Bennett & Gass, inc.
Consulting Geologists

P.O. Box 51
Westerville,
OH 43081
614/882-9122

December 16, 1982

Agency for International Development
CM/ROD/NE, Room 731 SA-14
Office of Contract Management
Washington, D.C. 20523

Reference: Contract NEB-0224-S-00-3007-00

Attention: Mr. Steve Freundlich; Tom Pearson; Walter Bollinger

Gentlemen:

In accordance with the terms of our contract, dated October 30, 1982, provided herein is a brief report of my activities. The report deals with three specific subjects:

a) The status of the work on the M-2 well at Mukheiba
b) An important redefinition of groundwater conditions in northwestern portion of Jordan
c) Technological problems in the ground-water development of the Jordan Valley Authority

A. Most of my work with regard to the flowing well at Mukheiba is summarized in memoranda 6-9, submitted to the Jordan Valley Authority prior to my departure from Jordan, and copies of which are attached to this report.

1) The relief well installed in the Wadi Shaqq el Barid, in accordance with my earlier recommendations, is not yet (as of my departure from Jordan) complete, but is not expected to have the impact required on the flowing well. The faulting between the two wells, which was known when the relief well was sited, is of greater magnitude than expected. The vertical displacement (147 m) of faulting substantially exceeds the thickness of the productive, or B-2, zone (130 m), minimizing hydraulic contact.

The relief well adds about 2000 gpm supply to the site but creates no measurable reduction in flow from the M2 well.

2) It is now recommended that no further relief wells be installed in the Wadi, but that a relief well be installed 15 meters N 60° W, of the flowing well. This site, due to location, is thought to have the best probability of penetrating the high flow zone. Because of the elevation of this site the interference effects will not be as great as wished. It will reduce flow somewhat, however, and, if successful, will assure the continued high yield of the site in the event of misfortune to the uncased, flowing, M2 well. Casing programs, grouting, slope stability, and drilling procedures have all been reviewed with JVA.

3) It is recommended that salvage operations and casing installation be undertaken on the M2 well. Procedures have been defined. We have suggested that proposals be requested from qualified contractors, rather than bids. This will enable contractors to proceed as they are best qualified to do so. We have defined the scope of work, and suggested procedures that contractors should consider.

We have also offered to review the contractors proposals, by mail, if JVA wishes to take the time for transmittals. We must also state that our presence in the field during this salvage and casing operation is undoubtedly required.

We have mentioned several sources for technical help and equipment that can be utilized by the contractor. If the contractors cannot put this togehter, we may have to help them define their procedures, or negotiate additions to their proposal.

B. In addition to the work related to the M2 well we have, we believe at the very least, accelerated the JVA's understanding of the regional ground water picture. In my last report, dated August 10, 1982, I alluded to the fact that Jordan's ground water supply in this area was much greater than suspected. At that time the accepted concept was that the recharge area for northern Jordan was north of the Yarmouk River, beneath the Golan Heights in Israeli occupied territory. I did not feel that the data, though very limited, supported that interpretation. I urged them to install some pressure gauges and get additional head data that was reliable. They did this during the past six weeks.

This time I urged them to map what they had acquired, and see what could be learned. On November 10 and 11, lacking personnel to which the job could be assigned, Dr. Joudeh mapped the area himself. The results were outstanding. Data is still scarce. It is

It is obvious however that flow is not from the Golan Heights, but from the Ajlun highlands, within Jordan. Both the Jordan Valley and the Yarmouk Valley appear to be discharge areas. The elevation of the potential head in the recharge area beneath the Ajlun hills is at approximately +200 meters, indicating a very large amount of ground water in storage beneath the Ajlun District.

Dr. Joudeh immediately realized the significance of what he had discovered. Two days later, after discussions with his superiors, he sheepishly informed me that he could not provide me with a copy of the map, nor data, that we had been working upon. It is considered, at least for the time being, to be secret. Under the circumstances I can understand.

A well thoughtout plan of exploration, development, and management will be the obvious requirement for this area in the very near future. Since the resource is almost entirely within Jordan's boundaries they are substantially in charge of their own destiny; a much better position than being dependent upon recharge from the other side of the Yarmouk.

This supply, if substantiated, will offer many advantages as a consequence of its location, size, and reliability. Among these advantages are increased water for irrigation, and for public water supply in proximity to Irbid, and other areas farther south. Problems that are initially evident will be related to its cost of development and operation.

Much of the area in the Ajlun District, where the piezometric surface elevation appears to be at about +200 meters, has a surface elevation, in the high areas, of +300 to 400 meters. Thus both drilling costs and lifting costs will be substantial in the higher elevation areas. Drilling in the valleys will be less expensive, and the wells drilled in the valleys will probably also be more productive, due to increased incidence of fractures.

It will very quickly become evident that policy decisions must be made regarding the yield of the aquifer; priorization of use; short-term objectives versus long-term including the interrelated problems of natural recharge and permissible storage depletion. There is obvious discharge from the aquifer through natural springs in the region. There is also probable discharge from this aquifer into the Yarmouk and Jordan Rivers. The disposition, control, and magnitude of this discharge needs to be evaluated. Preliminary water budgets, or water balances, need to be prepared, then calibrated as new control

points (i.e. monitoring wells, flow gauge data etc.) become available. A computer model based upon the proceeding would make it possible to create a variety of scenarios of different demand requirements, and assist in making judgements about how much water would be available, for how long, and at what cost.

Obviously, this is a thumbnail sketch of the ground water management program. Most of this has been mentioned to JVA. The program should be put in place within the next few months in order to prevent the expectations from substantially exceeding the supply, with resultant serious policy mistakes.

This appears to be a very important supply, but the trade-offs of,for example, quantity "a" for fifty years at cost "x" vs. quantity "b" for a hundred years at cost "y", vs. quantity "c" in perpetuity, at cost "z" need to be understood before canals and/or pipelines are planned and built, and before too many more wells are drilled.

Water quality, incidently, appears to be good, but this should also be evaluated before final determinations are made.

It is my understanding that there is at present some level of model development underway in the NRA. I have no way of evaluating whether or not this will serve the present need of the JVA in the northwest. It must be stressed however that to be meaningful the model must be very specific to the area; be available as soon as possible; and be continuously updated as new data becomes available.

Summarizing, the following points should be considered as soon as possible with regard to understanding and managing this region:

1) Water budget should be developed--particular attention given to recharge, evaporation and discharge.

2) Long term vs. short term objectives for utilization should be defined.

3) Depth variations--to aquifer; to piezometric surface, should be mapped (essential for cost of production).

4) Losses or gains along Jordan and Yarmouk need to be measured, natural discharges measured, irrigation and other uses measured, or estimated, etc.

5) Well location techniques, particularly fracture trace analyses and remote photo methods, need to be evaluated to see which are most effective for area.

6) Monitoring network should be established.

7) The extent of the area, including hydrologic, geologic and geographic considerations, should be determined.

C. There are three primary areas where improvements in technologic capability would be of immediate benefit to the JVA. These are: drilling mud technology; grouting technology; and well-completion technology, specifically the technology required for gravel-packing and developing a flowing well in a fine-grained unstable sandstone formation. It must be stressed that the problems that are faced by JVA, and their contractors, are not the result of their being inept, nor unable to understand proper procedures. Their problems, specifically high heads, moderately high temperatures, and unstable formations, are more acute than is usually encountered by the better contractors in the water well industry in the United States. With problems exacerbated by logistical complications, there are very few contractors who could deal with these situations with initial success. For the most part a transfer of technology from the petroleum industry is required.

1) Until recently there was no practical comprehension on the part of either JVA or their contractor at Mukheiba that drilling mud can be utilized to stabilize the hole and control flow, under some conditions. We have now made several computations, demonstrating to them, to some extent what is possible, and what is not possible. There is an increased awareness, but still insufficient understanding, which becomes totally inadequate at the staff level.

It should be noted that the temperatures of the discharge of some wells indicate proximity to a geothermal heat source. At temperatures of about 90°C or above there will probably be problems with the phosphate mud they are using breaking down, with resultant loss of hole and flow control.

To deal with this problem we recommend that a comprehensive drilling mud technology training program be undertaken.

This can be accomplished either by sending JVA staff personnel to established training programs in the United States; or by presenting a seminar in Jordan, utilizing the required specialists.

Of the two approaches, we feel that the latter is the best, since it will directly reach all JVA personnel; the local contractors, by invitation; NRA personnel; and any other interested parties.

To be effective this cannot be approached as a generalized "training" program. The generalities here are not important--the specifics are. We suggest that two carefully selected drilling mud specialists be given a first-hand, conducted tour of problems in the area, including logistical problems, and that they then return to the United States and prepare both a seminar and an operating manual to be distributed at the seminar, dealing specifically with recommended procedures to be utilized in Jordan. This can all be accomplished in about one calendar month, but an additional two weeks will be need for internal review and revision prior to presentation.

2) There has been considerable difficulty in the past with ineffective grouting jobs. We have not yet given any attention to the quality of cement available for grouting, assuming that it is of adequate standard. This, perhaps, should be considered further in the future.

The failures that we have been made aware of, however, have been the result of faulty procedures. There is an obvious need for a thorough evaluation of the procedures that are required and/or permissible, and the range of geologic conditions to which they apply. Again, logistics and specific equipment availability must be considered. With these elements in mind a detailed set of enforcable specifications can be prepared, and the staff trained to enforce them.

This work could be coordinated with the drilling mud training program at minimal cost. Both are directed to the same audience.

3. At the present time difficulty is being encountered in the area west and southwest of Amman with an unstable, friable, fine-grained sandstone. The wells flow at a relatively high rate; artesian pressure is high enough to make flow control with drilling mud difficult; there is no local technology for installing a gravel pack under these conditions; there has been no local source of gravel for gravel-packing up to this time, although this is currently being sought; without a gravel pack these wells will produce large quantities of sand and will eventually fail as a consequence of hole failure or subsidence.

It is necessary to develop a procedure, or procedures, for completing a developing well in this formation that can be utilized by local contractors.

The simplest approach will probably be to adopt a crossover tool, such as has been used successfully in the oil field, to this

application. This technique has been used for similar purposes in Venezuela and Canada in oil wells, and to a very limited extent by a few water well contractors in the U.S. Other options can also be considered.

We recommend that detailed procedures be worked out, that can be utilized by either rotary or cable tool drillers, if possible; material and equipment requirements be determined, with source identified; and that one or two demonstration wells be installed to familiarize the local contractors, and the JVA, with the technique (while the technique is being de-bugged).

This concludes our commentary and recommendations regarding the status of various aspects of our work in Jordan. We have obviously omitted much detail which is beyond the scope of this report. We will, however, be pleased to respond to any questions you may have.

Thank you very much for your consideration. We look forward to an opportunity to be of further service.

Very truly yours,

BENNETT & GASS, INC.

Truman W. Bennett

Truman W. Bennett
Consulting Geologist

TWB/jwd

MEMORANDUM NO. 6

November , 19 2.

To: Jordan Valley Authority

From: Truman W. Bennett, Consulting Geologist

Reference: Flowing Well at Wadi Shaqq El Barid

Attention: Dr. Haddadin; Dr. Joudeh

Copy: Mr. Tom Pearson, USAID Project Officer

Status:

As recommended in my memorandum No. 1, July 31, 1982, the first relief well is under construction in the Wadi, about 150 - 200 meters northwest of the flowing (M-2) well. At the present time, based upon the latest report, this well is being drilled below 386 meters depth (as of Nov. 7) with a flow estimated at about 400 m^3 per hour (JVA estimate), or 1500 - 2000 gpm.

Surface casing was installed in this hole, 20 inch in diameter, to a depth of 51 meters, and grouted in place. At a depth of 96 meters, while drilling a 17½ inch hole with 13.9 pounds per gallon mud in the hole, site personnel became concerned about the flow that was being encountered (i.e. unable to maintain mud weight), and a second string of casing was installed, at this depth (96 meters, 13 3/8 inch casing). This was a very wise decision.

This casing was grouted in place by the two plug method, with good grout return to the surface, and pressure maintained to a final set by closure of the return valve. It appears to be a very good grout job.

Drilling was then continued. At a depth of 278 meters flow was reported to be about 50 - 60 m^3/hr. (220 - 265 gpm). At a depth of 234 meters an unsecured 9 5/8 liner was installed, with a sliding packer seal in the 13 3/8 inch casing, just above 96 meters (between 84 -96 m).

Drilling continued with an 8¾ inch hole being drilled for the balance of the depth, uncompleted at this time.

At the depth of 315 meters, while out of the hole for a new rock bit, the shut-off valve on top of the well, after repair and eventual replacement, was closed for twelve minutes. The twelve minute surface shut-in pressure was reported to be 170 psi.

Drilling continued. At the depth of 361 meters, per the site geologist, flow increased to approximately the present rate. Samples encountered below this depth indicated hard limestone and chert, and it is interpreted that the primary productive zone in the M-2 well, the B2 zone, was encountered at the depth of 361 meters.

With the surface elvation estimated to be at -103 meters, the elevation of the B2 zone is therefore (-103) + (-361) or -464 meters. Since the B2 zone was encountered in the M-2 well at an elevation of -317 meters, the relief well is found to be (464 - 317) 147 meters (482 feet) lower, structurally, than the M-2 well, which is only about 150 meters away. There thus appears to be a substantial fault between the two wells.

While drilling is continuing, hopefully at least to a depth of 500 meters, it is not presently expected that the relief well will have the impact required to substantially reduce the flow from the M-2 well. According to the log of the M-1 well (1.2 Km northeast, refer memorandum number 1), the B2 zone was 131 meters thick. This appears consistent with the prolific flow zone in the M-2 well (250 m - 354 m T.D.), although no samples were obtained with a 130 ± meter thickness, and a 147 meter displacement (vertical) there is no reasonable prospect for a good hydraulic communication between the two wells, unless an additional intersecting fault is encountered.

Present indications are that the productive zone in the M-2 well butts abruptly into the bituminous marl of the B-3 zone between the two wells, with the only hydraulic contact being via vertical leakage along the fracture, or fractures. Hence the interference effects we need will be slow, and small.

Options:

The purpose of placing the relief well in the Wadi was to take advantage of the elevation difference, creating greater drawdown in the M-2 well. Since the hydraulic connection is not good this will not work. For the same reason there does not appear to be any good reason for placing more wells in the Wadi.

Based upon limited field observations, limited subsurface information, regional considerations, and a liberal sprinkling of pure guesswork, the fault between the two wells is probably high angle reverse fault, trending west, northwest-east southeast, and dipping about 80° southwest. Its surface expression or trace, is along the Wadi just a few meters north of the M-2 well, and it intersects the B-2 zone in the 300-350 meter depth range, resulting in the high flow from this well.

If this interpretation is correct, the only way to intersect this zone will be parallel to the trend, on the high ground adjacent to the M-2 well. According to altimeter readings (of questionable accuracy-refer memorandum number 2, August 3, 1982), the top of the M-2 well is presently at elevation -74 m., and the level of the adjacent high ground is at elevation -67 m. Obviously installing a relief well at the higher elevation will have limited effectiveness.

On the basis of the 170 psi, twelve minute shut-in pressure obtained on the relief well in the Wadi, and assuming that the Wadi well is in the same pressure system as the flowing well, and further assuming that the 12 minute shut-in pressure is about 75% of the total head, then the total actual head with long-term shut-in would be about:

$$170 \times 1.33 = 225 \text{ psi}$$

or

$$225 \times 2.31 = 500 \text{ feet} \quad (158 \text{ meters}).$$

Since the elevation of the shut-in valve was about - 103 meters, the elevation of the piezometric surface would be about:

$$(-103) + (158) = + 55 \text{ meters}$$

If the actual total shut-in pressure was the observed 170 psi then the elevation of this pressure surface would be at +17 meters. Thus the possible range is between +17 and +55 meters, and most likely nearer to the +55 meter value.

Not knowing the formation transmissibity it is not possible to predict the impact of a nearby relief well, in other than a general manner. If, for example, the effective formation transmissibity is on the order of 1 x 10.5 gpd/ft, then a relief well at 15 meters, flowing 25,000 gpm, would create about 100 meters of drawdown in the flowing M-2 well. Obviously this would not occur, since both wells would mutually interfere, and the production would be substantially balanced with a lower rate from each well. This would help however, with reducing the flow to be dealt with in the M-2 well.

A relief well within 15 meters of the M-2 well, if successfull, would also provide an alternative supply in case a serious accident, such as a major hole collapse, should occur to the unprotected, uncased, M-2 well.

If the surface is cut down, for the new relief well, to the elevation (-74) of the discharging M-2 well it will increase the effectiveness of the relief well, and make the slope area more secure.

Since the final effectiveness of one or more relief wells discharging at the same elevation as the M-2 well will be limited (i.e. insufficient to completely kill the M-2 flow), it will be necessary to undertake the salvage of the M-2 well while it is still flowing. Hopefully the rate of flow will be reduced.

The decision regarding whether or not more relief wells, in addition to the next one, will be required, cannot be made until the effectiveness of the next one has been determined. The flow rate obtained, and the shut-in pressure, with observation of flow variation from M-2, should all be considered before the salvage work is undertaken.

Recommendations:

It is recommended that a relief well be installed about 15 meters northwest of the flowing well. Since this will not be sufficient to stop the flow from the M-2 well, it is recommended that plans proceed for the salvage of the M-2 well while it is still flowing.

Since slope stability is still of concern, and since it is necessary to lower the elevation of the discharge from the flowing well, work on the slope should be completed while the site is being prepared for the relief well. Procedures will be discussed in a subsequent memo.

Because of the possibility of slope failure, care should be exercised at all times while working on the site. Refer to memorandum number 5, August 5, 1982.

The work sequence is envisioned to be as follows:

a) Control flow. Lower invert if necessary. Expose upper meter of drill rod. Determine if existing concrete pad can be used. Stabilize slope, if required.

b) Cut (excavate) surface at relief well site to elevation -74±.

c) Install relief well.

d) While relief well is being installed review proposals for salvage of M-2 well.

e) Salvage M-2 well.

Respectfully submitted

Truman W. Bennett

Truman W. Bennett
Consulting Geologist

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MEMORANDUM NO. 7

November 9, 1982

To: Jordan Valley Authority

From: Truman W. Bennett, Consulting Geologist

Reference: Procedures - Site preparation, relief well construction, M-2 salvage.

Attention: Dr. Haddadin; Dr. Joudeh

Copy: Mr. Tom Pearson, USAID Project Officer

Site Work:

At the present time the culvert pipe that carries flow away from the M-2 site has its intake partially blocked. As a result, the concrete slab is covered with water and the immediate area is saturated, at least on the surface. This is a serious situation that should not be allowed to continue, nor to re-occur

In order to work on this site, and perform salvage work eventually, it will be necessary to lower the discharge water level to about one meter below the surface of the slab. This should expose the top of the drill rod, making it possible to cut-off the most severe portion of the bend, and start to work. This may require lowering the existing culvert pipe through which the water is discharging.

The water must be controlled in a single ditch, or confined in the culvert pipe. In the short exposed ditch between the well and the culvert pipe, the ditch must be protected by concrete slabs, or large boulders, Debris from this ditch must not be allowed to cave into the well. The length of exposed ditch should be kept to a minimum, since this is very near the work area, and is an area where saturation can occur. Culvert pipe should be as close to the well as is reasonably possible, Every erodable site should be protected by some appropriate method. Leakage around the outside perimeter of the culvert pipe must be prevented.

Since it is now nearly five months since this well started flowing and there has been no observed slope failure,

other than by erosion, and there have been no reported seepage nor saturation zones, it appears that the site will be safer to work upon than I originally feared. I will inspect the slope again, in detail, within the next three days. If no evidence of potential problems can be found, then I believe that work can proceed on the site with reasonable expectation of safety.

Nonetheless I recommend that the precautions outlined in Memorandum No. 5 be fully implemented.

Subsequent to, or co-incident with the drainage work on the site, the adjacent area, where the new relief well is to be installed (high ground about 15 m NW of M-2), should be excavated to the approximate elevation of the M-2 well. Actually, if the flow from the M-2 well has been properly controlled so that there is no risk of its being diverted to this direction, it will ve advantageous for this area to be cut down below the M-2 discharge as far as can be conveniently excavated.

Insofar as practical, a large portion of the hilltop should be removed, with safe slopes cut and formed, so as to assure slope stability. These slopes will be permanent.

The excavation appears to be very easy, short-push, dozer cutting with deposition immediately downslope toward the eroded gulley, and the present camp. I estimate a large dozer can do the entire excavation job in two weeks, or less.

When the excavation and drainage work has been completed mud pits and flow control structures, such as were built at the first relief well (in the Wadi), can be installed, and the site prepared to construct the relief well.

Because of the location near the flowing well, and the elevation, and the erodable nature of the downslope surficial material, control of discharge from this site is critical. All due precaution must be taken. Obviously, during the initial excavation of the site consideration should be given to shaping the area so as to make construction of drainage control features simpler. Erosion must be prevented for a distance down the slope sufficient to protect the stability of the site.

Relief Well Construction:

Procedures to be followed during the construction of the next relief well should be very similar to those utilized in the construction of the first relief well.

Specifically, the following should be emphasized:

1) Surface casing (20 inch diameter) should be installed to a depth of between 50 and 60 meters, and grouted securely in place. If any flow whatsoever is encountered in this shallow zone, drilling should be discontinued immediately, casing installed and grouted. There is no way to control the well until the first string is grouted in place.

2) Based upon a surface elevation of -74 meters, and the observed shut-in pressure in the first relief well (refer memorandum no. 6) Table 1 shows the relationship between the pressure exerted by the drilling mud, and the formation pressure, at various depths. Mud weight is assummed to be maintained at 14 pounds per gallon.

TABLE 1

FORMATION PRESSURE AND MUD WEIGHT

Depth	m ft	50 164	100 328	150 492	200 656	250 820	300 984	350 1148	400 1312
Formation Pressure	(1) max psi	253	324	394	465	536	606	677	748
	min	200	270	341	412	482	553	624	694
Mud Pressure (3)	(2) psi	120	240	360	480	601	721	841	961

1. Max. Psi = [(423 ft) + (depth ft)] x 0.431
   Min. Psi = [(299 ft) + (depth ft)] x 0.431
2. Mud psi = (depth ft) x 0.431 x 1.7
3. Mud weight = 14 pounds per gallon or 1.7 Sp. E.

It is apparent from Table 1 that the drilling mud cannot control discharge from the formation until

the approximate depth of 200 meters has been attained.

These computations are based upon the assumption that the shut-in pressure in the first relief well, in the Wadi, is transposible (i.e. in same hydraulic pressure system) to the site on top of the hill. This assumption is most likely correct, but there is a small possibility (less than 1 in 10, in my opinion) that the higher elevation site is in a seperate, significantly higher pressure system.

If there is only one pressure system present, the shut-in pressure for the proposed relief well, and also the flowing well (if we ever get it shut-in) will be between:

$$(55m + 74m) \times 3.251 \times 0.431 = 182 \text{ psi, and}$$
$$(17m + 74m) \times 3.281 \times 0.431 = 127 \text{ psi.}$$

Since the shut-in pressure of the first relief well was measured after only twelve minutes, and, of course with the M-2 well flowing, the higher valve of pressure is probably closer to correct.

3) As illustrated in Table 1, the drilling mud cannot prevent flow into the hole if a strong connection (along a fault etc.) to the aquifer is encountered in the upper 50 - 60 meters where the surface casing is to be installed. For this reason it it is not necessary to increase the mud weight while drilling this portion of the hole. The contractor should follow his usual procedure, as needed to cool the bit and clean cuttings from the hole.

Because it is of critical importance that the surface casing be grouted in place before high pressure zones are encountered, <u>constant</u> attention must be given to loss or increase of fluid while drilling this portion of the hole. If any suspicion develops that a pressurized zone has been encountered surface casing should be installed immediately.

Thirty meters, for example, of surface casing is not nearly as much as we would like to have, but it is <u>much</u> <u>much</u> better than none.

The top of the twenty inch surface casing should be flanged to recieve a valve, just in case we must control flow before we get the following string of 13 3/8 inch casing installed.

Just in case our 250 psi fittings are not sufficient to hold, I suggest that the casing and flanges be of at least a 350 psi rating. If a 250 psi valve fails, or leaks, it can be replaced, but the fittings <u>must hold.</u>

4) After the surface casing has been installed, and grouted in place, drilling of 17½" diameter hole should continue. In drilling this portion of the hole I recommend using drilling mud, weighing 14 lbs./gal., or even more if the contractors pumps will handle it. Small flows are less critical in this interval, assuming there is a good job on the surface casing, and even though the mud won't completely control flow, it will significantly reduce it in the interval between 100 and 150 meters.

If possible this hole should be continued to a depth of 150 meters. If flow becomes too strong at a shallower depth, then drilling should be discontinued and the 13 3/8 inch diameter casing should be installed, and grouted in place.

The term "too strong" in reference to flow implies an on-site judgement. It is a judgement made, hopefully, somewhat before panic, but as neat to 150 meters as is possible. For example, if the point is reached where the mud weight cannot be maintained, even though a serious effort is being made, then the flow is becoming "too strong".

5) When the casing depth has been reached the 13 3/8" casing should be installed, and grouted in place. This is the most critical of the grouting operations.

If it is at all possible the weight of the grout should exceed the weight of the drilling mud by about twenty-five percent. If the drilling mud weighs 14 lbs./gallon, then the grout should have a specific gravity of about 2.1, or 17.5 lbs./gallon. This minimizes mixing between the mud and grout during the grouting operation.

As was done in the previous well, grout should be emplaced by the two plug method, with the first plug separating the mud from the grout, and the second separating the grout from the wash down water.

To be certain that sufficient quantity is used, there should be return of grout to the surface before the second plug is pumped down. Pressure should be maintained on the system, by closing both the intake and discharge valves, until the grout has set. A minimum of 24 hours should be allowed for the grout to solidify, before any further activity is under taken in the hole.

6) After the 13 3/8 inch casing, flanges, and valve have been installed, again "beefed-up" 350 psi capability is recommended, drilling can be continued with a 9 3/8 inch hole.

If the 13 3/8 inch casing is of sufficient length, and the grout good, it is not likely that any additional casing will be needed. Unless an unexpectedly unstable zone is penetrated above the target production zone, the installation of an unsecured liner presents more risk than advantage. The weight of such a liner may not be sufficient to offset the total upward thrust of flow such as encountered in the M-2 well, unless the formation has collapsed around it. If this were to be the case, the lower liner would be displaced upward, inside of the upper casing.

If protective casing is needed to stabilize the formation, it is recommended that it be grouted in place.

7) During drilling operations, where flow of any magnitude is being encountered, the electrical conductivity and temperature of the discharge water should be measured each time the drill rig stops their pump to connect an additional section of drill pipe. This costs nothing, and adds inf information that in amny instances can be valuable.

Additional measurements should be made after any abrupt increase, or decrease, in flow.

This procedure is recommended for all wells.

8) Safety precautions regarding flow control and slope stability must be observed at all times. In the event of excessive erosion, or other evidence of slope failure, it must be possible to shut-off flow at any time until corrective measures can be taken.

It must be remembered that without a "blow-out preventer" installed the valve that shuts flow off cannot be closed with the kelley or drill pipe in the hole. In an emergency there must be sufficient advance warning to allow the drill string to be removed from the hole.

The only alternative to removing the stem would be to have a sub-assembly available with an eye or J-hook top. The kelley (and top joint of drill pipe, if necessary) could be removed, and the entire string of drill pipe lowered to the bottom of the hole by wire line, the line removed, and the valve closed. After the appropriate corrective action has been taken the valve can be re-opened, and the drill string fished out. The problem with this procedure is that the drilling tools may become stuck while the valve is closed. This, however, I would regard as proferable to losing the entire drilling rig and tools due to the inability to close the valve.

9) When drilling is completed geophysical logs should be run on both relief wells and the M-1 well. This will help our understanding of conditions in the M-2 well before work on it is undertaken.

Salvage Procedures on the M-2 Well:

1) It is not known at what depth the drill pipe is stuck. Flow continues with no measurable decrease, which clearly indicates that there has been no serious collapse of the borehole. As of this date the top of the drill pipe is not visible, due to the restriction of the discharge from the site. When last visible, however, flow from within the drill pipe was strong, indicating no serious blockage of the bit.

An attempt was made by the drilling contractor a few weeks ago, to pull the drill pipe. To do this he attached a cable to the bent portion of the drill pipe, and pulled a reported 60,000 lbs. with the rig block. He reported that there was no give whatsoever, nor stretch, in the stuck string of pipe, and from this concluded that it was stuck near the surface.

I'm not convinced that this logic is valid, although the conclusion may very well be correct. With the drill string itself weighing nearly 30,000 lbs., the net pull on the string was therefore only about 30,000 lbs. Depending upon his exact set-up, there could have been enough give in the rig mast and cable to mask much of the potential stretch of the pipe. I don't feel this is sufficient information upon which to base a judgement.

Once the surface water on the site has been controlled, and the bent portion of the drill rod exposed, the bent portion should be cut off, This must be done regardless of subsequent procedures.

When the bent portion has been removed, the simplest procedure is to unscrew the top portion of the drill string, allowing it to unscrew wherever it breaks a part removing the top (bent) section, replacing it with a good section, then lower the disconnected string back down into the lower (still stuck) string and screw them back together. If this succeeds,

it is now problem possible to connect the kelly, and restore both circulation and rotation. If necessary hydraulic jars can be used. It is probable that the drill pipe could now be removed.

However, there is a substantial risk in this procedure. The hole is known to be washed out, and oversize. Flow from the hole is very strong, and in the washed-out zones of unfathomable turbulence. Once the upper portion of the drill string is removed, the open end of the lower portion, with a strong jet-like flow coming through it may assume a position in the hole that is impossible to re-enter. I do not, therefore, recommend this procedure.

A better procedure, and one that I recommend, is to go into the hole with washover pipe, which will surround the drill pipe, and drill through (the washover pipe being equipped on the end with a core-type bit) any caved, or bridged, zones, until the drill pipe is free, and can be removed. The drill pipe is 4½ inch, with 6 inch tool joints; the drill collars are probable about 7½ inch O.D., but this should be confirmed; the drill bit, on bottom, is 17½ inch, O.D.

The wash pipe should be of sufficient diameter to wash over the drill collars (on the order of 8 inch - 9 inch I.D.), but not the bit. It will be more economical to cut off the bottom of the stern, if necessary, rather than wash over with large I.D. pipe.

It would be preferable to remove all of the drill string, but this is not essential. If only the upper portion of the drill string is removed (150 m ±) it should be possible to install enough casing to control the well.

I suggest that the drilling contractor should be required to carefully review his equipment to determine whether or not he has the necessary equipment to perform the work. Does he have sufficient lift capacity to handle the wash pipe, which is heavy wall, flush-joint pipe. Does he have sufficient torque to turn it, and good pump capacity? Does he have the necessary slips for flush joint casing?

I also suggest that the drilling contractor be required to have an experienced person, drilling engineer or specialist on the site and in responsible charge of all fishing operations. This person must be present at all times while recovery work is being performed. If the contractor does not have someone like this in his employ, he can engage someone as a consultants for this work. He can find specialists of this type, and the equipment he needs, through his usual rig and equipment supplier.

It is very important that this well be cased, and controlled. We should not proceed with half-hearted attempts to attain this.

2) When the drill pipe has been removed, casing can be installed. The first procedure will be to run a borehole geophysical (neutron, probably - whatever available) log, and caliper. The caliper log is what is important. This will tell us the hole diameter; indicate the location where packers can be installed; and the size of packer that is needed. The final decisions on the casing program grout procedure, and packer setting(s) cannot be made until this log is available. It may, for example, be found to be advantageous to install more than one string of casing, or a special packer size, or whatever, depending upon what this log shows.

Depth determinations from the caliper log will be extremely important. Depending upon the weight and area of the logging tool employed, it may be necessary to add extra weight to get the logging tool down. When retrieving the logging tool, the uphole velocity may exceed the take-up velocity of the wire-line retrieval drum. This will result in erroneous depth measurements. When this log is being run, strict attention must be given to every detail, and adjustments made as required.

3) Grout procedure is very important, and different from that which is usually recommended. With the casing in place, and the packer expanded so as to seal-off the annular space between the casing and the borehole wall neat the bottom of the casing, the annular space above the packer must be filled with grout.

Since there is no way to maintain pressure outside of this casing, and prevent flow return, this string of casing must be emplaced above any zones that are flowing into the well. Depending upon the results of the caliper log, this may be one factor that will force us to install more than one string of casing.

There is a possibility, after we have seen the caliper log, that we may decide to ream the upper 60 ± m. to 26 inches, and install, by means of a special packer, 20 inch surface casing. This would then simplify the installation of a secure string of 13 3/8 inch casing. This procedure will also be considered if for some reason we cannot obtain a caliper log.

When the casing is installed, grout pipes will be extended to just above (0.5 ± m.) the packer, in the annular space between the casing and the borehole wall. The number of grout pipes required will depend upon the hole size, and the clearance within the annular space. They will probably be between 2 inch end 4 inch diameter, with two to four utilized. If four are used their depths may be staggered, with the two deepest being welded to the casing as it is installed. These may all be left in place.

Grout will be pumped down these grout pipes, filling the annular space from the bottom to the top. Sufficient equipment must be available to insure that this be a continuous operation. If a long string of casing is subsequently installed, the grout will be pressurized to prevent water intrusion. This, of course, cannot be done on the surface casing, unless we install two packers and grout between them. This, of course, cannot be done on the surface casing, unless we install two packers and grout between them. This will be resolved after the caliper is available.

4) Contractually, this work is complicated to handle, because the equipment and material needed to install casing cannot be ordered in advance. Until the drill pipe is removed from the hole, and we know more about conditions in the hole, it is not advisable to select casing diameters nor lengths; nor is it advisable to order special packers.

For this reason I suggest handling this contract in two phases. The first phase will involve removing the drill pipe, and running a log of the hole. The second phase will involve installing casing and grouting it in place. The contract will provide for either standby, or remobilization between the two phases, depending upon our choice of procedures.

Respectfully submitted,

Truman W. Bennett

Truman W. Bennett
Consulting Geologist

SA/.

MEMORANDUM NO. 8

November 14, 1982

To: Jordan Valley Authority

From: Truman W. Bennett, Consulting Geologist

Reference: M-2 Well, Field Conditions.

Attention: Dr. Haddadin; Dr. Joudeh.

Copy: Mr. Tom Pearson, USAID Project Officer

Because of my reservations about the incompleteness of some of my field observations, November 11, was spent in the field trying to improve upon this situation. The following briefly describes my conclusions.

1) With regard to my concern about the stability of the slope surrounding the M-2 well, I made a detailed inspection of the entire area that could be of concern.

   a) The area is unquestionably brecciated, with abundant fine silt and clay being present, as well as beds of marl, limestone, and chert.

   b) The attitude, or tilting, of the bedding is such that there appears to be no fracture planes, nor bedding planes, so situated as to provide conduits for subsurface, horizontal, flow.

   c) There are no springs, seeps, nor wet spots indicating saturation due to subsurface flow and discharge.

   d) There is no evidence whatsoever of slope failure or slippage (other than erosion), after these several months of exposure to flow from the well.

   Based upon these observations, and the time that has elapsed without incident, I feel that my previous concerns were overly conservative, and that the site is safe to proceed with further work.

Obviously, it is still prudent for site personnel to be aware of the possibility of slope failure, and to be constantly alert for the signs of trouble. The procedures previously outlined are still recommended.

2) The elevation difference between the concrete slab at the M2 well, and the relief well in the Wadi was checked by hand level and Jacob Staff and found to be 30.5 m. This is approximately the same difference obtained by altimeter some time ago.

3) A close inspection of the concrete culvert pipe that is conducting the water from the M2 well revealed no seepage from around the perimeter of the pipe. This appears to be holding up well, and protecting the site. It should be inspected regularly, however, while we are working on the site.

4) There are probably two faults between the M2 well, and the relief well in the Wadi. The one closest to the relief well appears to strike about N-S, while the one closest to the M2 well strike about N 60° W. I still believe that the high rate of flow from the M2 well is due to intersecting this nearest fault in the B2 zone. For this reason I would place the next relief well about 15 meters N 60° W of the M2 well.

Respectfully submitted

Truman W. Bennett

Truman W. Bennett
Consulting Geologist

SA/.

MEMORANDUM NO. 9

November 16, 1982

To: Jordan Valley Authority

From: Truman W. Bennett, Consulting Geologist

Reference: M-2 well salvage; suggestions for scope of work.

Attention: Dr. Munther Haddadin; Dr. Omar Joudeh

Copy: Mr. Tom Pearson, USAID Project Officer

The work involved in the salvage of the M-2 well at Mukheiba is different than the daily circumstances encountered by drilling contractors, although it is something dealt with by most of them at least occassionally. In order to obtain the best of the required services that are locally available it is suggested that proposals be obtained from all such persons who express interest, and can demonstrate the requisite expertise.

Because the level of understanding of the problem, expertise, equipment availability, and probable ability to perform are much more important in this case than price, proposals are suggested, rather than bids.

The following points are presented as suggested content for the scope of work that should be considered by each contractor in his proposal. They are presented in "recipe" format which permits them to be selected individually, for the Request for Proposal, or listed in their entirely. They are not intended to be complete, especially with regard to contractual details.

It is anticipated that each responding contractor will be given an opportunity come in to the JVA office and discuss his proposal in terms of technical merit, availability of resources, and estimated cost. If the various proposals, or copies of these proposals, are forwarded to me at my office in Westerville, Ohio, I will promptly review them for technical merit, and return them with my comments.

Since it will be difficult for contractors to propose costs for the casing program prior to removal of the drill pipe that is stuck in the hole (casing sizes, lengths, and packers are unknown), it is suggested that the proposals be made in two phases. The first phase will include removing the drill pipe and logging the hole, and the second phase will involve installing the casing and grouting it in place:

1) Proposals are requested from responsible contractors for the salvaging of drill pipe and installation of casing in a flowing well. The well is at Wadi Shaqq El-Barid, near Mukheiba, in Ajlun District.

2) The well is flowing at the estimated rate of 5200 m^3/min. The hole is uncased, 17½ inches in diameter, when drilled, and 354 meters deep. The drill pipe was left in the hole when the site was eroded by the discharging water, and the drill rig fell over. The drill pipe is thought to be stuck but at an unknown depth. The drill pipe is standard 4½ inch outside offset drill rod, with a reported three, 6 meter, 7½ inch OD (±) drill collars at the bottom.

3) Interested contractors should make arrangements to visit the site, and be fully aware of all site conditions before submitting their proposal.

4) It is anticipated that this work will be conducted in two phases. The first phase will be completed when the drill pipe has been removed from the hole, and a caliper log, and associated geophysical logs, has been conducted on the hole.

5) Proposals will be evaluated on the basis of technical merit; capability of the contractor to provide the personnel and equipment required by the project; and cost.

   The cost portion of each proposal shall indicate the cost basis for each phase of work,(i.e. mobilization; rig time; special provisions etc.),

and the estimated time and cost.

Since there may be a time delay between phase 1 and phase 2 in order to obtain special equipment, the proposal shall specify the cost of standby and the alternative cost for remobilization.

6) There is presently a second well under construction on the site about 15 meters from the flowing well. It is anticipated that this well will be completed before salvage work is started.

The second well is expected to reduce the flow from the flowing well, but in an unknown amount. For the purpose of project planning it shall be assumed that there will be no appreciable reduction in flow while work is being conducted.

7) Contractors may propose any technique, procedure or method that they feel will be effective. However, "secret" methods techniques, or procedures will not be considered, since the owner has no way to evaluate the impact of failure, nor probability of success.

8) A condition of the final contract governing this work will be that the contractor performing the work under either phase must have on site, full time, an experienced drilling engineer, or other specialist, approved by the Owner, who will be in responsible control of all of the contractors activities on the site.

This person shall also be responsible for keeping the representative of the Owner fully advised of all operations. This specifically includes difficulty with the work operational procedures, equipment functions etc. This work is regarded as very important, and every portion of it must be fully understood by everyone involved.

9) The contractor may propose alternative procedures such as he feels are appropriate. However, the

following steps are presently considered by the Owner to be at least a portion of the work required

a) Cut off, and remove, the bent portion of the drill pipe that extends out of the hole. This appears to require the removal of about one meter of drill pipe.

b) Install heavy wall, flush joint, washover pipe, with hollow core bit, over and around the drill pipe. Wash and drill this down to total depth.

c) Remove the drill pipe from the hole.

d) Conduct geophysical and caliper log of hole.

e) Consult with Owner on alternative casing programs, packer requirements, grouting procedures etc.

f) Obtain any special equipment required.

g) Install and grout casing in place, complete with shut-off valve and pressure guage tap.

The contractors proposal must detail his procedures for removing the drill pipe, installing casing, controlling flow and grouting the casing in place.

Alternatives that may be included, for example, may involve more than one string of casing; reaming of the hole to permit larger casing; multiple packers; pressure grouting; the use of hydraulic jars, spears, overshots etc. to remove the drill pipe; or such as the contractor may find appropriate. But these must be detailed.

Every precaution must be taken to insure that no action undertaken by the contractor can result in making the problem worse than it is at present.

10) Contractors proposal must detail all equipment required by their proposed approach, its availabilit and include its cost in their cost of the work submitted.

The consideration of commercial equipment and services, such as Schlumberger (representative available in Amman) for caliper and geophysical logging; Lynnes International (Office in Sharjah, Telex No. 6[illegible]212) for inflatable packers; Haliburton (Office in Dubai, Telex No. 48044) for grouting service; or any specialised service company with washover equipment, power tongs etc, is encouraged, but by no means mandatory.

It is the contractors responsibility to propose the best technical package that he can provide, on the most reasonable cost basis possible.

11) The drillers (geologists) log of this hole, prepared as it was drilled, is included for information purposes only. There is no warranty as to the accuracy or reliability of this information.

There may be other technical notes that you wish to include in this request for proposal. However, I feel that it is advisable to make the various proposers <u>think</u>, but keep their options as open as possible.

This job is not as difficult as it appears <u>if</u> the proper techniques and equipment are obtained, and applied. The risk is, in my opinion, too great to proceed on any other basis.

Respectfully submitted

Truman W. Bennett

Truman W. Bennett
Consulting Geologist

SA/.