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Project No. 19-6089
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Via email: jonathan.horton@paradisedaminquiry.qld.gov.au

Mr. Jonathan Horton QC
Senior Counsel Assisting
Paradise Dam Commission of Inquiry |Office of the Commission
50 Ann Street, State Law Building
Brisbane QLD 4000

TRANSMITTAL
FRICTION ANGLE ANALYSIS – REVISION 1
PARADISE DAM
BUNDABERG, QLD

Dear Mr. Horton,

We are transmitting herewith a revised version of our letter dated March 17, 2020 where we reported the results of a specific stability analysis requested by the Commission. During our routine Quality Assurance check (post-report), we discovered some discrepancies in the final results, which we report in the attached letter. Some of the required friction angles increased slightly and some decreased—all within a degree or so.

I apologize for any inconvenience that this has caused. If you have any questions, please do not hesitate to contact me by telephone at + 1 (412) 849-3901 or by email at paul.rizzo@rizzointl.com.

Respectfully submitted,
RIZZO International, Inc.

Paul C. Rizzo,
Chief Technical Officer, RIZZO International Inc.

Paul C. Rizzo, Ph.D., P.E., P.Eng.
Chief Technical Officer

PCR/mfs

Attachment
L02 Friction Angle Analysis – Revision 1

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17 March 2020
Via email: jonathan.horton@paradisedaminquiry.qld.gov.au

Mr. Jonathan Horton QC
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50 Ann Street, State Law Building
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FRICTION ANGLE ANALYSIS
PARADISE DAM
BUNDABERG, QLD

Dear Mr. Horton,

BACKGROUND

During the hearing on 16 March 2020 when I appeared as a witness via telephone, you requested my opinion as to the value of the required friction angle (no cohesion) that would be required for a factor of safety against sliding equal to unity for a specific set of parameters, which are as follows:

1. Sliding failure is considered along a horizontal lift joint at RL 32.4 m at Monolith H.
2. The behaviour of the lift joint is purely frictional, i.e., cohesion should be ignored.
3. The unit weight of the RCC is 24.17 kN/m3
4. The unit weight of water is 9.81 kN/m3
5. The unit weight of sediment is 18.0 kN/m3
6. The top of the sediment in the reservoir is at RL 38.0 m, i.e., the height of the sediment above the sliding plane is 5.6 m = 38.0-32.4 m.
7. Only 80% of the depth of tailwater is effective in providing stability against sliding.
8. The maximum uplift pressure at the heel of the dam is (a) 50% and (b) 70% of the maximum headwater pressure.
9. The full tailwater pressure acts in uplift at the toe of the dam (not at the downstream end of the apron).
10. Headwater level – RL 88.6m AHD (AEP Flood – 1 in 33,000 Y)

    Tailwater level – RL 80.0m AHD (AEP Flood – 1 in 33,000 Y)

This letter report and the supporting calculation respond to the assumptions provided by the Commission and have been prepared to assist in understanding the theoretical issues surrounding dam stability. It is not intended for use in a practical engineering application nor for design.

RESULTS

Our results are presented in three forms as follows:

Form No. 1

In response to your specific question, the required friction angle along the roller-compacted concrete (RCC) lift joint at the specific lift indicated and for the specific conditions you stated is as follows:

With uplift pressure at the heel equal to 50% of the headwater, $\phi = 43.7^{o}$

With uplift pressure at the heel equal to 70% of the headwater, $\phi = 50.8^{o}$

Form No. 2

For a broader and expanded answer to your question for differing head water conditions, we present the following table.

TABLE 1
HEAD WATER CONDITION VS. REQUIRED ϕ WITH C = 0
FOR SLIDING FS OF UNITY

Storm AEP Flood 1 in Y	Headwater m- AHD	Tailwater m - AHD	Headwater 50%	Headwater 70%
			ϕ	ϕ
FSL	67.6	31.0	20.7	22.3
50	74.5	51.3	33.2	36.6
100	75.4	53.2	34.4	38.1
200	76.3	56.1	35.5	39.4
500	77.5	59.0	36.8	41.0
1,000	78.3	60.2	37.7	42.0
2,000	79.2	63.8	38.0	42.6
5,000	80.7	65.0	39.7	44.7
10,000	82.8	69.0	41.3	47.0
20,000	85.7	75.0	41.7	47.7
33,000	88.6	80.0	41.7	47.9

To develop this table, we used headwater levels and corresponding tailwater levels from the GHD Stability Analysis documents.

Form No. 3

To achieve a Factor of Safety to satisfy ANCOLD Guidelines for Extreme Conditions, these results indicate that either of the following approaches for remediation is appropriate:

1. Anchor the Dam to bedrock with vertical and/or inclined post-tensioned anchors, as has been done at several dams around the world. This increases the effective weight of the Dam, thereby increasing the friction on each RCC lift, as well as on the interface between the bottom of the Dam and the top of rock.

2. Rebuild the downstream toe of the Dam and its foundation and enhance the stilling basin to eliminate scouring and erosion as has occurred in the past. This approach has the benefit of increasing the friction force by increasing the overall weight of the Dam

and diminishes the magnitude of the uplift pressure acting on the downstream portion of the Dam. For this approach, we would recommend conventional concrete with a mix designed to resist erodibility.

We consider either approach to be technically viable and deserving of a feasibility analysis to allow for a technically defendable solution.

I hope that we have satisfied the interest of the Commission with this limited analysis

Respectfully submitted,

RIZZO International, Inc.

Paul C. Rizzo PhD. PE, Peng
Chief, Technical Officer