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Project No. 19-6089

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On Account of Bundaberg Fruit and Vegetable Growers
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LETTER REPORT
RECOMMENDED TESTING PROGRAM
PARADISE DAM
QUEENSLAND, AUSTRALIA

Dear Mr. Gunningham:

Introductory Remarks

Thank you for engaging our firm to assess the need from a safety perspective for possible remediation of Paradise Dam. The Dam is considered to be in a distressed state by its Owner, Sunwater, which is considering various options for its future ranging from "doing nothing" to various remediation concepts, temporary and permanent, to complete dismantlement of the Dam.

The postulated distress stems from an analysis of existing test data associated with the strength properties of the lift joints between successive lifts of Roller Compacted Concrete (RCC), the primary construction material used in the design and construction of Paradise Dam. The existing test data were obtained by Sunwater over the past decade or so and used to assess the integrity and safety of the Dam.

We have just begun our work with a visual inspection of the Dam on January 29, 2020, but in the meantime you have asked us for advance recommendations as regards to a new RCC sampling and testing program for the lift joints at Paradise Dam. The test data obtained with the program recommended here will supplement, if not fully replace, the existing data set that has been used by Sunwater and their consultants, GHD, to determine the distressed state of Paradise Dam. It is our view that the existing data set as critically reviewed by Tatro Hines is inadequate, misleading and insufficient to assess the integrity and safety of Paradise Dam.

The existing data set was critically reviewed by Tatro Hines, a USA consulting practice, who published a document in November 2019, referred to as the Tatro Hines Report. Their Report, together with an engineering analysis prepared by GHD based on the Tatro Hines Report are the only two major documents made available to us from a much longer list of requested documents. As a matter of record, we have asked for a group of additional documents related to this effort so that we can fully appreciate Sunwater's concerns and be able to act and converse on an equal footing with Sunwater and Sunwater's consultants. Although the documents have been requested more than one month ago, none of the additional documents have been forthcoming.

We strongly emphasize that this Document deals only with a recommended testing program and does not indicate our view on the need or type of remediation of Paradise Dam. It only documents what we deem necessary in terms of sampling and testing to be performed to allow for a complete analysis of the need and/or type of remediation that could be considered. Most importantly, the new test data will allow for a more definitive and defensible analysis of the factors of safety against sliding along the lift joints and compliance with the ANCOLD Guidelines.

Our Review of the Tatro Hines Report

We provide below a limited summary of definitive comments extracted from the Tatro Hines Report along with response by us based on our experience from other projects and test programs elsewhere around the world.

TABLE 1
SUMMARY OF COMMENTS AND RESPONSES
TATRO HINES REPORT

COMMENTS BY TATRO HINES	COMMENTS BY RIZZO
Televiewer inspection of the holes appears to be very useful in clarifying the breakage of the core. Observations in Reference 1 were that lift joint breakage in the core was more widespread than the same joints observed in the drill hole wall. This is not unexpected. It confirms expressed concerns regarding adverse impacts of drilling and segregated materials affecting the quality of the recovered core while the sidewall appears more intact.	**We concur. Drilling can have a very negative impact on sample quality and yield an inaccurate assessment of the shear strength along lift joints. and consequently, an inaccurate assessment of the factors of safety against sliding on the lift joints and compliance with ANCOLD Guidelines**

COMMENTS BY TATRO HINES	COMMENTS BY RIZZO
However cores, compared to large blocks, offer a small area to test where edge effects and aggregate size can dominate the observed performance. Hence larger core are better than smaller core. Our shear testing is done nearly exclusively on sawn blocks (nominal shear surface ranging in size from 250mm x 250mm to 300mm x 300mm) in order to achieve a more consistent and representative sample.	**We agree that the best type of test is a shear test on sawn blocks.**
It is our opinion the method of repetitive testing for unbonded peak and residual strengths is problematic. This method appears to degrade the sample surface and may negatively affects the sliding friction strength and residual shear strength test results.	**We agree that repetitive testing is not appropriate in this situation.**
In this program of shear testing it appears that an insufficient number of tests have been conducted given the high consequences associated with poor performance. This testing is presumed to have been designed to be a quick spot check of strength conditions to assure in-situ strength is as intended. The number of tests may be satisfactory to perform this spot check. However, the results were not satisfactory, hence this independent review. We recommend that many more shear tests be conducted in order to more accurately determine the strength condition of the RCC. The current number is too few for such an assessment.	**We agree that many more shear tests should be conducted.**
The testing process to determine intact shear strength is appropriate as one-time loadings are used on individual samples. Additional testing would establish a more reliable trend since the nine tests performed in the 2019 testing program comprise only one family of test results. It is noted however, that shear parameters of intact lift joint surfaces is of a lessor concern than shear parameters of unbonded lift joints.	**We agree that shear strength properties on unbonded lift joint are more important.**
The number of samples tested for this evaluation is very small and as a result may not accurately quantify the actual joint conditions. Since the testing relied on repetitive shearing on a single sample, the number of samples that were tested to fully characterize shear strength appears to be insufficient.	**We fully agree that the small number of tests does not accurately quantify actual joint conditions and that more tests are required.**

Considering all of the above comments and our responses summarized above, it is clear that the existing test data set is inadequate to make major decisions regarding the evaluation and possible remediation of Paradise Dam. The data set is problematic as it does not provide a sufficient basis for assessing dam safety, specifically as regards sliding failure along lift

joints. A new project-specific test program is strongly recommended to allow for proper engineering analysis, decision making and cost analysis. Consequently, we recommend a new program of sampling and testing, consisting of four parts (Parts A, B, C and D) described below be performed at Paradise Dam.

Logistical Comments

Before describing this four-part program, it is appropriate to make four logistical comments. Firstly, we contend that, as matter of convenience, all of the samples that we deem necessary for laboratory testing can be extracted from the Secondary Spillway with no resulting bias as regards the applicability of the results to the Primary Spillway at Paradise Dam. We state this position on the basis that we know of no difference in the RCC Mix Design or RCC construction procedures used for the Secondary Spillway and those used for the Primary Spillway. If Sunwater or the Burnett Dam Alliance has information that indicates that these two suppositions are not correct, the sampling should be done at the Primary Spillway.

Secondly, we believe that all of the testing could be performed in Brisbane with a local laboratory under the full-time supervision of an engineer from RIZZO, possibly with consultation from Tatro Hines, following the details of the recommended testing program below.

Thirdly, we emphasize that the sampling program recommended here will not diminish the safety or the integrity of Paradise Dam. All of the extracted samples of RCC will be replaced with conventional concrete having strength properties higher than the properties of the removed RCC samples. Hence no degradation in the safety of integrity of the Dam will result from this program.

Fourthly, from a schedule perspective, we recommend that this program be conducted and applied prior to any decision to permanently lower the normal pool, such as by reducing the level of the Primary Spillway. A permanent lowering of the normal pool is in our view a major decision that deserves the best information and analysis possible; this can only be developed on the basis of a solid, definitive testing program and appropriate analyses within the ANCOLD Guidelines.

Part A – Block Sampling Program

We recommend that two types of Lift Joint Samples be obtained at the Dam—six (6) sawn Block samples for high quality, indicative tests and nine (9) core borings from which we will select about 30 cores for tests of secondary quality to allow for an assessment of variability and uncertainty. This Part A addresses the sawn Block Sampling Program.

We recommend extracting six (6) Blocks from the downstream side of the Secondary Spillway at six locations to be recommended after consultation with Sunwater regarding access and logistics. The Blocks will be 300 mm by 300 mm in plan by about 600 mm thick. The two halves of the Block will straddle a lift joint that will be tested in a shear box.

The Blocks will be sawn from the Dam with conventional diamond-embedded wire saws used in concrete construction, but we will also consider local contractor experience and equipment. We will not accept pneumatic hammering or cutting to remove the Blocks—they need to be sawn. The Block samples eliminate concerns with edge effects disturbance caused by drilling and particle size if they are properly extracted.

We will provide details of the cutting procedure and specifications to be followed by a local specialty contractor working under the supervision of an engineer from RIZZO. We emphasize that the objective of Part A is to obtain high quality samples for high quality testing to be performed in Part C.

Part B – Core Sampling Program

The primary objective of the Core Sampling Program is to obtain a larger number of samples of secondary quality in an effort to assess variability through the Dam and allow for statistical analysis of the data if deemed necessary. We will define the location of nine (9) core borings on the Secondary Spillway after consultation with Sunwater regarding access and logistics.

The coring operation will be a slow methodical process emphasizing recovery with minimal rod and sampler chatter, minimum circulating water flow at low pressure, new or relatively new triple core barrels pushed under minimum down pressure. We emphasize that the goal is core recovery, not production. We will provide engineering supervision of the coring process with engineers and geologists who are highly experienced at maximizing core recovery. Of course, the lift joints are always problematical with core sampling, but we know in advance where breaks might occur and we are able to advise the drill rig operator accordingly.

To supplement the core recovery, we will run a televiewer in each core boring to allow for a more complete understanding of the in-hole condition.

Finally, after each core boring is completed, we will perform grout take tests at various intervals in the core at particular lift joints. Specifically, we will pump grout under low pressure at specific intervals, using double packers or possibly “tuba machetes.” These tests will provide information regarding possible remediation of lift joints should remediation be deemed necessary. Then the core borings will be backfilled with a conventional cement sand grout with strength properties in excess of the parent RCC that exists in the Dam presently.

We emphasize that the objective of the core boring program in Part B is to obtain a larger number of samples of secondary quality to allow for testing in a shear box in Part D to yield results to assess variability and uncertainty. The core boring program alone is not sufficient to determine the need for remediation or the type of remediation. Core boring alone may yield test results in the same range as to that already available and deemed unsatisfactory due to sample disturbance and testing procedures.

Part C – Block Testing Program

The Part C Block Testing program will utilize the six Blocks sawn from the Dam in Part A of this program and involve the following steps:

1. Trim and square up each sawn Block to rough dimensions of 300 mm by 300 mm in plan and about 600 mm in depth such that the Block can be sheared at the lift joint.

2. Place the Block in a shear box or specially fabricated shearing device that will allow for a constant vertical load and variable horizontal shear load across the lift joint. The load should be measurable to the nearest pound and deformation to the nearest 0.1 cm. Alignment and leveling are exceptionally important and should be carefully conducted.

3. Moisten the Block but do not submerge it.

4. Slowly shear the Block to failure and stop.

5. Either reverse the load or re-position the Block to allow shearing in the reverse direction one time.

6. Provide plots of load versus deformation for each Block test.

Part D – Core Testing Program

The Part D Core Testing Program involves testing about 30 cores extracted from the core borings drilled in Part B. The samples will be selected to allow for testing of lift joint material, both previously broken and unbroken as extracted from the boreholes. The samples will be carefully trimmed, fitted into a specially fabricated shear box and slowly tested in shear. Samples will be saturated but not submerged. The shear box is particularly critical to this effort and we will provide specific details of what is expected.

Tests will be conducted to allow for measurement to the nearest 0.05 pounds and nearest 0.1 cm. Load deformation plots will be developed for each sample and allow for assessment of ϕ (friction angle) and cohesion.

Data Compilation

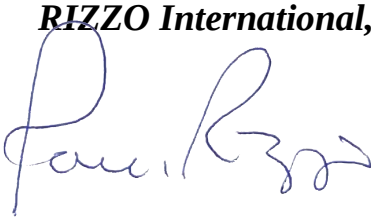
The data from all of the shear tests (both Blocks and cores) will be compiled and recommendations will be developed for the best estimate of ϕ and cohesion if applicable. The results of the Block testing will be the primary basis and the results of the core testing will be used to assess uncertainty and variability. The results of the grout take tests will be summarized and be available for remediation should it be deemed necessary.

Concluding Remarks

We emphasize again that this Report is meant to satisfy a request for recommendations regarding a test program to allow for a definitive course of action regarding the future of Paradise Dam. We expect to perform a detailed analysis after the test data are available and after we have received the remaining documents requested from Sunwater.

Respectfully submitted,

RIZZO International, Inc.



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