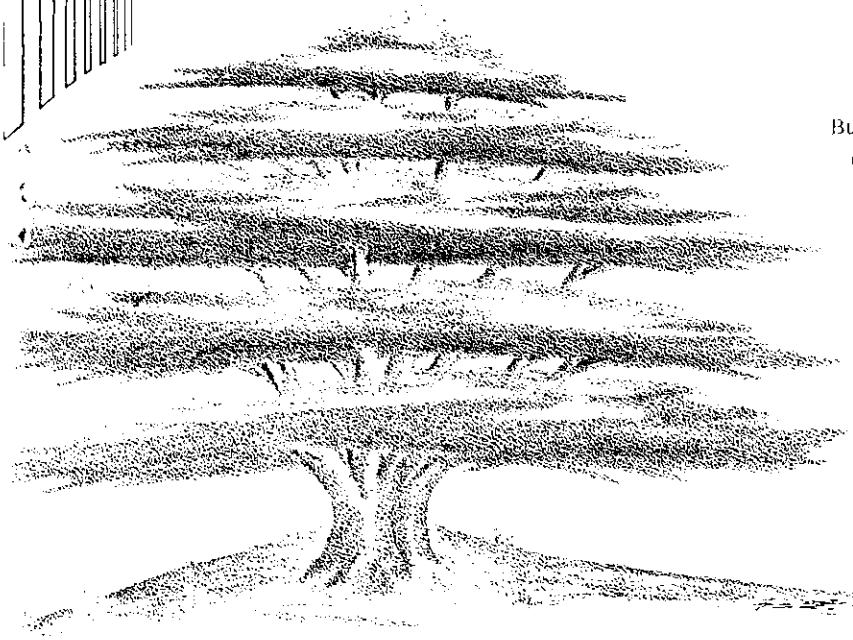
PLAN VERT LEBANON

الجمهورية اللبنانية
مكتب وزير الدولة لشؤون التنمية الإدارية
مركز مشاريع ودراسات القطاع العام

RESERVOIR LININGS

Prepared for

FOOD and AGRICULTURE ORGANIZATION of THE UNITED NATIONS



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UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation **Denver, Colorado**

November 1967

A REPORT ON ASSISTANCE TO THE GOVERNMENT IN LEBANON IN DEVELOPMENT OF EFFECTIVE AND ECONOMIC MEANS OF LINING CANALS AND SMALL RESERVOIRS

Prepared for the

Food and Agriculture Organization

of the United Nations

by

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WASHINGTON, D.C. 20240

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Mr. W. A. Lucas
Land and Water Development Division
Food and Agriculture Organization of
the United Nations
Via della Terme di Caracalla
Rome, Italy

Dear Mr. Lucas:

As a result of an exchange of correspondence between the Water Development Branch, Land and Water Development Division, Food and Agriculture Organization of the United Nations, and the Bureau of Reclamation, the Bureau provided the services of Mr. Lewis M. Ellsperman for technical assistance to the FAO. The specific assignment was "to advise and assist the government in Lebanon in developing effective and economic means of lining canals and small reservoirs." Mr. Ellsperman left Denver, Colorado, on August 31, 1967, and upon completion of the detail, returned to Denver on October 1, 1967. The assistance was primarily provided to the Green Plan (Plan Vert), the Lebanese organization in charge of land and water reclamation and development for the nation.

Enclosed is Mr. Ellsperman's final report which includes detailed information of the activities. This report has our approval.

Sincerely yours,

W. B. Bennett Jr.

Acting Commissioner

Enclosure

I. INTRODUCTION

There are three sources of water in Lebanon. Surface runoff during the wet season from about November 15 to March 15 is the primary source. There are flowing springs in the mountains limited generally to the winter season and some ground water sources particularly in the Bekaa Valley and in North Lebanon where pumping is prevalent.

One of the largest sources of agricultural income, is the production from apple orchards and vineyards on the mountain slopes.

A large segment of the population is dependent upon these crops. It is therefore extremely important to store winter runoff during the rainy season for use during July and August. I was advised that one or two good irrigations in the late summer can be expected to nearly triple the crop as compared with the same crop without irrigation.

The Green Plan is devoting considerable effort toward development of additional water storage for both individual and collective units of farmers. The use of newly developed and economical materials and construction techniques will assist the Green Plan in attaining its goal.

II. ACKNOWLEDGMENTS

I express my thanks to the many engineers in Lebanon who so ably assisted and cooperated in making the work productive and enjoyable. The effort of the staff members of the Green Plan, FAO in Rome and Beirut, and other agencies greatly facilitated the work. It would be impractical to list all whom I contacted; however, the following individuals were closely associated with me during the assignment and their assistance should be especially mentioned:

In FAO, Rome

Mr. W. A. Lucas, Chief, Water Development Branch
Mr. J. J. Ramsey, Water Development Branch
Mr. H. Marchand, Chief, Forestry Division, UNDP
Mr. M. E. deCoulon, Forestry Division, UNDP

In FAO, Beirut

Mr. M. Hashim Jawad, Resident Representative
Mr. M. Nordmo, Administrative Officer

In Green Plan, Beirut

Dr. Malek Basbous, President, Executive Committee
Mr. Michel Khouzami, Executive Committee
Mr. Hicham El-Hage, Executive Committee
Mr. Mahmoud Sabra, Technical Director
Mr. Sami Salame, Agricultural Engineer

Only through the interest and constant cooperation provided by Mr. Nalich Nahas, Chief, Engineering and Construction, was it possible to complete the assignment satisfactorily.

I wish to note that I also had the opportunity to work with members of the Ministry of Hydraulics and Electricity, Litani River Project, and Ministry of Public Works to a minor degree.

III. SUMMARY OF RECOMMENDATIONS

During visits to reservoirs and proposed sites, various materials and construction techniques were discussed and recommendations made. Technical information, laboratory reports, brochures, and specifications were provided and discussed in detail (see Appendix). A series of color motion picture films showing actual construction by the Bureau of Reclamation was presented and narrated.

IV. CONDUCT OF THE ASSIGNMENT

The Situation

At a planning conference with the Executive Committee and members of the engineering staff of the Green Plan on September 8, 1967, it was decided that Mr. Nalich Nahas and various engineers of his staff would accompany me on visits to different regions to observe examples of each type of small storage reservoir. I was requested to suggest repair methods where necessary and to provide information on lower cost materials as a substitute for the relatively high cost reinforced concrete tanks or reservoirs which are common in Lebanon.

Repair methods were discussed at the site where remedial work was required. Additional discussions were held enroute and at the headquarters in Beirut. Inspection of the reservoirs on the ground permitted me to evaluate local conditions and analyze the situation so that helpful suggestions could be made.

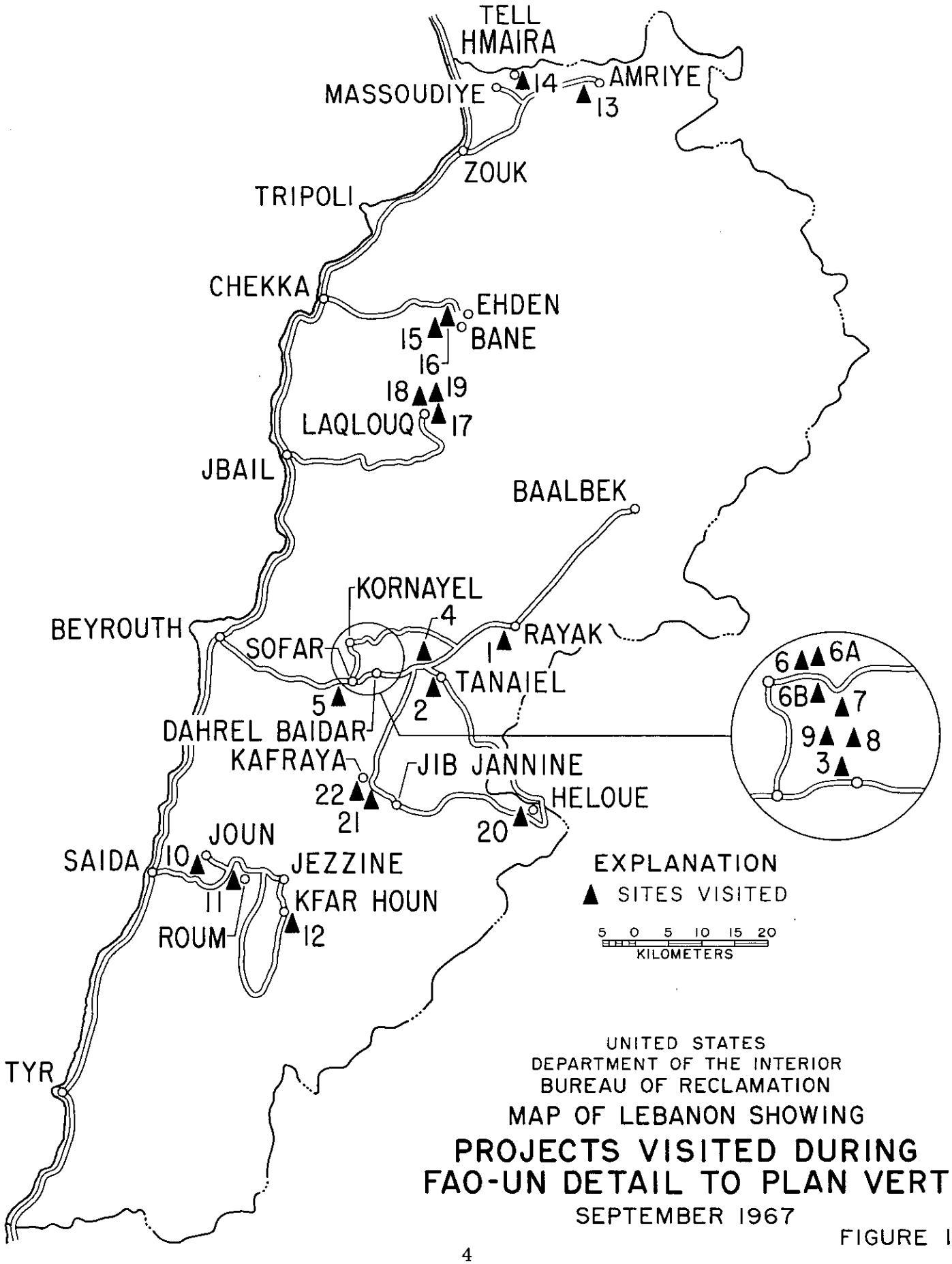
Construction Methods and Problems

During the period from September 7 to 22, I visited 19 reservoirs and 6 proposed sites. The general location of the various reservoir sites is shown on Figure 1. The results of my inspection at each site are discussed in detail in a subsequent section of this report. However, this summary of predominant construction methods and related problems precedes the detailed accounts.

The individual areas to be benefited by stored irrigation water are numerous but generally not extensive. Therefore, the volume of storage necessary to serve each area is relatively small. There are a number of difficulties encountered in providing this small storage volume.

Probably the most important are the mountainous locations having steep slopes and generally difficult access for any large construction equipment. The cost to provide roads to each location is prohibitive. The present reservoirs are mostly in the upper reaches of the mountain valleys where they intercept the runoff from small drainage basins. The expected rainfall intensities and snowmelt are high for the 3- to 4-month wet season. Steep land slopes, rocky terrain, and depletion of forest cover in most places result in large water yelds per unit area of watershed. For the above reasons, where the landowner can afford it, reinforced concrete tanks of various shapes with vertical walls are most often constructed. There is no doubt that the cost-benefit ratio is extremely favorable; however, a large percentage of small landowners simply do not have the funds.

Another prevalent type of reservoir is constructed by cutting into the hillside with dozers and using the removed material for an embankment on the downhill side. Normally, the only compaction given the embankment is that provided by the dozers. No attempt is made to provide the required moisture or rolling to obtain optimum compaction which often results in low density and very high seepage losses through the embankment. Occassionally, a clay lining is installed on the inner surface of the reservoir and this reduces the losses. Natural sedimentation has also been effective in certain cases in reducing seepage losses. Some reservoirs are unlined while others are lined with earth, rock masonry, concrete and one each of butyl rubber and asphaltic concrete.



UNITED STATES
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MAP OF LEBANON SHOWING

PROJECTS VISITED DURING FAO-UN DETAIL TO PLAN VERT

SEPTEMBER 1967

FIGURE 1

Inspection of Reservoirs

September 7

Site No. 1 - Agricultural Research Station, Tel Amara, near Rayak.

Description and Remarks: Oval shaped, 65 x 30 meters and 3 meters deep. Excavated earth used to construct the embankment around the excavation. Side slopes 2 horizontal to 1 vertical. Capacity: 3,000 cubic meters. Lined with butyl rubber sheeting 30 mils thick. Pump inlet and valve-controlled pipe outlet.

This is a test installation only 1 month old. The lining material was donated by Polymers Incorporated, Canada, through Mr. Sami H. Toutounji, Water Resources Development Company, Beirut. Although the subgrade had been moistened and rolled prior to installation of the liner, many clods were noted which put the butyl rubber under tension in local areas. It was pointed out that under such tension the exposed butyl-rubber sheet will show cracking and deterioration about 10 times more rapidly than a sheet in the relaxed condition. Originally, the liner was installed with slack, but the liner had conformed to the subgrade and some settlement occurred on filling so that now it is tight. Plans were made to loosen the lining at the berm anchor and provide more slack. No other problem was apparent.

In discussions with Dr. Tony M. Aboukhaled it was learned that the field station plans to install a complete selection of reservoir liners for demonstration and observation purposes. These linings will include polyvinyl-chloride and polyethylene as buried membranes.

Site No. 2 - Near Tanaiel.

Description and Remarks: A large unlined earthen reservoir operated by the Jesuits. Although there is some seepage, it is not serious. Drainage channels provide enough water for most of the irrigation and the reservoir water may be used if required. The reservoir is filled by diverting water from the nearby river and carries a high silt load. According to reports, the sediment deposit is reducing seepage each year.

Site No. 3 - Near Dahr El Bairdar.

Description and Remarks: Two concrete reservoirs with a capacity of about 8,000 cubic meters. Although slight cracking was evident, Mr. Abdallah, who accompanied me on this visit, felt there was no problem.

Site No. 4 - Near Jdita north of Tanaiel.

Description and Remarks: Proposed site. It was estimated by the Jesuit priest with us that a dam, properly located in this valley with a crest length approximately 800 meters long, could store about 3,000,000 cubic meters of water.

September 11

Site No. 5 - Near Sofar.

Description and Remarks: Rock masonry and reinforeced concrete. Original volume was 200 cubic meters. Reservoir was enlarged by adding sloping concrete aprons. The problem is leakage through cracks in the concrete. Also, it was reported that hydrostatic backpressure builds up on the uphill side of the reservoir during wet weather. Mr. Sami Sarieddine, who is on the staff of the Green Plan and is in charge of operations in this area, intends to remove the earth in back of the uphill wall, then waterproof with a hot-mopped asphalt waterproofing, and carefully replace the backfill. The following technique is suggested for waterproofing the wall. After the earth is removed, clean the concrete surface and apply a primer meeting specifications ASTM Designation: D 41-41 (1965). The primer should be allowed to dry and then apply waterproofing asphalt conforming with ASTM Designation: D 449-49 (1965), Type B. If available, an asphalt-saturated, asbestos felt should be embedded in the asphalt while soft in order to minimize the possibility of injuring the asphalt coating during the backfilling operation. (Copies of the ASTM Designations have been provided.)

The inner surface of the reservoir has been coated with a cement-mortar layer about one-fourth inch thick. The mortar is badly cracked, friable, and poorly bonded to the concrete. The mortar coating should be removed and all cracks in the concrete cleaned and enlarged to not less than one-fourth inch wide and one-fourth inch deep. The enlarged cracks should be clean and dry and be filled with a polysulfide, rubber-base, two-component, sealing compound conforming with Federal Specifications TT-S-00227C, Type II.

On September 16, Mr. Nahas and I met with Mr. L. P. Bardawill who can supply a sealing compound meeting this requirement An alternate method for repair of the sloping aprons and bottom consisting of a hot-applied surface seal of ashpalt-sand mastic about one-fourth inch thick was discussed and the mix composition provided.

Another repair method consists of adhering butyl-rubber sheeting or nylon-reinforced butyl-rubber sheeting to the surface. Specifications, brochures, and descriptive literature for this method was provided. Also, a color motion film of several successful Bureau installations of butyl rubber was presented and narrated.

Site No. 6 - Near Kornayel.

Description and Remarks: This is a proposed site for a new reservoir. Depending upon the information provided from a survey of the area, the embankment may be constructed using a compacted earth lining or a buried plastic membrane. Complete information on both types of construction was provided.

Site No. 6A - Near Kornayel.

Description and Remarks: A concrete reservoir having sloping sidewalls. The problem is serious leakage through the cracks in the concrete. Repair can be accomplished using the methods outlined in No. 5 above.

Site No. 6B - Near Kornayel.

Description and Remarks: This was a rectangular concrete reservoir in the final stages of completion.

Site No. 7 - Near Kfar Salona; east of Kornayel.

Description and Remarks: An irregular rock masonry and concrete reservoir with a capacity of about 17,000 cubic meters which is much larger than the average reservoir in the area. Apparently, this structure was enlarged in various stages leading to a number of wall sections having different slopes. Leakage through cracks and joints in the concrete is caught in an underdrain, piped to a small concrete tank downhill and then pumped back into the reservoir. Several methods of seepage control have been tried. The suggestions in No. 5 above could be investigated for a solution to the leakage problem.

Site No. 8 - Near Kfar Salona, east of Kornayel.

Description and Remarks: Earth reservoir. Downhill embankment failed by sliding. It appeared that the embankment became saturated and, due to insufficient compaction, failed.

Ample material for reconstruction of the embankment is located on the uphill slope opposite the embankment. A blended compacted earth lining may be used depending upon the availability of ample clay for use in blending with the in-place material to provide an impervious lining. Moisture control and adequate sheepsfoot roller compaction are required to obtain the necessary watertightness and stability. A layer of coarse material should be placed on the surface of the lining to reduce rain and wave-action erosion. Bureau specifications for typical blended earth lining were provided and discussed.

A buried plastic membrane lining may be used if desired or if tests indicate insufficient clay to assure an impervious lining. The embankment should be rebuilt having the inside slope 2 horizontal to 1 vertical or flatter. A 6-inch-thick layer of fine material should be placed on the surface and rolled with smooth steel-wheeled roller or hand dressed to remove sharp rocks that could puncture the plastic membrane. The 10-mil-thick polyvinyl-chloride liner should extend into the foundation in a trench about 5 feet below the natural ground line to prevent piping through the base of the embankment. The plastic should be installed in a slackened condition to accommodate possible settlement without rupturing. The top and both sides of the liner should be anchored by burying the ends in a trench 12 to 18 inches deep and carefully backfilling. The plastic must be covered to prevent early deterioration by exposure to sunlight. A free-draining material similar to pit run sand and fine gravel is preferred. Specifications for construction and material have been furnished for use as a guide. The owner intends to install a bottom drain near one side so that the reservoir may be emptied if necessary during the winter. Also, an emergency spillway is to be included to prevent overtopping.

Site No. 9 - Southeast of Kornayel.

Description and Remarks: Earth reservoir. Operating satisfactorily. It was reported that approximately 100 similar small reservoirs are located in this area.

September 14

Site No. 10 - Near Joun.

Description and Remarks: Asphaltic concrete-lined holding reservoir at the outlet of the powerplant. Presently under construction by the Litani River Project. Observations and discussions indicated that an excellent mix design had been developed and the latest construction techniques were being followed.

A drainage layer of crushed rock was placed over the entire subgrade. A perforated draintile was installed at the toe of the side slope around the reservoir and will collect any seepage through the lining and divert it through the embankment to the river. A coarse open-graded leveling layer of asphaltic concrete approximately 10 centimeters thick was installed over the drainage layer. Two layers of dense, rich, impervious asphaltic concrete each 5 centimeters thick completed the lining. Satisfactory compaction was obtained with a steel-wheeled vibratory roller. The panels, measuring 3 meters wide, were placed using a Blaw-Knox self-propelled paver in the bottom. On the side slopes a truckload of mix was lowered downslope by a cable connected to a winch. The mix was spread and leveled by hand between parallel iron channels to provide the correct uniform uncompacted thickness. The vibratory roller connected to the winch located on the top of the embankment compacted the asphaltic concrete on the slopes. All joints between adjacent panels were cut or tapered on a 45° angle and painted with asphalt to obtain a watertight joint. All layers are offset so that no series of joints are located one above the other. The asphaltic concrete is manufactured at the site in a central batch plant with gradation control hoppers. The dense-graded aggregate used for the impervious mix all passed the 1/2-inch screen with approximately 11 percent filler passing the No. 200. The binder is 40 to 60 penetration asphalt cement.

The mix design was prepared at the Ministry of Public Works Laboratory in Beirut. One of the most significant tests used in developing an asphaltic concrete mix design for use in hydraulic construction is the immersion-compression test. From a group of companion specimens, part are air cured and part are immersed in water. In order to be an acceptable mix, the unconfined compressive strength of the immersed specimens must equal at least 80 percent of the strength of

the air-cured specimens. Mr. Wakil reported that the French version of the immersion-compression test was followed as part of this mix design procedure. The Marshall Design Method was used for design and construction control. The density of cores obtained from the lining was used to assure adequate compaction of the asphaltic concrete lining.

Site No. 11 - Near Roum.

Description and Remarks: Concrete-lined reservoir at the inlet of the penstocks at the powerplant. No reported trouble or seepage.

Site No. 12 - Near Kfar-Houne.

Description and Remarks: The Dahr Darage Reservoir south of Jezzine near Kfar-Houne is under the jurisdiction of the Litani River Project. It is a large natural basin with gently sloping sides and up to 10 meters (32 feet) of clay, silt, and fine sand deposited on the bottom. It is now 4 years old and seepage is increasing through small cracks and fissures that form in the bottom during the storage of winter runoff. Apparently there are porous or faulted strata underlying the silty deposit and with saturation and an increase in waterhead, maximum about 5 meters (16.4 feet), the fines percolate into the foundation.

Three critical areas on the slopes which developed cracks and seeps have been covered with concrete lining consisting of panels about 3 meters (9.6 feet) square. The concrete lining was placed on a pervious drainage layer and any seepage collected is diverted out of the reservoir through "french drains."

At present, an area of about 52,000 square meters (62,400 square yards) in the bottom seems to be the major problem. Several methods of treatment were discussed with engineers during a visit to the site on September 14, and during a meeting with Mr. S. Haloini, General Director, Litani River Project and his staff on September 25. These methods are listed below:

1. No simple surface spray application could be considered as a satisfactory temporary seepage control measure since the clay and silt sediment deposit would prevent deep penetration of a liquid asphalt and result in a surface coat that would be easily injured or destroyed by the

traffic of the numerous herds of goats using the reservoir for drinking water.

2. The results of initial gradation tests conducted on the top 6 inches of soil in the reservoir indicate ample clay in this material to provide an impervious lining if properly mixed and then densified by sheepsfoot rolling. The minimum thickness of such a lining should be 0.5 meter (approximately 20 inches). Typical construction specifications were provided to Mr. Nahas, Green Plan.

3. The use of 10-mil thick polyvinyl chloride plastic lining with at least a 1-foot (30 cms) thick protective cover was described. The present surface must be shaped removing all sharp rocks and vegetation which might puncture the liner and rolled with a smooth steel-wheeled roller. The liner should be installed in a slackened condition to allow for subgrade settlement without rupture and well anchored in a trench 18 inches (45 cms) deep around the perimeter. Mr. Nahas has detailed installation procedures and material specifications.

It should be pointed out that the above described treatments (2 and 3), although relatively low in cost and when properly installed are excellent seepage control measures, are not recommended because they are almost certain to be injured by the large number of goats frequenting this reservoir. For this reason a hard-surfaced, impervious lining is suggested as follows:

4. Remove the vegetation, shape and roll the subgrade with a smooth steel-wheeled (vibratory if possible) roller. Apply a soil sterilant to the prepared subgrade. (A polyborchlorate soil sterilant may be the preferred type for this work since it is probably cheaper and more easily obtained in Lebanon. Also, it does not rapidly break down in the soil but is removed by leaching which should be negligible under an asphalt pavement.) Apply a prime coat consisting of a hard-base cutback asphalt at a rate of 1 gallon per square meter. After the prime coat is dry, install a 2 to 3 inch (5 to 7 cms) thick asphaltic concrete surfacing similar to that used for the second layer of the lining for the holding reservoir at the outlet of the powerplant. The mix design was developed by Mr. Nicolas Wakil, Chief Engineer of the Laboratory of the Public Works, and consists of a densely graded material all passing the 1/2-inch screen and about 11 percent

filler (passing the No. 200 mesh). The binder is approximately 9 percent 40-60 penetration asphalt cement based upon the dry weight of aggregates. Similar to the reservoir at the powerplant, the pavement should be placed with a self-propelled paver and compacted with a vibratory steel-wheeled roller while the mix is as hot as possible without shoving under the roller. The joints between adjacent panels should be tapered on a 45° angle, painted with asphalt and carefully compacted to insure a watertight joint. A seal coat of asphalt-sand mastic about 1/4-inch thick should be applied to the surface. The composition of the asphalt-sand mastic is not extremely critical; however, a few laboratory tests should be performed to determine the flow and sag characteristics of the mixture with local sands at 400° F. On the basis of a limited investigation conducted in the Denver Laboratories, asphalt, limestone dust, and fine sand (passing No. 30 sieve) with a weight ratio of 3:4:3 was satisfactory. A 30-40 penetration paving grade binder should be satisfactory.

It was reported that in the near future it is planned to treat the water from this reservoir and use it for drinking purposes. A lining such as that described in 4 above could be easily cleaned of sediment using small equipment. Linings 2 and 3 would be extremely difficult to clean.

Based upon construction and service reports and observations of asphaltic concrete used for hydraulic purposes, the suggested lining should be economical, durable, and watertight. As a specific example of similar construction, with Dr. Walter Becker and Dr. Herbert W. Schmidt, Esso A. G., I inspected the Geesthacht pumped storage reservoir near Hamburg, Germany on July 18, 1966. This reservoir was completed in 1957. An asphalt lining on a 2.5 on 1 slope consists of 5 centimeters (2 inches) sand-asphalt base, two layers each 3.5 centimeters thick (2.75 inches total) of dense asphaltic concrete and a surface seal of asphalt-sand mastic. The storage area measures about 500 meters (1,650 feet) by 600 meters (1,980 feet) and holds 3,300,000 cubic meters. The embankment varies from 12 to 24 meters (39.6 to 79.2 feet) above original ground line. After 9 year's operation with a maximum water fluctuation of about 14.6 meters (48 feet), the lining remains in excellent condition except for some minor localized blistering of the seal coat.

September 15

Site No. 13 - Near Amriye.

Description and Remarks: Kouachra Dam is a rockfill structure with a reinforced portland cement concrete upstream facing. Approximately 200,000 cubic meters of rock were required. Maximum height is 25 meters. The overflow spillway is a weir about 50 meters long at one abutment with the top of the weir about 3 meters lower than the elevation at the crest of the dam. The concrete panels measure 3 meters wide with rubber water stops between adjacent panels and the joint opening (about three-fourths inch wide) filled with asphalt joint filler. A bedding layer of porous concrete was placed between the rockfill and the concrete facing. Many panels were carefully examined but no evidence of cracking was noted. Very minor leakage was observed at the downstream base of the structure.

Site No. 14 - Near Tell Hmaira.

Description and Remarks: A rectangular concrete reservoir 45 by 20 meters, 2.5 meters deep, with a storage capacity of 1,850 cubic meters. The sidewalls were 50 centimeters thick. No construction joints were used. The reported total cost was 22,000 Lebanese pounds ($17,000). The water is pumped from an underground aquifer. No problems were evident.

Site No. 15 - Near Bane.

Description and Remarks: A 9- by 6- by 2-meter-deep (originally) concrete reservoir. The unsupported wall (downhill) failed after the height of the reservoir had been increased to 6 meters. An examination of the broken wall indicated that very large rock was used in the construction of the 50-centimeter-thick walls. One piece of aggregate was estimated to be 30 centimeters square and 45 centimeters long. The mortar was too lean and was not bonded well to the aggregate. I was informed that the reservoir will be rebuilt with concrete of the correct proportions and sizes of aggregate. This was not a seepage problem but a design problem.

Site No. 16 - Near Ehden.

Description and Remarks: A rectangular concrete reservoir, 22 by 12 meters and 6 meters deep, cracked open at the

corners and between the bottom and the walls probably due to foundation settlement. Presently the erection of a new wall on the downhill side about two-thirds the height of the present wall is being considered. No work will be done until the engineers have time for additonal study of the problem.

September 18

Site No. 17 - Near El Laqlouq.

Description and Remarks: A reservoir with a 4, 000-cubic-meter capacity was under construction. The contractor had stripped the vegetation from the ground surface and was starting embankment construction at the time of the visit. Earth was obtained from the uphill side of area and placed in layers about 15 centimeters thick at the embankment location. By careful application of water using a pressure spray and continuous rolling with a sheepsfoot roller, the compaction of the earth appeared excellent.

The lining will consist of a crushed-rock drainage layer using 20 centimeter rock filled with smaller key stone, rolled and sprayed with hot 80-100 penetration asphalt cement at a rate of 2. 5 kilograms per square meter. Next, a layer 1. 5 centimeters thick of hot asphaltic concrete using fine gravel and sand with the 80-100 penetration asphalt cement will be placed. Two final layers of mix will be placed with each consisting of fine sand (5 mm maximum), 25 percent filler, and 1 kilogram of asphalt per square meter.

Each layer will be rolled with a smooth steel-wheeled roller. A provision was made for a "french drain" to remove ground water from the drainage layer to prevent a buildup of hydrostatic backpressure during the snowmelt. A pipe outlet and an emergency spillway will also be included. The total cost of the reservoir was 13, 200 Lebanese pounds ($3, 500). The total cost of the lining was 7. 5 Lebanese pounds ($2. 35) per square meter. Based upon observations of the construction and discussions regarding the design, this reservoir should be watertight, durable, and relatively low cost per cubic meter of storage.

Sites No. 18 and 19 - Near El Laqlouq.

Description and Remarks: Proposed reservoir sites. Material at the sites is clayey and would provide an impervious embankment and lining if properly placed and compacted to

near optimum density. The terrain appears excellent for reservoirs of considerable capacity (60, 000 + cubic meters) by construction embankments between two hills.

September 20

Site No. 20 - Near Heloue.

Description and Remarks: Earth embankment failed by overtopping. Although there is a diversion channel on the left bank outside of the reservoir proper which acts as an emergency spillway, the main embankment was overtopped during high runoff and the center of the embankment was washed away. It is very likely that the diversion channel was blocked, either accidentally or on purpose, during the high inflow. The soil is clay and reportedly functions satisfactorily. Present plans include repair of the breached embankment, enlarging the reservoir basin, raising the embankment, and placing a concrete cap on the side of the diversion channel.

Sites No. 21 and 22 - Near Kafraya.

Description and Remarks: Proposed reservoir sites. Clayey soil and ample area for storage of a relatively large volume of water. The owner plans to pump from underground supply during the night and irrigate during the day. Since the reservoir will be filled and emptied daily, it may be beneficial to line the reservoir. A lining is not necessary for imperviousness but to prevent scour and erosion of the earth due to constant cycling. Several liners were discussed. An exposed butyl-rubber lining can be used. An asphalt lining is also practical. No ground water or hydrostatic backpressure is expected to develop in these locations.

Visit to Laboratory, Ministry of Public Works

On September 12, I visited the laboratory of the Ministry of Public Works with Mr. Nahas. The laboratory tests required for road construction are conducted using standard methods with satisfactory apparatus. Mr. Wakil and his staff appeared to be extremely competent in both design and control techniques for road construction materials, particularly in asphaltic concrete.

In discussions, I was advised that presently liquid cutback asphalt used in Lebanon for prime and tack coats is prepared by mixing an 80-100 penetration asphalt cement with gas oil or diesel fuel in a roofing kettle and heating and stirring the mixture until fluid.

The proportions vary from job to job. This is extremely poor practice and the resulting material exhibits very low adhesive or binding characteristics. A diluent such as gas oil volatilizes very slowly producing a "slow-cure" mixture or coating that will not provide the necessary stability or waterproofing for roads. A standard MC (medium curing) cutback should be used.

Information regarding colored pavements for use as sidewalk surfacing was requested and provided.

It was suggested that the "thin-film oven test" be added to the specifications requirements in order to improve the quality of the asphalt cement.

Mr. Wakil explained that presently limestone is crushed into three sizes, coarse, fine, and crusher dust. The crusher dust is used as filler but does not meet the particle size requirements since it is too coarse and often dirty. For use in asphaltic concrete these aggregates are usually blended and feed directly to the weight bucket at a plant. Without the use of individual hoppers and a tighter gradation control, it is difficult, if not impossible, to produce a satisfactory asphaltic concrete.

Visit to Ministry of Hydro-Electric Resources

On September 12 I met with Mr. Mohammed Fawaz, General Director, Ministry of Hydro-Electric Resources, who described a few problems. I talked with members of his staff on September 22. Mr. V. P. Vordanov explained that they have a number of cylinder-shaped concrete water tanks that are cracked and leak when loaded but when empty the cracks are closed and cannot be repaired. I suggested a butyl-rubber liner preferably nylon reinforced. The liner could be prefabricated as a one-piece cylinder to fit inside of the tank and anchored at the top and midpoint with a mechanical fastener such as a ring of 1.5-inch-wide, 0.25-inch-thick iron held in place with concrete studs or Ramset studs. Butyl sheets approximately 10 feet wide could also be used, being cut to the correct length to cover the inside circumference and using a 4-inch-wide overlapped joint. In either case the butyl rubber should be adhered to the concrete using butyl cement.

I was asked for suggestions to provide a watertight verticle cutoff (10 meters) in pervious soils where no clay is available. A dense, rich, asphaltic concrete, such as that described under Site No. 10 above, 10 to 12 inches thick, was suggested. Butyl-rubber sheeting and a rich sand-asphalt mastic grout in an open-graded coarse gravel were also mentioned.

I was informed that there were small depressions in the mountains where the present overburden and slope wash could be removed to make a catch basin. However, the rock surface is fissured and will not hold water. There are herds of goats in the area so that any waterproofing method used should not be easily punctured even when under water. Due to the remote location it would not be practical to use a hot-mix asphaltic concrete surfacing. My only suggestion was to try to fill the fissures with a portland cement-sand grout and follow with a hot-applied sand-asphalt mastic surface seal about 0.25 inch thick for waterproofing.

Visit to Office National Du Litani

With Mr. Nahas I visited the Litani River Project Office on September 22 and 25 for discussions on seepage control measures. The most urgent problem is described above under Site No. 12. I was requested to provide an advance report containing suggested methods of repair as soon as possible. The report was forwarded on October 27.

On September 25, Mr. Salah Haloini, General Director, and members of his staff were shown motion pictures of actual construction methods used by the Bureau of Reclamation in canal and reservoir lining work.

Contractors', Suppliers', and Manufacturers' Representatives

Throughout the entire assignment I met with various contractors', suppliers', and manufacturers' representatives to discuss construction techniques and materials. Mr. Nahas and Green Plan personnel were present at all these discussions. Some of the primary contacts and their interests are:

Mr. George T. Nassar, Shell Lebanon. Mr. Nassar advised that the Shell Refinery in Tripoli would be in operation by January 1968. He assured me that the products offered will meet all the standard specifications requirements. Among the products are: paving grade asphalt cement 80-100, 60-70, and 20-30 penetration; blown asphalts R 85/55 and R 85/40 (useful for buried asphalt membrane); also MC-0 and MC-1 cutback grade. The special "hard-based" asphalt prime was discussed and it can also be obtained on firm order basis. Among other interesting materials locally available from Shell are: a Flintkote system for tank lining consisting of asphalt emulsion, fiberglass mat and a trowel-type fibered asphalt emulsion; a colored acrylic thermoplastic mix for surfacing walks, tennis courts, roofs, etc.; and epoxy resin mixes for repair of concrete.

Mr. Henry Nazarian, Esso Standard Near East, Inc., and Mr. L. P. Bardawill. Esso can supply any grade of asphaltic material by importing in drums. Butyl-rubber sheeting is available in prefabricated sizes to order. The material specifications were examined and found to be similar to that used by the Bureau of Reclamation. One- and two-component polysulfide sealing compounds manufactured by Grace and Company that will meet the standard specifications are warehoused in Beirut. Polyethylene sheeting in pieces 40 feet wide and 100 feet long are in stock. Complete information on these materials has been provided to the Green Plan Office.

Mr. Sami H. Toutounji, Water Resources Development Company, donated the butyl-rubber liner for the reservoir at the Agricultural Research Institute. The material was obtained from Polymers Incorporated, Canada, and prefabricated to the correct size in a Beirut plant.

Mr. Aref Elawar, representing Seepage Control Incorporated, handles Soil Sealer No. 13 and Sealo W (Chevron sealant) which are chemical soil sealants. These materials are among those investigated in a Bureau of Reclamation research program and full particulars and laboratory reports were provided for use by the Green Plan. The cost of these materials appears prohibitive in Lebanon. At $1.20 per gallon the estimated cost to treat an earth reservoir with a capacity of 4,000 cubic meters would be approximately $1.60 per square meter. Also, in our experience, the chemical soil sealants have not yet proved durable.

Mr. Arthur Daou, Agence Gererale Libanaise de Distribution, Beirut, has been interested in providing polyvinyl-chloride liners for reservoirs. His plastic will meet the present Bureau of Reclamation specifications.

V. GENERAL RECOMMENDATIONS

The simplest method of providing an economical water storage reservoir is to dig a large hole, use the excavated material to form a surrounding embankment, and then to line the interior with a waterproof material. In many locations in Lebanon, ample clay exists for use in blending with in-place materials to form a watertight lining. To obtain a stable, watertight lining it is mandatory to densify the soils. Proper blending or mixing of the soils, the addition of moisture if required, and compaction by sheepsfoot rollers is recommended. A protective layer of gravel will minimize rain, wind, and wave erosion.

In areas where clay is unavailable or the site too remote for the use of construction equipment to be practical, a membrane lining may be used. The membrane may consist of hot-sprayed asphalt or plastic sheeting. A protective cover at least 1 foot thick must be placed over the membrane and carefully maintained. In the mountains where the hillside is excavated and the material used for the downhill embankment, often a membrane will be required only on the inside of the embankment.

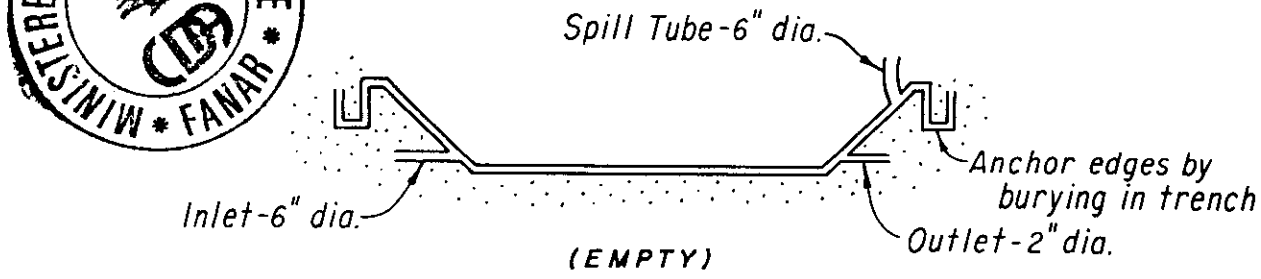
During the last few years, butyl-rubber sheeting has been successfully employed for various waterproofing applications. Its physical characteristics are almost unaffected by exposure to sunlight and weathering; therefore, a protective cover is not required. Similar to the plastic linings, butyl may be prefabricated to the desired size and installed by unskilled labor. A new development, which has considerable possibilities, is the application of nylon-reinforced butyl rubber in the construction of covered reservoirs. A two-piece storage bag, see Figure 2, would prevent the high evaporation loss prevalent in much of Lebanon.

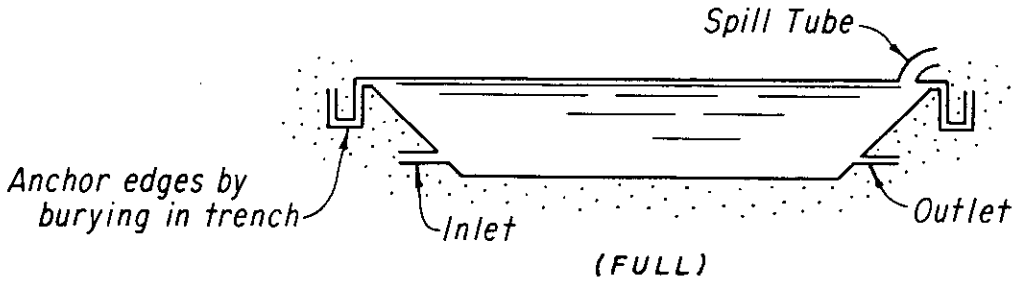
A dense, rich asphaltic concrete reservoir lining was being installed on the Litani River Project at the powerplant. A similar surfacing can be used in numerous instances without the sophisticated drainage layer design in order to reduce costs.

Cracks in the concrete reservoirs may be repaired with two-component polysulfide sealing compound or butyl-rubber sheeting. A hot-applied, rich sand-asphalt mastic surface seal is suggested for use as an economic repair and waterproofing for the bottom of the concrete reservoirs.

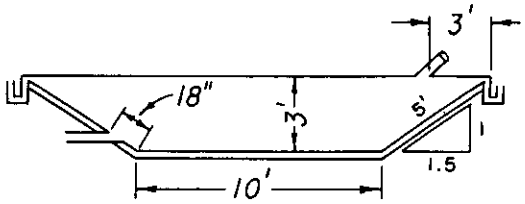
Provisions must be made to install a drainage layer, tiles, or "french drains" where the possibility of hydrostatic backpressure can develop under lined reservoirs.

Complete details for the above listed recommendations have been provided and discussed with engineering personnel in Lebanon. Figures 3 and 4 provide recent cost estimates and typical details for alternative reservoir linings from 25- to 200-million-gallon capacity. The costs shown on Figure 3 include an additional 30 percent for overhead and 20 percent for contingencies.

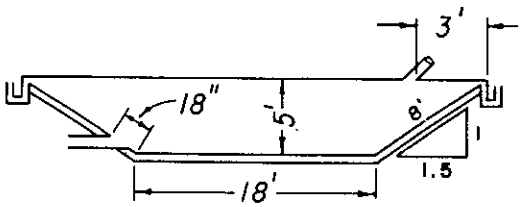




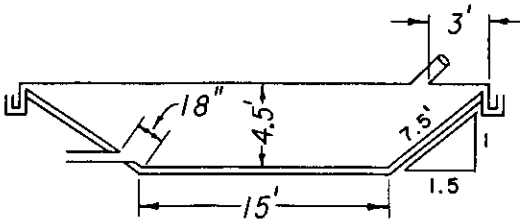
DESIGN FOR A TWO-PIECE STORAGE BAG



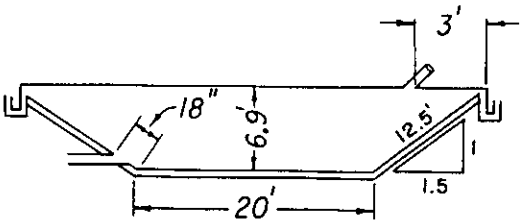
5,000 GALLONS - 20'x 20'



30,000 GALLONS - 34'x 46'



15,000 GALLONS - 29'x 29'



50,000 GALLONS - 43'x 43'

CAPACITIES AND DIMENSIONS OF STORAGE BAGS AND CONFINING BASINS

FIGURE 2

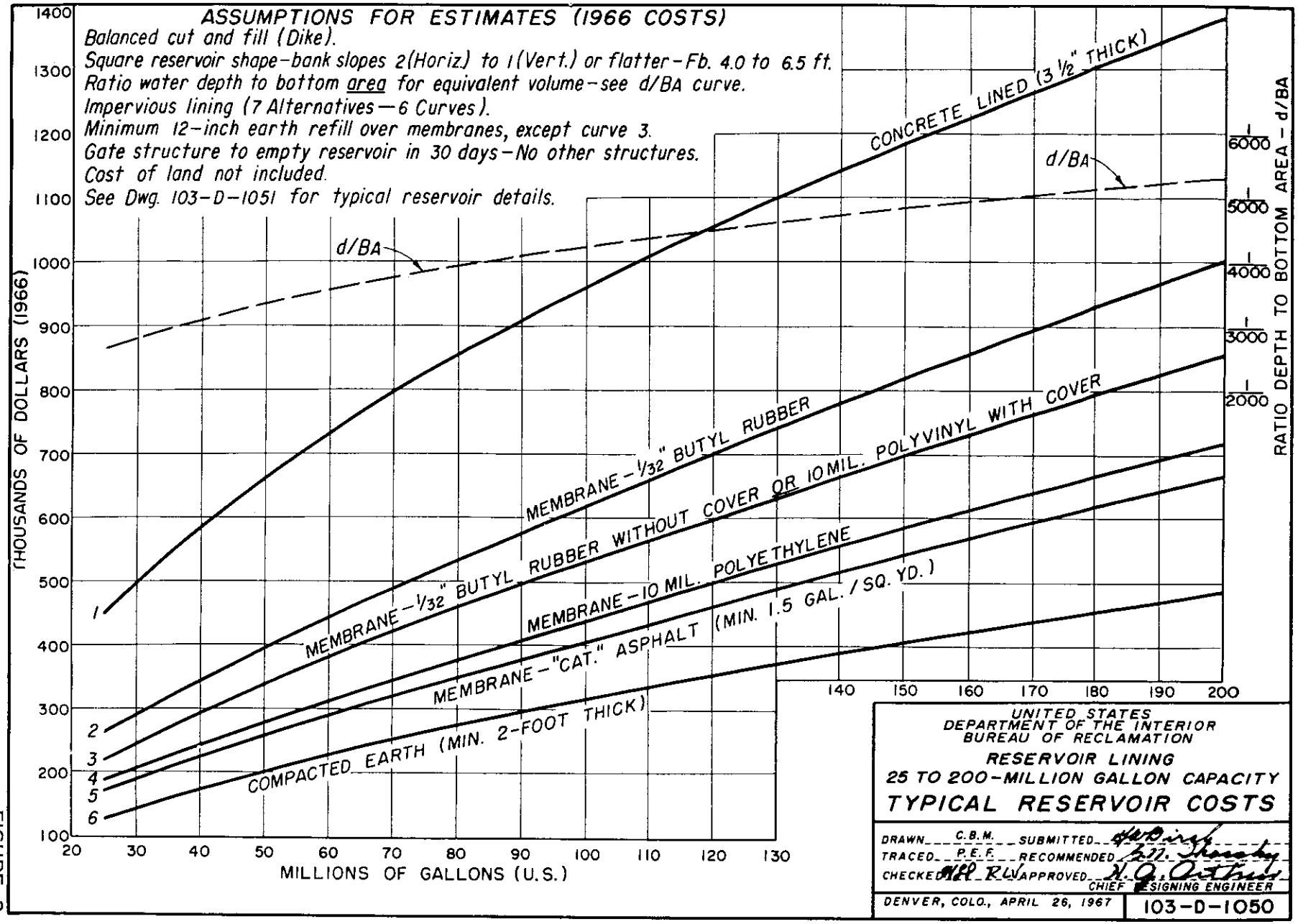
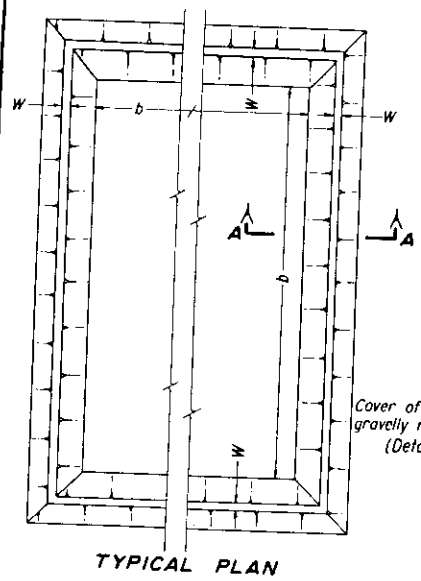
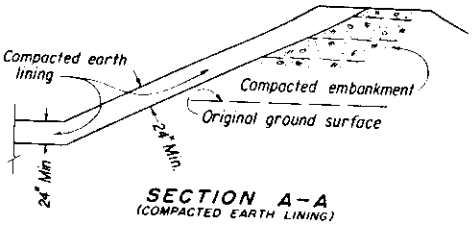

ASSUMPTIONS FOR ESTIMATES (1966 COSTS)
Balanced cut and fill (Dike).
Square reservoir shape-bank slopes 2(Horiz.) to 1(Vert.) or flatter-Fb. 4.0 to 6.5 ft.
Ratio water depth to bottom area for equivalent volume-see d/BA curve.
Impervious lining (7 Alternatives—6 Curves).
Minimum 12-inch earth refill over membranes, except curve 3.
Gate structure to empty reservoir in 30 days-No other structures.
Cost of land not included.
See Dwg. 103-D-1051 for typical reservoir details.
THOUSANDS OF DOLLARS (1966)
MILLIONS OF GALLONS (U.S.)
RATIO DEPTH TO BOTTOM AREA - d/BA
d/BA
d/BA
CONCRETE LINED (3 1/2" THICK)
MEMBRANE - 1/32" BUTYL RUBBER
MEMBRANE - 1/32" BUTYL RUBBER WITHOUT COVER OR 10 MIL. POLYVINYL WITH COVER
MEMBRANE - 10 MIL. POLYETHYLENE
MEMBRANE - "CAT." ASPHALT (MIN. 1.5 GAL. / SQ. YD.)
COMPACTED EARTH (MIN. 2-FOOT THICK)
1
2
3
4
5
6
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESERVOIR LINING
25 TO 200-MILLION GALLON CAPACITY
TYPICAL RESERVOIR COSTS
DRAWN C.B.M. SUBMITTED
TRACED P.E.F. RECOMMENDED
CHECKED APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLO., APRIL 26, 1967
103-D-1050

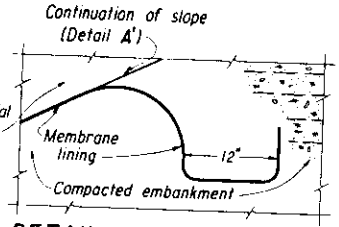
FIGURE 3



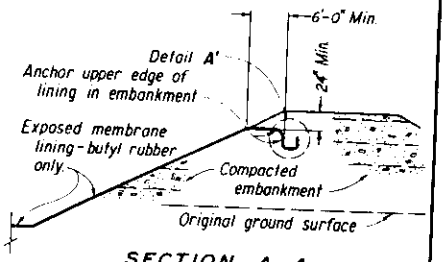
TYPICAL PLAN



SECTION A-A
(COMPACTED EARTH LINING)

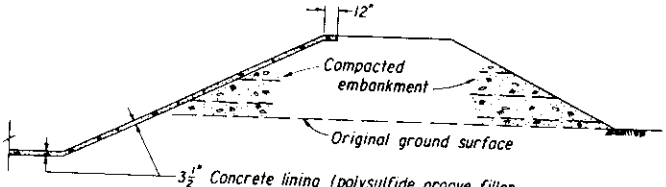


DETAIL A AND DETAIL A'
(ANCHORING MEMBRANE LINING)



SECTION A-A
(EXPOSED MEMBRANE LINING)

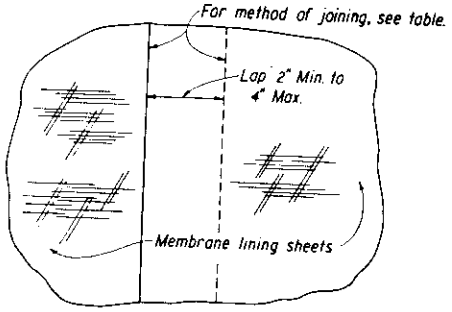
DETAIL	MEMBRANE LINING MATERIAL		
	Plasticized Polyvinyl Chloride (P.V.C.)	Butyl Rubber	Polyethylene
Method of joining	Heat, solvent, or adhesive	Adhesive	Heat and adhesive



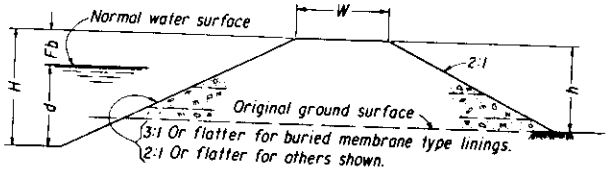
SECTION A-A
(CONCRETE LINING)

TABLE OF DIMENSIONS & DATA			
UNIT FEET	RESERVOIR CAPACITY (U.S. GALLONS)		
	25,000,000	100,000,000	200,000,000
b	837.0	852.0	1073.0
H	15.0	23.0	28.0
*d	10.73	17.03	21.45
h	11.2	17.8	22.0
Fb	4.0±	6.0±	6.5±
W (Min.)	12.0	12.0	12.0

*See Section A-A. Use d in inches for value of C.



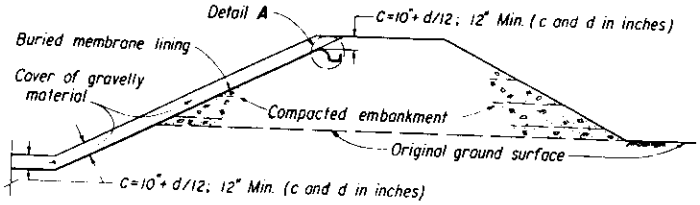
LAP JOINT DETAIL FOR MEMBRANE LINING



SECTION A-A
(TYPICAL)

NOTE

See graph 103-D-1050 for Typical Reservoir Costs.



SECTION A-A
(TYPICAL BURIED MEMBRANE LINING)

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESERVOIR LINING
25 TO 200-MILLION GALLON CAPACITY
TYPICAL DETAILS

DRAWN W.L.P. SUBMITTED
TRACED P.E.F. RECOMMENDED
CHECKED CBM R.L.V. APPROVED
CHIEF DESIGNING ENGINEER

DENVER, COLORADO, APRIL 25, 1967

103-D-1051

FIGURE 4

APPENDIX

BUREAU OF RECLAMATION TECHNICAL MATERIALS

Laboratory Reports

B-15	Report on asphalt undersealing a portion of the concrete canal lining--Wyoming Canal--Riverton Project
B-16	The effect of micro-organisms on membranes proposed for low-cost canal lining
B-24	Erosion resistance investigation of asphaltic materials
B-25	Evaluation of plastic films as canal lining materials
B-26	Laboratory tests of asphaltic concrete resurfacing--New York Canal and Kittias Main Canal--Region 1
B-27	Changes in rate of flow of water through a 1/8-inch hole in asphaltic concrete
B-28	Laboratory tests of asphaltic concrete canal lining material--New York Canal--Boise Project
B-31A	An evaluation of jute-reinforced prefabricated asphaltic canal lining after 2 and 3 years field service
B-33	Isolation and evaluation of canal subsurface membranes produced by a waterborne petroleum-based, emulsion-type soil sealant; Eden Project, Wyoming
B-34	Evaluation of field aging on the physical characteristics of buried hot-applied asphaltic membrane canal lining
B-36	Evaluation of Sand-Phenolic Resin Mixtures as a hard-surface lining
B-37	Installation of butyl rubber roofing, Bituminous Investigation FY64--Enders Reservoir Gatehouse--Kansas River Projects
ChE-22	Evaluation of special liquid asphalts for stabilization of sandy soil
ChE-42	Mix design investigations of asphaltic concrete for dam facing--Glen Elder Dam--Missouri River Basin Project, Kansas

Laboratory Reports--Continued

CH-102 A review of the use of chemical sealant for the reduction of canal seepage losses

GEN-29 Drawdown tests on earth cover material placed over an asphalt membrane East Bench Canal--Missouri Basin Project, Montana

GEN-32 Evaluation of cationic asphalt emulsion as a waterborne canal sealant by hydraulic flume testing

EM-743 Laboratory Studies for Final Design on Embankment and Foundation Soils and on Proposed Soils for Soil-Cement, Terminal Reservoir; Dikes 2 and 4 and 64th Avenue Evacuation Channel--Coachella Division--All American Canal System, California

Tech Memo 665 Field Tests of Sodium Carbonate as a Sealant to Reduce Seepage from Canals

Tentative Specifications

1. Canal lining, Plastic film Flexible, Polyvinyl Chloride
2. Asphaltic Membrane Lining
3. Butyl Rubber Canal Lining
4. Butyl Rubber Conduit Covering

Standard Specifications Paragraphs

1. Asphaltic Penetrated Macadam
2. Asphaltic Concrete Canal Lining

Technical Books

Linings for Irrigation Canals (4 copies)

O&M Releases

1. No. 29
2. No. 40
3. No. 46

Liners

Samples of various plastic and rubber sheeting

Sources of supply for Polyvinyl Chloride and Butyl Rubber

Technical Papers (USBR)

1. Laboratory and Field Studies of Asphaltic Concrete for Controlling Seepage
2. Buried Asphalt Membrane Canal Linings
3. Controlling Canal Seepage with Soil Sealants
4. Laboratory Testing and Construction of Asphaltic Concrete Dam Facing
5. Permeability Test for Evaluation of Canal Soils
6. Laboratory Studies of Asphaltic Concrete Containing Asbestos, Rubber, and Epoxy Resin

Drawings (USBR)

No. 103-D-632 Details of Buried Asphalt Membrane

Working Drawing of Slip-form Paver

No. 103-D-1050 Reservoir Lining, 25 to 200 million gallon capacity--Typical Reservoir Costs

Bureau of Reclamation Specifications

1. No. DC-6000 (Compacted Earth and Soil-cement Reservoir Linings--Canadian River Project)
2. No. DC-5945 (Concrete Reservoir Linings--Brays Landing--Chief Joseph Dam Project)
3. Portion of DC-6026 Buried Asphalt Membrane Canal Lining
4. Portion of DC-604C-62 Buried Asphalt Membrane Canal Lining
5. Portion of DC-6147 Asphaltic Concrete Slope Protection

Bureau of Reclamation Specifications--Continued

6. Specifications for Rubberized Joint Sealants

7. No. DC-6550 Supplemental Notice No. 1--Treating Areas with a Soil-applied Herbicide

The Asphalt Institute Publications

1. Asphalt for Conservation and Control of Water
2. Asphalt in Beach Erosion Control Structures
3. Asphalt in Hydraulic Structures
4. Asphalt Mixed-in-Place (Road Mix) Manual
5. Asphalt Paving Manual
6. Canal and Reservoir Linings
7. Compaction of Asphalt Pavements
8. Construction Specifications, Undersealing P.C. Concrete Pavements with Asphalt
9. Eastern Reservoir Borrows Western Ideas
10. Liquid Asphalts, New Specifications and Uses
11. Specifications and Construction Methods for Asphaltic Concrete and Other Plant-mix Types
12. Mix Design Manual
13. The Asphalt Handbook
14. Asphalt Plant Manual
15. Pocket Book of Useful Information
16. Specifications for Asphalt Cement
17. Soils, Part II
18. Drainage of Asphalt Pavement Structures
19. Hot-mix Sand-asphalt Base
20. Asphalt Institute Quarterly, April 1967

Outside Source Materials, Miscellaneous

1. Careymat Liners
2. Enjay Butyl, flexible seepage barrier
3. Sealtight-Meadowmat Liners
4. All About Peneprime
5. Uniroyal Waterproof Rubber Surfaces
6. Hydraulic Linings Inc.
7. Infra-red Equipment for Asphaltic Concrete
8. Use of Asphalt on California Reservoirs
9. Asphalt Linings for Filtered Water Reservoirs
10. Flexible Membrane for Seepage Prevention
11. Asphalt Linings for Waste Ponds
12. Reservoir Rehabilitation with Butyl Rubber Lining
13. Special Equipment for Paving Reservoir Slopes
14. Delivery and Spreader Equipment for Paving Slopes
15. Asphalt Used to Waterproof a Lake
16. Water Storage--A Half Million Gallons for $15,000
17. Plastic Films in Water Conservation
18. How to Prevent Sewage Lagoon Seepage
19. Aluminum Covered Reservoir
20. More than Engineering Needed--New Reservoir, San Francisco, California
21. Portions of "Bitumen in Hydraulic Engineering" by Baron W. F. VanAsbeck
22. Vinyl Film Liner for Earthfill Reservoir
23. New Reservoir Lining Being Tested
24. Soil-cement Slope Protection for Earth Dams, Laboratory Tests

Films, 16-mm Color Motion Picture

1. Use of Asphalt in Hydraulic Construction--1,400 feet
2. Plastic and Butyl Installation--800 feet
3. Chemical Canal Sealant, Eden Project--300 feet
4. Cationic Asphalt Emulsion Sealant, Aspen Canal--200 feet
5. Butyl Rubber Reservoir Liner, Wenatchie, Washington--300 feet
6. Asphaltic Concrete Resurfacing, Yakima, Washington--150 feet.

الجمهورية اللبنانية
مكتب وزير الدولة لشؤون التنمية الإدارية
مركز مشاريع ودراسات القطاع العام

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