

FOX-M
SKETCH 2 OF 4

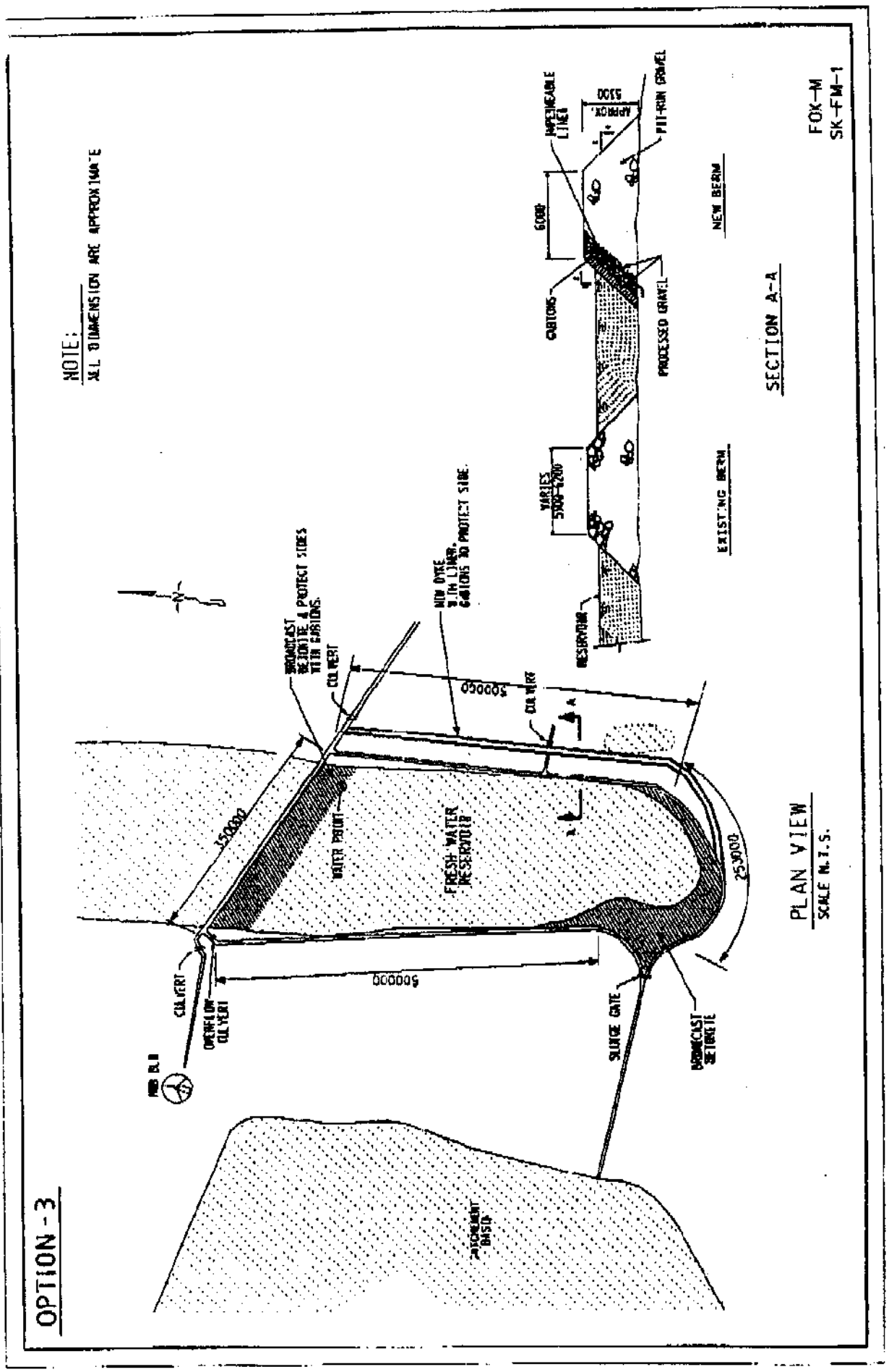
\dgn\tom\fox-m.dgn Aug. 13, 1993 11:04:37



d: \dgn\ton\fox-m.dgn Aug. 13, 1993 11:04:18



d:\dgn\tom\fox-m.dgn Aug. 13, 1993 11:05:19


OPTION-3
NOTE:
ALL DIMENSION ARE APPROXIMATE
PLAN VIEW
SCALE N.T.S.
SECTION A-A
FOX-M
SK-FM-1
FRESH WATER RESERVOIR
NEW DYKE
NEW BERM
EXISTING BERM
PROCESSED GRAVEL
PIT-RUN GRAVEL
IMPERMEABLE LINER
CULVERT
SLUICE GATE
RESERVOIR
WATER INTAKE
SEDIMENT BASIN

Baroid
Product Information

BENSEAL®
Sealing and Plugging Agent

BENSEAL® is a specially processed coarse ground, non-drilling mud grade bentonite for use in sealing and grouting well casings and earthen structures.

Recommended Uses:

BENSEAL® provides superior sealing qualities to:

Seal and grout plastic or steel casings

Seal engineering test study holes.

Plug and abandon minerals exploration holes and seismic shot holes.

Seal conductor pipe in and around mud tanks.

Seal ponds, dams and ditches.

Major Advantages:

Convenient, single sack product. BENSEAL® is safe and easy to use.

Stable in storage.

Yields slowly for maximum solids without excessive thickening.

Pumps easily with minimum pump pressure.

Eliminates problems caused by premature setting up.

Forms a permanent, flexible seal. BENSEAL is not subject to permanent drying, shrinking or cracking.

Reduces formation fracturing which could cause sealing loss because BENSEAL is lighter than cement.

Does not generate heat upon setting up.

Prevents commingling of aquifers and contamination from surface sources.

Protects casing from corrosive waters.

Allows hole reentry without mud contamination.

Compatible with BAROID® weight material. Density may be increased to control artesian conditions or other subsurface overpressures.

Recommended Treatment:

BENSEAL® forms an excellent seal when properly applied. For effective sealing the maximum number of swelling particles is required; this is contrary to what is desired in a drilling fluid. BENSEAL performs most efficiently in fresh water.

Casing Seal — Cable Tools

1. Dig a cone-shaped depression around the casing (diameter 1 foot, depth 1 foot).
2. Keep cone-shaped depression filled with **dry** BENSEAL as the casing is being driven.
3. Example: 2½ pounds per foot of 4" casing.

Lost Returns

1. Begin with the pit full of mud or water.
2. Raise pump suction off bottom and place a shovel next to it and slightly under suction.
3. **Slowly pour** dry BENSEAL into space between shovel and suction, and pump it down the hole.

BENSEAL/Sand Mixture — Grouting and Pumping

BENSEAL and sand, mix well, dry, in a ratio of 1:2, develop permeabilities of $K = 1 \times 10^{-5}$ cm/sec.

This mixture can be poured from top into holes not over 100 feet deep and through less than 50 feet of water.

BENSEAL/Sand is often used to set shallow casing, heat-pumps, etc.

Permeability test data available on request.

Sealing Earthen Structures

Work BENSEAL® into the soil, covering completely the area which will be under water. Normal treatment is between 1 and 2 pounds per square foot depending on the condition of the soil. To treat a water filled structure, broadcast BENSEAL evenly over the entire area, in above amounts.

SP-00
Printed in U.S.A.

Baroid Drilling Fluids, Inc.
P.O. Box 1675, Houston, Texas 77251

Typical Physical Properties:

Bulk Density, uncompacted:		71.7 lb/ft³
Bulk Density, compacted:		73.4 lb/ft³
Moisture:		10%
Dry Screen Analysis:	**% on 8 mesh**	1
	% on 20 mesh	85
	% thru 200 mesh	3

Environmental Information:

Toxic Substances Control Act:
Listed by components in Initial Inventory, July 1979.
Toxicity Data:
LC_{50} = 96 HR (Rainbow trout)
10,000 ppm
LC_{50} - 96 HR (Mysidopsis bahia)
>1,000,000 ppm
BENSEAL® is not a hazardous waste or a hazardous material as defined in EPA criteria and listing 40 CFR Part 261, or DOT criteria and listing 49 CFR Part 172.
BENSEAL® and other bentonites contain free silica which according to IARC has exhibited limited evidence of carcinogenicity in humans.

Physical Characteristics:

Appearance — beige to tan powder
Specific gravity — 2.5 to 2.6
Mineralogical Analyses (typical)
85% Montmorillonite
5% Quartz
5% Feldspars
2% Cristobalite
2% Illite
1% Calcium and Gypsum
Chemical Analyses (typical)
55.44% SiO_2
20.14% Al_2O_3
3.67% Fe_2O_3
0.49% CaO
2.49% MgO
2.76% Na_2O
0.60% K_2O
5.50% Bound Water
8.00% Moisture at 220°F
99.09% TOTAL

Availability:

BENSEAL® may be purchased through Baroid Service Centers, QUIK-GEL® retailers, or from the Houston Customer Service Department.

Packaging:

BENSEAL® is packaged in multi-walled, water resistant paper bags containing 50 pounds (22.7 kg).