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Proposed Cruise Berthing Facility, Grand Cayman

Environmental and Engineering Consultancy Services
EIA Task M - Cruise and Cargo Operations

May 14, 2015
12214.100

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EIA Task M - Cruise and Cargo Operations

Prepared for

Ministry of District Administration Tourism & Transport
and The Port Authority of the Cayman Islands

Prepared by

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12214.100

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APPENDIX M.1

Quay Wall Inspection Summary

CAYMAN CRUISE BERTHING FACILITY (P12214)

Date: June 24, 2014

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From: Matthew Armstrong, Thomas Bolas

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Re: Summary of Quay Wall Inspection at the George Town Port

Intro

On Monday June 09, 2014 representatives of Baird, Bolas Engineering, and WI Marine conducted a visual inspection of the quay wall at the George Town Port in Grand Cayman. This memo summarizes the findings of that inspection.

Quay Wall Inspection

The quay wall was broken up into 6 reaches as labeled in Figure 1a, with both above and underwater visual inspections of each reach. The sheet piled area to the north of Reach 1 is a privately owned piece of land and represents the northern boundary of the inspection while the southern boundary was taken as the north side of Hog Sty Bay. Survey boundaries are shown as blue lines in Figure 1a. All dimensions are approximate (visual estimate) unless noted otherwise.

On the day of the inspection there was a tugboat berthed at the Royal Watler (RW) pier, a second tug berthed alongside the quay wall midway along reach 3, and a tug/barge at the Ro-Ro berth unloading aggregate. There were no cruise ships and no other cargo ships in port at the time.

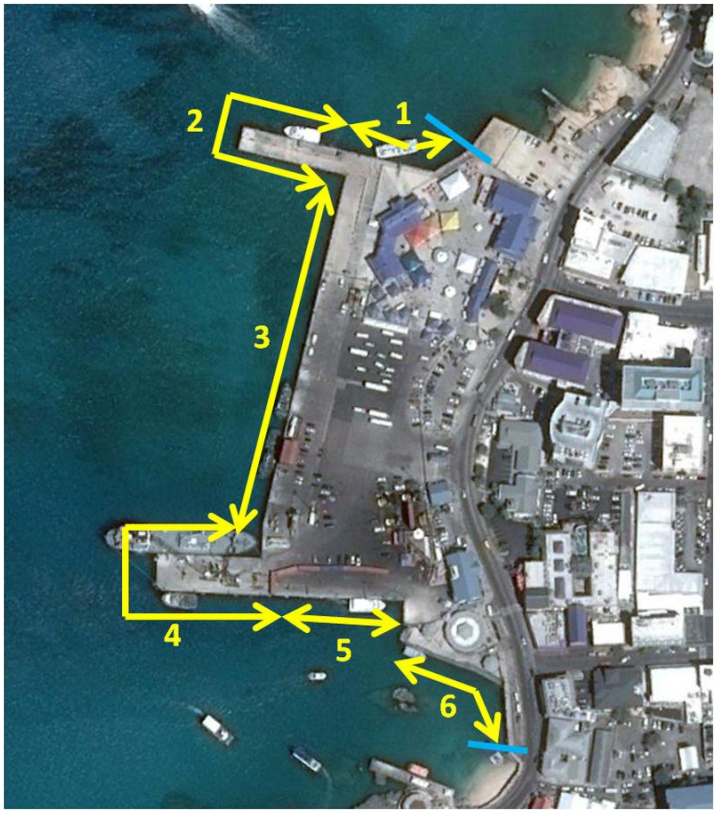

Figure 1a - Reaches of the Quay wall Inspection

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Reach 1

The water depths are relatively shallow (5 ft). The sheet pile cap extends 2ft below the water surface. Exposed sheet piles extend another 3 ft and are cut into the rock. There is growth on the piles but they are generally in good condition (original construction in 2004/2005 port expansion) with no obvious structural deficiencies. The concrete cap and apron slab are generally in good condition (Figure 1b) with some loss of concrete cover at the edge (Figure 1c). This damage was likely caused by inadequate fendering of vessels during energetic conditions would which leads to minor bumping/collisions with the wall and chipping of the concrete edge. No exposed reinforcement steel was observed, and no rust stains suggesting that the reinforcement has been compromised.

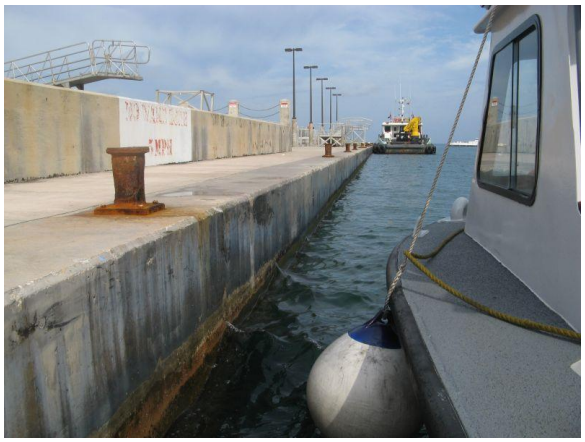

Figure 1b – Reach 2 quay wall generally in good condition

Figure 1c – Reach 1 minor cracking of edges, no exposed reinforcement

Reach 2

Reach 2 is heavily used on cruise ship days as the tender berthing area of the Royal Watler Terminal. The construction is similar to Reach 1 with a concrete cap extending 2ft below the water surface and sheet piles down to bedrock. The water is deeper and the sheet piles are protected by zinc anodes which were installed during the original construction (2004/2005). WI Marine undertook an anode inspection in April 2013 and observed that most of the anodes are extensively/completely corroded and require replacement. Similar to Reach 1 there is damage to the edge of the concrete cap/apron slab which was likely caused by inadequate fendering of vessels during rough conditions. No exposed reinforcement steel was observed. There is also evidence that fenders were installed during the original construction but have broken off and not been replaced with rust staining evident where the broken bolts remain in the wall. Figures 2a and 2b show the quay wall in generally good condition and with some minor chipping of edges. Figure 2c and 2d show representative images of a fully and partially corroded anode with the complete anode inspection report available from WI Marine.

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Figure 2a - Reach 2 quay wall generally in good condition

Figure 2b - Reach 2 minor cracking of edges, no exposed reinforcement

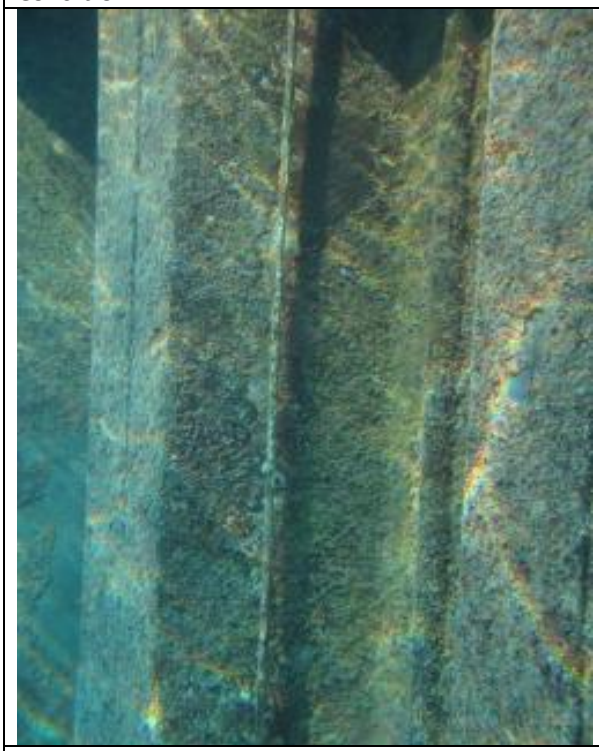

Figure 2c –Fully Corroded Anode (West Wall - Reach 3)

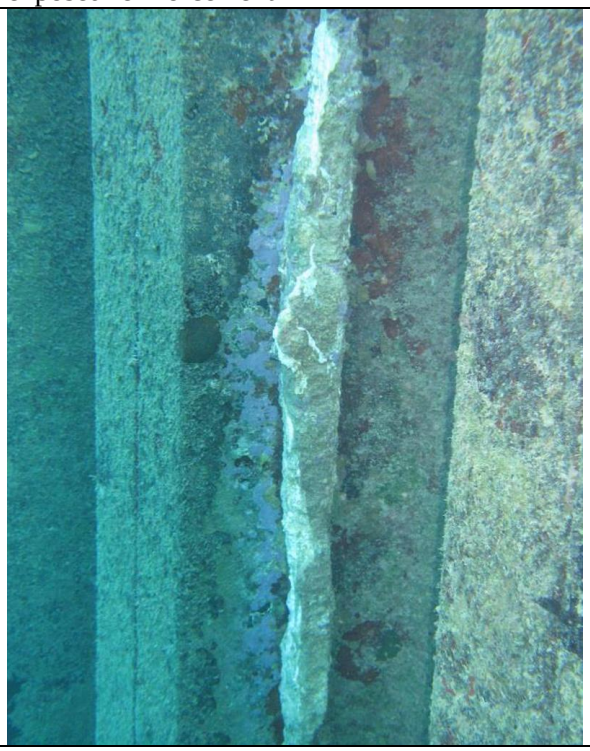

Figure 2d - Partially Corroded Anode (North Dock - Reach 5)

Reach 3

Reach 3 has a similar sheet pile and concrete cap construction to Reaches 1 and 2. The deck level of Reach 3 was raised approximately 1-2ft in response to extensive flooding during a Northwester which occurred in 2005/2006 (exact date unconfirmed) but there is evidence of rust staining from cracks suggesting that the reinforcement steel has been exposed to salt/air and started to corrode (Figure 3a). In addition to that work there is other concrete patching and refinishing of edges in some areas (Figure 3b)

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while other areas show extensive chipping to the point of rebar being exposed (Figures 3c, 3d, and 3f). There is an (unconfirmed) storm water drain outlet about midway along reach 3 which discharges 1-2ft above sea level (Figure 3d). In the area of the Ro-Ro ramp the concrete cap/apron step back down to the original level (Figure 3e). Old railroad tracks have been used as tie-back reinforcement in some areas. Fenders used to be installed all along the wall but have broken off over the years and never been replaced. There is only one fender remaining so it is up to vessels to provide their own fenders to prevent damage to themselves and the dock.

Figure 3a – Rust staining from cracks suggests corroded reinforcement lies underneath

Figure 3b – Patchy Repair works and rust staining

Figure 3c – Exposed reinforcement along edges

Figure 3d – Unconfirmed storm water drain outlet and exposed reinforcement

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Figure 3e - Reach 3 – Step down to original deck level

Figure 3f - Reach 3 – Exposed reinforcement along wall edge

Reach 4

Reach 4 has a similar sheet pile and concrete cap construction to Reaches 1-3. The seaward corners of the cargo pier are protected by 4 cylindrical steel piles (two on each corner) with rubber tire fenders (Figures 4a and 4b). These piles are unsupported at the top and deflect under very little load (a human is able to rock them easily with their foot). It was observed that the piles are used to supplement the bollards, with mooring lines attached to the tops of the piles (Figure 4a). When loaded towards the pier the piles will deflect and bear on the concrete cap thus transferring most of the loads to the pier, but with loads away from the pier there can be greater deflections and their structural integrity is questionable. Zinc anodes were attached to these piles but appear to be inactive due to a poor fastening mechanism (WIM, 2013). The south side of Reach 4 is typically used for container cargo operations and has a variety of fenders installed (Figures 4b and 4c). The cap/apron edge is chipped with reinforcement exposed in a several areas (Figure 4d).

Figure 4a – Reach 4 – Cylindrical pile fenders being used as mooring bollards

Figure 4b – Reach 4 - Various fender types along the Cargo Pier

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Figure 4c – Reach 4 - Various damaged and missing fenders along the cargo pier

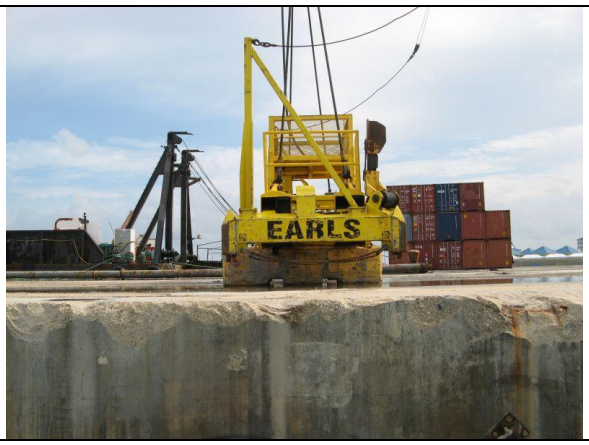

Figure 4d – Reach 4 – Exposed reinforcement along pier edges

Reach 5

At Reach 5 the construction changes to a gravity block type structure with a concrete cap (Figures 5a and 5b). It is unclear what structural connection exists between the sheet piled section and the gravity block sections but there are no visually obvious concerns at the interface (Figure 5a and 5c). Some of the gravity blocks have been moved/twisted from their original position (Figures 5b and 5d) which is reported to have occurred during Hurricane Gilbert (1988). At the time the apron was asphalt and suffered extensive damage from large uplift forces and was replaced with the existing concrete apron. The gravity blocks that were moved/twisted were not repaired and although no longer in exact alignment they do not appear to be an immediate structural concern. There is extensive reinforcement steel exposed due to abrasion of the concrete cap/apron (Figures 5e and 5f).

The very east end of Reach 5 consists of another short section of sheet piles with no concrete cap. The sheet piles appear to have been a "quick fix" and have suffered some collision damage (Figure 5f). Figures 5g and 5h provide underwater views approximately corresponding to the above water views shown in Figures 5e and 5f and show that there is no visible undercutting of the wall in those areas.

Figure 5a – Reach 5 – Offshore transition between sheet pile (left) and gravity block wall (right)

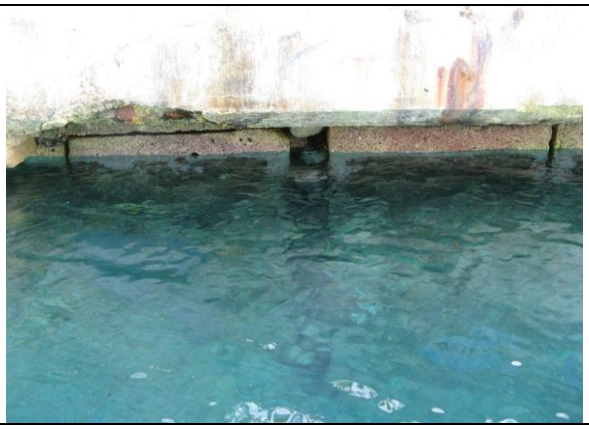

Figure 5b – Reach 5 – Shifted gravity blocks

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Figure 5c – Reach 5 – Offshore transition between sheet pile (left) and gravity block wall (right)

Figure 5d – Reach 5 - Shifted gravity blocks

Figure 5e – Reach 5 – Exposed reinforcement

Figure 5f – Reach 5 – Shoreward transition from gravity blocks to sheet piles with apparent collision damage to the sheet piles

Figure 5g – Reach 5 – No Apparent undercutting of gravity blocks

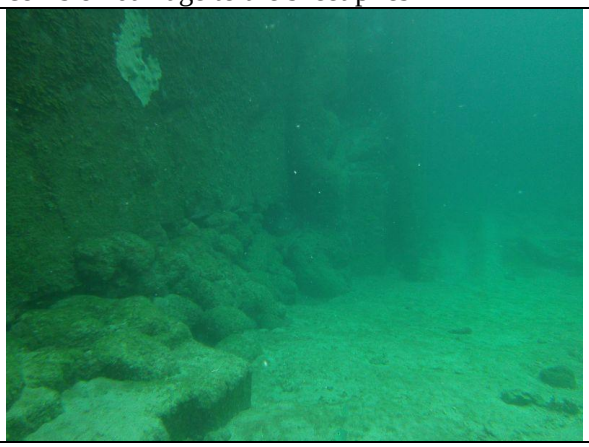

Figure 5h – Reach 5 - No Apparent undercutting at shoreward gravity block to sheet pile transition

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Reach 6

Reach 6 is known as North terminal and its construction predates the George Town Port (exact construction date unconfirmed). The construction consists of concrete poured directly on to ironshore bedrock and is used as an overflow terminal to receive tenders on busy cruise ship days. There is significant undercutting of the ironshore rock (8-10ft) reported by WIMarine divers (June 09, 2014) and the interface between the concrete and the ironshore is eroded in many areas. The bottom has very little loose sediment cover so erosion and undercutting is likely a slow process and has not occurred as a response to some recent event. However, failure of an unsupported section could occur rapidly and would require a more thorough inspection to determine that risk. The concrete finishing is generally quite rough in appearance, though the structure has been functional for several decades without major repairs.

Figure 6a – Reach 6 – North Terminal built directly on ironshore

Figure 6b – Reach 6 – Undercutting of the North Terminal dock

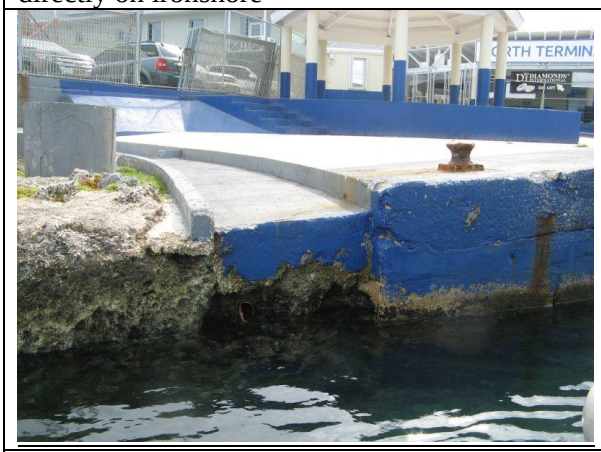

Figure 6b – Reach 6 - North Terminal built directly on ironshore

Figure 6b – Reach 6 - North Terminal built directly on ironshore

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General Comments

WI Marine Anode Inspection report suggests that all of the anodes require replacement to prevent corrosion of the existing sheet piles.

The South side of the RW pier is rarely used for tender operations as there are significant trapped wave reflections which make it difficult to berth and load/offload the tenders even under calm/moderate wave conditions.

Conclusions

The quay wall of the port is generally in good condition with no visually observed features that suggest immediate structural concerns. Areas of exposed reinforcement, especially in the cargo and Ro-Ro area, undercutting of the deck at the North Terminal, and fully corroded anodes on the sheet pile wall are some areas of concern that need to be addressed by general maintenance and medium term repairs. The anodes are generally no longer functional and replacement would be recommended as soon as possible to minimize corrosion damage to the sheet piles. A more detailed structural assessment will be able to give a better understanding of the required timeline for repairs to exposed reinforcement and the undercutting at the North Terminal.

APPENDIX M.2

Numerical Simulation of Moored Ship Response Results

Navigation, Moored Ship Response and Downtime

The preliminary layout concepts presented in IR1 included pier orientations ranging from W to NW; these orientations generally correspond to the prevailing wind and wave directions, and hence were deemed likely to be preferable with respect to navigation, moored ship response and downtime. The new layout concepts (Option 4A and 4B) include pier orientations of SSW, SW and NNW. At the time IR1 was submitted, the assessment of navigation, moored ship response and downtime was ongoing, and the impact of pier orientation on downtime had not been quantified.

Regarding navigation issues, the geometric configuration of the different concept layouts are based on published guidance for key parameters, such as pier length and spacing and dredge basin limits and depths. Given the relatively high maneuverability of most cruise ships, as well as the generally mild wind and wave conditions in the region, navigation to/from the facility is not anticipated to be a significant issue. That being said, a W pier orientation is best from a navigation perspective, as it is in line with the prevailing winds; as the pier orientation rotates (either N or S) from this orientation, navigation will become more challenging, though it is unlikely to be of concern. It is recommended that navigation simulations be undertaken once the preferred project layout has been selected in order to confirm safe operating limits and requirements for navigation aids.

Regarding moored ship response (MSR) and downtime, Baird has now completed a numerical modeling and analyses in order to estimate downtime as a function of pier orientation. The following bullet points summarize key elements of these analyses:

- MSR simulations completed for pier orientations of SW to NNW, and for three vessels that span the range in vessel sizes that typically call at Grand Cayman, including:
    - Royal's *Freedom* - LOA = 338.9 m, B = 36.8 m, d = 8.5 m,
    - Carnival's *Conquest* - LOA = 290.5 m, B = 35.4 m, d = 8.2 m,
    - Carnival's *Fantasy* - LOA = 260.6 m, B = 31.5 m, d = 7.8 m;
- Assumed safe operational limits as follows:
    - Maximum 1 m motion (horizontal or vertical) at passenger door (based on literature review, and discussions with Captains),
    - Maximum line load of 55% of the mean breaking load (as per OCIMF, 1997);
- Limiting wind and wave conditions defined for each vessel and pier orientation;
- Downtime estimated on a monthly basis over the 34 year duration of the operational wind and wave climate developed for this study;
- Sensitivity analyses completed to assess the impact of uncertainty in safe operational limits (and associated limiting wind and wave conditions) on the results.

Tables 3.1 and 3.2 present a summary of the results for the three representative vessels moored at piers with four different orientations for the cruise season (Nov-Apr) and the off-season (May-Oct).

Table 3.1: Estimated Downtime (days) by Vessel and Pier Orientation - Cruise Season

Vessel	**RCCL *Freedom***				**CCL *Conquest***				**CCL *Fantasy***			
Pier Orient.	**220°**	**270°**	**315°**	**348°**	**220°**	**270°**	**315°**	**348°**	**220°**	**270°**	**315°**	**348°**
November	0-5	0-2	0-3	0-3	0-6	0-2	0-2	0-5	0-7	0-2	0-4	0-5
December	0-3	0-2	0-3	0-4	0-6	0-2	0-2	0-3	0-7	0-3	0-4	0-4
January	0-4	0-4	0-4	0-4	0-7	0-2	0-4	0-4	0-8	0-4	0-5	0-6
February	0-5	0-3	0-3	0-4	0-5	0-3	0-3	0-5	0-8	0-4	0-4	0-5
March	0-6	0-2	0-4	0-5	0-8	0-2	0-2	0-6	0-11	0-3	0-4	0-6
April	0-2	0-1	0-1	0-1	0-2	0-1	0-1	0-2	0-3	0-1	0-2	0-2
Range in Downtime over 34 Seasons												
Days	0-11	0-7	0-9	0-11	1-16	0-5	0-7	0-12	7-28	0-9	0-14	0-15
%	0-6.1	0-3.9	0-5.0	0-6.1	0.6-8.8	0-2.8	0-3.9	0-6.6	3.9-15.5	0-5.0	0-7.7	0-8.3
Average Downtime over 34 Seasons												
Days	4.1	1.5	2.6	3.8	7.6	0.9	1.3	4.6	14.6	1.8	5.6	6.8
%	2.3	0.8	1.4	2.1	4.2	0.5	0.7	2.5	8.1	1.0	3.1	3.8

Table 3.2: Estimated Downtime (days) by Vessel and Pier Orientation - Off Season

Vessel	**RCCL *Freedom***				**CCL *Conquest***				**CCL *Fantasy***			
Pier Orient.	**220°**	**270°**	**315°**	**348°**	**220°**	**270°**	**315°**	**348°**	**220°**	**270°**	**315°**	**348°**
May	0-1	0-0	0-0	0-0	0-3	0-0	0-0	0-1	0-3	0-0	0-1	0-2
June	0-2	0-1	0-1	0-1	0-2	0-1	0-1	0-2	0-2	0-1	0-1	0-2
July	0-0	0-0	0-1	0-1	0-0	0-0	0-0	0-0	0-0	0-0	0-2	0-1
August	0-1	0-0	0-1	0-1	0-2	0-0	0-0	0-1	0-2	0-0	0-1	0-1
September	0-3	0-2	0-2	0-3	0-4	0-2	0-2	0-3	0-8	0-2	0-2	0-3
October	0-5	0-2	0-3	0-5	0-8	0-2	0-2	0-5	0-10	0-3	0-6	0-8
Range in Downtime over 34 Seasons												
Days	0-5	0-2	0-4	0-6	0-8	0-2	0-2	0-5	0-12	0-3	0-7	0-9
%	0-2.8	0-1.1	0-2.2	0-3.3	0-4.4	0-1.1	0-1.1	0-2.8	0-6.6	0-1.6	0-3.8	0-5.0
Average Downtime over 34 Seasons												
Days	1.3	0.4	0.7	1.0	2.2	0.4	0.3	1.3	4.1	0.4	1.3	2.0
%	0.7	0.2	0.4	0.5	1.2	0.2	0.2	0.7	2.2	0.2	0.7	1.1

These results indicate that a W pier orientation (as utilized for Options 1A, 1B, 1C and 1D) will minimize downtime associated with wind and wave action at the project site. A NW pier orientation (as utilized for Options 0, 2A, 2B, 3A and 3B) results in slightly higher downtime, while SSW-SW and NNW pier orientations (as utilized for Options 4A and 4B) result in significantly higher downtime. In addition, the results indicate that downtime is greater during the cruise season than during the off-season; this is due to the fact that "Northwesters" occur during the winter months. Finally, the results indicate that downtime is greater for

smaller vessels. As such, downtime for Royal Caribbean's *Oasis* (their largest ship) is expected to be lower than that for the *Freedom*, while downtime for Carnival's *Dream* (their largest ship) is expected to fall between that of the *Freedom* and the *Conquest*.

For comparison purposes, information on missed calls for the 2010-2014 seasons, as provided to Baird by PACI, is presented in Table 3.3.

Table 3.3 – Summary of Missed Calls with Present Tender Operation (2010 – 2014)

Description	2010	2011	2012	2013	2014**	Total
Total Scheduled	611	557	550	496	323	2,537
George Town*	520	519	516	471	302	2,328
Spotts	56	10	15	16	8	105
Missed	35	28	19	9	13	104
Total - Spotts + Missed						
Number of Calls	91	38	34	25	21	209
% of Calls	15%	7%	6%	5%	7%	8%

*Includes Royal Watler, North and South Terminals and Cargo Dock
** 2014 through June 30 only

This information indicates that downtime associated with the present tender operation is typically in the order of 5-7%, but may reach 15% (2010). Referring to the downtime estimates for the cruise season for the proposed cruise berthing facility (Table 3.1), the estimated downtime for W and NW pier orientations is generally lower than that for the present tender operation, while that for the SW and NNW pier orientations is similar to or higher than that for the present tender operation.