Appendix C

Early Project Correspondence

4. <u>Depressed Area Floor</u>

A. <u>Reasons to suspect leakage</u>

1. Leakage from this area has been excessive from September, 1963 to April 1964 as shown by visible leaks on outside.

B. <u>Contrary evidence</u>

None

C. <u>Corrective measures</u>

1. Early in September 1963, a sudden increase in leakage up to 103 cfs occurred, most of which appeared outside opposite the depressed area. Reservoir was drained September 5th and 6th, and two holes in floor at Panels 91 and 92 were filled with concrete.

2. After the above repair, leakage was reduced to about 25 cfs. at a comparable elevation. About three days later another sudden increase in leakage caused the reservoir to be drained for further repairs. Large voids were observed under the floor and toe block where erodable material had been washed out. This condition was observed by J. Barry Cooke, and on his recommendation a four foot wide trench was excavated to "sound rock" in front of the toe block at Panels 90 to 90 to 93 and at 95. This trench, about 230 feet long and varying in depth from two feet to 10 feet was filled with concrete and covered with 2" of hot-mix asphalt. In addition approximately 200 grout holes 10 feet deep were drilled through the toe block apron and poured full of grout. After this repair the leakage was considerably reduced, but was still in the range of 35 to 40 cfs. with pool at 1580.

3. By November 4, 1963, leakage had increased to 59 cfs at 1584, and reservoir was again drained for repairs. A long crack was discovered in the asphalt floor at Panels 91 and 92, and additional voids and washed-out areas were found under the floor and toe block. Voids were cleaned out and filled with concrete. A grout curtain was placed from panel 95 to 90 along the cut-off wall and thence across the floor to panel 107. 20 ft. holes on 10 ft. centers were pumped full of asphalt underseal, and then intermediate holes 30 ft. deep were drilled and pressure grouted with cement. After this repair, reservoir leakage was reduced to about 35 cfs at a comparable head.

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4. Disturbed Area Floor (Continued)

C. Corrective measures

4. On January 31, 1964, leakage had increased to 55 cfs at elevation 1585. Reservoir was drained and it was found that crack in front of cut-off wall was opened up for about 100 ft. at panels 90-91. This was covered with old conveyor belting held down by 4 inches of concrete reinforced with wire mesh. Reservoir was filled before all concrete was set up, and part of the repair was washed out. Leakage after this repair was about 44 cfs at a comparable head.

5. In March, 1964, (leakage was 59 cfs at 1596 pool) reservoir was drained for repairs. Crack along cut-off wall was again evident. This crack was covered with conveyor belt placed on a 4" bed of soft concrete, and then covered with a reinforced concrete slab 10" thick and a minimum of 10 ft. wide. Additional holes were drilled and pressure grouted along this slab and partially along the line of old grout holes placed in November.

After this repair, reservoir leakage was reduced to 27 cfs at a 1596 pool.

D. Subsequent observations

1. After the final repair in April, 1964, visible leakage outside the reservoir in this area was reduced to a relatively small value - about 1 to 2 cfs. This leakage has not increased significantly since that date.

J. BARRY COOKE
CONSULTING ENGINEER
253 LAUREL GROVE AVENUE
KENTFIELD, CALIFORNIA 94904

TELEPHONE (415) 454-9331
CABLE: COOKE, KENTFIELD, CALIF.

August 19, 1967

Mr. John K. Bryan, Chief Engineer
Union Electric Company
1901 Gratiot Street
St. Louis, Missouri 63166

RECEIVED
AUG 28 1967
JOHN K. BRYAN

TAUM SAUK UPPER RESERVOIR
REPORT ON SAFETY

Dear Mr. Bryan:

I have reviewed the performance data furnished with Ray Weldy's letter of June 26, 1967, inspected the dam with Frank Drake, Paul Pickel and Ray Weldy on August 15th and engaged in discussions with Union Electric engineers on August 16, 1967. The purpose of my review was to evaluate the safety of the dam and make recommendations for any work that I considered necessary to improve safety.

Conclusion

Based on my knowledge of design and construction, review of performance data, and site inspection, I see no feature where work is required to improve safety. The dam and foundation could safely withstand much greater leakage than has occurred to date, and could withstand more leakage than could be visualized to conceivably occur.

Crest Settlement (Vertical)

The crest settlement after 1 yr - 8 months, six months after the first complete filling, the settlement was higher than normal but quite acceptable, the range of readings being 0.3 to 0.6 feet. In the next 1 yr. - 6 mo. the rate of settlement decreased. However, in the last two 8 month intervals of readings the settlement has been more than in the preceding 8 months. It has been 0.06 to 0.08 ft. in each 8 month period, a rate of nearly 0.10 ft/year.

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The 0.10 ft/year rate for a 100 ft high dumped rockfill after 4.5 years of service is high, and unexpected. It would cause joint and face trouble as well as freeboard impairment in several to 10 years. There is nothing that can be done except to continue to observe the rate of movement and hope it decreases.

The vertical crest settlement in 4.5 years (Nov. '62 - June '67) has been about 0.5 ft (0.53% height) for 94 ft height at axis, and 0.8 ft (0.73% height for 110 ft height. Maximum has been 0.98 ft for 141 ft ht. (0.70% height). These movements in the 4.5 year period are high. The slab and parapet has satisfactorily accepted them.

The settlement on the whole perimeter is similar and reasonably related to height. It does not show any pattern with respect to curvature of the axis of the dam. It therefore appears that the continuing high rate of settlement is a characteristic of this particular rockfill or a consequence of the repeated reapplication of load on a dumped rockfill.

The Taum Sauk rhyolite porphyry is an excellent high compressive strength rock that should have stabilized in its settlement. However, the formation contained frequent zones of soft weathered rock, all of which could not have been selectively wasted. The frequent cycling of the water load should not cause continued adjustment of competent rock but would affect the poor rock. Actually, there is no other experience with such frequent cycling of load on a dumped rockfill, and whether a dumped rockfill of all sound rock would have stabilized by this time is not known. I believe a fill of 100% competent rock would have stabilized and that the percentage of weathered rock in the Taum Sauk is the cause.

Crest Elongation

The crest lengthens when the center of curvature of the axis is in the reservoir. It has been computed that between panels #40 and #67 (1260 ft) the lengthening has been 15 inches, which is 1 in 1000. This stretch or loosening of the fill is associated with slightly higher settlement and could be visualized to cause continued settlement. The movement to date has opened some joints to their limit, which is a problem, but I don't see this feature as a cause of continuing settlement.

This tension or stretch of rockfill occurs in dams that have a bend in the axis (a bend that gives a central angle in the reservoir of less than 180°), and it occurs in the rockfill on steep dam abutments. Relief

Dam (California) and La Joie Dam (British Columbia) both are concrete face dams with "adverse" angles in the axis. They have opened cracks at the junctions, which cracks essentailly stopped moving after several years. On high rockfill dams there is a stretch in line with the axis in the one-fourth of crest length near each abutment, and a compression or shortening in the central portion of the dam. The lengthening has been measured at 1 in 300 to 1 in 500 at Mud Mountain, Akosombo and other 300 ft high rockfill dams. The stretch is accompanied by a higher settlement but the settlement does essentially stop.

Parapet Wall

The storage of 8 ft of water on the 10 ft parapet wall is more than has been experienced before. Measurements and visual observations indicate the 6300 ft long wall to be performing very well, and the relative movements to be small.

Panel joint spacing. Joints were initially constructed to 1 inch open. Most have opened, due to the curvature of the axis. The amount of opening has been nominal 1/4 to 1/2 inch except for about 10 of the 111 joints which have opened more than 1 inch. Only several have approached 2 inches and required an inner seal to be installed. Closing of joints has been small and has given no problem in leakage or repair work. The opening of joints in itself would accept 3 inches or more, but combined with a small vertical offset wrinkles occur that cause tears and consequent leakage before joint is fully opened. Future joint opening combined with vertical offsets, it appears, will require further repairs.

Horizontal Panel Misalignment at Joint. On March 10, 1966, offsets were on the order of 1/4 inch with several near Panel #88 at 1 to 1.5 inches. In the 6 month period to September 20, 1966, the movements were generally 1/8 to 1/4 inch with nearly half being in a direction to decrease the offset. This is favorable. There is no indication of trouble developing in these small and in many cases restoring movements.

Vertical Deflections of Parapet Wall. These measurements give the amount the walls are out of plumb. The measurements show the walls to be remaining remarkably plumb. Changes Sept. '63 - Sept '66 indicate about half tilting outward and more than half tilting inward, the amounts out of plumb being usually 1/8 to 1/4 inch, with few being as much as 1/2 inch.

Cracks. All of the 60 ft long parapet panels seem to have settled more at the center than at the edges. This is evidenced by vertical cracks at about 10 ft spacing that start at the bottom and stop about 5 to 6 ft up on the 10 ft wall. In two slabs spalling has occurred near the top and center, indicating high compressive stress. It is possible that the shear at the base of the 10 ft wall has caused slight movement and the leakage in the Panel 10 to 25 area, in combination with a poor cold joint. Otherwise, this "phenomena" has caused no trouble. It is probable that the redistribution of water load on the rock by the stiffness of the wall & its base will keep relative settlement compatible with the stresses in the parapet wall and base slab. I don't know why this stress and differential settlement occurs, but there must be a reason since it is so consistent among all panels.

Crest Road - Berm Sloughing

Sloughing of the berm of the crest road has occurred in the Panel 43 to 63 area, the deepest sloughs being in areas of Panels 50-51-52. At Panels 50-52 the sloughs removed as much as 6 ft of the 12 ft road, and they caused a surface slide that piled up some rock at the toe of the rockfill. This is a surface stability problem only and has now taken care of itself. It could only have happened due to excessive fines in the top of the dumped fill and in the four 4 ft lifts above the top of the dumped rockfill.

The Panel 43 to 63 area was the last zone of the dam that was completed and excessive fines were known to have been included in the rockfill. Excavation for the hand dry rock masonry, in restoring the berm, was in fine material. The top of the dumped rockfill, 16 ft below the crest would be impervious. Leakage above that level and rainfall could saturate the upper zone of the dumped rockfill as well as some of the 4 ft layered rock with excessive fines. Local sloughing would be possible under these conditions. The local nature of what occurred compared to the 60 ft width of slab and the dimensions of the rockfill make it impossible to imagine any hazard to the crest of the dam, other than maintenance for roadway width.

Leakage

The reservoir leakage is now 8 cfs, which is substantially lower than the high leakages associated with problems in the initial operating period. The downstream toe of the dam and the foundation in that area were inspected. The leakage channels have never caused erosion of consequence and the saturation has not caused slides or any indication of potential slides. From the known conditions of the foundation and the dam, and from the inspection, there is no stability problem due to the leakage. The base of the rockfill is of large sound rock, as segregated during the process of dumping from the high lift, and could safely take hundreds of cfs leakage.

Proposed October 1967 Shutdown

The reservoir will be unwatered for work on the spherical valve. The shutdown will be for about 3 weeks. Any work on the dikes and reservoir floor during that time would be as determined to be economical in reducing present or future leakage. No work is necessary to improve safety beyond the present adequately safe conditions.

Sincerely yours,

JBC:dm

Barry Cooke

IMG031310

UNION ELECTRIC COMPANY
1901 GRATIOT STREET
SAINT LOUIS, MISSOURI 63166

August 9, 1968

MAILING ADDRESS:
P.O. BOX 149
SAINT LOUIS, MISSOURI 63166

Mr. J. Barry Cooke
Consulting Engineer
253 Laurel Grove Avenue
Kentfield, California 94904

Dear Barry,

TAUM SAUK PROJECT UPPER RESERVOIR
F.P.C. SAFETY REPORT

Mr. Vencill and I have talked about your letter of July 26, and we have decided that we should maintain that the controls and alarms are reliable and no spillway or overpour provisions are needed. That is the position we have maintained from the beginning. If the F.P.C. should reverse their present Taum Sauk stand, in view of spillway requirements for recent projects, then we could ask you for an additional study and recommendation. In this you could bring out your recommendations that you have made for the safety of the parapet from overpour and the safety of the rockfill from erosion.

The plant is unattended and is operated automatically from our Osage Plant (103 miles distant) over microwave channels. Maintenance men are on duty from 8:00 A.M. to 4:30 P.M. five days a week and one or two men keep the visitors' center cleaned up on Saturday and Sunday. A Pinkerton guard is on duty from 6:30 A.M. to 6:30 P.M. every day of the year. He makes numerous trips to the reservoir area and would notice any overpour if it extended beyond 6:30 A.M. The normal procedure is to pump back with only one pump, and shutdown varies from 3:00 A.M. to 5:00 A.M. On the few occasions when two pumps are used, shutdown is seldom before 6:30 A.M.

The normal procedure is to rely on the automatic controls with any backup that is provided. If these fail, then an "urgent alarm" is transmitted to the Osage Plant and a maintenance man is called out. It takes him 30 minutes to an hour to reach the plant depending on the distance he has to travel.

The pump shutdown controls operate as follows. The surface detector (headwater gage) is accuated by a displacer that follows the water's surface in an inclined pipe. The instrument (made by Leupold & Stevens) has three built-in shutdown switches that operate at elevation 1595, 1596 and 1597. The first switch operates to shutdown the first pump (when two are operating) at elevation 1595. The second operates to shut-down the second pump (or either pump if only one is operating) at elevation

1596. Shutdown takes about six minutes and the reservoir rises an additional 0.25 foot after the switches operate. The third switch operates at elevation 1597. This is a backup switch that shuts down either or both units if the first two switches fail to operate properly. Complete shutdown occurs in about 2.5 minutes after this switch operates.

In case of power failure to the surface detector an "urgent alarm" signal is received at Osage and there is a call out to determine the trouble. There is a separate set of float switches which operate in case the surface detector fails from any cause. These backup switches are in a separate float mechanism which is mounted over a stilling well on the inside of the parapet wall. These switches are all set to operate at levels 0.1 foot above the normal shutdown switches. If the first or second switch should operate (elevation 1595.1 and 1596.1) a target shows up on the annunciator panel and the trouble is corrected during the normal day shift. If the first two backup switches should fail to operate, the third switch will operate at elevation 1597.1 and will trip the circuit breakers and shut the unit or units down immediately. A lockout will occur and the units cannot be started as a pump or generator until a maintenance man corrects the trouble.

All six of the switches are wired for fail-safe operation. They are normally closed and operate at 125 volts D.C. If any circuit from the plant to the reservoir opens up due to any cause including lightning blowing a fuse, the unit or units automatically shut down. If the units are not operating, the automatic controls prevent starting as a pump or generator.

Another safety feature is that an "urgent alarm" is received at Osage when the total volume of water falls below about 4,300 acre feet. The volume controller would get this indication if there was a mechanical failure that would keep the surface detector from following the water level upward. However, there would be no "urgent alarm" signal in the top 11 or 12 feet because we operate with 4800 AF in the system under the assumption the last 10 feet of water will not be drawn out of the upper reservoir.

There is also a provision for automatic shutdown of each unit in case of low tailwater (lower reservoir) level. A float switch connected to the draft tube of Unit No. 2 will shut it down when the pumping level in the draft tube reaches 726. A similar switch will shut down Unit No. 1 at elevation 725. The velocity head at the throat of the draft tube is 7.86 feet with a pumping rate of 2,000 c.f.s. with full upper reservoir, and the friction loss may be as much as one foot. This makes a total head loss of about 9 feet which means that No. 2 and No. 1 pumps would not pump much below a lower reservoir elevation of 735 and 734 respectively before automatic shutdown would occur. The exact elevation has never been determined. The float switch for No. 2 Unit was set to operate at a draft tube water level when cavitation just began to occur as indicated by a loud popping sound. No. 1 Unit was set to operate one foot lower. During

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the early days of operation, before the binwall dam was constructed across the East Fork of the Black River, a flood washed gravel into the excavated channel and partially restricted it so there was considerable drawdown when pumping at low pool level. The float switches were installed then to prevent pumping at low levels where cavitation occurs.

There is an indicating upper reservoir level meter in both the Load Dispatcher's Office in St. Louis and the control room at Osage. Men at both of these places watch these meters but do not record levels each hour. Also they have a general feel of how long the pump or pumps should run, and it is inconceivable that either of them could let the pumps run very long after the reservoir is full without noticing that they had failed to stop.

Now I will comment on your ideas for making the parapet and rockfill safe from overpour. You asked the following question. Assuming pumping continued and there was no lower reservoir inflow, how long would it take to drain the lower reservoir? Right now with the upper reservoir full (1596.25), the lower reservoir is at elevation 736.25. If the automatic controls in the upper reservoir failed to shut down both pumps, then they would continue to pump until the float switches attached to the draft tube shut them down. The upper reservoir would rise to elevation 1598.43, the elevation of the lowest parapet (No. 95), and then start to run over the top. This is not actually the elevation but is the comparative elevation with Panel 58 where the gage is located. After the water started to flow over the top, it would continue to flow over more and more parapets for about 20 minutes when Pump No. 2 would shut down with the lower reservoir at elevation 735. No. 1 pump would continue pumping 2,000 c.f.s. for another hour before it would shut down when the lower reservoir reached 734. If both pumps failed to shut down, they theoretically could pump until they ran out of water with the lower reservoir down to 724, the bottom of the excavated channel. However, the pumps would begin to experience a shortage of water at a higher elevation of say 730 due to the slope in the channel. The volume between 736.25 and 730 is 1130 AF and it would take 3.4 hours to pump this amount at the rate of 4,000 c.f.s. All of the overpouring water from the parapet would return to the lower reservoir in perhaps an hour, then there would be a continuous recirculation system and the lower reservoir could never be emptied.

I like your idea for deflectors to aerate the overflow of the parapet and the caps to limit the overflow to one c.f.s. per foot. We already have deflectors (one-foot concrete blocks) on Panels 5, 10, 15, 20 and 58 which were installed for another purpose. Additional deflectors and caps could be installed at a fairly nominal cost, I believe. They could be made out of half hard aluminum sheets (like we used over expansion joints for repairs) bolted to the outside of the parapet with cinch anchors. However, if this is done it will shorten the length of overflow and increase the head and flow per foot of length. We will run another computation on this to determine the pool elevation using your suggestion for capping about 62 panels. In the meantime we will give consideration to your suggestions and there is the chance that we can work it in with some maintenance at a later date, say in 1969.

We would like to review the draft copy of your Upper Reservoir Report as soon as your finish it. We are getting to the point now where we would like to file your report with the F.P.C. as soon as it can be done conveniently.

If you will send us the original of your final report, we will make the nine additional copies which we will need. This includes one copy which we will return for your use.

Incidentally, Mr. Jack Shepley of the F.P.C. Washington Office called Mr. Vencill recently and asked for information about the upper reservoir level detection and pump shutdown which I sent him. He is writing an A.S.C.E. paper and I presume he will cover most of the licensed projects. I told him there would be no structural damage if the pumps failed to shut down, but there would be some washing of the roadway surface.

Very truly yours,

Raymond N. Weldy

Raymond N. Weldy
Sr. Supervising Engineer
Hydraulic Engineering

mgw

cc: Messrs. M. W. Fleer
E. W. Nielson ✓

IMG031328

May 22, 1970

Mr. E. Dille

Taum Sauk Upper Reservoir Leakage

The computed leakage for the period April 9, 1970 through May 14, 1970 is 13.13 cfs which is a numerical increase of 1.42 cfs from the previous period. However, during this period the leakage has had an additional head of six (6) feet. This increase in leakage had been anticipated when raising to the summer elevation.

The Monthly Inspection of the Upper Reservoir Rockfill was made on May 13, 1970; no significant structural changes were noted. There were several small washes noted in the "fine" fill area between panels 88 through 110 because of the recent heavy precipitation.

Original Signed By M. W. FLEER

M. W. Fleer
General Superintendent
Osage & Taum Sauk Plants

RJM/jmd
cc: F. Drake
R. Roettger
G. Vancill
R. Miller

IMG054638

TAUM SAUK Inspection, Wed., May 13, 1970

Gage Comparisons.

gage no.	4-9-70 Last month	5-13-70 This month	change
1	11 1/2"	12"	Down 1/2"
2	8 1/4"	9"	Down 3/4"
3	13"	13 1/4"	Down 1/4"
4	6 1/4"	7"	Down 3/4"
5	28"	28 1/4"	Down 1/4"
6	19"	19 1/2"	Down 1/2"
7	16 1/4"	16 3/4"	Down 1/2"
8	15"	16 1/4"	Down 1 1/4"
9	-4"	-2 3/8"	Down 1 5/8"
10	20 3/4"	21 3/4"	Down 1"
11	15 1/4"	16"	Down 3/4"
12	7 3/4"	8 1/4"	Down 1/2"
13	-2 1/2"	-6 3/4" same as 26 1/2" on new gage	
14	14"		
15	28 3/4"	30"	Down 1 1/4"

computed leakage 4/9 – 5/14 is 13.13 up 1.91 cfs.

gage #13 up 4 1/4"
gage #14 was being cleaned with back hoe not possible to get a good reading.

The gage readings are generally down while the computed leakage is up. The "fish pond" area – say between panels 90 & 102, is up in leakage. The increase in leakage in the fishpond area represents from 2 to 3 cfs.

accompanied by FTD.

RJM

IMG054639

REPORT OF INSPECTION
TAUM SAUK UPPER RESERVOIR

RJH & FTD

Date: Wed, May 13, 1992

Reservoir Elev: 1592 & Generating

Weather: fair & warm   Surface water temp 64°F

Gage No.	Gage Height*	Condition of Gage	Comments
1	12"	OK	
2	9"	OK	
3	13¼"	OK	
4	7"	OK	
5	28¼"	OK	
6	19½"	OK	little cattle spare
7	16¾"	OK	
8	16¼"	OK	
9	-2 3/8"	OK	
10	21¾"	OK	
11	16"	OK	
12	8¼"	OK	
13	-6¾		installed new gage 26¼" equivalent
14			Men removing slide Minor slides choked discharge.
15	30"		
16			
17			

* Amount of gage above water surface

General Comments: leakage was generally down except for area between panels 88 & 102 where it has increased. Drainage channel below panel 30 should be opened to allow water passage to relieve head on sink hole.

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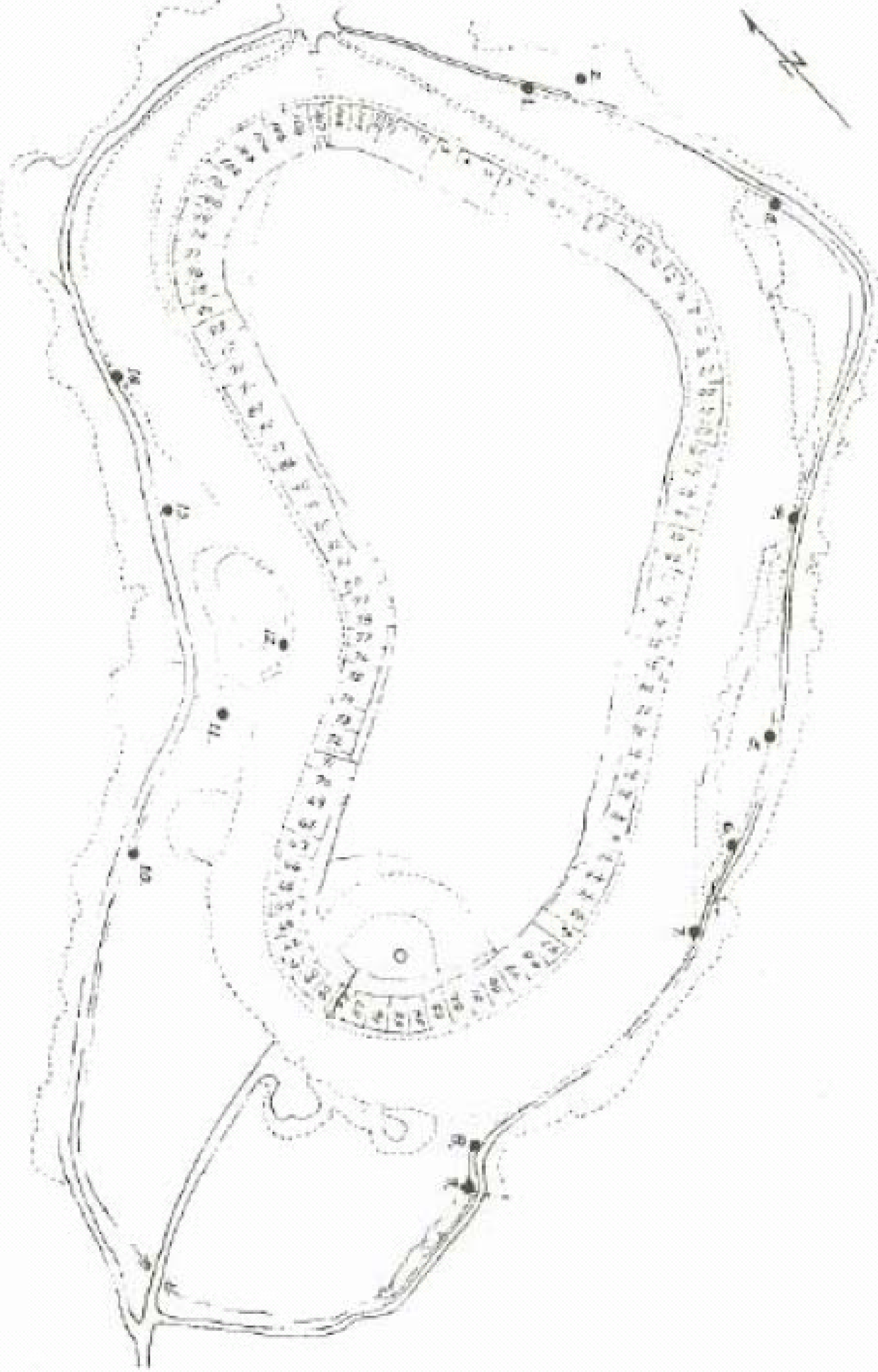

TAUM SAUK UPPER RESERVOIR
Location of Leakage Flow Gages

IMG054641