資料　５：　　参考資料

資料5-1　　PEARとCEARの要求事項比較

章	題	内容	PEAR	CEAR	備考
I	Title Page	Name of Author	x	x	
		Name of the proposed development	x	x	
		Location where the development will take place	x	x	
		Date in which the EIA report was finished prepared	x	x	
II	Table of content	Content including attachments	x	x	
III	Summary of the development proposal and its consequences	Description of the development proposal	x	x	
		Significant adverse impacts	x	x	
		Controversial and Unresolved Issues	x	x	
		A summary of the stakeholder consultation	x	x	
		A summary of the proposed measures to avoid, minimize and mitigate adverse impacts	x	x	
		Major conclusions and recommendations	x	x	
IV	Purpose of the Development	Purpose of Development	x	x	
		Location	x	x	Aerial image is required
		Construction & Operational Activities	x	x	
		Infrastructure, Utilities and Services	x	x	
		Justification of the Proposed Development	x	x	
V	Alternatives	Review and evaluate all reasonable alternatives including locations and methods and the alternative of no action		x	
		Identify the proponents preferred alternative or alternatives		x	
VI	Affected environment	Existing Environment		x	
		Conflict		x	
VII	Environmental consequences	key issues that should be identified		x	
		Geotechnical		x	
		Construction effects		x	
		Noise – address noise emissions that may be generated		x	
		Wastewater		x	
		Access and Traffic		x	
		Storm water management and drainage		x	
		Erosion and sediment control		x	
		Social and economic impacts	x	x	
		Sustainable Development - detail any proposed measures for reduction of water and energy usage		x	
		Natural hazard		x	
		Cumulative impacts		x	
		Ecological impacts	x	x	
VII	Mitigation and condition	Adverse Impacts that Cannot be Avoided	x	x	
		Mitigation Measures to minimize significant environmental impacts	x	x	
IX	Monitoring Schedule	Monitoring indicator		x	
		Monitored activity		x	
		Detail of Mitigation Strategies and Proposed Monitoring		x	
		Environmental Monitoring Agent		x	
X	Consultations	Includes feedbacks and perspectives about the benefits and drawbacks of the proposed development	x	x	List of all the names of the individuals and organizations shall be attached.
XI	Conclusion and	A final bold justification	x	x	
XII	Bibliography and appendix	Sources used in the preparation of the EIA	x	x	

資料 5-2　騒音・振動予測

本事業で予定されている工種のうち、騒音・振動の大きな発生源となるものとしては、くい打ち機（油圧ハンマー）による鋼管杭の打設が考えられるため、くい打ち作業による騒音・振動の検討を行った。

事業地予定地周辺図を下図に示す。港湾敷地境界外には、レストラン、ホテル、輸出入代理店業者の事務所が並んでいる。くい打ち予定区域から直近のレストランまでは直線距離で約 245m ある。

基本図出典：Google Earth

図 1　事業地予定周辺

(1) 騒音

油圧ハンマーを使用したくい打ち作業の場合の、音源での騒音レベルは 129dB である[1]。そこから 245m 離れた地点での騒音レベルは、点音源に係る予測式[2]を用い、以下のようになる。

[1] 道路環境影響評価の技術手法, 財団法人道路環境研究所, 2007 年
[2] 建設工事騒音の予測モデル“ASJ CN-Model 2007”,日本音響学会, 2008 年

$$L_{Aeq} = L_{Aw} - 8 - 20 \times Log_{10}(r) = 73(\text{dB})$$

L_{Aeq}: 音源(建設機械)による予測地点の等価騒音レベル(dB)
L_{Aw}: 音源(建設機械)のパワーレベル(dB)
r: 音源(建設機械)と予測地点の距離(245m)

サモア国の Commercial Area における昼間の建設騒音規制値は 75dB[3]であるため、基準値は満足する。なお、上記の式では音の遮蔽物による回折効果、空気の音響吸収、海面効果等の影響は考慮していないため、予測結果はそれらの影響を考慮した場合よりも高めの値となり、実際にはもう少し低いレベルになると思われる。

(2) 振動

油圧ハンマーを使用したくい打ち作業の場合の、振動源から 5m 離れた場所での振動レベルは 81dB である[4]。振動源から 245m 離れた地点での振動レベルは、以下の予測式[4]により計算され、予測値は 53dB となる。

$$L_r = L_{r0} - 15 \times Log(r / r_0) - 8.68 \times \alpha \times (r - r_0) = 53\text{dB}$$

L_r: 振動発生源から r(m)の距離における予測振動レベル(dB)
L_{r0}: 振動発生源から r0(m)の距離における実測振動レベル(dB)
α: 地盤の内部減衰係数（未固結地盤：0.01）

サモア国には振動に関する規制値がないため、日本における震動規制法による規制基準値（特定建設作業に係る敷地境界での振動規制基準値）と比較した。予測結果は 53dB、日本での規制基準値は 75dB[5]であり、予測値は規制値を下回っているため、くい打ち作業中での振動の影響は考えられない。

(3) 結論

予測により、最も騒音・振動の影響が大きいと思われるくい打ち作業中でも、それにより発生した騒音、振動はいずれも規制値を超えないがわかった。しかしながら、予測結果、特に騒音は規制値に近い値となっており、風向き、その他の要因により規制値を超える可能性も考えられるため、工事中は機器によりモニタリングし、規制値の範囲内で工事が行われていることを確認することが望ましい。

---

[3] Noise Policy, 2011, MNRE
[4] 道路環境影響評価の技術手法, 財団法人道路環境研究所, 2007 年
[5] 震動規制法（環境省, 1976 年）による特定建設作業（くい打ち機含む）に係る敷地境界での振動規制基準値

資料 5-3　モニタリングフォーム

モニタリングフォーム（工事前・工事中）

(1) 住民から出された要求に対する事業者からの回答と対応

モニタリング項目	報告期間中の状況
住民より出された意見の数と内容	
事業者からの回答の数と内容	

(2) 汚染対策

大気汚染

日程	大気汚染、粉じん等の状況	判断、対策
第 1 日目		
第 2 日目		
第 3 日目		
. .		

水質汚濁、保護区、生態系

日程	降雨	水質汚濁の状況	雨水排水の状況	判断、対策
第 1 日目	有 / 無			
第 2 日目	有 / 無			
第 3 日目	有 / 無			
. .				

水質汚濁（異常発生時）

日程	項目	単位	St.1	St.2	St.3	St.4	St.5	基準値*	判定
1 日目	濁度	NTU						1-20	
月　日	pH	-						8.0-8.4	
	T-N	mg/L						0.1	
	T-P	mg/L						0.015	
	COD	mg/L						-	
	Oil and grease	mg/L						-	
	6 価クロム	mg/L						0.020	
	鉛	mg/L						0.007	

日程	項目	単位	St.1	St.2	St.3	St.4	St.5	基準値*	判定
3 日目	濁度	NTU						1-20	
	pH	-						8.0-8.4	
月　日	T-N	mg/L						0.1	
	T-P	mg/L						0.015	
	COD	mg/L						-	
	Oil and grease	mg/L						-	
	6 価クロム	mg/L						0.020	
	鉛	mg/L						0.007	
5 日目	濁度	NTU						1-20	
	pH	-						8.0-8.4	
月　日	T-N	mg/L						0.1	
	T-P	mg/L						0.015	
	COD	mg/L						-	
	Oil and grease	mg/L						-	
	6 価クロム	mg/L						0.020	
	鉛	mg/L						0.007	
7 日目	濁度	NTU						1-20	
	pH	-						8.0-8.4	
月　日	T-N	mg/L						0.1	
	T-P	mg/L						0.015	
	COD	mg/L						-	
	Oil and grease	mg/L						-	
	6 価クロム	mg/L						0.020	
	鉛	mg/L						0.007	

*:サモアに環境基準値がないため、Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Chapter 3 – Aquatic Ecosystems, Tropical Australia を参照した。
６価クロム及び鉛については、上記ガイドライン値の中から、日本の環境省による「人の健康の保護に関する環境基準」に近い、Level of protection=90%species の値を採用した。

廃棄物（工事区域内）

日程	内容	量(m^3)	処理の方法
第 1 日目			
第 2 日目			
第 3 日目			
. .			

土壌汚染、悪臭 （タンク内容物の転換時）

日程	施行方法	土壌汚染の有無	悪臭発生の有無	問題の対処方法
第 1 日目				
第 2 日目				
. .				

騒音・振動

項目（単位）	測定値（平均値）	測定値（最大値）	現地基準	参照した国際基準	頻度（くい打ち社業中）	方法	測定場所
騒音レベル (dB)			75 (7AM-6PM)	-	10 分間 2 回/日	騒音計	敷地境界
			65 (7AM-6PM)	-			沿道
振動レベル (dB)			-	75 (7AM-7PM)		振動計	敷地境界
			-	70 (7AM-7PM)			沿道

注：平均値は騒音レベルについては L_{eq} を、振動レベルについては L_{V10} を測定結果とする。
参考：振動レベルの基準については、日本の震動規制法（1976 年）による規制基準値を参照した。

底質汚染

日程	海底泥の攪乱の有無	判断、対策
第 1 日目		
第 2 日目		
第 3 日目		
. .		

(3) 社会環境

モニタリング項目	項目	方法	頻度	報告期間中の状況
生活・生計	交通渋滞 騒音・振動	目視およびヒアリング	週 1 回	
少数民族・先住民族	漁業の不便さ	ヒアリング	適宜	
労働環境	安全衛生管理実施状況	工事進捗月報の確認	月 1 回	
事故	安全衛生管理実施状況	工事進捗月報の確認	月 1 回	

モニタリングフォーム（供用時）

(1) 住民から出された要求に対する事業者からの回答と対応

モニタリング項目	報告期間中の状況
住民より出された意見の数と内容	
事業者からの回答の数と内容	

(2) 社会環境

モニタリング項目	項目	方法	頻度	報告期間中の状況
事故	安全衛生管理実施状況 旅客動線の安全性	事業月報の確認	月 1 回	

環境チェックリスト：１０．港湾（1）

分類	環境項目	主なチェック事項	Yes: Y No: N	具体的な環境社会配慮 (Yes/Noの理由、根拠、緩和策等)
1 許認可・説明	(1)EIAおよび環境許認可	(a) 環境アセスメント報告書（EIAレポート)等は作成済みか。 (b) EIAレポート等は当該国政府により承認されているか。 (c) EIAレポート等の承認は付帯条件を伴うか。付帯条件がある場合は、その条件は満たされるか。 (d) 上記以外に、必要な場合には現地の所管官庁からの環境に関する許認可は取得済みか。	(a)N (b)N (c)N (d)N	(a)サモア国の環境手続きに沿ったEIAレポートが2015年1月末までに作成される予定である。 (b)SPAにより手続きを行い、2015年4月末までに承認される予定である。 (c)PUMAより指示のある項目を網羅しており、付帯条件は付かないものと思われる。 (d)工事に関して必要な許認可はすべて確認済みであり、SPAにより工事開始までに取得予定である。
	(2)現地ステークホルダーへの説明	(a) プロジェクトの内容および影響について、情報公開を含めて現地ステークホルダーに適切な説明を行い、理解を得ているか。 (b) 住民等からのコメントを、プロジェクト内容に反映させたか。	(a)Y (b)Y	(a)ステークフォルダー会議は、SPAにより2015年1月16日に実施され、関係者の同意が得られている。 (b)会議の際に出た、懸念、意見はSPAにより回答され、必要に応じて事業に反映させることになっている。
	(3)代替案の検討	(a) プロジェクト計画の複数の代替案は（検討の際、環境・社会に係る項目も含めて）検討されているか。	(a)Y	(a)近隣の候補地について環境・社会に係る項目も含めて検討済みである。
2 汚染対策	(1)大気質	(a) 船舶・車輌・付帯設備等から排出される硫黄酸化物（SOx）、窒素酸化物（NOx）、煤じん等の大気汚染物質は、当該国の排出基準、環境基準等と整合するか。大気質に対する対策はとられるか。	(a)Y	(a)工事中、供用後を含め、船舶・車輌の現況からの増加は少ないと予想されるため、大気質への排出影響は軽微である。 付帯施設の改変がないため、それに伴う影響変化はない。 工事中は区域への散水、車両タイヤ洗浄、船舶、工事車両に対してエンジン整備による排出ガス改善等の対策が取られる。
	(2)水質	(a) 関連施設からの一般排水は、当該国の排出基準、環境基準等と整合するか。 (b) 船舶・付帯設備等（ドック等）からの排水は、当該国の排出基準、環境基準等と整合するか。 (c) 油、有害物質等が周辺水域に流出・排出しない対策がなされるか。 (d) 水際線の変更、既存水面の消滅、新規水面の創出等によって、流況変化・海水交換率の低下等（海水循環が悪くなる）が発生し、水温・水質の変化が引き起こされるか。 (e) 埋め立てを行う場合、埋立地からの浸透水が表流水、海水、地下水を汚染しない対策がなされるか。	(a)Y (b)Y (c)Y (d)N (e)N	(a)付帯施設の建設、改変は行なわれないため、関連施設からの一般排水の増減はない。 当該国の環境基準はないため、オーストラリアの海域の環境基準と比較しても、現況海域の水質は概ね基準を満足している。大腸菌偶数については河川水の影響が大きい河口部では基準を超過している。 (b)排水基準、環境水質基準は当該国にないが、MARPOL条約（Annex IV)、Marine Pollution Prevention Act 2008に基づき、規制を受ける。 (c)陸上部では既存の沈砂枡により油膜、濁水除去等の流出対策がなされる。油流出対策計画が事業者により策定される。 (d)埋め立ては行なわれず、鋼管杭構造の埠頭であり、既存の護岸方向への延伸であるため、流況、海水交換への影響は少ない。 (e)埋め立ては行なわれない。
	(3)廃棄物	(a) 船舶、関連施設からの廃棄物は当該国の規定に従って適切に処理・処分されるか。 (b) 浚渫土・沖捨土の投棄が周辺水域に影響を及ぼすことがないよう、当該国の基準に従って適切に処理・処分されるか。 (c) 有害物質が周辺水域に排出・投棄されないよう対策がなされるか。	(a)Y (b)Y (c)Y	(a)MARPOL条約(Annex V)、Marine Pollution Prevention Act 2008およびWaste Management Act 2010に基づき、規制される。 (b)本工事では浚渫の予定はない。 (c)(a)と同様。
	(4)騒音・振動	(a) 騒音・振動は当該国の基準等と整合するか。	(a)Y	(a)騒音については、Noise Policy 2011に従い規制される。振動基準はないが、予測では日本の規制値を満足している。一番大きな杭打設工事中については機器測定によるモニタリングにより、騒音・振動が基準値/規制値を満足しているかの確認が行われる。
	(5)地盤沈下	(a) 大量の地下水汲み上げを行う場合、地盤沈下が生じる恐れがあるか。	(a)N	(a)地下水の汲み上げは伴わない。
	(6)悪　臭	(a) 悪臭源はあるか。悪臭防止の対策はとられるか。	(a)Y	(a)既存のオイルタンクの内容物変更については、専門業者によりバキューム装置等を使用し手順を踏まえ、内容物が環境中にはもれないように作業が行われる。
	(7)底　質	(a) 船舶及び関連施設からの有害物質等の排出・投棄によって底質を汚染しないよう対策がなされるか。	(a)Y	(a)MARPOL条約、Marine Pollution Prevention Act 2008およびWaste Management Act 2010に基づき、規制されるため、船舶、関連施設からの排出、投棄は行なわれない。

環境チェックリスト：１０．港湾（2）

分類	環境項目	主なチェック事項	Yes：Y No：N	具体的な環境社会配慮 (Yes/Noの理由、根拠、緩和策等)
3 自然環境	(1)保護区	(a) サイトは当該国の法律・国際条約等に定められた保護区内に立地するか。プロジェクトが保護区に影響を与えるか。	(a)Y	(a)サイトは保護区内ではないが、岸壁を隔ててサイトの裏側に海洋保護区がある。浚渫等濁りを発生する工事は予定されないが、濁りの発生を含めてその場所への工事の影響がないか、目視による確認が行われる。
	(2)生態系	(a) サイトは原生林、熱帯の自然林、生態学的に重要な生息地（珊瑚礁、マングローブ湿地、干潟等）を含むか。 (b) サイトは当該国の法律・国際条約等で保護が必要とされる貴重種の生息地を含むか。 (c) 生態系への重大な影響が懸念される場合、生態系への影響を減らす対策はなされるか。 (d) 水生生物に悪影響を及ぼす恐れはあるか。影響がある場合、対策はなされるか。 (e) 沿岸域の植生、野生動物に悪影響を及ぼす恐れはあるか。影響がある場合、対策はなされるか。	(a)Y (b)N (c)Y (d)Y (e)N	(a)サイトの対岸にサンゴ群落があり、工事の影響が及ばないよう対策が取られる。 (b)サイト内には、貴重種の生息域はない。少し離れた河口部で希少リストにあがった魚種が確認されたが、常に濁りの強い場所でもあり、そこまで工事の影響は及ばないと考えられる。 (c)生態系への重大な懸念はないが、工事中は濁りの拡散がないか等、目視による確認が行われる。工事船の国外からの回航の際には、外来生物の移入防止対策として、回航前の船底掃除、到着後の確認が行われる。 (d)同上 (e)沿岸域の植生、野生動物に悪影響は及ぼさない。
	(3)水象	(a) 港湾施設の設置による水系の変化は生じるか。流況、波浪、潮流等に悪影響を及ぼすか。	(a)N	(a)工事は既存埠頭方向の延長であり、現況の流況方向に沿っているため、流況、波浪、潮流等に悪影響は及ぼさない。
	(4)地形・地質	(a) 港湾施設の設置による計画地周辺の地形・地質の大規模な改変や自然海浜の消失が生じるか。	(a)N	(a)地形・地質の大規模な改変や自然海浜の消失は生じない。
4 社会環境	(1)住民移転	(a) プロジェクトの実施に伴い非自発的住民移転は生じるか。生じる場合は、移転による影響を最小限とする努力がなされるか。 (b) 移転する住民に対し、移転前に補償・生活再建対策に関する適切な説明が行われるか。 (c) 住民移転のための調査がなされ、再取得価格による補償、移転後の生活基盤の回復を含む移転計画が立てられるか。 (d) 補償金の支払いは移転前に行われるか。 (e) 補償方針は文書で策定されているか。 (f) 移転住民のうち特に女性、子供、老人、貧困層、少数民族・先住民族等の社会的弱者に適切な配慮がなされた計画か。 (g) 移転住民について移転前の合意は得られるか。 (h) 住民移転を適切に実施するための体制は整えられるか。十分な実施能力と予算措置が講じられるか。 (i) 移転による影響のモニタリングが計画されるか。 (j) 苦情処理の仕組みが構築されているか。	(a)N (b)N (c)N (d)N (e)N (f)N (g)N (h)N (i)N (j)N	(a)-(j)事業地は事業者の所有地内にあり、土地収用は伴わず、住民移転も発生しない。
	(2)生活・生計	(a) プロジェクトによる住民の生活への悪影響が生じるか。必要な場合は影響を緩和する配慮が行われるか。 (b) プロジェクトにより周辺の水域利用（漁業、レクリエーション利用を含む）が変化して住民の生計に悪影響を及ぼすか。 (c) 港湾施設が住民の既存水域交通及び周辺の道路交通に悪影響を及ぼすか。 (d) 他の地域からの人口流入により病気の発生（HIV等の感染症を含む）の危険はあるか。必要に応じて適切な公衆衛生への配慮は行われるか。	(a)Y (b)N (c)Y (d)N	(a)工事中、工事車両により周辺道路の交通への影響が考えられるが、車両数は少なく、影響は軽微である。事前に工事予定の周知が行われる。 (b)水域利用への影響はない。 (c)(a)と同様。 (d)プロジェクトによる他地域からの人口流入はない。

環境チェックリスト：１０．港湾（3）

分類	環境項目	主なチェック事項	Yes: Y No: N	具体的な環境社会配慮 (Yes/Noの理由、根拠、緩和策等)
4 社会環境	(3)文化遺産	(a) プロジェクトにより、考古学的、歴史的、文化的、宗教的に貴重な遺産、史跡等を損なう恐れはあるか。また、当該国の国内法上定められた措置が考慮されるか。	(a)N	(a)サイトおよび周辺に文化遺産、史跡はない。
	(4)景　観	(a) 特に配慮すべき景観が存在する場合、それに対し悪影響を及ぼすか。影響がある場合には必要な対策はとられるか。	(a)N	(a)サイトは既に港湾区域として機能しており、工事による景観への影響は考えられない。
	(5)少数民族、先住民族	(a) 少数民族、先住民族の文化、生活様式への影響を軽減する配慮がなされているか。 (b) 少数民族、先住民族の土地及び資源に関する諸権利は尊重されるか。	(a)Y (b)N	(a)湾奥の川の河口部で非公式ながら先住民による小規模な漁業が営まれており、工事船舶の航行等、漁業への影響が及ばないよう配慮がなされる。 (b)サイト付近には少数民族、先住民族の集落がなく、資源に関する負の影響も考えられない。
	(6)労働環境	(a) プロジェクトにおいて遵守すべき当該国の労働環境に関する法律が守られるか。 (b) 労働災害防止に係る安全設備の設置、有害物質の管理等、プロジェクト関係者へのハード面での安全配慮が措置されているか。 (c) 安全衛生計画の策定や作業員等に対する安全教育（交通安全や公衆衛生を含む）の実施等、プロジェクト関係者へのソフト面での対応が計画・実施されているか。 (d) プロジェクトに関係する警備要員が、プロジェクト関係者・地域住民の安全を侵害することのないよう、適切な措置が講じられているか。	(a)Y (b)Y (c)Y (d)Y	(a)当該国の関係法令は遵守される。 (b)管理施設の防護フェンスの設置、警告標識の設置等安全対策が計画されている。 (c)労働者への衛生、地元社会への配慮等の教育を行う計画である。 (d)地元での採用を優先し、労働者には地域社会の文化に敬意を払うよう指導する。
5 その他	(1)工事中の影響	(a) 工事中の汚染（騒音、振動、濁水、粉じん、排ガス、廃棄物等）に対して緩和策が用意されるか。 (b) 工事により自然環境（生態系）に悪影響を及ぼすか。また、影響に対する緩和策が用意されるか。 (c) 工事により社会環境に悪影響を及ぼすか。また、影響に対する緩和策が用意されるか。	(a)Y (b)N (c)N	(a)工事量を最小化し、粉じん、騒音、振動、排ガス、濁水等にいては機器もしくは目視にて毎日モニタリングし、周辺地域への影響がないかを確認する。 (b)汚濁を発生する工事は想定されていないが、汚濁発生の有無を毎日確認することで、自然生態系への影響は小さいと考えられる。その他の自然生態系への影響はない。 (c)建設期間中の交通量増加は少ないが、影響が最小になるよう考慮し、定期的な周辺住民へのヒアリング等により影響を把握する。
	(2)モニタリング	(a) 上記の環境項目のうち、影響が考えられる項目に対して、事業者のモニタリングが計画・実施されるか。 (b) 当該計画の項目、方法、頻度等はどのように定められているか。 (c) 事業者のモニタリング体制（組織、人員、機材、予算等とそれらの継続性）は確立されるか。 (d) 事業者から所管官庁等への報告の方法、頻度等は規定されているか。	(a)Y (b)Y (c)Y (d)Y	(a)騒音・振動については機器により、その他については定性的であるが、モニタリングが計画されている。 (b)施工方法、発生する影響の挙動を考慮し、その影響を把握する範囲、方法で計画されている。 (c)影響が生じるのはごく短期間あるいは軽微であり、施工業者と事業者によるモニタリングが計画されている。 (d)所管官庁等への報告の方法、頻度等は規定されている。
6 留意点	環境チェックリスト使用上の注意	(a) 埋立地造成、港湾の掘込み等による地下水系への影響(水位低下、塩化）や地下水利用による地盤沈下等の影響についても必要に応じて検討され所要の措置が講じられる必要がある。 (b) 必要な場合には、越境または地球規模の環境問題への影響も確認する（廃棄物の越境、酸性雨、オゾン層破壊、地球温暖化の問題に係る要素が考えられる場合等）。	(a)N (b)N	(a)地下水系への影響(水位低下、塩化）や地下水利用による地盤沈下等の影響は考えられない。 (b)サイトは当該国の島の中央部北側にあり、工事による影響が越境する可能性は考えられない。

注１）　表中『当該国の基準』については、国際的に認められた基準と比較して著しい乖離がある場合には、必要に応じ対応策を検討する。
当該国において現在規制が確立されていない項目については、当該国以外（日本における経験も含めて）の適切な基準との比較により検討を行う。
注２）　環境チェックリストはあくまでも標準的な環境チェック項目を示したものであり、事業および地域の特性によっては、項目の削除または追加を行う必要がある。

略語：　SPA：Samoa Port Authority
PUMA: Planning and Urban Management Agency, Ministry of Natural Resources and Environment
E/N: Exchange of Notes

資料 5-5：アピア港静穏度の検討

アピア港静穏度解析

アピア港では、毎年雨季にあたる 11 月～4 月における、うねり性波浪に港内侵入による港内の擾乱が発生し、船舶の安全係留、荷役作業等に支障をきたしている。
既存防波堤は、1988 年～1991 年に実施された「アピア港整備計画」により建設され、2000 年～2003 年に実施された「第二次アピア港拡張計画」により、ブロックを追加することによる透過率の低減を図る改良が加えられている。これらの努力により、改善が図られているが、雨季における港内擾乱の問題は依然として発生している実状にある。
今回、新たな無償資金協力を前提とした準備調査において、既存防波堤の若干の延長により、港内静穏度の向上を図ることができないか否かを検討した。検討内容とその結果をここに取りまとめた。

1　防波堤及び延長岸壁の構造形式

(1) 防波堤の形状

うねり性波浪の侵入を防ぐためには、沖合に本格的な防波堤の建設が必要である。しかしながら、水深が 20m程度におよぶため、建設費が高額であり、本無償資金協力での実施は無理である。そのため、既存防波堤の延長により、静穏度改善の可能性が無いかを検討した。ただし、既存防波堤の延長は、アピア港への入港路を狭めることになるため、操船上への影響をできる限り少なくできると考えれる３ケースについて検討した。

a. 防波堤延長なし（現状）

b. まっすぐ 50m 延伸した場合

c. 湾内側に 30 度振って 70m 延伸した場合

d. 湾外側に 45 度振って 70m 延伸した場合

静穏度の計算は、既設新岸壁を 165m延長し、全体で 300mの岸壁が完成した状態における、上記４ケースについて実施した。

(2) 延長桟橋の構造形式

延長した桟橋の構造は、既設新岸壁と同じ鋼管矢板構造について上記４ケースを計算し、このうち、最も効果発現の大きいケースに対し、透過型である杭式桟橋計算を行い、２つの構造形式による効果を比較検討した。

a. 鋼管矢板式岸壁（不透過型）：反射率 0.9

b. 杭式桟橋（透過型）：反射率：0.0

2　波浪条件

波浪条件の設定は既往の報告書を参考にした。過去に実施された案件において、沖波の推算が幾つか実施されている。1991 年 12 月に発生したサイクロン「ヴ

ァル」により被災した施設の復旧を目的として 1992 年～1994 年に実施された「港湾・護岸災害復旧及び整備計画」の基本設計報告書（1992 年）では、それまでの調査で実施された波浪推算結果が下記の通り整理されている。

表 1　波浪推算結果

調査名	対象サイクロン	沖波諸元		
		波向	波高 H0	周期 T0
港湾・護岸災害復旧計画	ヴァル	N	10.9m	12.5 sec
港湾災害普及計画	オファ	N	8.6m	12.0 sec
アピア港整備計画	モデルサイクロン	N	7.0m	10.0 sec

「第二次アピア港拡張計画」では、防波堤を改良しているが、その際の設計波の沖波諸元は 1987 年の開発調査「全国港湾整備総合計画調査」で設定された波浪（上表のモデルサイクロンによる）及び、防波堤前面までの波浪の変形計算も下記で示す同調査の結果が用いられている。

表２　波浪諸元

	波向	周期	波高比
沖波	N10°E	10　秒	1.00
防波堤前面	N	〃	0.64

今回検討する港内静穏度は、サイクロン等により発生する極限波浪ではなく、比較的高頻度で発生する通常のうねりに対するものであるが、防波堤前面での波浪の入力が必要である。そのため、計算に必要となる波浪は、表１のモデルサイクロンによる沖波が表２に示す波高比 0.64 で浅水変形した場合の下記の波浪諸元を用いる。

防波堤前面波浪：　　波 高：4.5m、波向き：N、周期：10 秒

港内静穏度の計算は上記条件により計算するが、静穏度の効果は、上記の波高 4.5mに対して計算された波高ではなく、波高比（防波堤前面での波高と静穏度を確保する必要がある岸壁前面での波高との比）をもって評価するものとする。

3　計算モデル

計算は高山法によった。

4　検討ケース

下記、５ケースを実施した。

表３　検討ケース

CASE	防波堤形状	延長桟橋構造形式
1	現状：延長なし	鋼管矢板式岸壁
2	まっすぐ 50m延長	
3	湾内側に 30 度振って 70m 延長	
4	湾外側に 45 度振って 70m 延伸	
5	現状：延長なし	鋼管杭式岸壁

5　検討結果

表４　検討結果

CASE	既存新岸壁前面波高比	延長岸壁前面波高比
1	0.23～0.42	0.34～0.41
2	0.21～0.36	0.27～0.35
3	0.19～0.29	0.22～0.32
4	0.34～0.48	0.34～0.41
5	0.23～0.42	0.33～0.35

以上より明らかな通り、仮に防波堤前面での波高が１ｍ、周期 10 秒であった場合、何れの場合も岸壁前面で波高 30cm～40cm 程度、周期 10 秒の波浪が発生することになり、明瞭な効果は認められない。

桟橋構造とした場合、延長岸壁前面での擾乱が若干良くなる傾向にあることがわかる。

6　結論

以上から、既存防波堤の延長は港内静穏度向上にほとんど寄与せず、入出港船舶の航路を狭めて安全性を低下させる要因となり、投資効果がほとんどない。従って、協力コンポーネントには加えないのが妥当である。

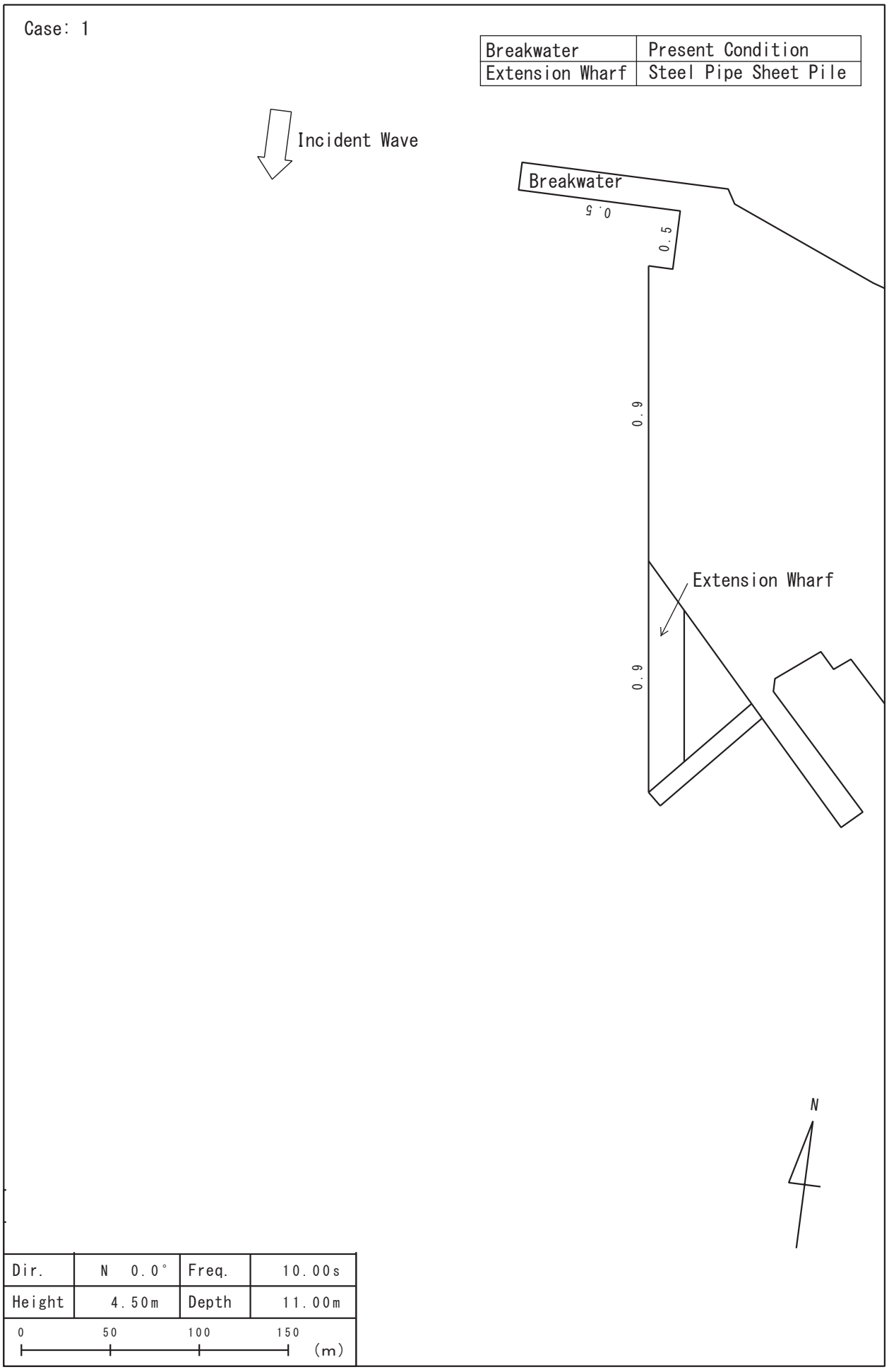


Figure Reflection Coefficient

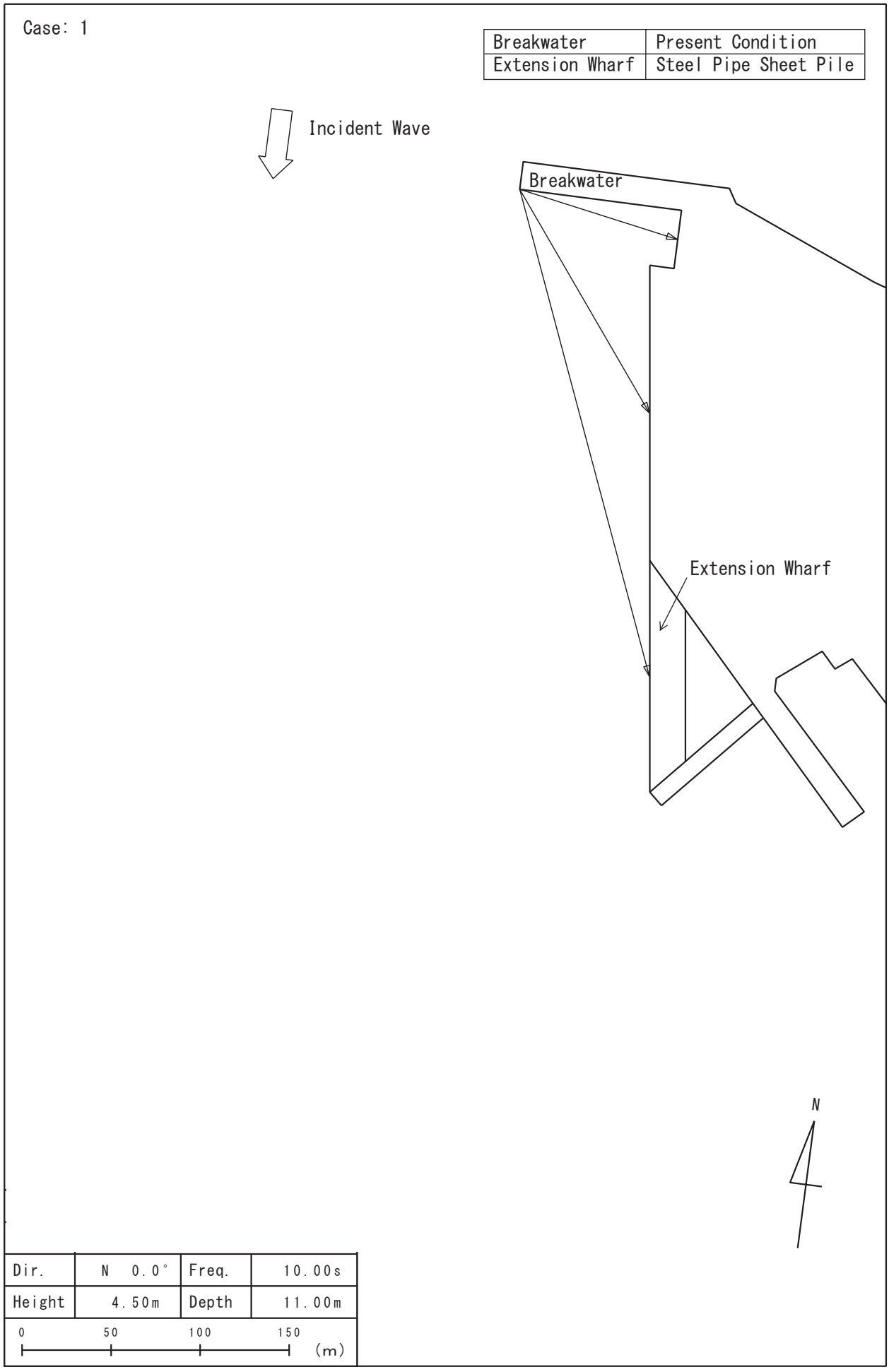


Figure Reflection

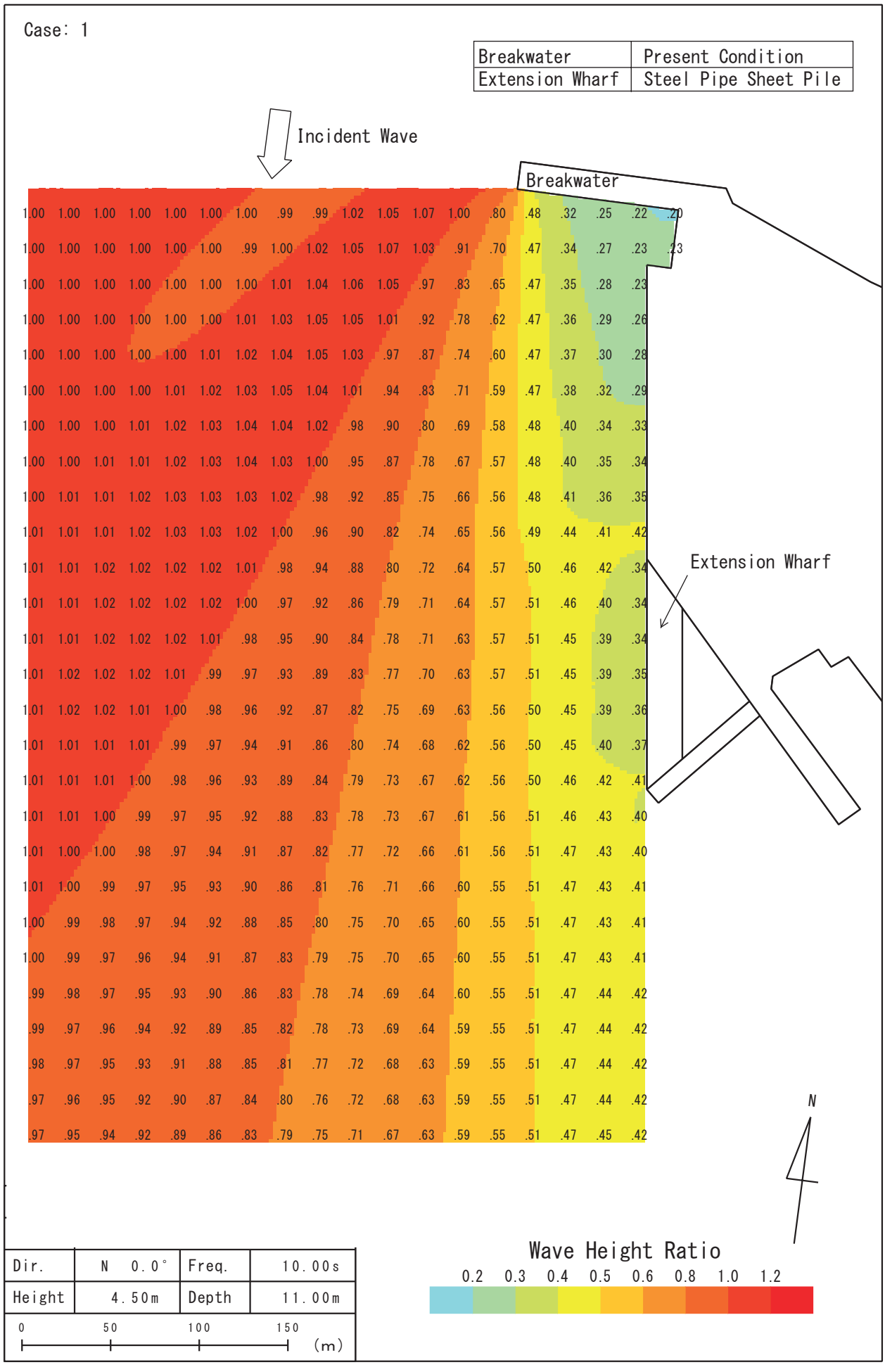


Figure Wave Height Ratio

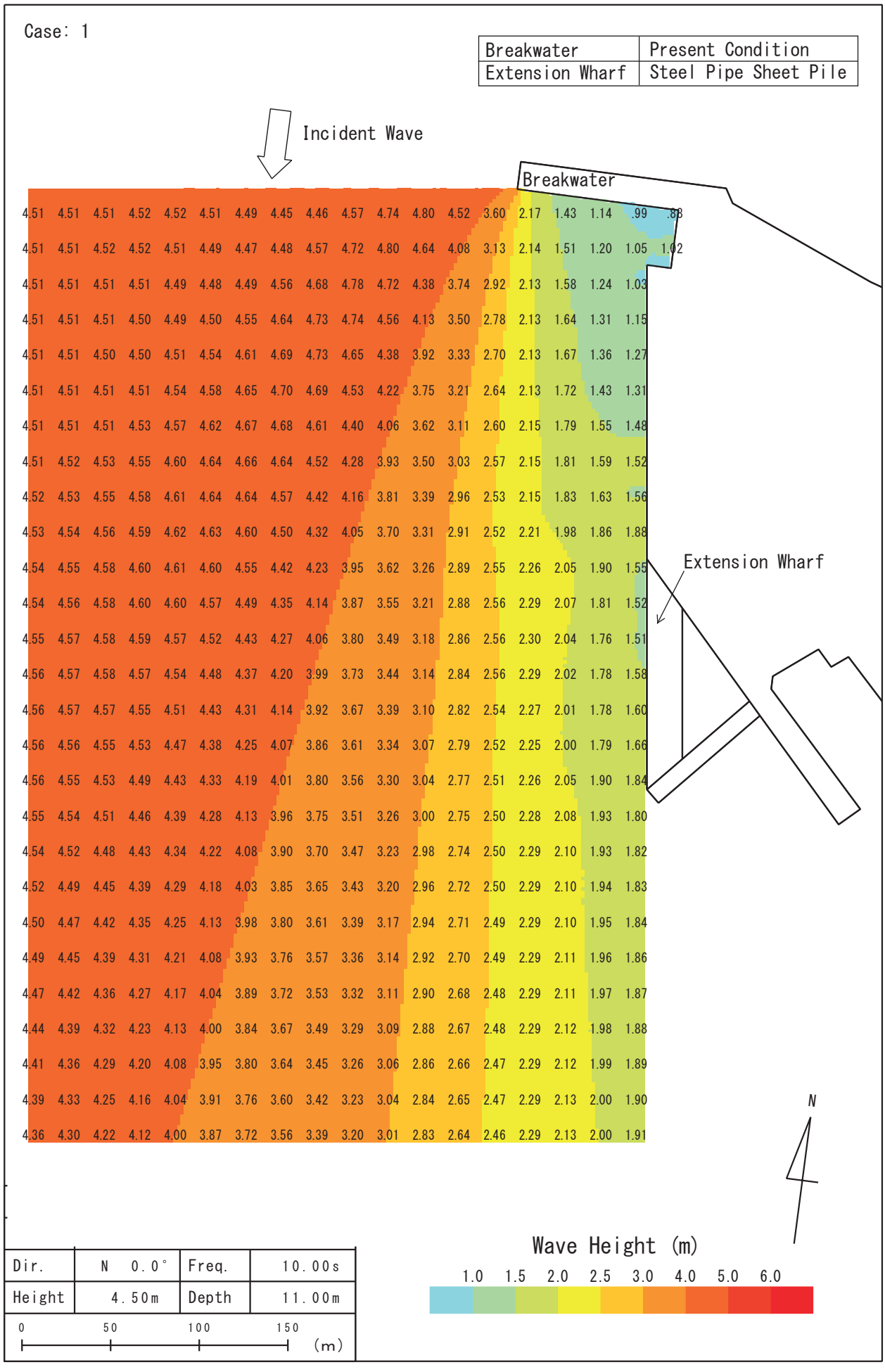


Figure Wave Height (m)

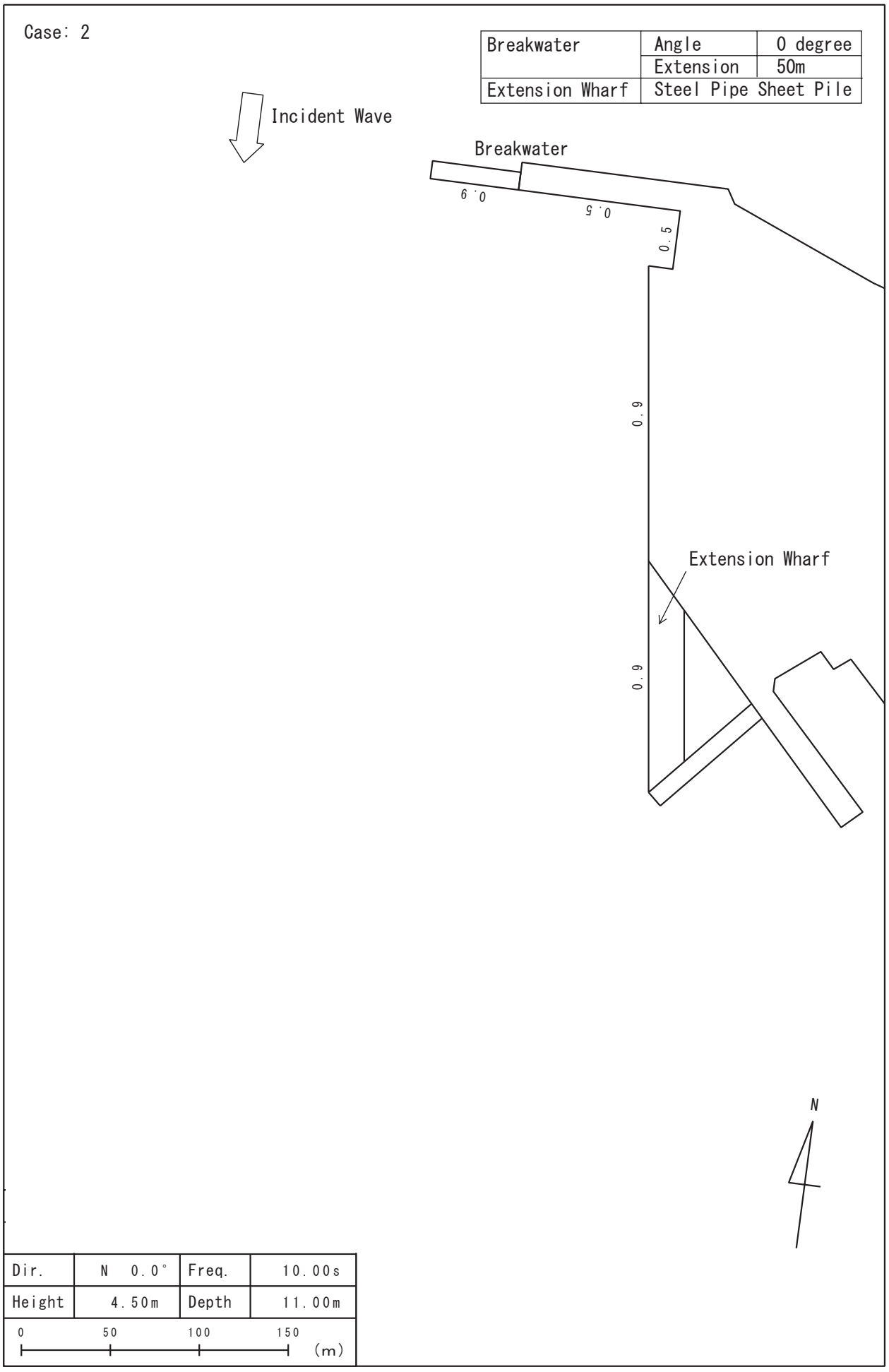


Figure Reflection Coefficient

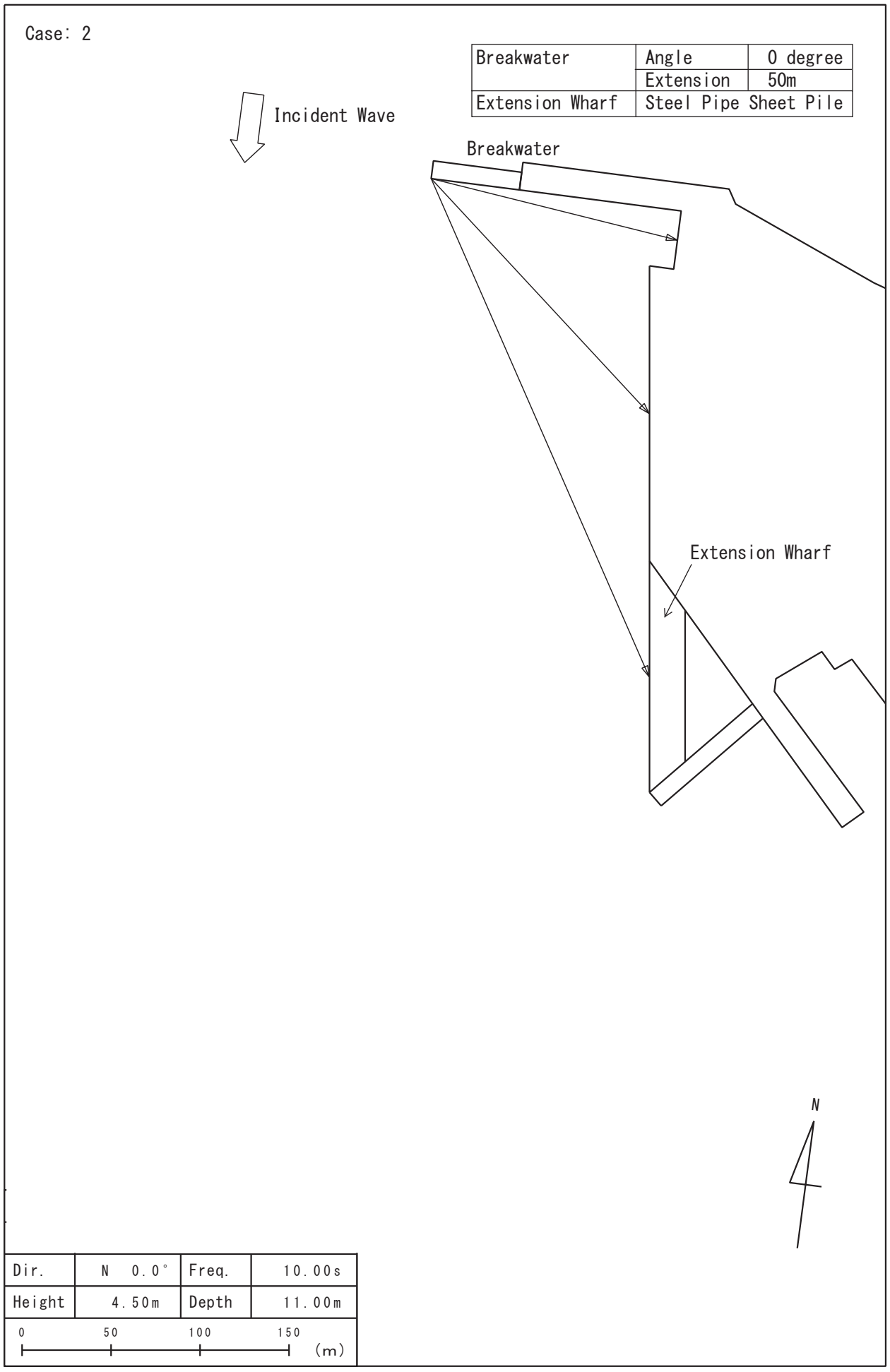


Figure Reflection

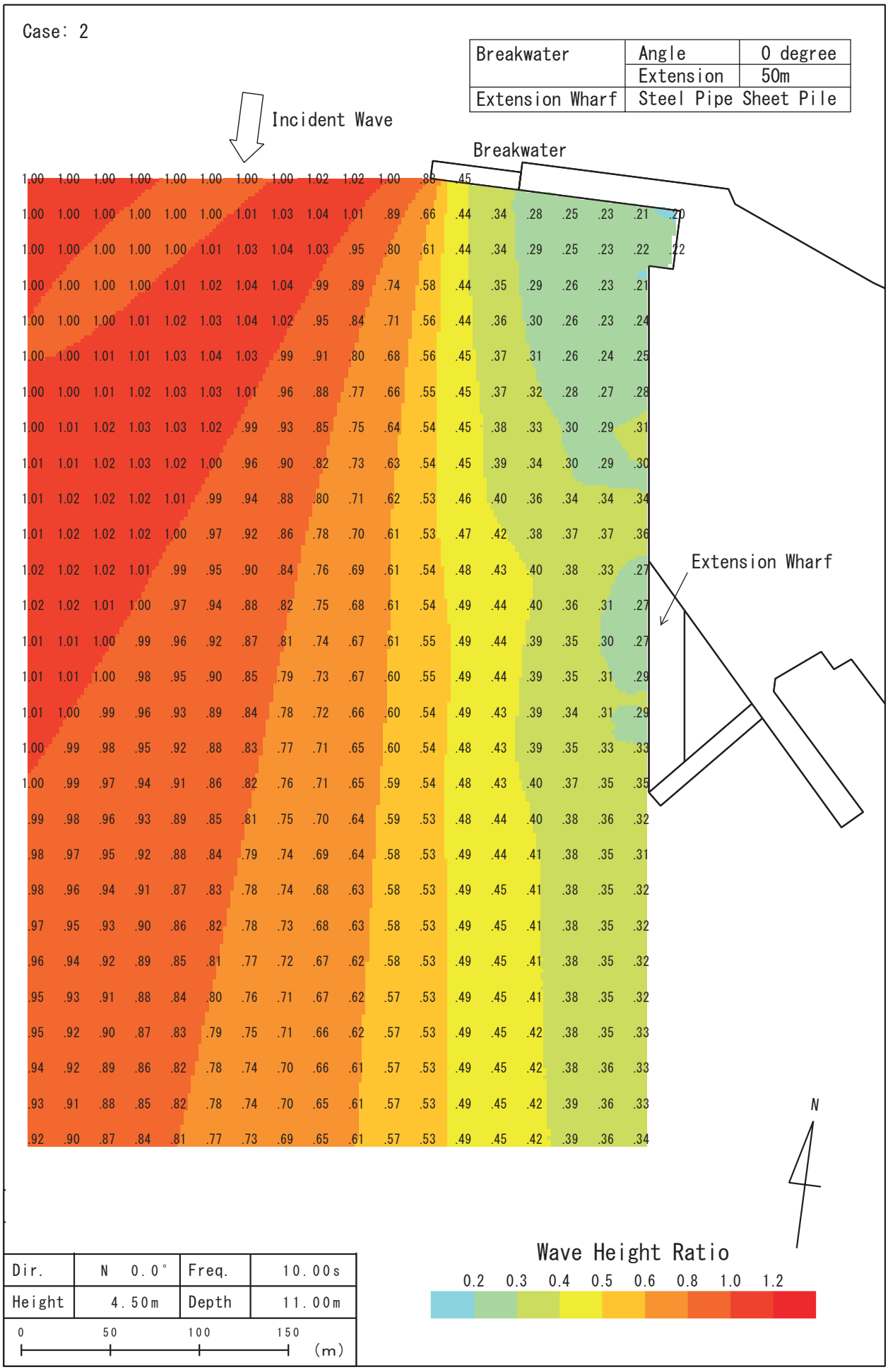


Figure Wave Height Ratio

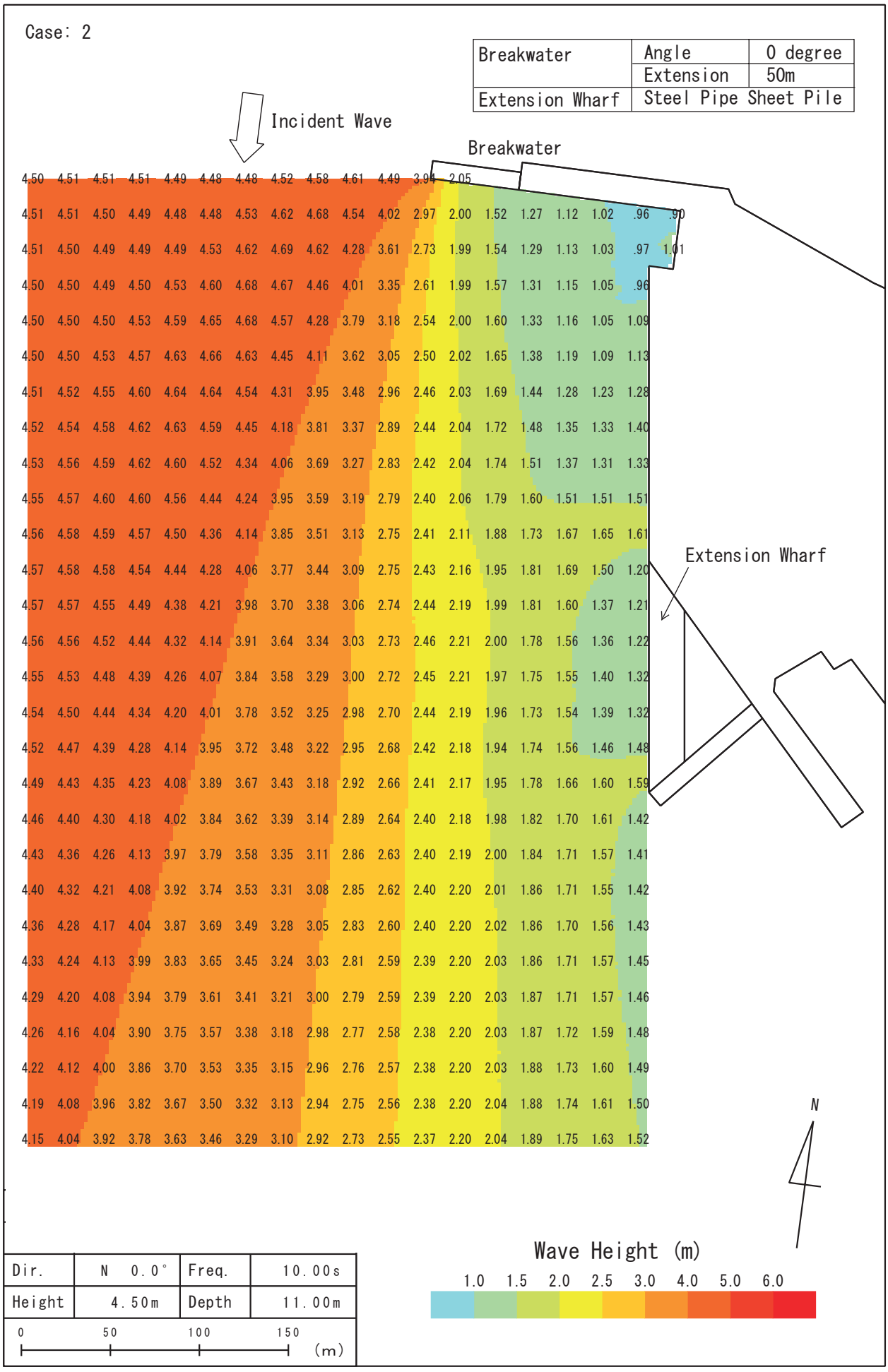
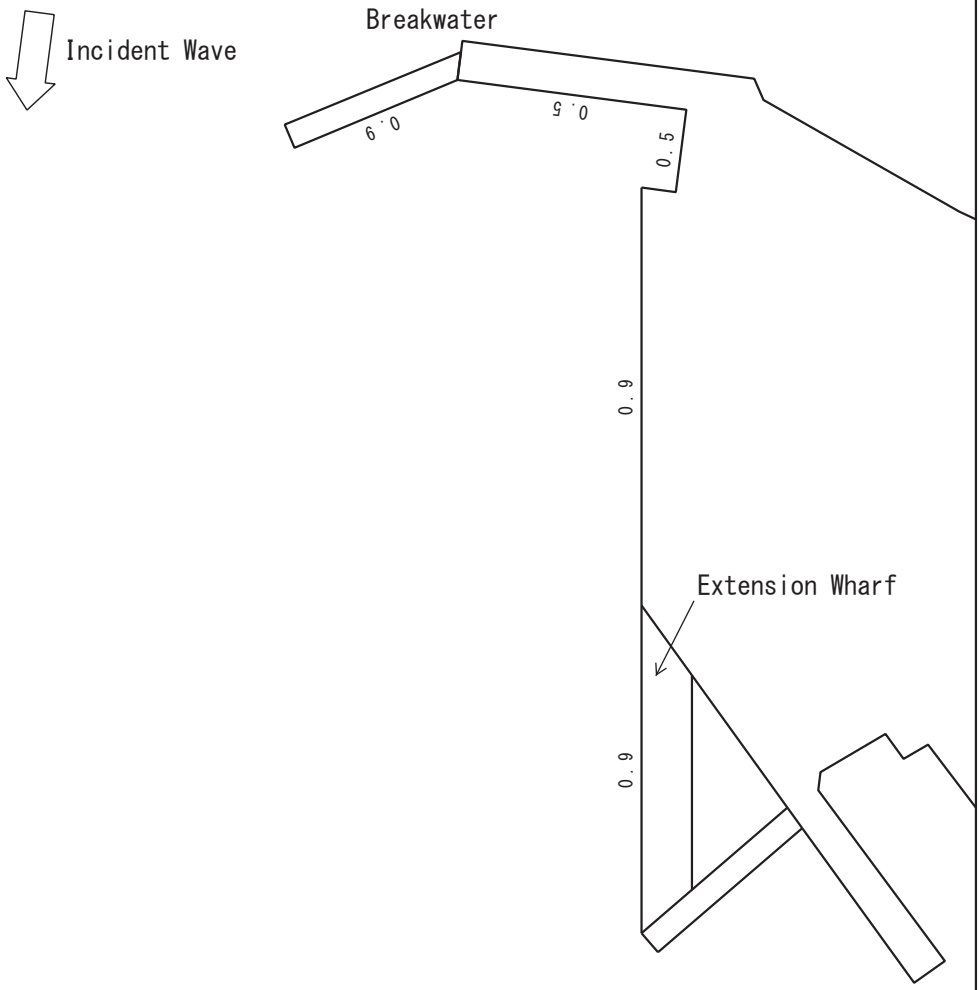


Figure Wave Height (m)

Case: 3

Breakwater	Angle	30 degree (to Port)
	Extension	70m
Extension Wharf	Steel Pipe Sheet Pile	



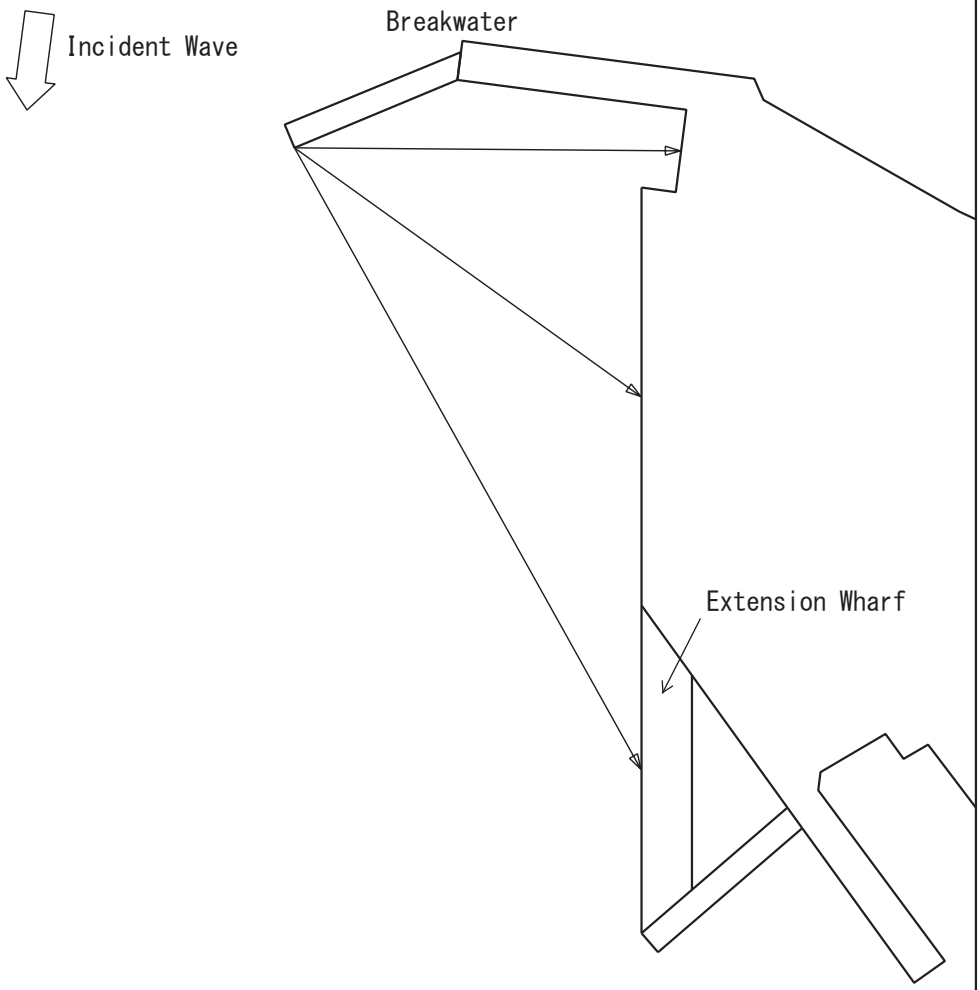
Dir.	N 0.0°	Freq.	10.00s
Height	4.50m	Depth	11.00m

0 50 100 150 (m)

Figure Reflection Coefficient

Case: 3

Breakwater	Angle	30 degree (to Port)
	Extension	70m
Extension Wharf	Steel Pipe Sheet Pile	



Dir.	N 0.0°	Freq.	10.00s
Height	4.50m	Depth	11.00m

0 50 100 150 (m)

Figure Reflection

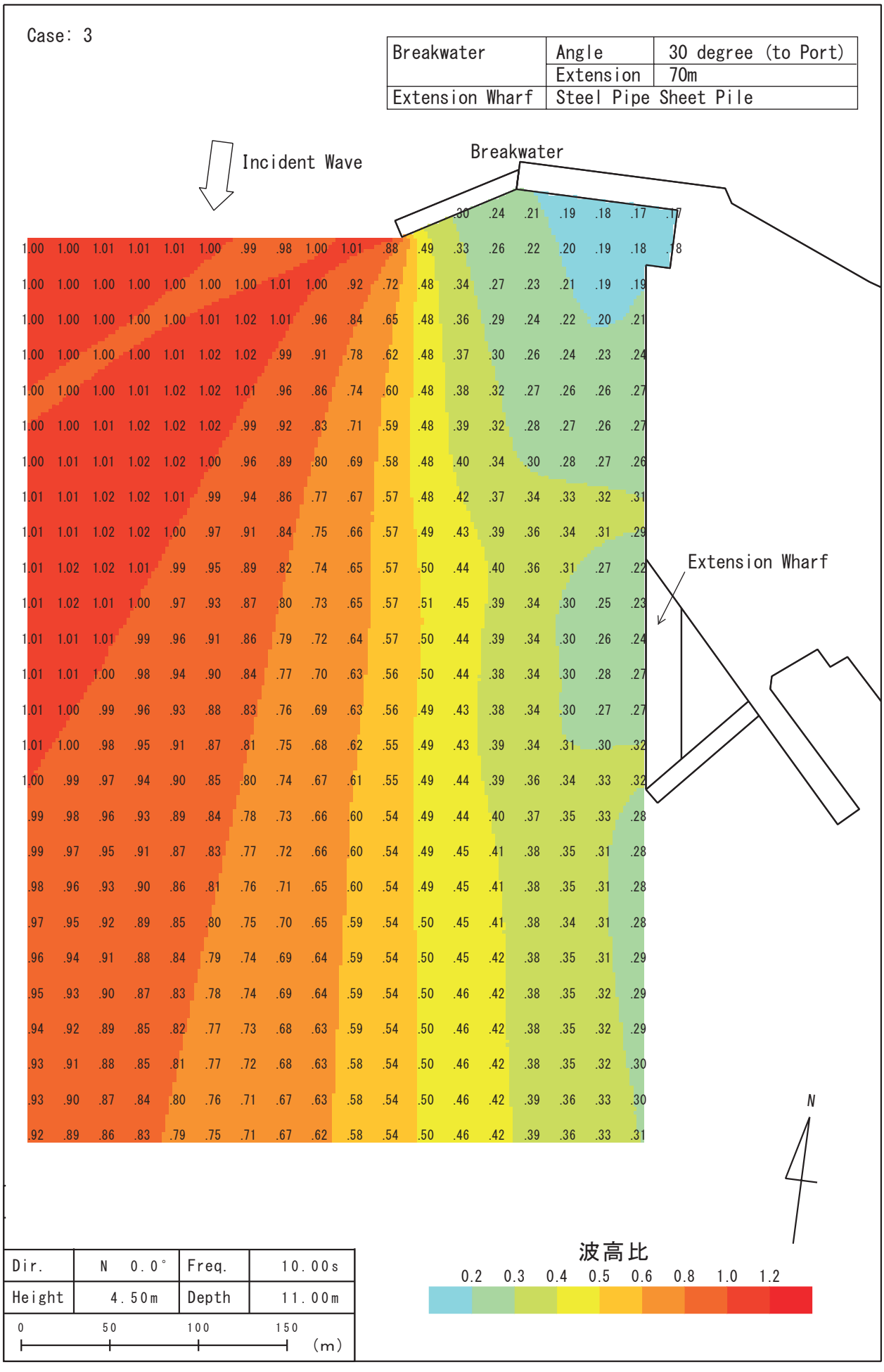


Figure Wave Height Ratio

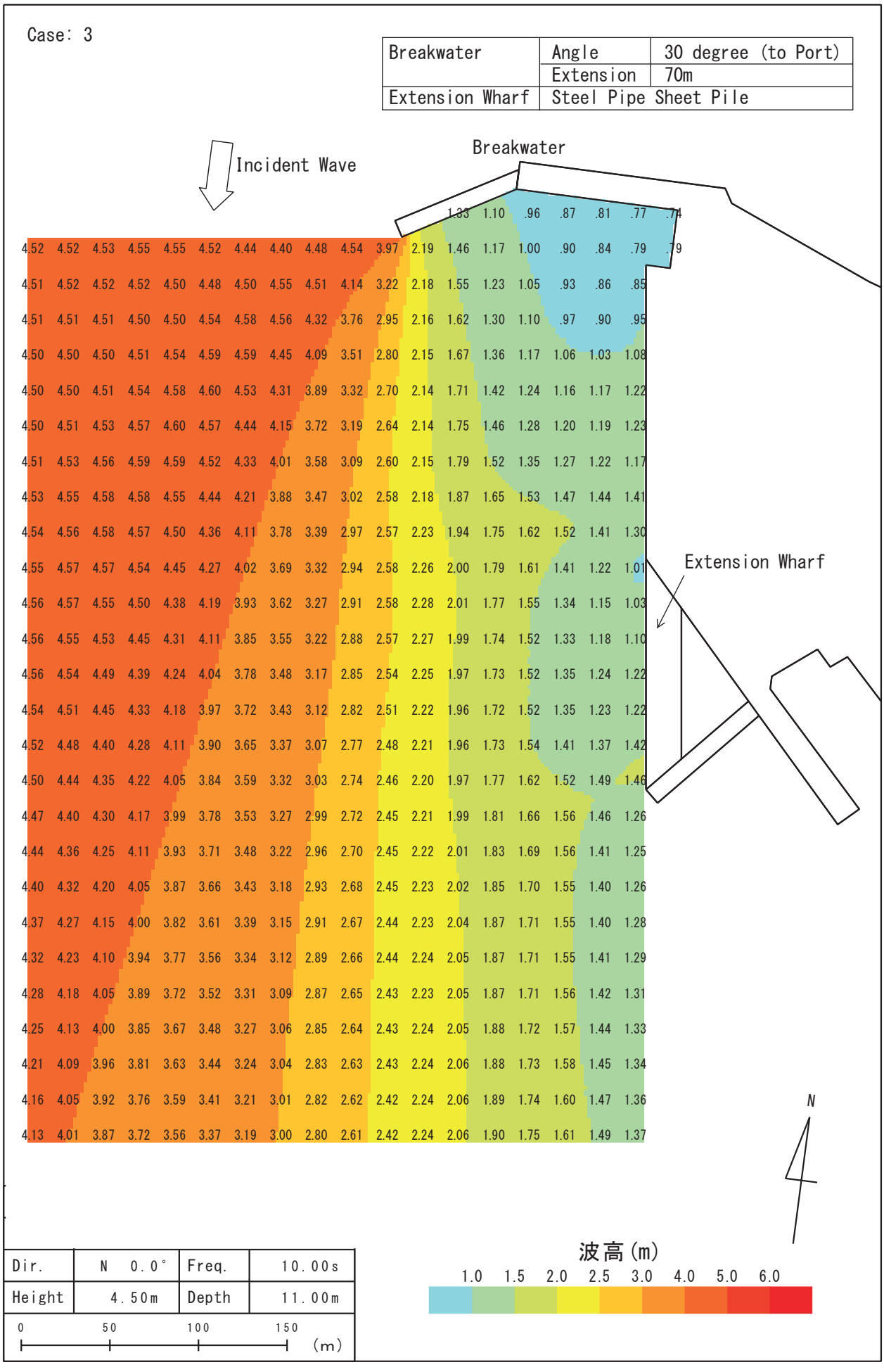


Figure Wave Height (m)

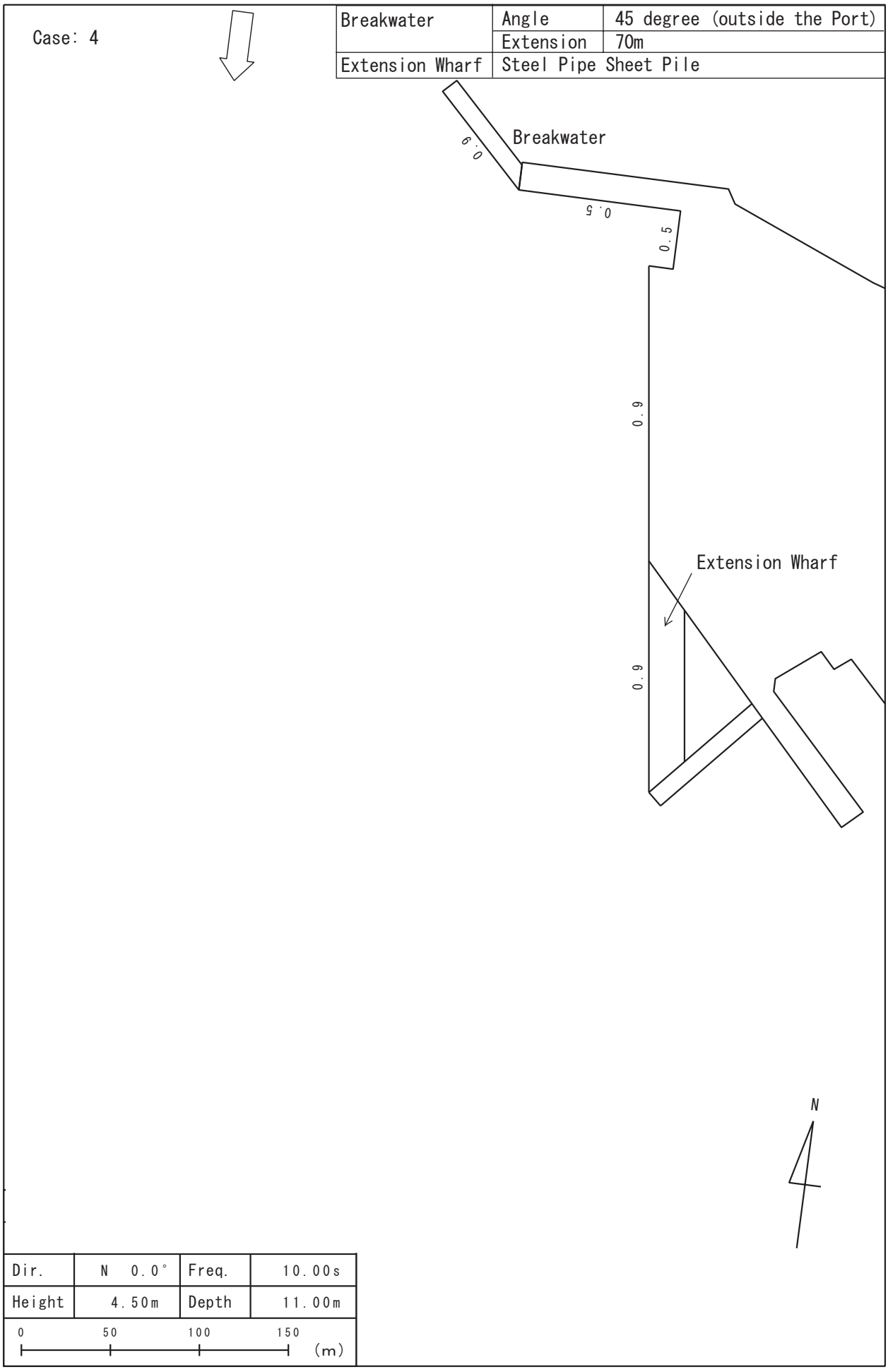


Figure Reflection Coefficient

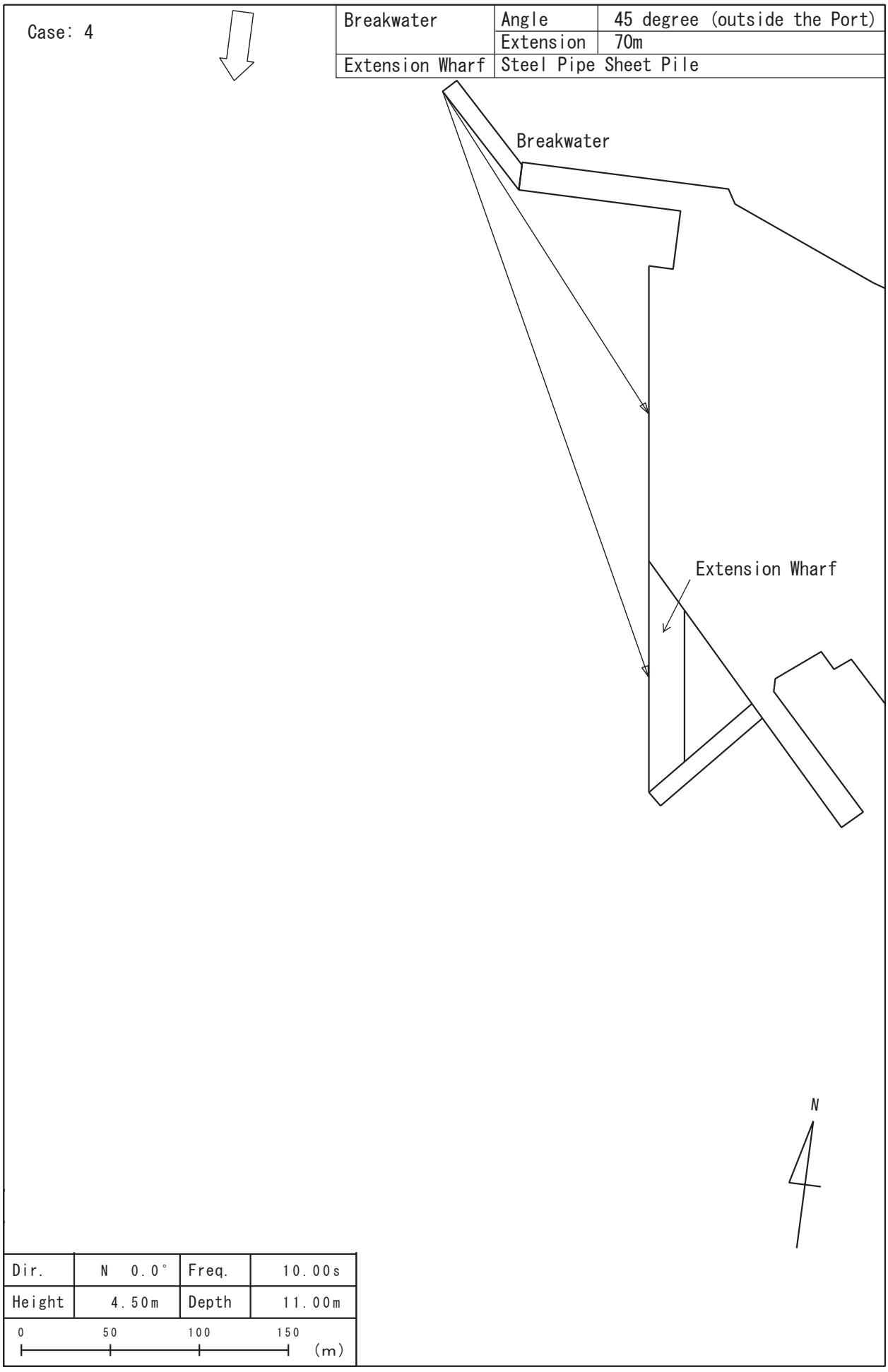


Figure Reflection

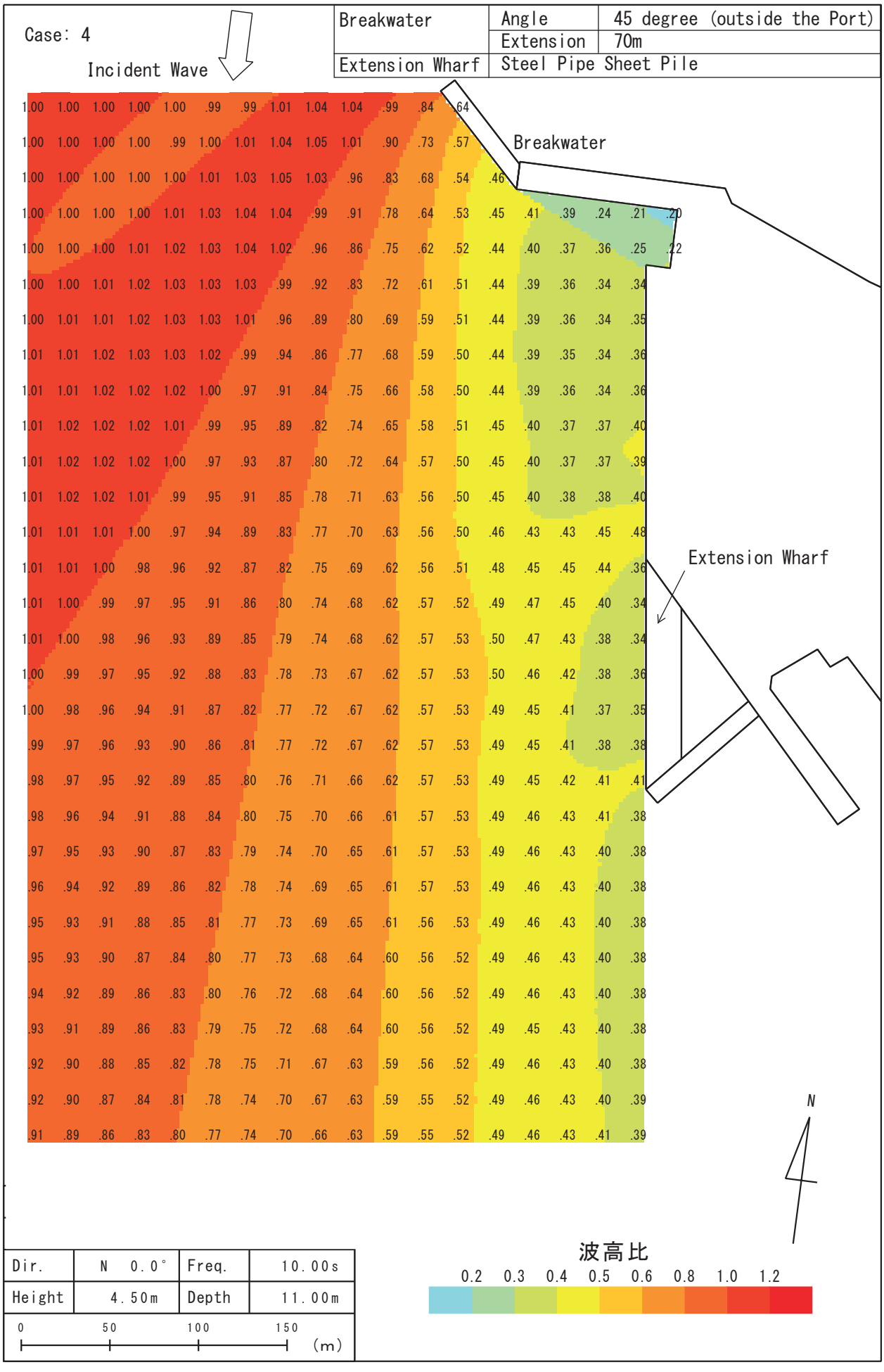


Figure Wave Height Ratio

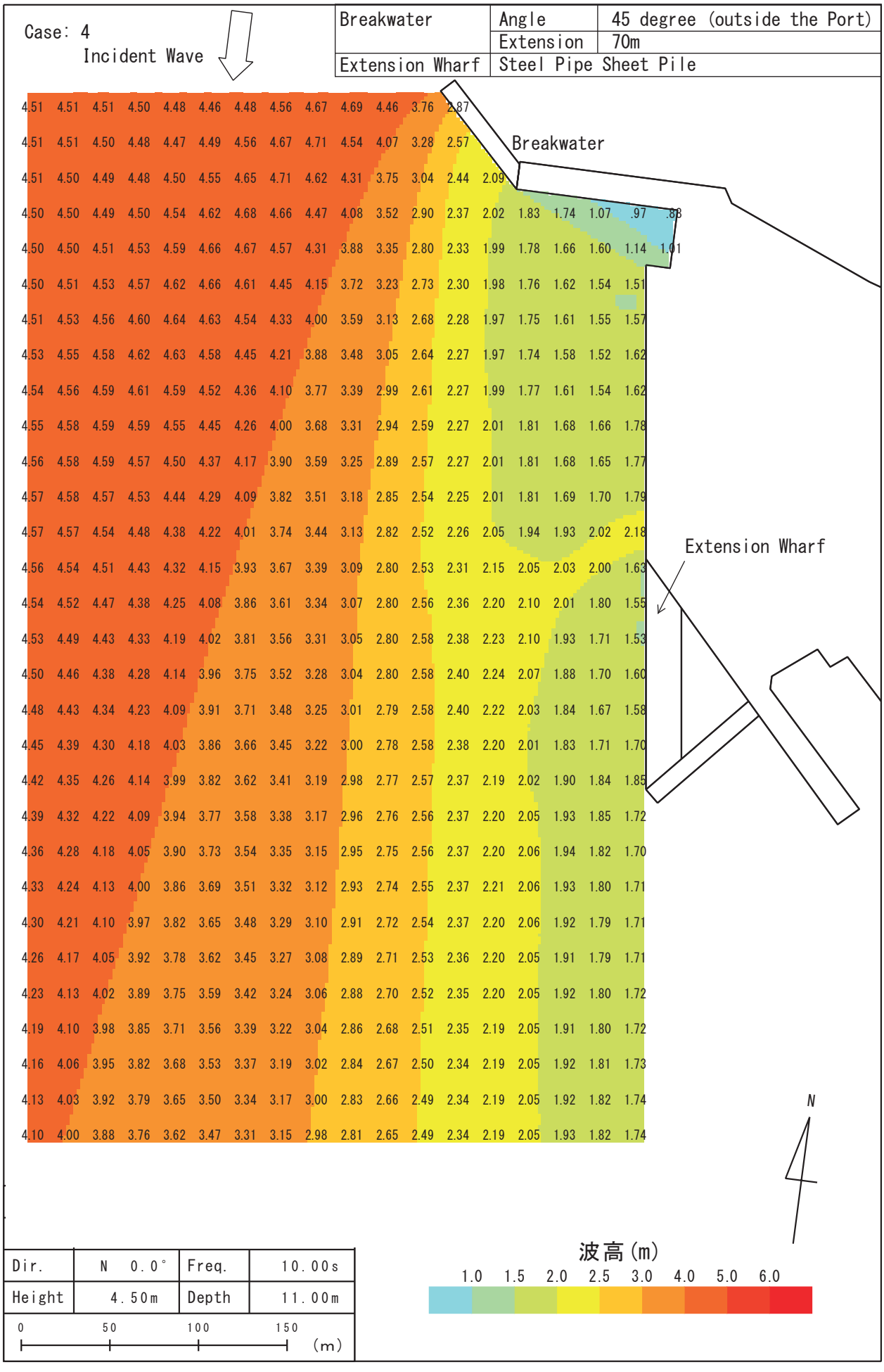


Figure Wave Height (m)

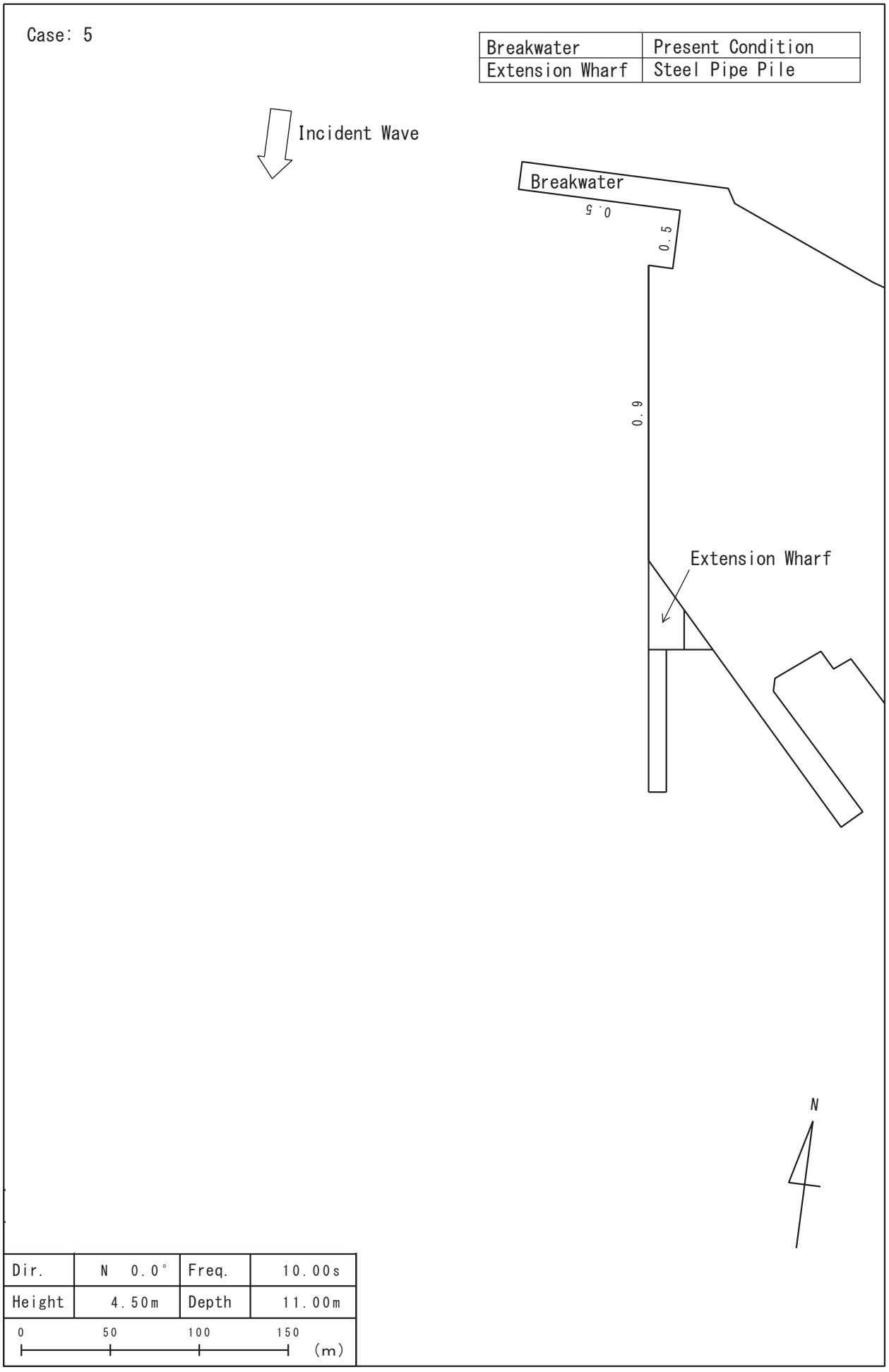


Figure Reflection Coefficient

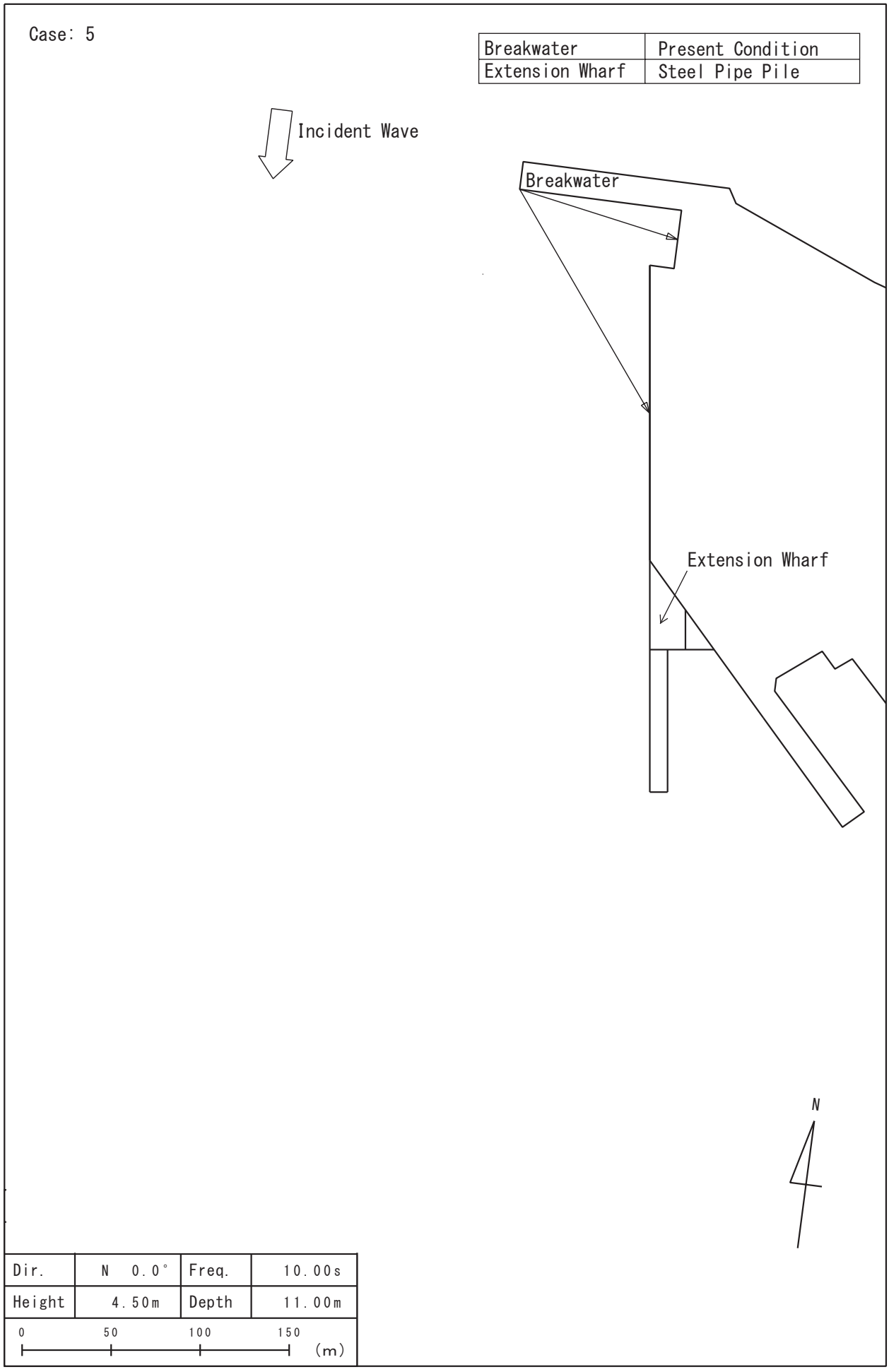


Figure Reflection

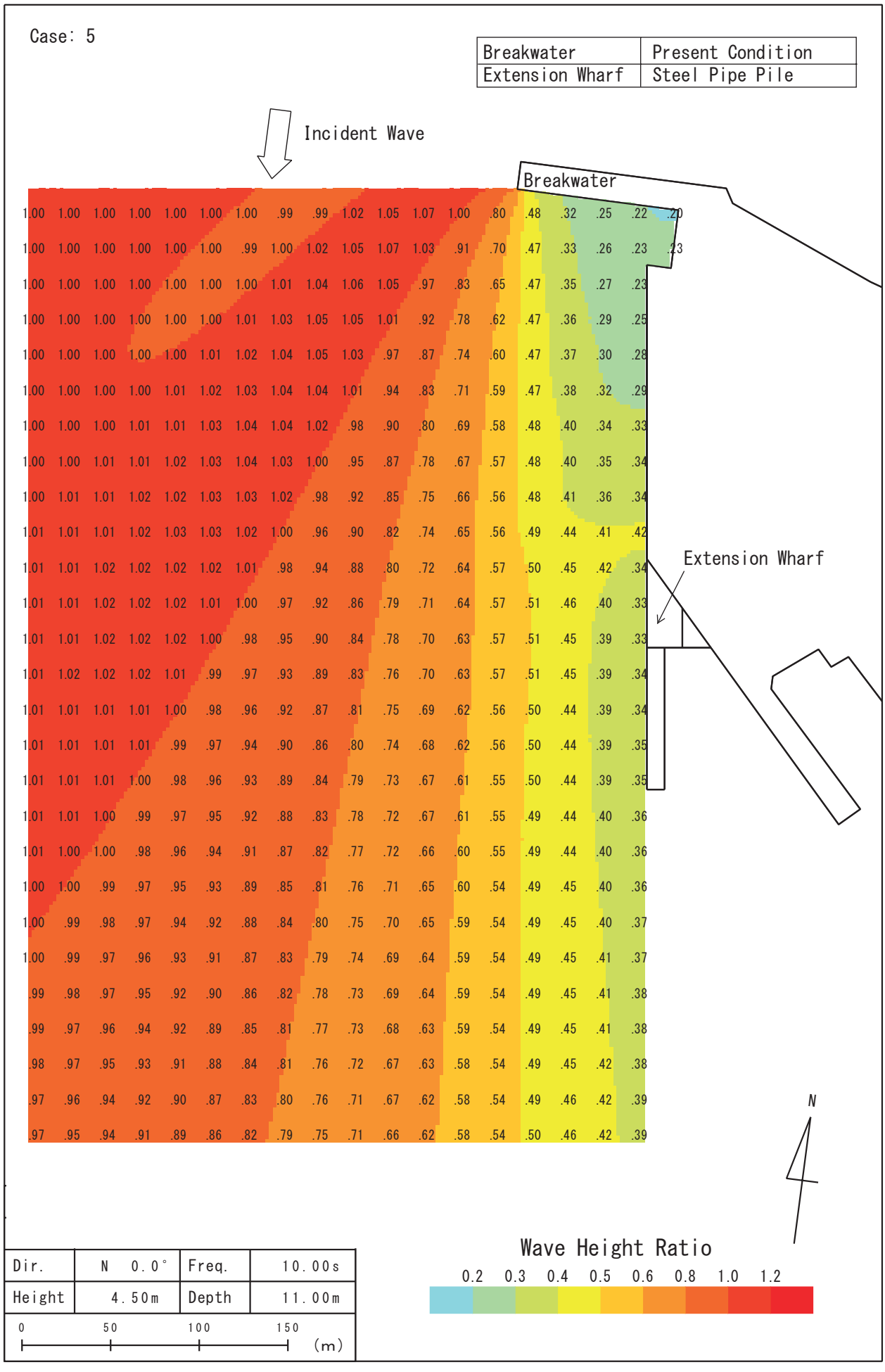


Figure Wave Height Ratio

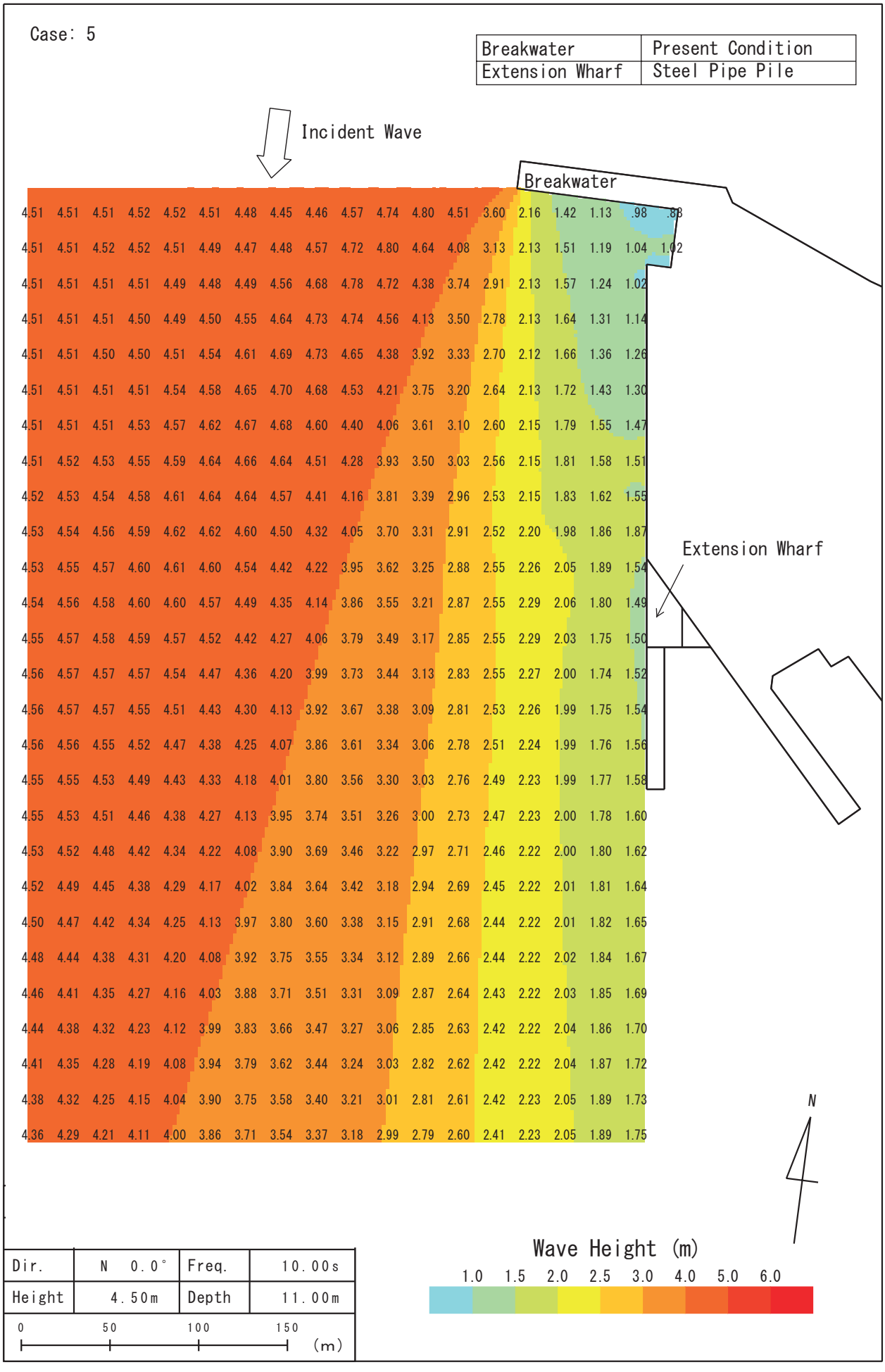
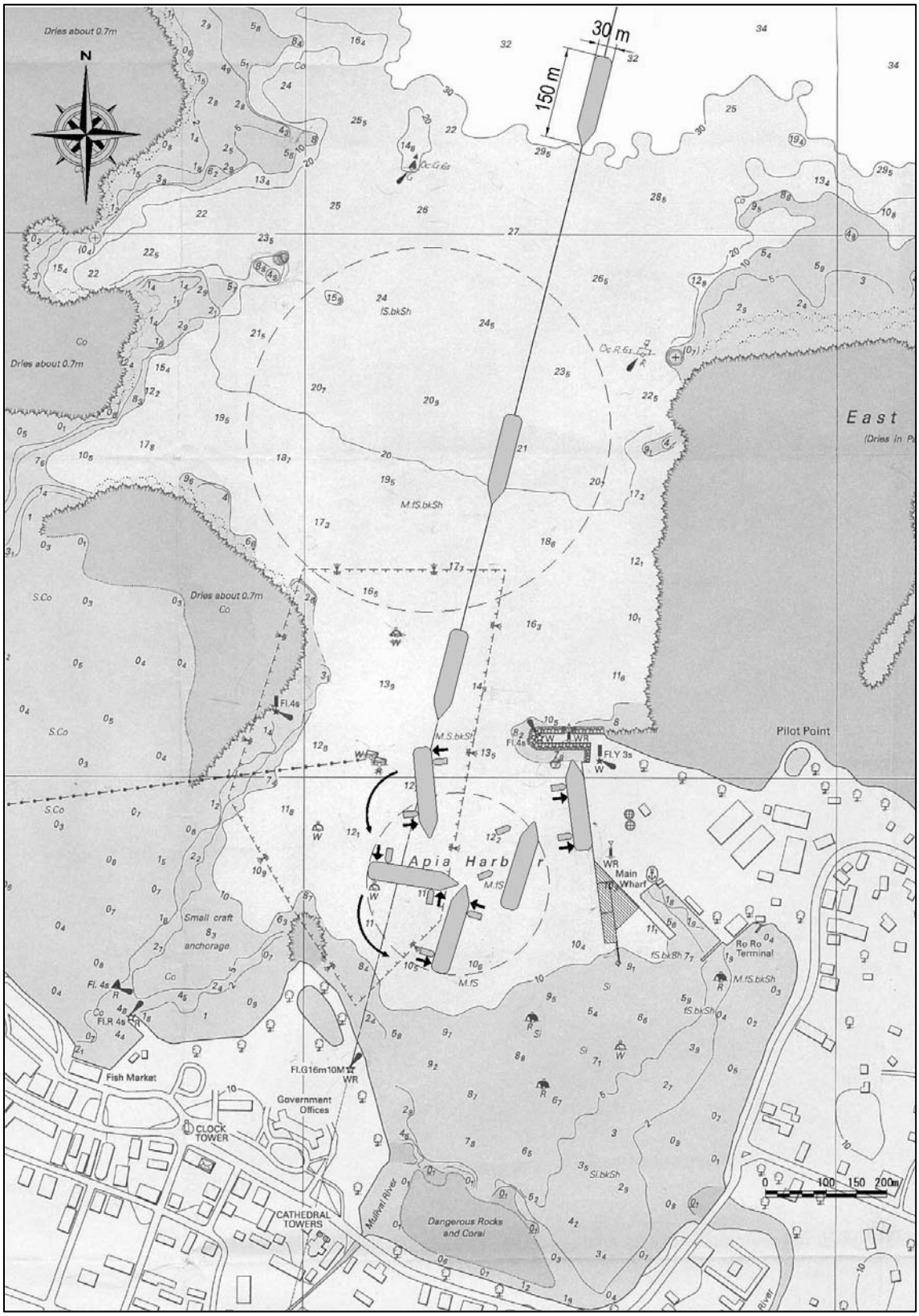


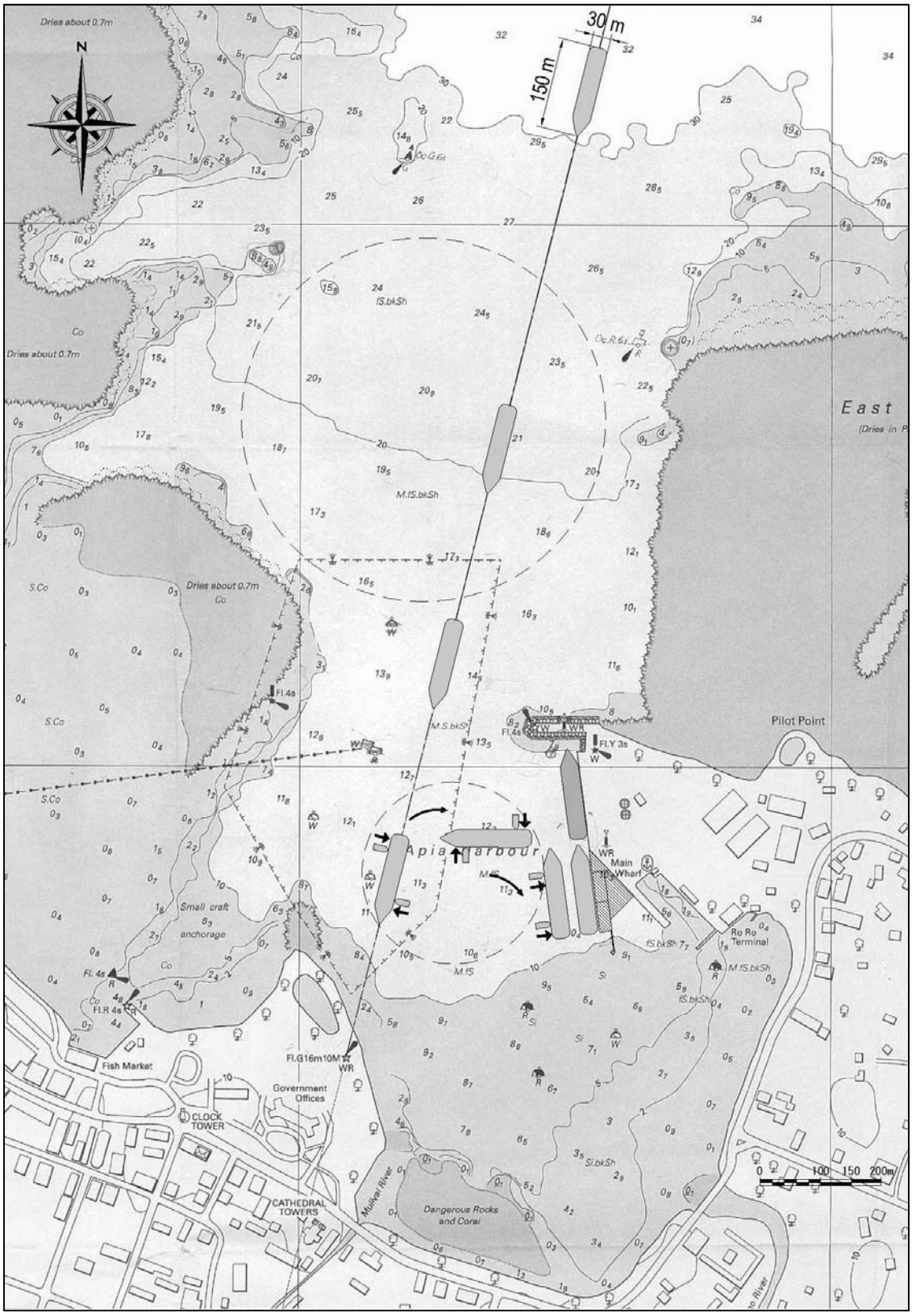
Figure Wave Height (m)

資料 5-6：　操船検討図



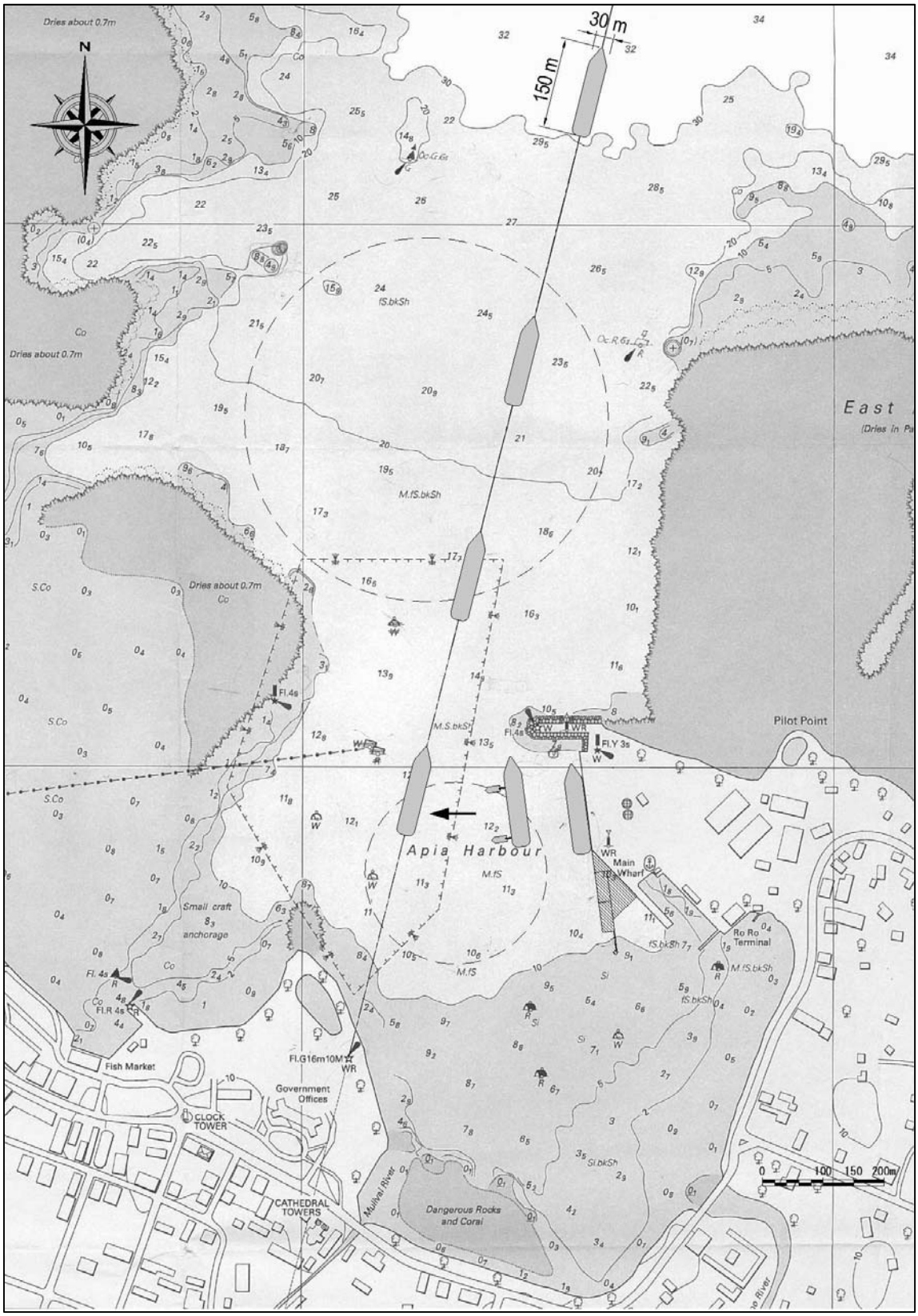
検討図 1-1　貨物船入港：出船接岸への着岸操船（1/2）

資料 5-6：　操船検討図



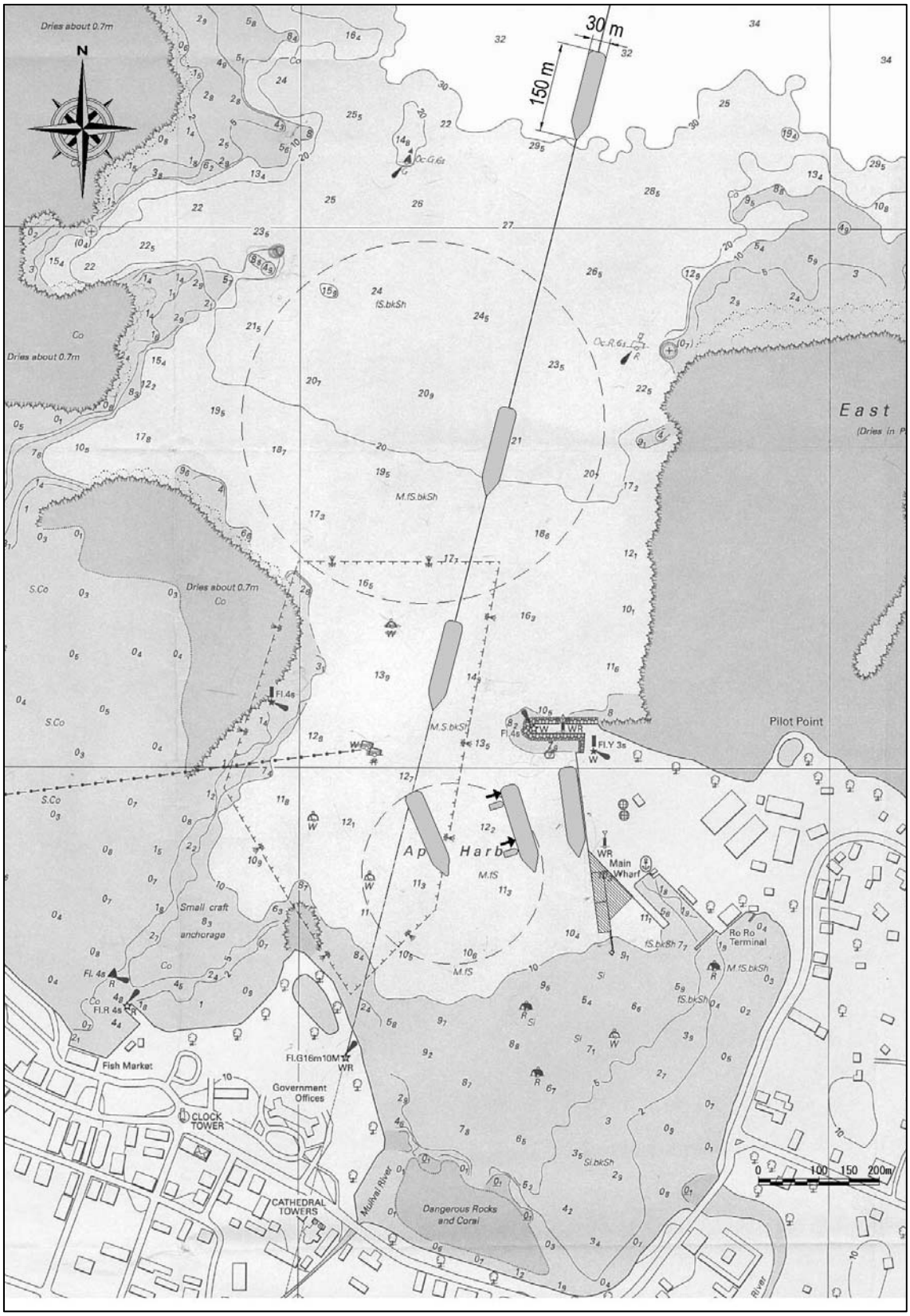
検討図 1-2　貨物船入港：出船接岸への着岸操船（2/2）

資料 5-6：　操船検討図



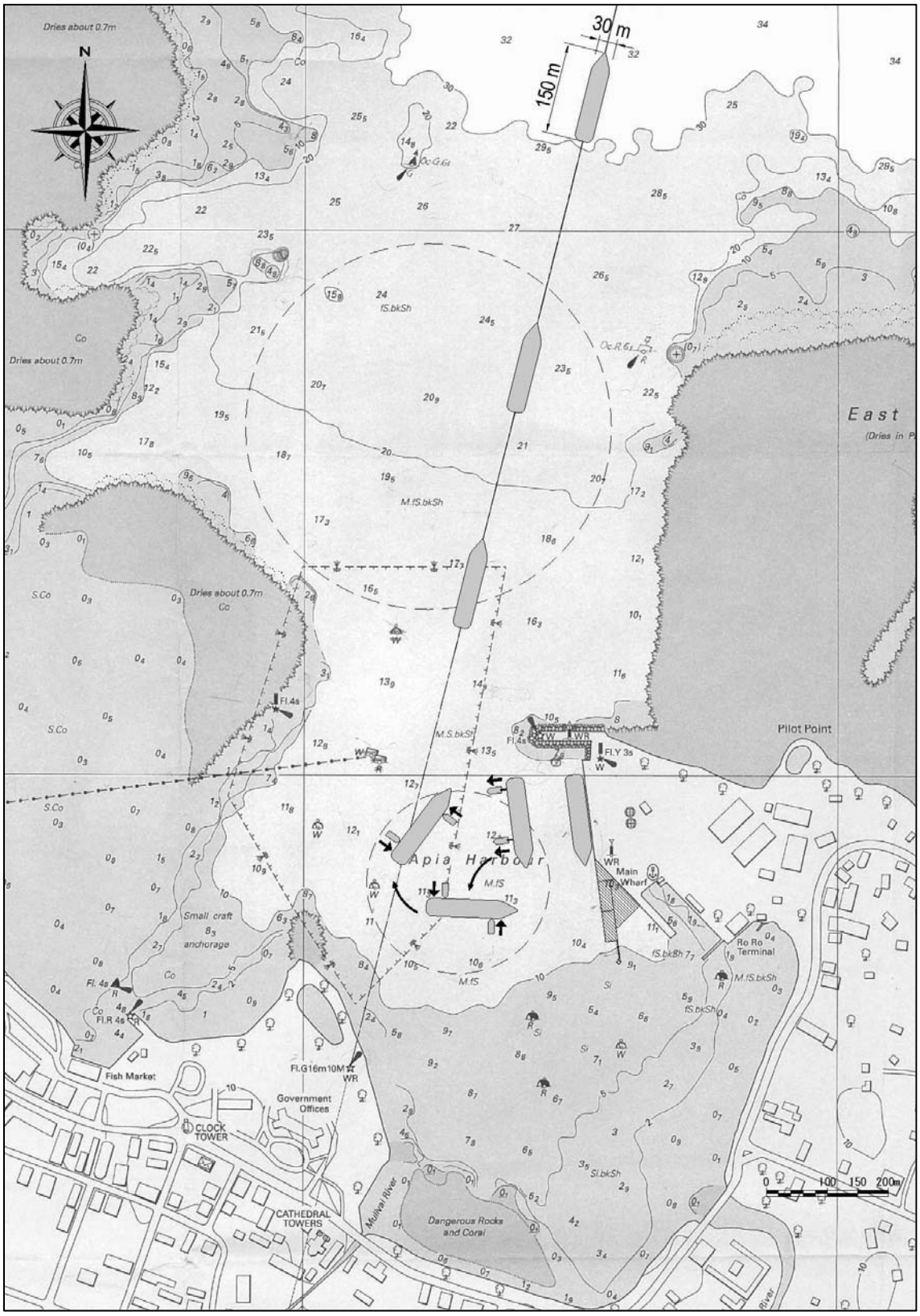
検討図 1-3　貨物船出港：出船接岸からの離岸操船

資料 5-6：　操船検討図



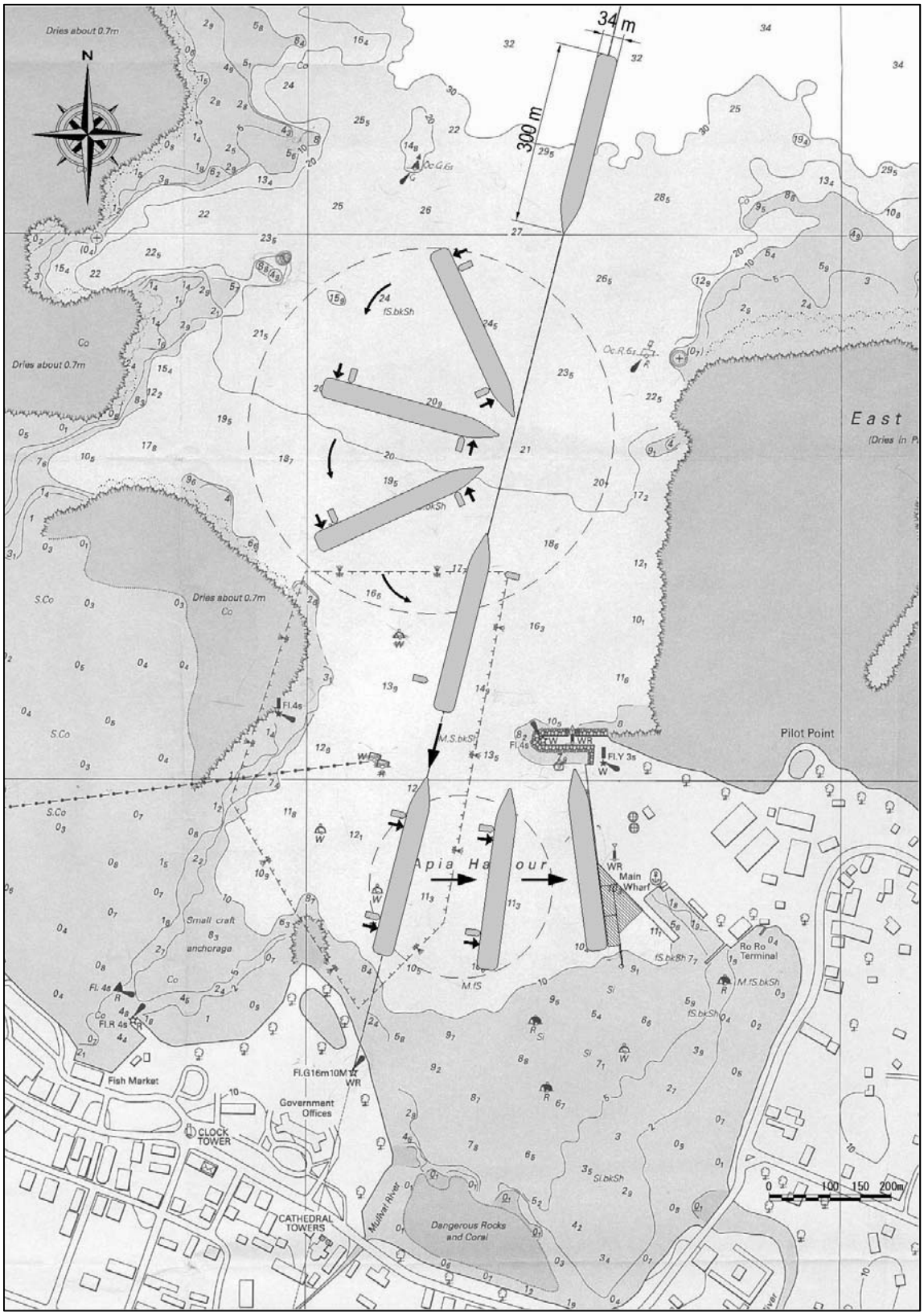
検討図 1-4　貨物船入港：入船接岸への接岸操船

資料 5-6：　操船検討図



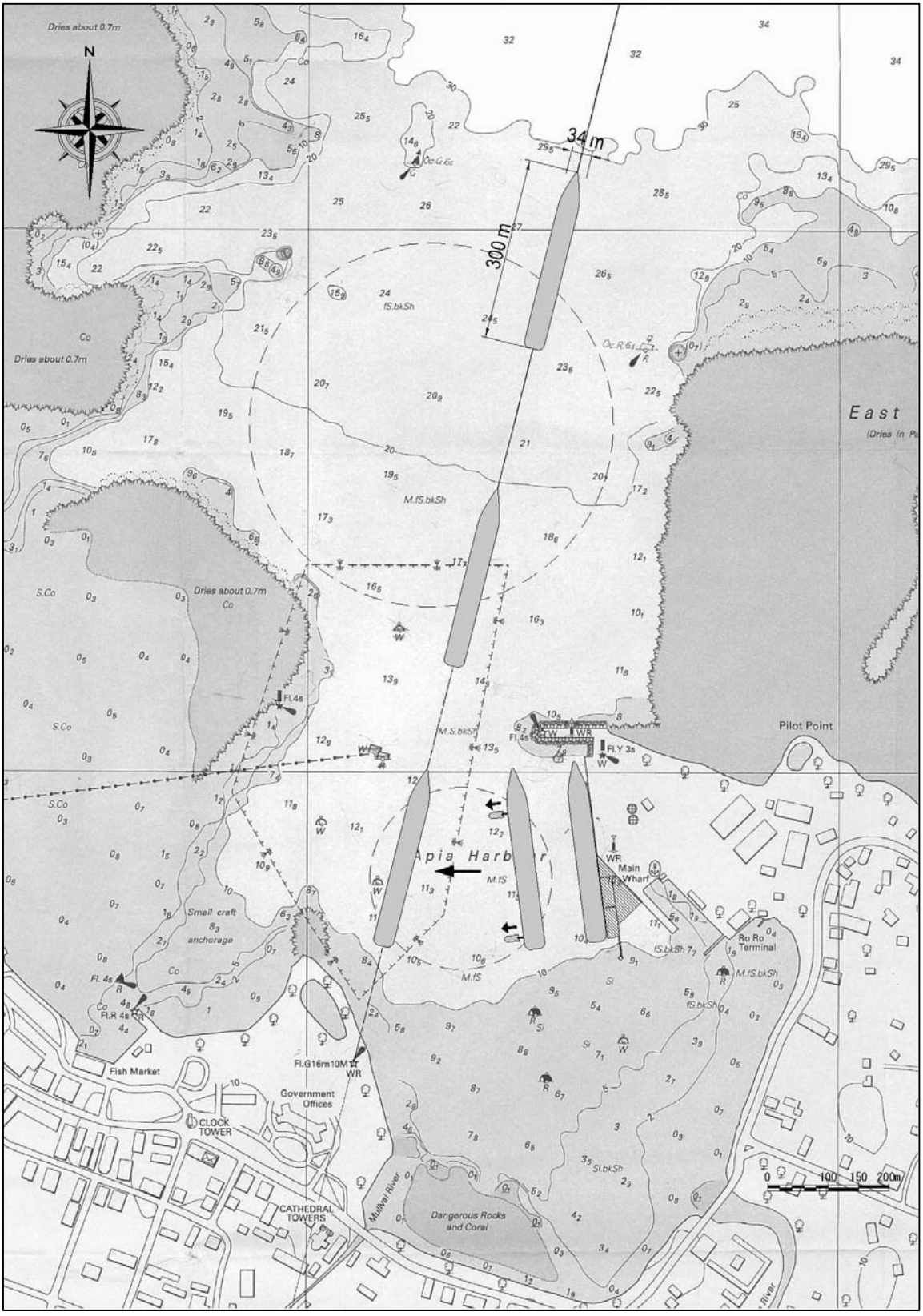
検討図 1-5　貨物船出港：入船接岸からの離岸操船

資料 5-6：　操船検討図



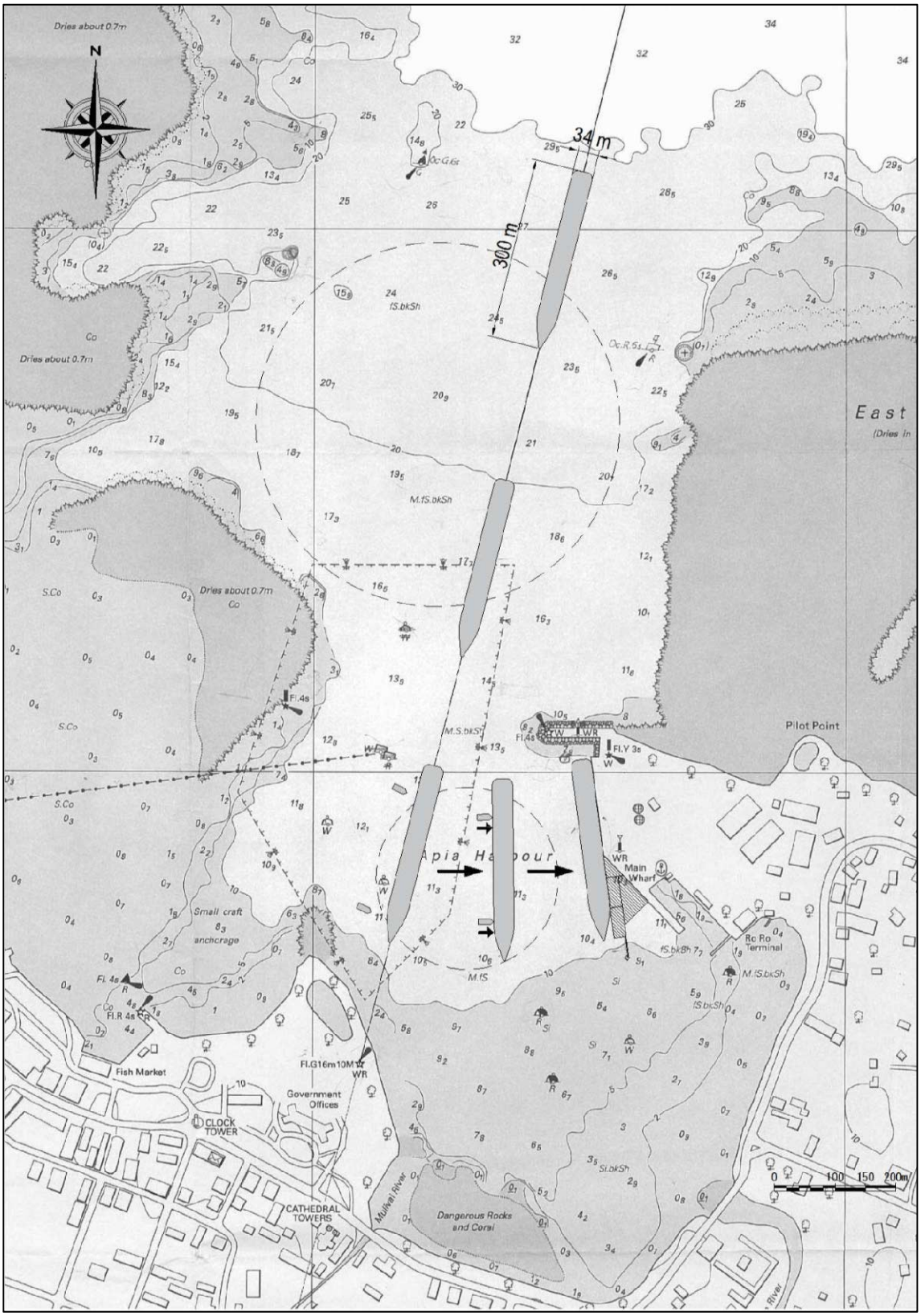
検討図 2-1　クルーズ船入港：出船接岸への接岸操船

資料 5-6：　操船検討図



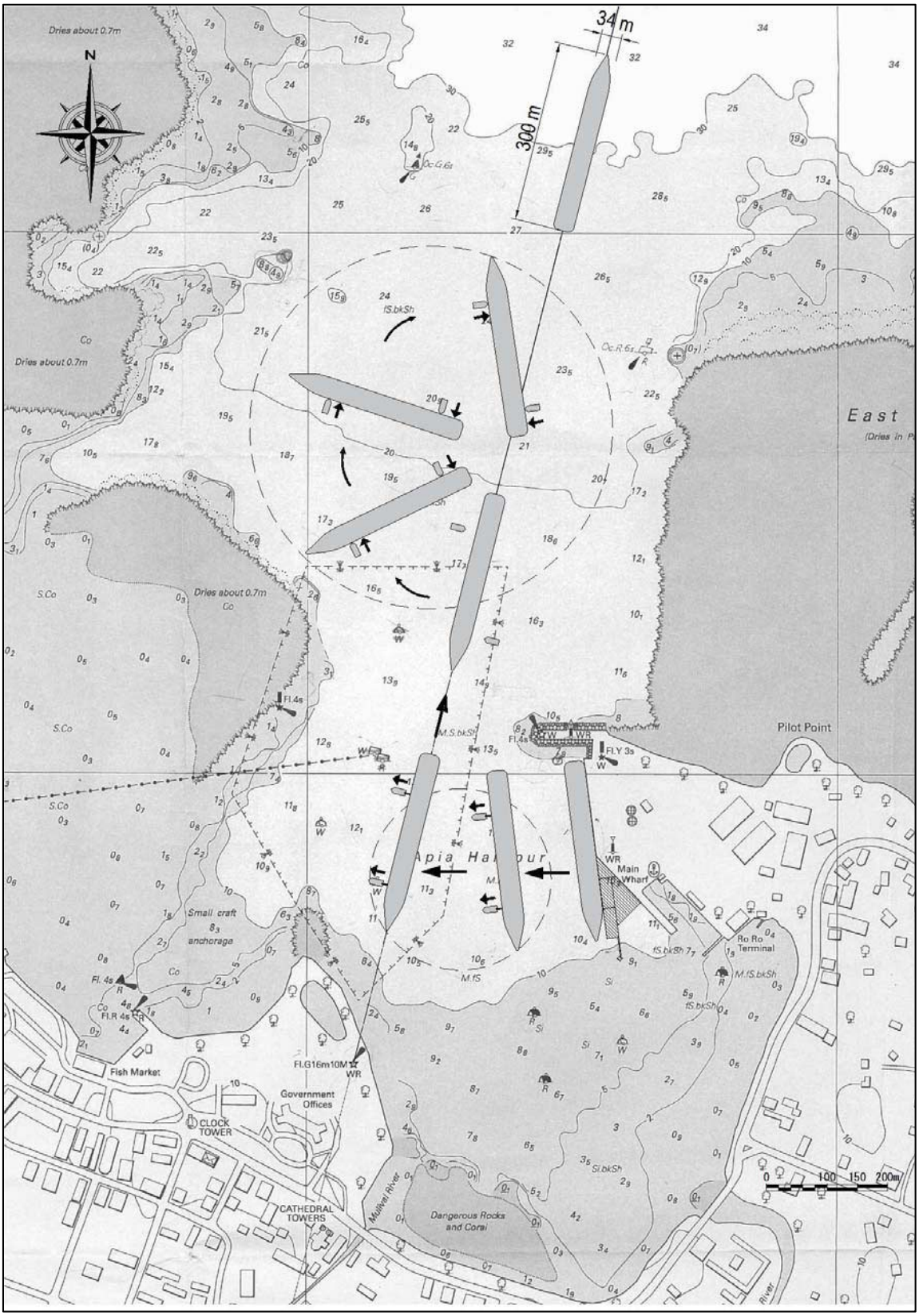
検討図 2-2　クルーズ船出航：出船接岸からの離岸操船

資料 5-6：　操船検討図



検討図 2-3　クルーズ船入航：入船接岸への接岸操船

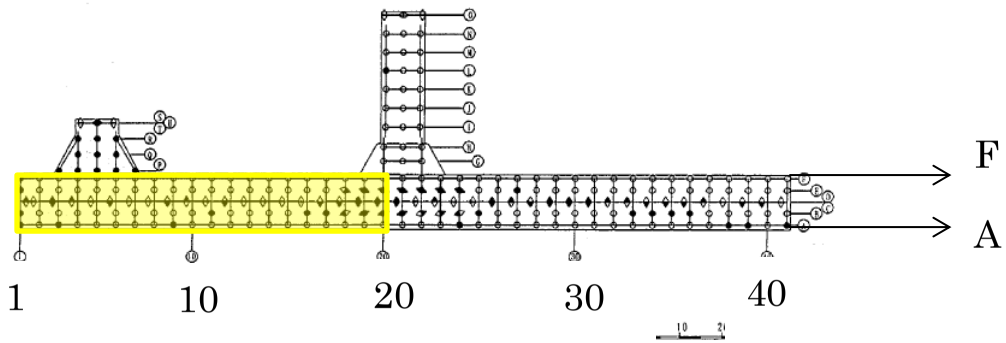
資料 5-6：　操船検討図



検討図 2-4　クルーズ船出航：入船接岸からの離岸操船

Inspection Record：Old Wharf (No.1~20)

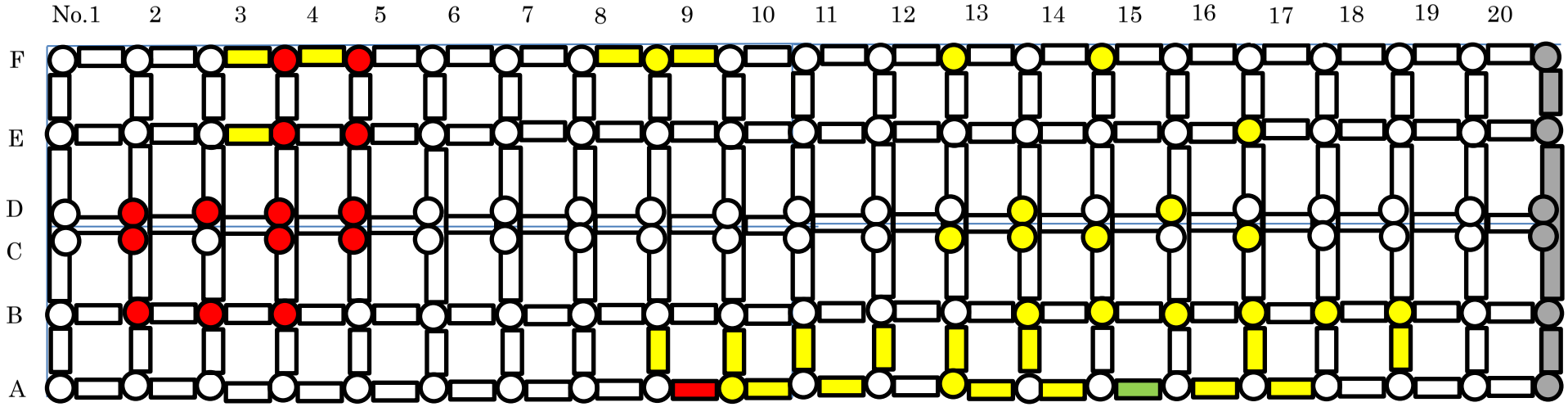
Date: 15th/July/2014



：Collapse & Crack

：Collapse

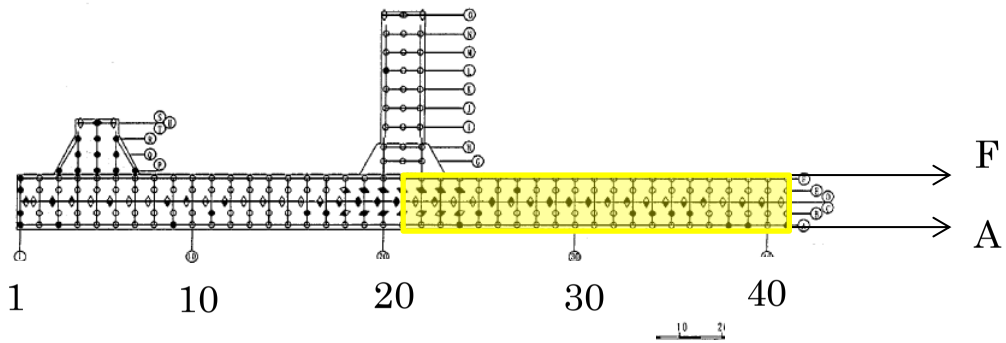
：Crack



A6-1-1

Inspection Record : Old Wharf (No.21~41)

Date: 15th/July/2014

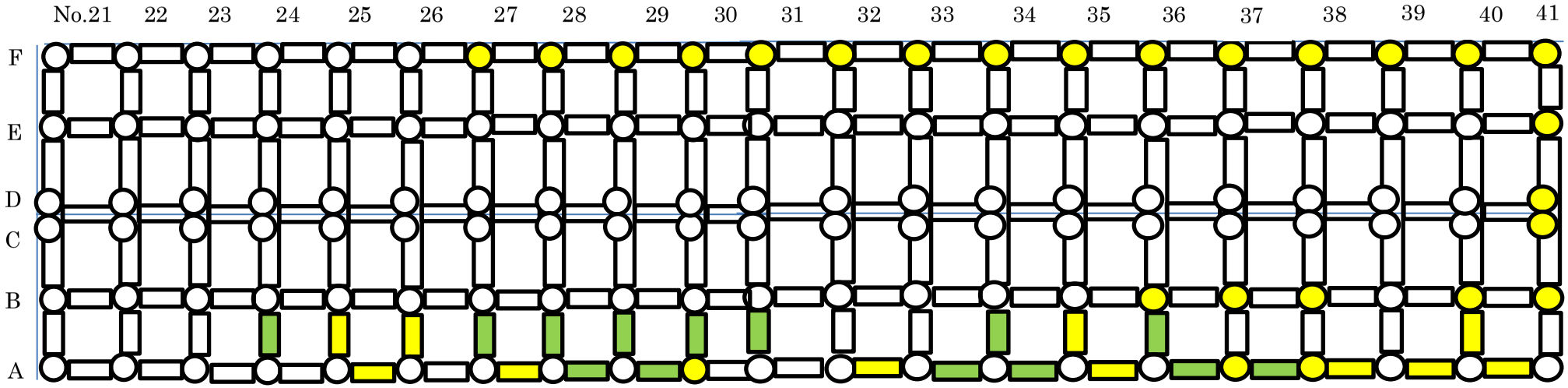


: Collapse & Crack

: Collapse

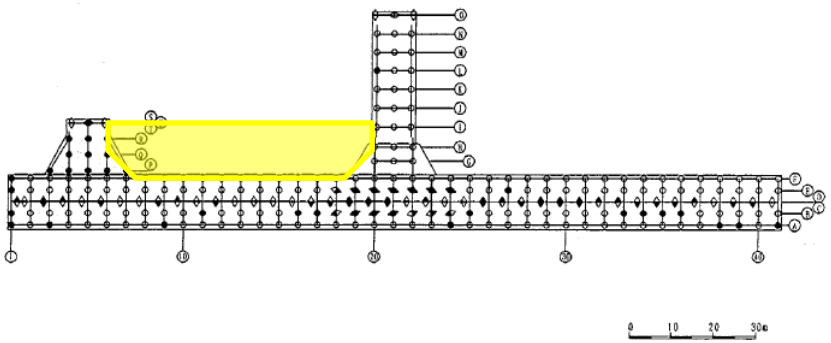
: Crack

A6-1-2



Inspection Record　: Under the Deck

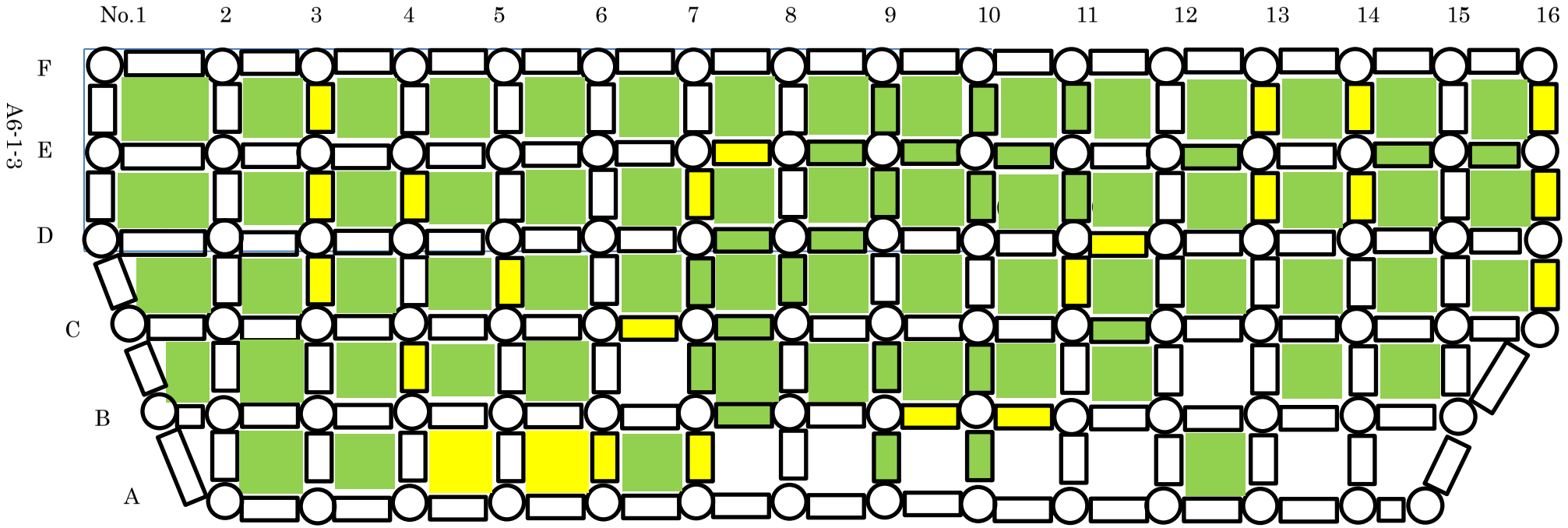
Date: 15th/July/2014



: Collapse & Crack

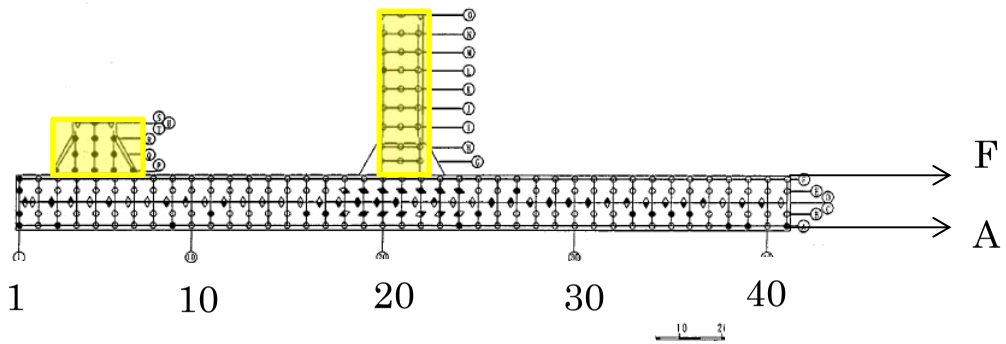
: Collapse

: Crack

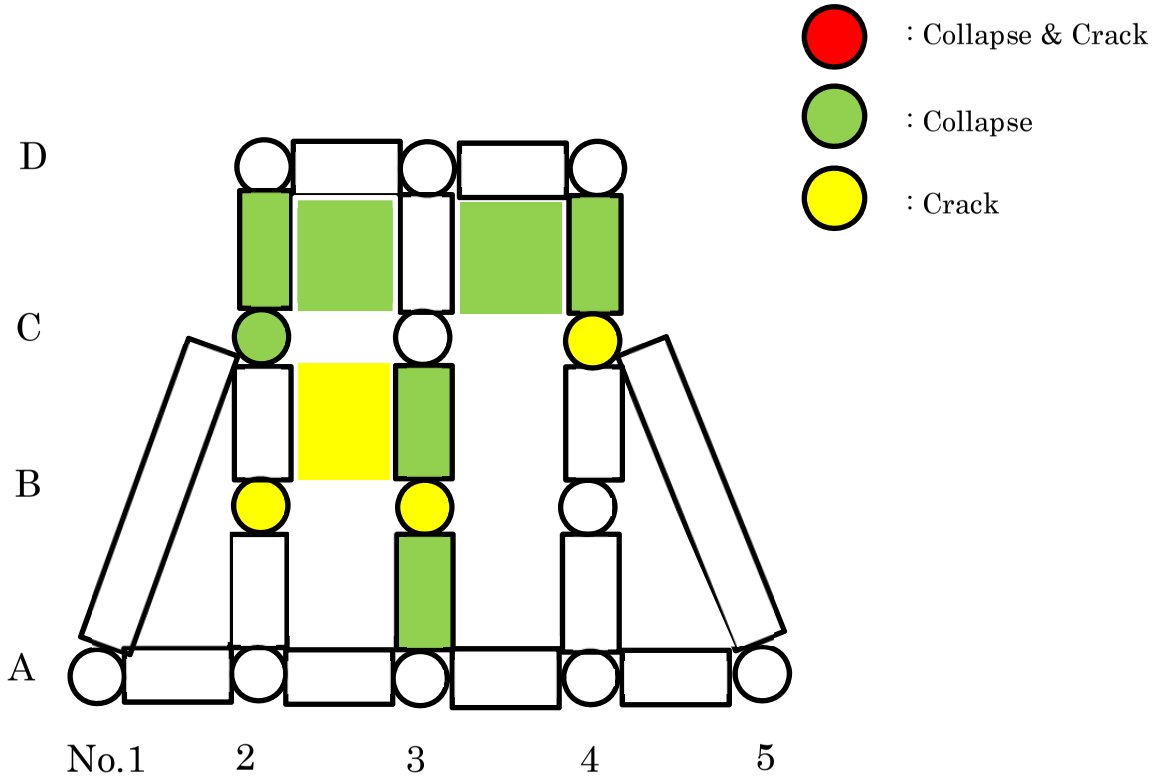


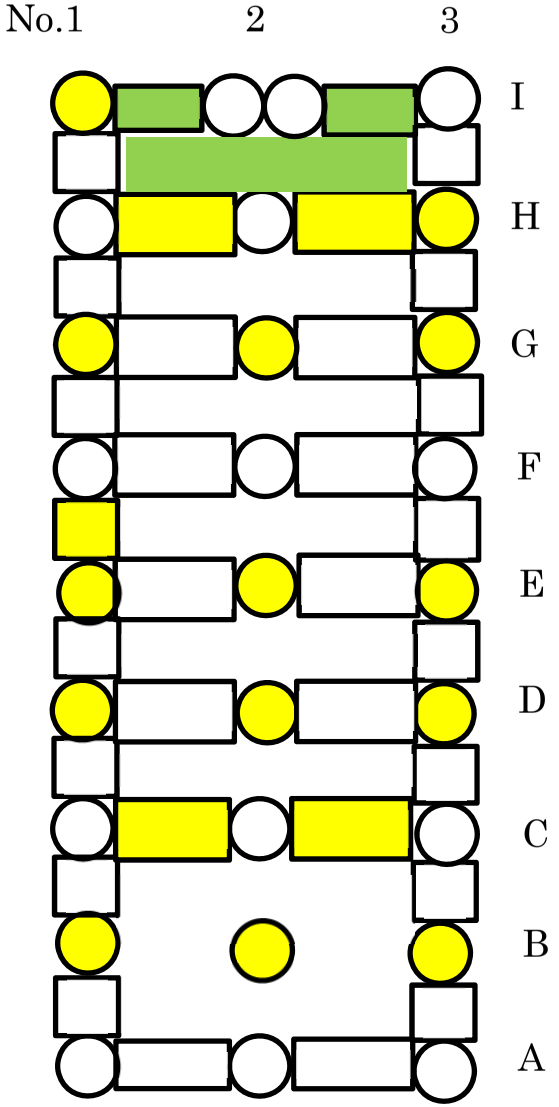
Inspection Record : Approach

Date: 15th/July/2014

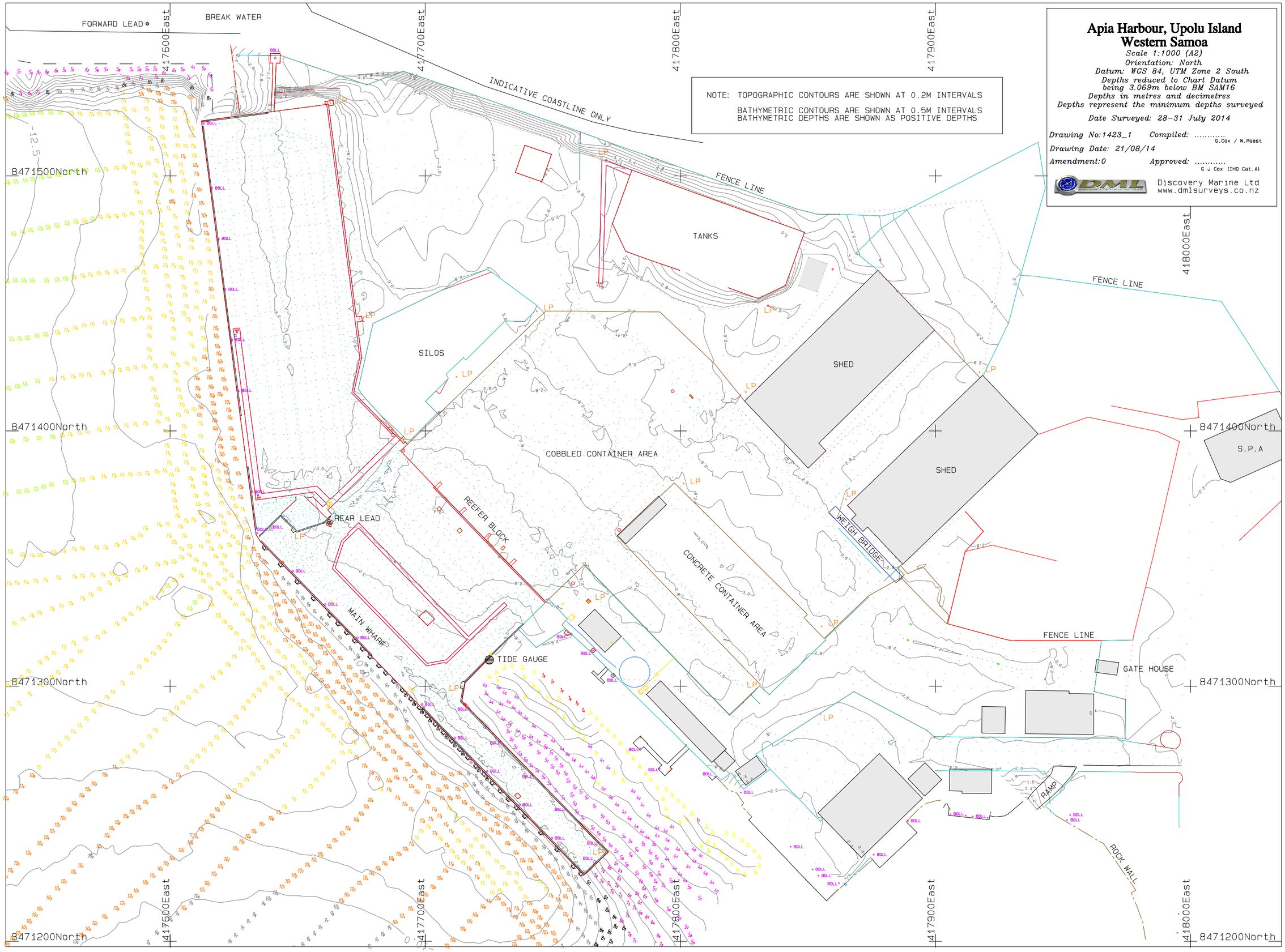


A6-1-4





資料6-2：測量図



A6-2-1

資料6-3：土質調査結果

NOTES :

1. Aerial photo sourced from Google Earth(Copyright: 2012). Imagery Date: May 5, 2014 Copyright 2009.
2. Survey data Supplied by DML Hydrographic & Coastal Management Services, reference "Apia Survey Report, dated July 2014.
3. Horizontal Datum: WGS84, UTM Z2S Vertical Datum: Apia Chart Datum (Lowest Astronomical Tide)

LEGEND:

BH2 T&Tl Ltd. Machine Borehole Location (August 2014)

—12— Existing Bathymetry Level (1m Interval)

DRAWN	AGI	Sep. 14
DRAFTING CHECKED		
APPROVED		
CADFILE	\\75 1055. 1000–F 1.dwg	

Tonkin & Taylor
Environmental and Engineering Consultan
105 Carlton Gore Road, Newmarket, Auckland
www.tonkin.co.nz

ORIENTAL CONSULTANTS

THE PREPARATORY SURVEY FOR THE PROJECT FOR ENHANCEMENT OF SAFETY IN APIA PORT, SAMOA

Site Plan

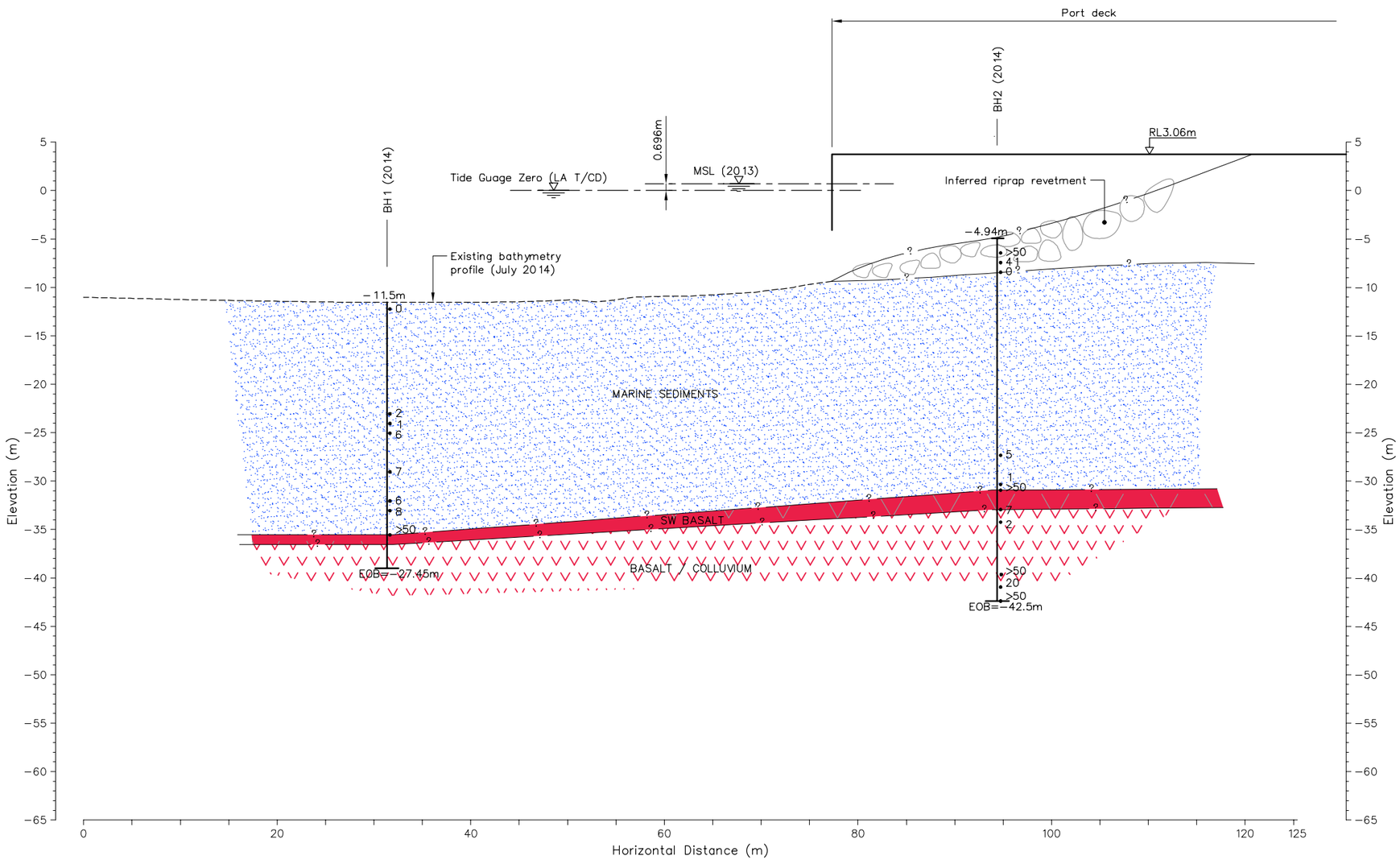
SCALES (AT A3 SIZE)
AS SHOWN

PROJECT No.
75 1055. 1000

FIG. No.
Figure 1

REV.
0

L:\751055\751055.1000\WorkingMaterial\CAD\FIG\751055.1000-F1.dwg, F1, 1/10/2014 2:35:05 p.m., jatg, 1:1



SECTION 1 / F1

SCALE 1:500

NOTE: Elevation are based on Tide Guage Zero (LA T/CD)

SCALE 1:500

0 5 10 15 20 25 (m)

NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Survey data Supplied by DML Hydrographic & Coastal Management Services, reference "Apia Survey Report, dated July 2014.
3. Horizontal Datum: WGS84, UTM Z2S
   Vertical Datum: Apia Chart Datum (Lowest Astronomical Tide)
   Tide Guage Zero (LA T/CD)
   Bench Mark
   SAM 16: 8471312.30mN, 417725.74mE 3.069m

LEGEND

- Borehole Location and SPT N Value
- Marine Sediments
- SW Basalt
- Basalt / Colluvium

DRAWN	JATG	Oct. 14
DRAFTING CHECKED		
APPROVED		
CADFILE	\\75 1055. 1000−F2.dwg	

Tonkin & Taylor
Environmental and Engineering Consultan
105 Carlton Gore Road, Newmarket, Auckland
www.tonkin.co.nz

ORIENTAL CONSULTANTS

THE PREPARATORY SURVEY FOR THE PROJECT FOR ENHANCEMENT OF SAFETY IN APIA PORT, SAMOA

Geological Section

SCALES (AT A3 SIZE): AS SHOWN
PROJECT No.: 75 1055. 1000
FIG. No.: Figure 2
REV.: 0

FIGURE STATUS: CUSTOM

L:\75105\751055.1000\WorkingMaterial\CAD\FIG\751055.1000-F2.dwg, F2, 23/10/2014 11:48:08 a.m., jatg, 1:1

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No:BH1
Hole Location: Apia, Samoa

SHEET 1 OF 3

PROJECT: Apia Port	LOCATION: Apia, Samoa	JOB No: 751055.100
CO-ORDINATES: 134936.99 mN 1714543.56 mE	DRILL TYPE: Heli Rig	HOLE STARTED: 20/8/14
	DRILL METHOD: ROTARY	HOLE FINISHED: 22/8/14
R.L.:		DRILLED BY: Webster Drilling Ltd
DATUM: WGS84	DRILL FLUID: Water	LOGGED BY: MJCC CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

FLUID LOSS | WATER | CORE RECOVERY (%) | METHOD | CASING | TESTS | SAMPLES | R.L. (m) | DEPTH (m) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MOISTURE CONDITION / WEATHERING | STRENGTH/DENSITY CLASSIFICATION | SHEAR STRENGTH (kPa) | COMPRESSIVE STRENGTH (MPa) | DEFECT SPACING (mm)

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.

SEA LEVEL (VARIABLE)

Depth (m)	Core recovery (%)	Method	Tests	Moisture / Weathering	Strength/Density	Description
	0	WASH				MARINE SEDIMENTS Wash drilled. Depth to seabed based on drill rig height on barge. See DML bathymetric survey for accurate depth to sea floor from Chart Datum
1	89	SPT	0 0 0 N=0	W	S-MD	CORE LOSS.
	0	WASH				Silty SAND, with some shell fragments; dark greyish black. Soft/medium dense, wet, poorly graded. Wash drilled.
2	100	SPT	0 0 0 N=0			SAND, with minor silt, with some shell fragments; dark grey. Soft/medium dense to loose, wet, poorly graded.
	0	WASH				Wash drilled.
3	100	SPT	0 0 0 N=0			Silty SAND, with some shell fragments; dark grey. Soft/medium dense, wet, poorly graded.
	100	PT				Silty SAND, with trace clay and some shell fragments. Soft/medium dense, wet, poorly graded.
4	0	W				Push tube attempted at 3.45m for 500mm. End appeared to be back to SAND, with some silt and some shell fragments; dark grey. Soft/medium dense, wet, poorly graded.
	0	SPT	0 0 0 N=0			CORE LOSS.
	0	WASH				Wash drilled.
5	0	SPT	1/0 0/0 0 N=0			MARINE SEDIMENTS CORE LOSS. Minor shell fragments present and coral in a sand matrix of the very small (less than 10% piece) that recovered.
	0	WASH				Wash drilled.
6	44	SPT	1/0 0/0 0 N=0	M	S	SILT, with some sand and minor clay and some shell fragments; dark grey. Soft, moist, low plasticity.
	0	WASH				Wash drilled.
7	100	SPT	0/0 0/0 0 N=0			Sandy SILT, with minor clay and some shell fragments; dark grey. Soft, moist, low plasticity; sand, fine.
	0	WASH			L	Coarse SAND, with minor silt and shell fragments; dark grey. Loose, moist, gap graded.
8	66	SPT	2/1 0/0 0 N=1		S-MD	Wash drilled. CORE LOSS.
	0	WASH				Fine sandy SILT, with some coarse shell fragments; dark grey. Soft/medium dense, moist, poorly graded.
9	33	SPT	1/0 0/0 0 N=0		L	Wash drilled. CORE LOSS.
	0	WASH				SAND, with shell fragments; dark grey. Loose, moist, gap graded. Wash drilled.
10						

T+T DATATEMPLATE.GDT mjcc

Log Scale 1:50

BORELOG 751055.GPJ 21-Nov-2014

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No:BH1
Hole Location: Apia, Samoa

PROJECT: Apia Port | LOCATION: Apia, Samoa | JOB No: 751055.100

CO-ORDINATES: 134936.99 mN, 1714543.56 mE
R.L.:
DATUM: WGS84

DRILL TYPE: Heli Rig
DRILL METHOD: ROTARY
DRILL FLUID: Water

HOLE STARTED: 20/8/14
HOLE FINISHED: 22/8/14
DRILLED BY: Webster Drilling Ltd
LOGGED BY: MJCC CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION / ROCK DESCRIPTION
MARINE SEDIMENTS			100	SPT		1/0 0/0 0 N=0			11				MD-L				SAND, with minor silt, with intermixed shells; dark grey. Medium dense to loose, moist, poorly graded.
			0	WASH													Wash drilled.
			77	SPT		1/1 1/0 0 N=2											CORE LOSS. 11 Silty, medium to fine SAND, with intermixed shells; dark grey. Medium dense to loose, wet, gap graded.
			0	WASH					12								Wash drilled.
			89	SPT		1/1 0/0 0 N=1							MD				CORE LOSS. 12 Silty SAND; dark grey with white flecks. Medium dense, moist, poorly graded. 12.0-12.1m: Intermixed coarse shells, loose.
			0	WASH													Wash drilled.
			55	SPT		5/2 1/1 2 N=6			13								CORE LOSS. 13 Silty SAND; dark grey with white flecks. Medium dense, moist, poorly graded. 13-13.1m: wood. 13.1m: small shell fragments.
			0	WASH													Wash drilled.
			58	SPT		3/2 1/1 1 N=5			14								CORE LOSS. 14 Silty, fine SAND; dark grey with white flecks. Medium dense, moist, poorly graded. 14-14.05m: wood fragments, shell fragments.
			0	WASH					15								Wash drilled. 15
MARINE SEDIMENTS			0	WASH													Wash drilled.
									16								16
			22	SPT		2/1 2/2 2 N=7			17								CORE LOSS. 17
			0	WASH													Silty SAND, with minor shell fragments; dark grey with white flecks. Medium dense, moist, poorly graded. Wash drilled.
									18								18
									19								19
									20								

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.
ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.

T+T DATATEMPLATE.GDT mjcc

Log Scale 1:50

BORELOG 751055.GPJ 21-Nov-2014

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No:BH1
Hole Location: Apia, Samoa

SHEET 3 OF 3

PROJECT: Apia Port	LOCATION: Apia, Samoa	JOB No: 751055.100
CO-ORDINATES: 134936.99 mN 1714543.56 mE	DRILL TYPE: Heli Rig	HOLE STARTED: 20/8/14
	DRILL METHOD: ROTARY	HOLE FINISHED: 22/8/14
R.L.:		DRILLED BY: Webster Drilling Ltd
DATUM: WGS84	DRILL FLUID: Water	LOGGED BY: MJCC CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION / ROCK DESCRIPTION
MARINE SEDIMENTS			0	SPT		3/1 2/1 2 N=6			21								CORE LOSS/NO RECOVERY.
			0	WASH													Wash drilled.
			24	SPT		4/2 2/2 2 N=8						M-W	L				CORE LOSS. Coarse SAND, with frequent shell fragments; dark grey, speckled white. Loose, moist to wet, poorly graded.
			0	WASH					22								Wash drilled.
									23								
SW BASALT			100	SPT		50 for 90mm N>50			24				S				Slightly weathered, dark grey BASALT rubble. Strong, moderately vesicular, highly fractured. Basalt ranges between 5mm to 30mm dia., some shell material intermixed.
			0	WASH													Wash drilled.
BASALT/COLLUVIUM			100	SPT		26 for 80mm N>50			25				L MS				Silty SAND, with some gravel; dark brown. Loose, moist, gap graded. SPT bouncing after 20mm.
			0	WASH													Moderately weathered, dark grey BASALT. Moderately strong, slightly vesicular, highly fractured (5-20mm).
			100	SPT		18 10 for 65mm N>50			26				VW-EW				Wash drilled. Highly weathered, greyish brown BASALT. Very to extremely weak.
			0	WASH													Soil description: Sandy GRAVEL; dark brown. Very dense, mosit, gap graded. SPT bouncing after 210mm.
			100	SPT		21 for 131mm N>50			27				S				Wash drilled. Moderately weathered, dark grey BASALT. Strong, slightly vesicular, highly fractured ~~rubble (5-25mm).~~
																	SPT bouncing after 131mm. **END OF BOREHOLE AT 27.45m.**
									28								SPT N>50 from 24 to 27m.
									29								
									30								

T+T DATATEMPLATE.GDT mjcc

Log Scale 1:50

BORELOG 751055.GPJ 21-Nov-2014

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No:BH2
Hole Location: Apia, Samoa

SHEET 1 OF 4

PROJECT: Apia Port | LOCATION: Apia, Samoa | JOB No: 751055.100

CO-ORDINATES: 134935.4 mN, 1714542.08 mE
R.L.:
DATUM: WGS84

DRILL TYPE: Heli Rig
DRILL METHOD: ROTARY
DRILL FLUID: Water

HOLE STARTED: 23/8/14
HOLE FINISHED: 25/8/14
DRILLED BY: Webster Drilling Ltd
LOGGED BY: MJCC CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION / ROCK DESCRIPTION
DISPLACED BASALT BOULDER		SEA LEVEL (VARIABLE)	90	HQ					1				VS				CORE LOSS. Drillers report soft sediments for 200 mm (Depth to seabed 8.0m from port surface)
DISPLACED BASALT BOULDER			0	SPT		24 for 100mm Bouncing N>50							S				Slightly weathered, dark grey BASALT. Very strong, moderately vesicular (soft sand above for 100mm, not recovered). Likely to be basalt boulder rock wrap displaced when port was constructed.
			0	WASH													Slightly weathered, dark grey BASALT. Strong, moderately to highly vesicular. Wash drilled.
			11	SPT		8/8 8/12 13 N=41			2								CORE LOSS.
			0	WASH									L				Sandy GRAVEL (Basalt); dark grey. Loose, wet, gap graded (rock wrap). Wash drilled.
MARINE SEDIMENTS			100	SPT		0/0 0/0 0 N=0			3		SC	W	S				Silty, fine SAND, with minor clay; dark grey. Soft, wet, poorly graded.
			0	WASH													Push Tube attempted - no recovery.
			0	WASH					4								Wash drilled.
MARINE SEDIMENTS			100	SPT		0/0 0/0 0 N=0			5								Fine sandy SILT, with trace clay; dark grey. Soft/medium dense, wet, poorly graded.
			0	WASH													Push Tube attempted - no recovery.
			100	PISTON					6								Piston Sample - successful. Material in base was silty, fine SAND, with trace clay, as above.
			0	WASH					7								Wash drilled.
			100	SPT		0/0 0/0 0 N=0			8		MH	M	S-MD				Fine sandy SILT, with minor clay and some coral (~10mm); dark grey. Soft/medium dense, moist, gap graded.
			0	PISTON													Wash drilled. Piston Sample.
			0	WASH					9								Wash drilled.
									10								

T+T DATATEMPLATE.GDT mjcc

Log Scale 1:50

BORELOG 751055.GPJ 21-Nov-2014

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No:BH2
Hole Location: Apia, Samoa

PROJECT: Apia Port | LOCATION: Apia, Samoa | JOB No: 751055.100

CO-ORDINATES: 134935.4 mN, 1714542.08 mE
R.L.:
DATUM: WGS84

DRILL TYPE: Heli Rig
DRILL METHOD: ROTARY
DRILL FLUID: Water

HOLE STARTED: 23/8/14
HOLE FINISHED: 25/8/14
DRILLED BY: Webster Drilling Ltd
LOGGED BY: MJCC CHECKED:

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION / ROCK DESCRIPTION
MARINE SEDIMENTS			0	WASH					11								Wash drilled.
			100	SPT		1/0 0/0 0 N=0					MH	M	S				Sandy SILT, with trace clay; dark grey, some white flecks. Soft, moist, low plasticity; sand, fine.
			0	WASH					12								Wash drilled.
									13								
			100	PT					14								Push Tube -successful.
			66	SPT		0/0 0/0 0 N=0											Sandy SILT, with trace clay; dark grey with white flecks. Soft, moist, low plasticity; sand, fine to medium.
MARINE SEDIMENTS			0	WASH					15								Wash drilled.
									16								
			100	SPT		1/0 0/0 0 N=0			17		MH		L				Fine sandy SILT; dark grey with white flecks. Medium dense, moist, poorly graded. 17m: Wood fragment.
			0	WASH													Wash drilled.
									18								
			78	SPT		1/0 0/0 0 N=0			19		SM	W	L				CORE LOSS.
			60	PT	W												Silty, fine to medium SAND, with minor gravel and shell fragments; dark grey with some red wood fragments. Loose, wet, gap graded.
									20								Wash drilled.

T+T DATATEMPLATE.GDT mjcc

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No:BH2
Hole Location: Apia, Samoa

SHEET 3 OF 4

PROJECT: Apia Port	LOCATION: Apia, Samoa	JOB No: 751055.100
CO-ORDINATES: 134935.4 mN 1714542.08 mE	DRILL TYPE: Heli Rig	HOLE STARTED: 23/8/14
	DRILL METHOD: ROTARY	HOLE FINISHED: 25/8/14
R.L.:		DRILLED BY: Webster Drilling Ltd
DATUM: WGS84	DRILL FLUID: Water	LOGGED BY: MJCC CHECKED:

GEOLOGICAL									ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m) / DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
MARINE SEDIMENTS			0	WASH				21								Push Tube. Wash drilled.
			100	SPT		1/1 1/1 2 N=5		22		MH	M	MD				Fine sandy SILT; dark grey with white flecks. Medium dense, moist, poorly graded.
			0	WASH				23								Wash drilled.
								24								
MARINE SEDIMENTS			44	SPT		6/0 0/0 1 N=1		25		SP	M	L S				CORE LOSS. Gravelly, coarse SAND (coral in sand matrix); dark grey and white. Loose, moist, gap graded.
			0	WASH												Wash drilled.
SW BASALT			100	SPT		31 for 140mm N>50		26		GW	SW					Slightly weathered, dark grey BASALT. Strong, slightly vesicular, highly fractured (cobble sized). SPT bouncing after 140mm. CORE LOSS.
			0	WASH												Wash drilled.
			0	SPT		20 for 25mm N>50		27								CORE LOSS. SPT bouncing after 25mm.
			0	WASH												Wash drilled.
BASALT/COLLUVIUM WITH INTERMIXED MARINE SEDIMENTS			78	SPT		6/5 2/0 0 N=7		28			W					Moderately weathered, dark reddish grey BASALT. Weak, moderately vesicular, highly fractured (gravel sized) in a coarse sand matrix. SOIL DESCRIPTION: Coarse sandy GRAVEL (Basalt); dark reddish grey. Loose, wet, gap graded.
			0	WASH						GP						Wash drilled.
			33	SPT		2/0 1/1 0 N=2		29			MW	L-S				CORE LOSS. Silty SAND; dark brown. Loose/soft, wet, poorly graded.
								30								

T+T DATATEMPLATE.GDT mjcc

Log Scale 1:50

BORELOG 751055.GPJ 21-Nov-2014

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No:BH2
Hole Location: Apia, Samoa

SHEET 4 OF 4

PROJECT: Apia Port	LOCATION: Apia, Samoa	JOB No: 751055.100
CO-ORDINATES: 134935.4 mN 1714542.08 mE	DRILL TYPE: Heli Rig	HOLE STARTED: 23/8/14
	DRILL METHOD: ROTARY	HOLE FINISHED: 25/8/14
R.L.:		DRILLED BY: Webster Drilling Ltd
DATUM: WGS84	DRILL FLUID: Water	LOGGED BY: MJCC CHECKED:

GEOLOGICAL									ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m) / DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 2000	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
BASALT/COLLUVIUM WITH INTERMIXED MARINE SEDIMENTS			0	WASH				31								Drilling now reported to be in weak material. Drilling continues until the material is deemed to be considered rock again by contractor
								32								
								33								
			0	SPT		19 for 60mm N>50										NO RECOVERY - SPT refusal. SPT bouncing after 60mm.
			0	WASH				34								Wash drilled.
			0	SPT		25 for 50mm N>50										NO RECOVERY - SPT refusal. SPT bouncing after 50mm.
BASALT/COLLUVIUM WITH INTERMIXED MARINE SEDIMENTS			0	WASH				35								Wash drilled.
			55	SPT		9/5 6/5 4 N=20				MH	M	L-MD				CORE LOSS. Sandy GRAVEL (Basalt); dark reddish brown and grey. Loose to medium dense, moist, gap graded.
			0	WASH				36								Wash drilled.
			80	SPT		10/8 8/10 14 for 30mm N>50		37			M	MD				CORE LOSS. Sandy GRAVEL (Basalt); dark reddish brown and grey. Medium dense, moist, gap graded. SPT bouncing after 405mm. **END OF BOREHOLE AT 37.45m.**
								38								
								39								
								40								

T+T DATATEMPLATE.GDT mjcc

Report
for
the Environmental Survey on the Preparatory Survey
for
the Project for Enhancement of Safety of Apia Port
by
Japan International Cooperation Agency

November 2014

Oriental Consultants Co. Ltd.

This report was prepared based on the report by the subcontractor for the environmental survey, Tonkin & Taylor International Ltd.

資料6-4： 環境調査報告書

Table of contents

Supplement A

1 Introduction

Japan International Cooperation Agency (JICA) is undertaking a preparatory survey on the project for enhancement of safety of Apia Port. The aim of the Preparatory Survey is to provide the basic documents necessary for the appraisal of the Project by the Government of Japan. With that regard, a field survey in Samoa was conducted from June 2014 to August 2014, including this environmental survey.
The environmental survey is consisted of two (2) parts; 1) Water quality and Sediment quality survey and 2) Ecosystem survey.

2 Water quality and Sediment Quality Survey

2.1 Methodology

2.1.1 Sampling

The water quality and sediment quality sampling was carried out on 31 July 2014. A total of ten water samples were collected from five sampling points. At each sampling point, one sample was collected from 0.5 m below the water surface by water sampler and one from 1.0 m above the seabed by SCUBA diving. A sediment sample was collected from each of the five sampling points by SCUBA diving. Samples were collected between 11:55 am and 1:25 pm local time. The sampling locations are shown in Figure 2.1 below and the GPS coordinates for each site are presented in Table 2.1.
Photographs of each site and its sea bed are presented in Supplement A.

Source: Google Earth Image ©2014 CNES/Astrium, dated 5/5/2014

Figure 2.1 Sampling points

Table 2.1 Sampling point

Date: July 31, 2014

Sampling	Latitude	Longitude
Site A	13° 49' 25.0" S	171° 45' 51.9" W
Site B	13° 49' 36.9" S	171° 45' 44.5" W
Site C	13° 49' 40.4" S	171° 45' 37.7" W
Site D	13° 49' 50.1" S	171° 45' 40.1" W
Site E	13° 49' 49.6" S	171° 45' 53.9" W

2.1.2 Field measurement

Dissolved oxygen and temperature measurements were taken on site using a YSI ProDO dissolved oxygen field meter that was calibrated on the day of sampling. Bottled samples were collected for turbidity, pH, salinity, total suspended solids (SS), total nitrogen, total phosphorus, chemical oxygen demand, oil and grease, total petroleum hydrocarbons (TPH), total coliforms (sterile bottle) and Escherichia coli (sterile bottle).

2.1.3 Laboratory analysis

Water samples were air freighted to New Zealand in a chilled container and delivered to RJ Hill Laboratories in Hamilton, New Zealand, for analysis. Sediment samples were air freighted to New Zealand and delivered to Geotechnics laboratory in Auckland, New Zealand and RJ Hill Laboratories, Hamilton, New Zealand.
Parameters and analytical methods are listed in Table 2.2 and Table 2.3.

Table 2.2 Parameter and method for laboratory analysis (Water)

Parameter	Method
Turbidity	Hach 2100N Turbidity meter, APHA[1] 2130 B 22nd ed. 2012
pH	pH meter, APHA 4500-H^+ B 22nd ed. 2012
Salinity	Conductivity Meter (WTW Cond 340i with nonlinear temperature compensation according to EN 27 888), APHA 2520 B 22nd ed. 2012
Total Suspended Solids	APHA 2540 D 22nd ed. 2012
Total Nitrogen	Total Kjeldahl Nitrogen + Nitrate-N + Nitrite-N
Total Kjeldahl Nitrogen	APHA 4500-Norg D. (modified) 4500 NH3F (modified) 22nd ed. 2012
Nitrate-N + Nitrite-N	APHA 4500- NO 3-I 22nd ed. 2012
Total Phosphorus	APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NWASCA, Water & Soil Miscellaneous Publication No. 38, 1982.
Chemical Oxygen Demand	APHA 5220 D 22nd ed. 2012
Oil and Grease	APHA 5520 D (modified) 22nd ed. 2012
Total Petroleum Hydrocarbons in water (TPH)	US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803, 10734]
Total Coliforms	APHA 9222 B (modified), 22nd ed. 2012. Analysis was carried out within 24 hours of sample collection
Escherichia coli	APHA 9222 G, 22nd ed. 2012. Analysis was carried out within 24 hours of sample collection

[1] APHA: American Public Health Association

Table 2.3 Parameter and method for laboratory analysis (Sediment)

Parameter	Method
Specific Gravity	Solid density measurements in accordance with NZS 4402:1986
Water content	Determination of water content NZS 4402:1986
Particle distribution	Particle size analyses in accordance with NZS 4402:1986
Total Organic Carbon	Acid pre-treatment to remove carbonates if present, neutralization
Heavy metals (Hg, As, Cd, Cr, Cu, Ni, Pb, Zn)	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level
Dichlorodiphenyltrichloroethane (DDT)	Sonication extraction, Florisil clean-up, GC-ECD analysis. Tested on dried sample.
Polychlorinated Biphenyls (PCB)	Sonication extraction, SPE clean-up, GPC clean-up (if required), GC-MS analysis. Tested on dried sample.
Tributyl Tin (TBT)	Solvent extraction, ethylation, SPE clean-up, GC-MS SIM analysis. Tested on dried sample.
Total Petroleum Hydrocarbons (TPH)	Sonication extraction in DCM, Silica clean-up. GC_FID analysis USEPA 8015B/MfE Petroleum Industry Guidelines

2.2 Results

Since no specific environmental standards have been identified for Samoa, water quality and sediment quality results have been compared to the appropriate Australian, New Zealand and European guidelines for marine water quality and sediment quality. The Australian and New Zealand guidelines have been derived using available scientific, national and international information and therefore are an appropriate environmental standard. The average, minimum and maximum values for each tested parameter has also been calculated[2]. Results can be summarized as follows:

2.2.1 Water quality

The results of the water quality survey are presented in Table 2.4 and Table 2.5 along with relevant ANZECC[3] and European Union Bathing Water Directive[4] guidelines. Any exceedances of the guidelines have been highlighted in bold.
Where a result of a tested parameter is below the laboratory detection limit, a value has been calculated by multiplying the detection limit by 0.5.

Major findings are as follows:

- Water clarity was low near river mouths and near the wharf when fine sediments were disturbed. Elsewhere, underwater visibility was reasonable, around 10 m.
- No guideline exists for temperature, turbidity, salinity, total suspended solids, oil and grease or chemical oxygen demand. However, the levels measured were all relatively low or below laboratory detection limits and give no cause for concern.
- Dissolved oxygen levels at all sites were generally above the ANZECC guideline value with the exception of the samples 0.5 m below the surface at Sites A and C and both samples from Site E which were slightly lower than 90 % saturation.
- pH values at all sites were generally within ANZECC guideline range of values with the exception of the samples 1 m from the seabed at Sites B and E which were slightly below pH 8.0.
- Total Nitrogen levels were slightly above the ANZECC trigger value at Site E (0.5 m below the surface) and were below laboratory detection limits at every other sampled site. The average Total Nitrogen value for all sites exceeded the ANZECC trigger value.
- Total Phosphorus was slightly above the guideline level at Sites C and D (1.0 m above seabed) and at Site E. However, total phosphorus is not a toxicant and is only measured in terms of eutrophication risk. These results give no particular cause for concern. Total phosphorus at the other sampled sites were all below ANZECC

[2] Where a result of a tested parameter is below the laboratory detection limit, a value has been calculated by multiplying the detection limit by 0.5.
[3] Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Chapter 3 – Aquatic Ecosystems.
[4] European Union Bathing Water Directive, 2006. 2006/7/EC.

guidelines. The average Phosphorus value for all sites exceeded the ANZECC trigger value.

- Water clarity observations were clear at Sites A, B, C and D. The water at Site E was more turbid, which was caused by suspended sediment flowing from a river near Site E. Samples from all sites had no detectable odors.
- No ANZECC guideline exists for total coliforms or Escherichia coli. The European Union Bathing Water Directive outlines a guideline value of 500 cfu/100 ml and an imperative value of 10000 cfu/100 ml. Samples 1.5 m below the surface from Sites A, B, D and E were all above the guideline value. Site E also exceeded the imperative value. The average total coliform value also exceeded the imperative value. The samples arrived at RJ Hill Laboratories in New Zealand at a temperature > 8 ^{o}C, but the results suggest that the rivers that flow into Apia Bay have bacterial contamination issues.

Table 2.4 Results of water quality field observations

	Trigger value*	Site A		Site B		Site C		Site D		Site E		Average	Minimum -Maximum
		U	B	U	B	U	B	U	B	U	B		
Date	-	31/07/ 2014		31/07/ 2014		31/07/ 2014		31/07/ 2014		31/07/ 2014		-	-
Time	-	11:55 a.m.		12:20 p.m.		12:45 p.m.		1:00 p.m.		1:25 p.m.		-	-
Water depth (m)	-	15.5	15.5	12.0	12.0	4.5	4.5	1.8	1.8	4.0	4.0	-	-
Water clarity	-	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Turbid	Turbid	-	-
Water odour	-	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-	-
Temperature (^{O}C)	-	28.0	28.5	27.0	29.0	27.0	29.0	27.0	28.5	27.8	28.5	28.0	27.0 – 29.0
Dissolved Oxygen (%)	90 – no data	**89.8**	104.6	96.3	109.7	**88.3**	99.1	92.4	96.9	**86.5**	**89.5**	95.3	86.5 – 109.7
Dissolved oxygen (mg/L)	-	7.05	8.23	7.5	8.59	6.84	7.74	7.15	7.54	6.76	7.04	7.44	6.76 – 8.59

* Trigger value: ANZECC 2000, Values exceeding or falling outside of the range of trigger values for slightly disturbed ecosystems (Tropical Australia) are highlighted in bold.
U: 0.5m below surface, B: 1m above seabed

Table 2.5 Results of water quality laboratory tests

	Trigger value 1*	Trigger value 2*	Site A		Site B		Site C		Site D		Site E		Average	Minimum - Maximum
			U	B	U	B	U	B	U	B	U	B		
Turbidity (NTU)	-	-	0.88	0.82	0.76	2.2	1.67	5.7	1.59	2.4	9.2	7	3.2	0.7 – 9.2
pH (pH units)	8.0 – 8.4	-	8.2	8.2	8.2	**7.4**	8.2	8.2	8.2	8.2	8.1	7.2	8.0	7.2 – 8.2
Salinity	-	-	34	35	34	35	35	35	34	35	29	33	34	29 – 35
Total Suspended Solids (g/m^3)	-	-	< 3	4	< 3	7	5	13	7	9	11	23	8.2	1.5 – 23
Total Nitrogen (g/m^3)	0.10	-	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	**0.2**	< 0.3	**0.16**	0.15 – 0.2
Nitrate-N + Nitrite-N (g/m^3)	-	-	0.029	0.009	0.01	0.009	0.02	0.012	0.019	0.01	0.188	0.078	0.038	0.009 – 0.188
Total Kjeldahl Nitrogen (TKN) (g/m^3)	-	-	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.1	0.1 – 0.1
Total Phosphorus (g/m^3)	0.015	-	0.011	0.008	0.009	0.01	0.011	**0.019**	0.012	**0.017**	**0.048**	**0.029**	**0.017**	0.008 – 0.048
Chemical Oxygen Demand (COD) ($g\ O2/m^3$)	-	-	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	200	200 – 200
Oil and Grease (g/m^3)	-	-	< 4	< 4	< 4	< 4	< 4	5	< 4	< 4	< 4	< 4	2.3	2 – 5
Total Coliforms (cfu / 100 mL)	-	$5x10^2$/ 10^4**	**570**	10	**890**	14	80	130	**2,500**	80	**$13x10^4$**	450	**13,472**	10 – 130,000
Escherichia coli (cfu / 100 mL)	-	-	70	1	30	2	70	15	160	20	9,000	20	939	1 – 9,000

* Trigger value 1: ANZECC 2000, Trigger value 2: European Union Bathing Water Directive 2006
Values exceeding or falling outside of the range of trigger values for slightly disturbed inshore marine ecosystems (Tropical Australia) are highlighted in bold.
**500 cfu / 100 mL is the EU guideline value for bathing waters, 10,000 cfu / 100 mL is the imperative value.
U: 0.5m below surface, B: 1m above seabed

2.2.2 Sediment

The results of the sediment quality survey are presented in Table 2.6 and Table 2.7 along with relevant ANZECC guideline[5]. Any exceedances of the guidelines have been highlighted in bold.

Where a result of a tested parameter is below the laboratory detection limit, a value has been calculated by multiplying the detection limit by 0.5.

Major findings are as follows:

- The seabed around Apia bay naturally consists of coral reefs and coarse brown sand. However, the entire bay is heavily impacted by land-based sediments and there is a layer of fine brown silt in many places, particularly near the Vailima River mouth, and collected in deep drifts against the main wharf (Site B), where Silt were dominant (74%) in the grain size composition.
- Heavy metal concentrations were below ANZECC ISQG -Low trigger values at all sites, except for Chromium and Nickel, which exceeded ANZECC ISQG-Low trigger values at all sites. The average value for Chromium and Nickel also exceeded ANZECC ISQG-Low trigger values.
- DDT concentrations were below laboratory detection limits at all sites. Where a result of a tested parameter is below the laboratory detection limit, a value has been calculated by multiplying the detection limit by 0.5.
- PCB concentrations for all congeners were below laboratory detection limits at all site.
- TBT concentrations were below laboratory detection limits at all sites.
- TPH concentrations were below laboratory detection limits at all sites.

[5] Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Sediment Quality Guidelines.

Table 2.6 Results of sediment quality field observations and laboratory test

	Site A	Site B	Site C	Site D	Site E	Average	Minimum - Maximum values
Date	31/07/2014	31/07/2014	31/07/2014	31/07/2014	31/07/2014	-	-
Time	11:55 a.m.	12:20 p.m.	12:45 p.m.	1:00 p.m.	1:25 p.m.	-	-
Water depth (m)	15.5	12.0	4.5	1.8	4.0	-	-
Sediment temperature (^{o}C)	28.5	29.0	29.0	28.5	28.5	28.7	28.5 – 29.0
Sediment characteristics	Sand mixed with shell fragments and minor silt, loose	Sandy silt mixed with shell fragments, few rootlets, very soft (free water)	Coral sand mixed with shell fragments, some silts, very soft	Sand mixed with shell fragments and minor silt, loose	Sandy coral mixed with shell fragments, some silt, very soft (free water)	-	-
Sediment colour	Dark grayish brown with white	Dark grayish brown with white	Dark grayish brown with white	Dark grayish brown with white, mottled red	Dark grayish brown with white	-	-
Odor	Nil	Slight sulphur smell	Slight sulphur smell	Nil	Nil	-	-
Specific gravity (Solid density t/m^3)	2.98	3.06	2.99	3.26	2.9	-	-
Water content (%)	34.7	115.0*	40.1	35.7	58.3	-	-
Grain size (Silts) (% of sample)	12	74	18	6	19	-	-
Grain size (Sands) (% of sample)	88	25	57	93	34	-	-
Grain size (Gravels) (% of sample)	-	1	25	1	47	-	-

*: The water content of this sample was oversaturated due to the sample being very soft (high amount of free water contained within the sample).

Table 2.7 Results of sediment quality laboratory tests

Sample Type: Sediment	Trigger value*	Site A	Site B	Site C	Site D	Site E	Average	Minimum - Maximum
Dry Matter (g/100g as	N/A	68	45	55	66	35	54	35 – 68
Total Organic Carbon (g/100g dry wt)	N/A	0.41	1.69	1.41	0.48	2.00	1.20	0.41 – 2.00
Heavy metals (mg/kg dry wt)								
Total Recoverable Arsenic	20	16	4	10	2	16	10	2 - 16
Total Recoverable Cadmium	1.5	< 0.10	0.11	< 0.10	0.11	0.1	0.1	0.05 – 0.11
Total Recoverable Chromium	80	**153**	**184**	**145**	**156**	**110**	**150**	110 – 184
Total Recoverable Copper	65	14	60	61	41	41	43	14 – 61
Total Recoverable Lead	50	5.6	7.1	17	6.2	23	11.8	5.6 – 23
Total Recoverable Mercury	0.15	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.05	0.05 – 0.05
Total Recoverable Nickel	21	**290**	**270**	**280**	**510**	**161**	**302**	161 – 510
Total Recoverable Zinc	200	77	127	172	120	132	126	77 – 172
DDT screening in Soil (mg/kg dry wt)								
2,4'-DDD	N/A	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.0025	0.0025 – 0.0025
4,4'-DDD	N/A	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.0025	0.0025 – 0.0025
2,4'-DDE	N/A	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.0025	0.0025 – 0.0025
4,4'-DDE	N/A	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.0025	0.0025 – 0.0025
2,4'-DDT	N/A	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.0025	0.0025 – 0.0025
4,4'-DDT	N/A	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.0025	0.0025 – 0.0025
Total DDT Isomers	0.0016	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	0.015	0.015 – 0.015

Sample Type: Sediment	Trigger value*	Site A	Site B	Site C	Site D	Site E	Average	Minimum - Maximum
Polychlorinated Biphenyls Trace in Soil(mg/kg dry wt)								
PCB-18	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-28	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-31	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-44	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-49	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-52	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-60	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-77	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-81	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-86	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-101	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-105	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-110	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-114	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-118	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-121	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-123	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-126	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-128	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-138	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005

Sample Type: Sediment	Trigger value*	Site A	Site B	Site C	Site D	Site E	Average	Minimum - Maximum
PCB-141	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-149	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-151	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-153	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-156	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-157	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-159	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-167	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-169	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-170	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-180	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-189	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-194	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-206	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
PCB-209	N/A	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0005	0.0005 – 0.0005
Total PCB (Sum of 35 congeners)	0.023	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.02	0.02 – 0.02
Tributyl Tin Trace in Soil samples (mg/kg dry wt)								
Dibutyltin (as Sn)	N/A	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.0025	0.0025 – 0.0025
Monobutyltin (as Sn)	N/A	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	0.0035	0.0035 – 0.0035
Tributyltin (as Sn)	0.005	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	0.002	0.002 – 0.002
Triphenyltin (as Sn)	N/A	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	0.0015	0.0015 – 0.0015

Sample Type: Sediment	Trigger value*	Site A	Site B	Site C	Site D	Site E	Average	Minimum - Maximum
Total Petroleum Hydrocarbons in Soil (mg/kg dry wt)								
C7 - C9	N/A	< 10	< 40	< 30	< 10	< 40	13	5 – 20
C10 - C14	N/A	< 20	< 70	< 50	< 20	< 80	24	10 – 40
C15 - C36	N/A	< 40	< 130	< 100	< 40	< 160	47	20 – 80
Total hydrocarbons (C7 - C36)	N/A	< 70	< 300	< 170	< 70	< 300	91	35 – 150

*Trigger value: ANZECC 2000 , Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Sediment Quality Guidelines.

Values exceeding or falling outside of the range of trigger values are highlighted in bold.

2.3 Discussion

2.3.1 Water quality

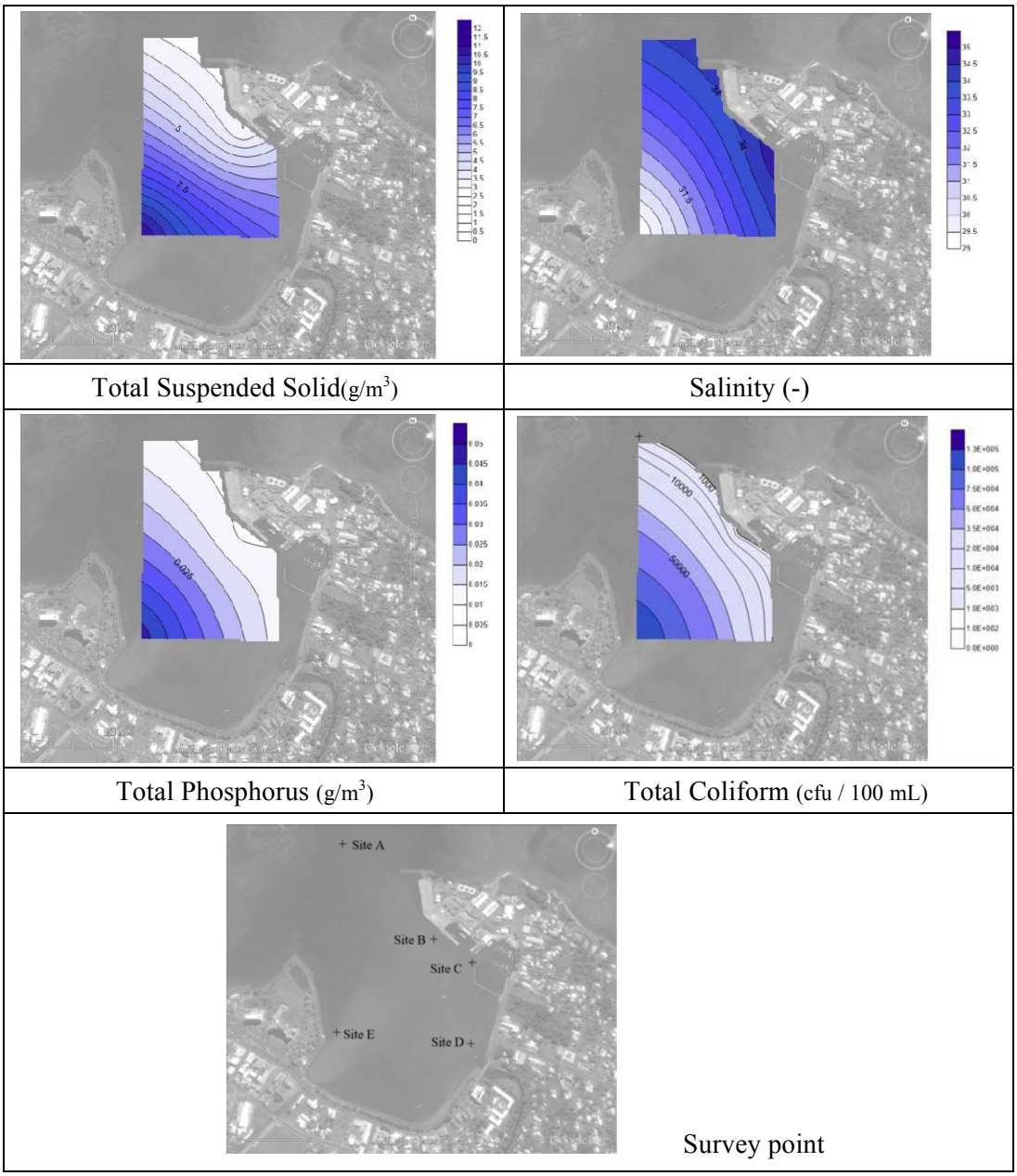
Figure 2.2 shows horizontal distribution of major water quality parameters at 0.5m below sea surface.

There are two (2) rivers flow into Apia Bay, Vailima River near to the Site E and Vaicigano River near to the Site D.

As shown in Figure 2.1, a plume from the Vailima River is recognized and it reaches to Site E. As Salinity is low at Site E, it is considered that the influence of fresh water from Vailima River is considerably high. And thus, the concentration of Suspended Solid is high bringing the substance from upper stream, leading high concentration of Total Phosphorus. At time of the survey, a construction for river bed improvement has been implemented. According to the interview with local resident, this construction has been continued for about one year.

The concentration of Total Coliforms in this area is high (130,000 cfu/100mL at Site E exceeding EU imperative value and three other site (Site A, B and D) exceed the EU trigger value). As the origin of Total Coliforms is usually sewage, untreated or overloaded sewage water might be discharged in the upstream of the rivers. This suggests that influence of river water in this area, especially from Vailima River, is quite high and contaminated by land-based water.

Other parameters do not show any particular values. Therefore it is considered that the condition of water quality is influenced by river water flow and negative impact by the port operation is not seen at moment.



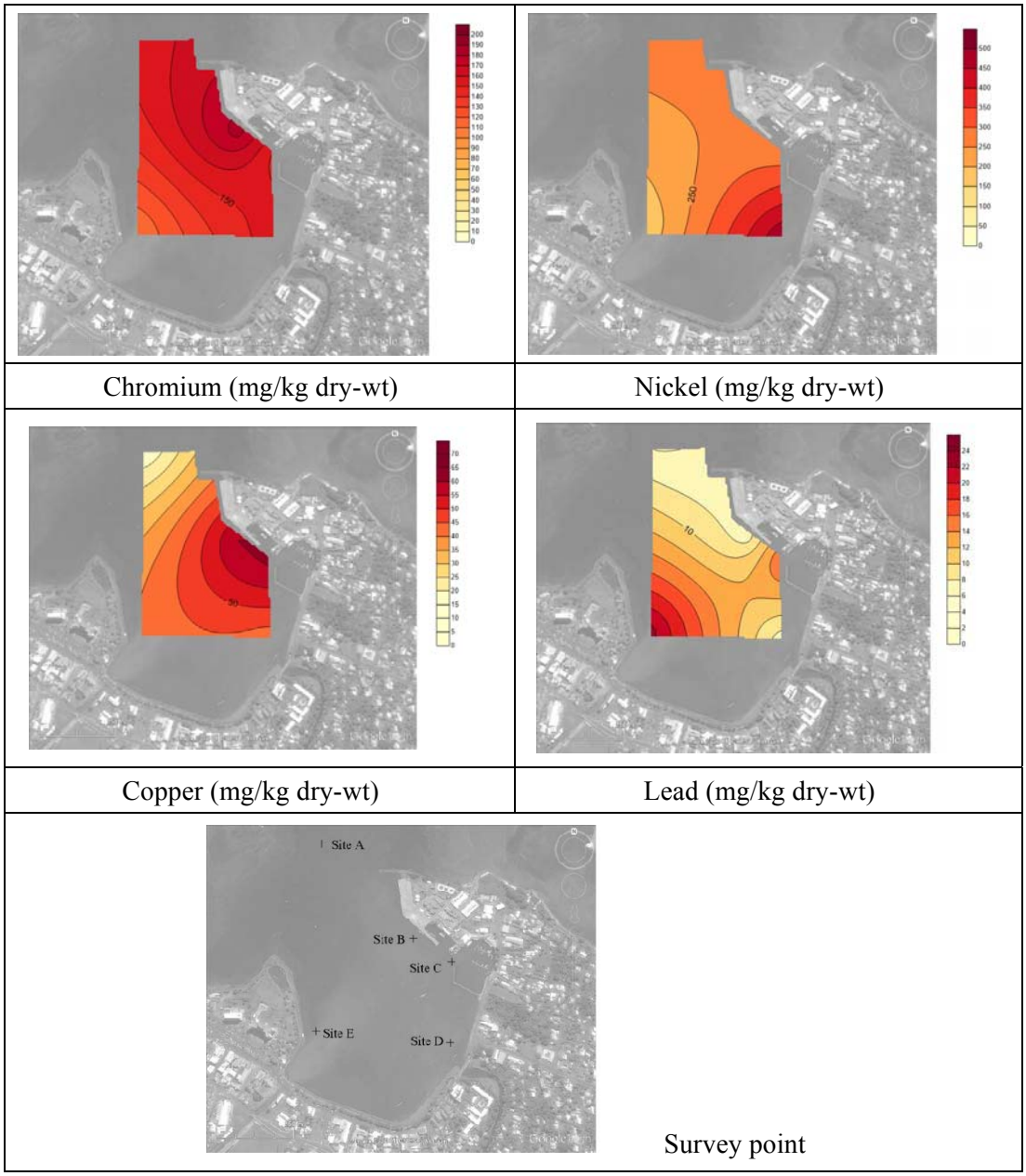
Map source: Google Earth Image
Major parameters at 0.5m below sea surface are plotted.

Figure 2.2 Horizontal distribution of water quality parameters

2.3.2 Sediment quality

Figure 2.3 shows horizontal distribution of major sediment quality parameters. The distribution pattern of heavy metals is different between each parameter. That is; high concentration area is widely spread like Chromium suggesting natural cause of the substance, high concentration point is near the Apia Port like Cupper suggesting the origin of the high concentration is port activities and land-based source can be considered like

Nickel and Lead of which high concentration point is located at river mouth.



Map source: Google Earth Image
Major parameters are plotted.

Figure 2.3 Horizontal distribution of sediment quality parameters

The concentrations of Chromium and Nickel in sediment exceeded the ANZECC 2000 trigger values at all sites.

Previous work undertaken by MWH New Zealand Ltd[6] found Chromium and Nickel levels were above ANZECC guidelines in Apia Bay. The MWH report does not comment on the possible industrial source of the high levels of Nickel and Chromium. It is possible that these high levels may be naturally occurring due to the volcanic soils that would have washed into the bay. The specific gravity results obtained in the sediment survey are very high, indicating metalliferous elements within the sediments. This was proved in the laboratory by using a magnet which attracted the sediment particles.

According to WHO Drinking Water Guideline[7], Chromium is widely distributed in the Earth's crust and Chromium (VI) is classified as 'carcinogenic to humans', while Chromium (III) is classified as 'not classifiable as to its carcinogenicity to humans'. The composition ratio between Chromium (III) and Chromium (IV) was not studied this time.
Other than the Trigger value (ISQG-Low) in sediment that is used for the evaluation of the concentration level, ANZECC 2000 lists other guideline value, ISQG-High value. The difference between the two values is that ISQG-Low value is biological effect level at lower 10 percentile, while ISQG-High value is median concentrations. Usually, it is considered that the concentration less than ISQG-Low is minimal-effects range, the concentration between ISQG-Low and High is possible-effects range and the concentration greater than ISOG-High is probable-effects range[8]. The ISQG-High value for Chromium is 370mg/kg dry-wt and all obtained data are within the value.
Although Chromium in sediment distributes widely around the Apia Bay as shown in Figure 2.3, the concentration level is possible-effects level and, therefore, the impact by the Chromium is not significant at moment unless this substance elutes to the water by significant disturbance of bottom sediment such as dredging.

Nickel is used mainly in the production of stainless steel and nickel alloys, and it is categorized as 'carcinogenic' or 'possible carcinogenic', according to WHO Drinking Water Guideline. The ISQG-High value for Nickel is 52 mg/kg dry-wt and all obtained data exceeded the value. Although Nickel in sediment also distributes widely around the Apia Bay as shown in Figure 2.3, it is considered that there would be no negative impact at moment unless the bottom sediment is disturbed, by which Nickel elutes into the water as water solubility acid.

---

[6] MHW New Zealand Ltd, 2003. Preparation of an initial inventory of persistent organic pollutants (POPs) and persistent toxic substances (PTS) presence, levels and trends in humans and the environment in Samoa. Prepared for the Ministry of Natural Resources and Environment, Government of Samoa.
[7] Guidelines for Drinking-water Quality -Fourth Edition-, WHO, 2011
[8] Relationship between sediment quality and benthic macrofauna in Japanese ports and harbors,

Based on the above mentioned, although the origin of guideline exceeded heavy metals might be natural cause and stable at moment, a possibility that the substances might elute into water with disturbance of bottom sediment, such as dredging, can be considered. This may lead to biological accumulation and reaches to human beings through food-chain. Therefore detailed study for the distribution of those substances and countermeasures to avoid elusion of the substances will be necessary if maintenance dredging would be planned in the future.

3 Ecosystem Survey

3.1 Methodology

Ecosystem survey was carried out to know the situation and distribution of natural habitat around the Apia port at three transect line as shown in Figure 3.1.

At each transect line, species composition of marine and terrestrial flora and fauna were observed by scuba diving in underwater and observed at land area. Presence of endangered species and important habitats were checked base on the list by national and international authority. Observed terrestrial and marine flora and fauna were also photographed.

In addition, rapid habitat assessments were made in two areas: tidal mangrove pool near to the Government Building and the marine reserve, Palolo Deep (see Figure 3.1).

Literature survey and interviews with local experts and residents to supplement the field survey and to know the past distribution of ecosystem, such as coral, mangrove, fauna and flora (especially endangered species), status of any environmentally protected or culturally significant areas, use of resource by ethnic minorities and indigenous people, including fishing practices in the area, were also conducted.

Latitude	Longitude	Survey line
13^{o} 49.767’ S	171^{o} 45.918’ W	West: near Government Buildings
13^{o} 49.926’ S	171^{o} 45.670’ W	East: near Aggie Grey's Hotel
13^{o} 49.450’ S	171^{o} 45.694’ W	North: outside Port Breakwater

Source: Google Earth Image

Figure 3.1 Ecosystem Survey Point

2.3.3 General parameters

Depth and water temperature measurements were measured at the start of each survey line. In addition, survey dates, times and weather were recorded.

2.3.4 Habitat Type

Habitat type were checked as an initial survey, using low tide walks and snorkel equipment in five areas and marked with GPS.

2.3.5 Benthic Cover

Detailed 100m x 5m belt transects for marine life were carried out on SCUBA at three lines. The start point of the transect line were marked by a Garmin hand held GPS 76 and sea bed distances were measured along a 100m tape, and depths were recorded using a HawkEye H22PX hand-held digital sonar depth finder and UWATEC dive computer.
Photographs were taken of each habitat using a Canon Powershot SD1100 IS camera in a dive housing.
Along each 100m Linear Transect, benthic cover was recorded under 200 points at 50cm intervals, to coral and algal life form category and/or family using the categories listed in Table 3.1, as defined by the Australian Institute of Marine Science (AIMS), with notes as to genus and species where possible.

Table 3.1 AIMS Life form Categories

Substrate cover (Life form categories)	Code
Acropora branching coral	ACB
Acropora digitate coral	ACD
Acropora tabular coral	ACT
Acropora encrusting coral	ACE
Acropora submassive coral	ACS
Non-*Acropora* coral branching	CB
Non-*Acropora* coral massive	CM
Non-*Acropora* coral encrusting	CE
Non-*Acropora* coral foliose	CF
Non-*Acropora* coral submassive	CS
Non-*Acropora* coral fungoid (mushroom)	CMR
Non-Acropora coral Millipora (fire)	CME
Non-Acropora coral Heliopora (blue)	CHE
Soft coral	SC
Sponge	SP
Zoanthid	ZO
Other biota	OT
Coralline algae	CA
Halimeda algae	HA
Turf algae	TA
Macro algae	MA
Algal assemblage	AA
Dead coral	DC

Substrate cover (Life form categories)	Code
Dead coral + algae	DCA
Rock (> 15cm in length)	RC
Rubble (> 0.5cm but < 15cm in length)	RB
Sand (< 0.5cm and falls quickly to the bottom if dropped	SD
Silt (0.002 – 0.05mm sediments that remain in suspension if disturbed)	SI

Additional information such as coral bleaching, disease and predation was also recorded.

2.3.6 Macro-Invertebrates

Key macro-invertebrates seen in a 5m belt along each 100m transect were recorded to species level and size.

2.3.7 Fish

All fish seen in a 5m belt along each 100m transect were recorded to species level and size category.

2.3.8 Interviews and Observations of Fishing in and around Apia Bay

Interviews were conducted with local experts and those found fishing or selling fish during the survey period, including:

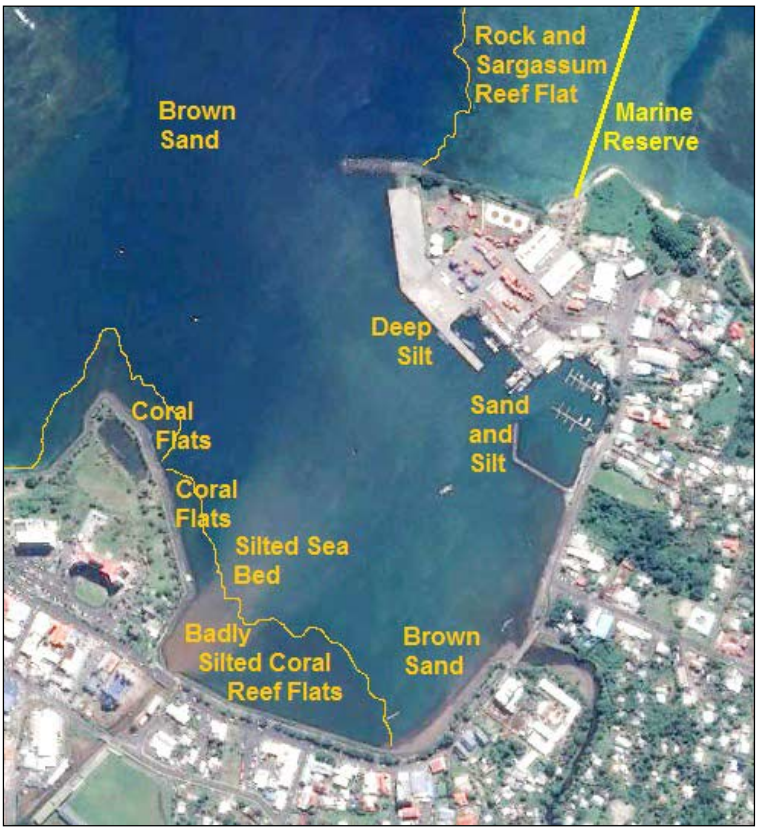
Table 3.2 Names and contacts of interviewees

Name	Position	Agency	Phone	Email
Joyce Samuelu-Ah Leong	Assistant Chief Executive Officer, Fisheries Division	Ministry of Agriculture and Fisheries	(685) 23863	joyce.ahleong@maf.gov.ws
Paul Anderson	Environmental Monitoring Analyst	Secretariat of the Pacific Regional Environment Program (SPREP)	(685) 21929	paula@sprep.org
Mark Graham	Environmental Monitoring & Reporting Adviser			markg@sprep.org
Warren Lee Leong	Coastal and Marine Adviser			warrenl@sprep.org
Kat and Ted Thompson	Dive Operators	Aqua Samoa	(685) 77 74744	dive@aquasamoa.com
-	Skiff crew	Samoa Ports Authority		
-	Fishermen and vendors	Apia Fishermen's Wharf Market		
-	Fishers	Apia Bay		

3.2 Results

3.2.1 Habitat type

Figure 3.2 explains brief habitat map based on the results from the field survey. Sand and silt dominates around the APIA Port and coral reef flat exists at the other side of the port (west side of the Apia bay). And rock-and-sargassum reef flat spread at outside of breakwater of the Apia Port.



Source: Google Earth Image

Figure 3.2 Habitat map around the Apia Port

(1) Mangrove pond

On the western side of Apia Bay, on what appears to be reclaimed land where the Government Buildings are situated, there is a tidal pool approximately 120 m long by 45 m wide, enclosed by sea walls, but connected to the sea by culverts. A rapid assessment of habitat at the pond was carried out (see Figure 3.3).

Source: Google Earth Image

Figure 3.3 Main features of the mangrove pond

The pond is shallow and tidal, with sea water flowing in and out through several small, and one main, culverts through the sea wall. There is an arch in the centre of the pool, a remnant of what was once a performance platform built as part of the Cultural Village tourist centre.

The muddy sea water pool has a small amount (5 trees) of young *Rhizophora samoensis* mangrove at the southern end. These trees are about 2 m high with stems of 20 – 25cm Girth at Breast height (GBH). The remainder of the pond has no mangrove growth, except for a few saplings rooting along the western shore. The other vegetation is a mixture of grasses and Morning Glory beach vine *Ipomoea pes-caprae*.

There are fish in the pond, but these could not be seen due to the high turbidity of the water. It is likely that they are estuarine species such as the Crescent Grunter (Avaava) *Therapon jarbua* or Mullet.

There were many small Orange-clawed Fiddler Crabs *Uca lactea* feeding on algae on the low-tide mud flats near the mangroves at the south end.

This pond is not a significant part of the marine environment, but would make an excellent mangrove planting demonstration site, and if planted and allowed to mature could, in time, contribute some of the nursery and feeding ground functions that would probably have been supplied by mangroves in the area before reclamation and sea wall construction took place.

Pool from the south: small mangrove trees

Mangrove propogule

Grass and *Ipomoea* vines along poolsides

Leaves and flowers of *Rhizophora samoenses*

Low tide mud flats, mangrove seedlings and arch

Fiddler Crabs, *Uca lactea*

Figure 3.4 Photographs of the mangrove pool

(2) Palolo Deep

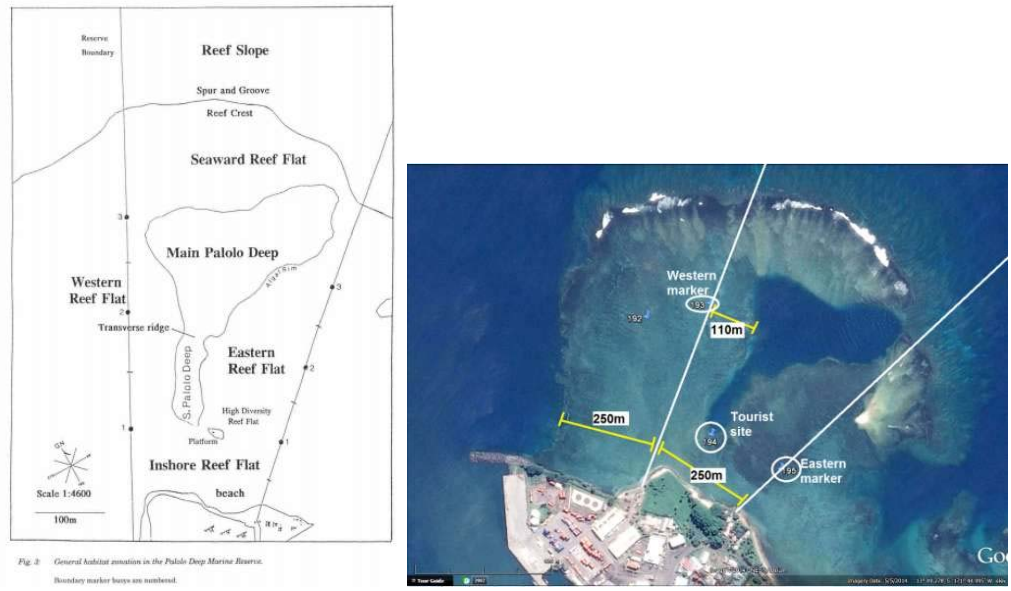
Palolo Deep was one of the first marine reserves formed in Samoa, formalized in 1974. The first scientific surveys of the area were carried out in 1994 (Lovell, E, 1994). It functions as a tourism reserve where visitors to Apia can snorkel for a fee of SAT $3.00, and as a nursery site for Giant Clam, Trochus Shell and Sea Cucumber projects for the Department of Fisheries.

The reserve is situated just outside the breakwater north of Apia Port, with the reserve boundaries starting about 250m east of the reef edge where transect North was carried out.

The reserve is 250m wide at its narrowest point along the shore, tapering out towards the reef edge and slope. The western boundary is approximately 110m from the slope into the deep itself.

The “deep” is a lagoon within the fringing reef, 25m deep at the deepest point, but mostly ranging from 12 to 20m deep.

Since Palolo Deep is located outside the bay, north of the breakwater is close enough, it might potentially be affected by any future construction activities at the port (in particular any extension of the breakwater), and also by sedimentation from river run off, and should be taken into consideration.



Latitude	Longitude	Survey point in 2014	Survey point in1994
13^{O} 49.277’ S	171^{O} 45.566’ W	192: Fallen reef marker	
13^{O} 49.256’ S	171^{O} 45.486’ W	193: Marker western edge	West 3
13^{O} 49.420’ S	171^{O} 45.475’ W	194: Marker southern edge	
13^{O} 49.459’ S	171^{O} 45.384’ W	195: Marker eastern edge	East 1

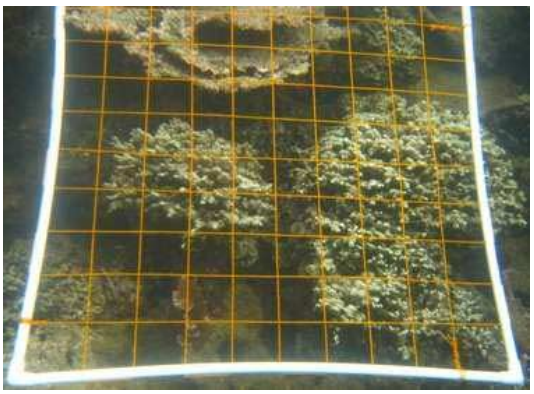
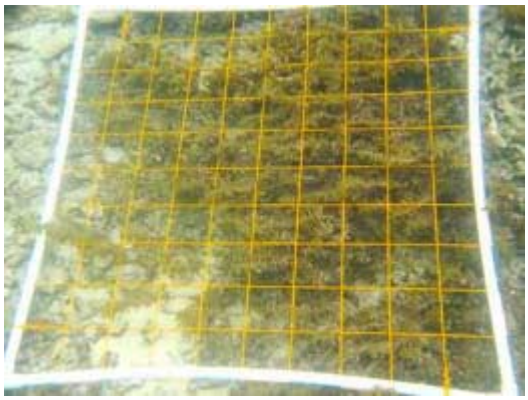
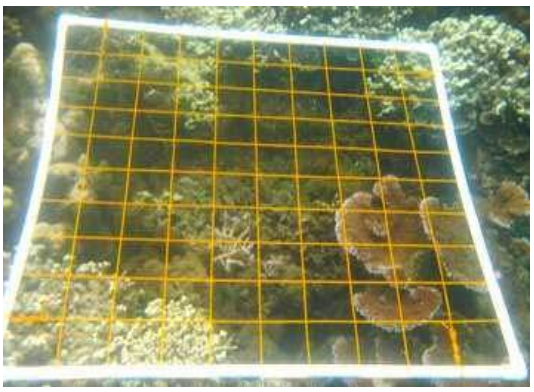
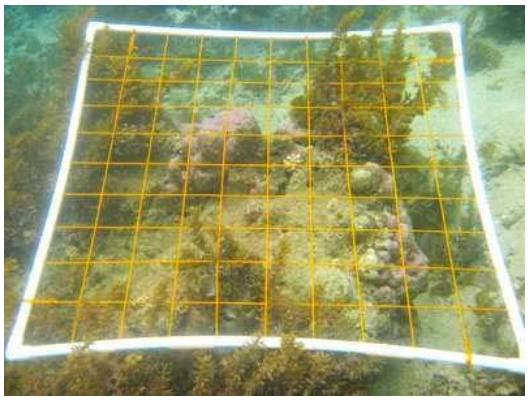
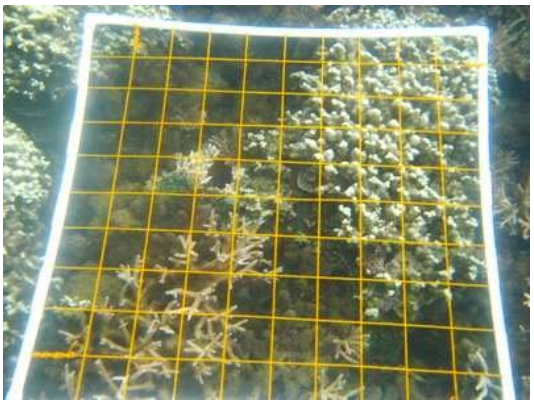
Source: Google Earth Image

Figure 3.5 Survey point at Palolo Deep

In 1994, baseline surveys described the reserve as “a thriving and diverse coral reef”. Main threats were identified as Cyclones (to the flats, not the deep), sedimentation especially from the Vaisigano River (by Aggie Grey’s hotel), sewage from Apia in general, and occasional outbreaks of the coral-eating starfish Crown of Thorns (*Acanthaster planci*) (Lovell, E).

This time, a rapid assessment of habitat in the reserve was carried out.
Figure 3.6 shows the photographs of the Palolo Deep at reef flat and edge of deep slope.
Although a few living coral boulders remain, reef flats were largely overgrown with *Sargassum* algae, indicative of nutrient enrichment and/or overfishing of herbivores.
One Greenfish *Stichopus chloronotus* Sea Cucumber was found, and no other macro invertebrates.
About 5m from the edge of the deep slope, *Sargassum* algae disappeared and coral

cover was high and varied, possibly indicating the presence of large numbers of herbivorous fish in the deep. Schools of surgeonfish and parrotfish were seen.

Reef flat by marker (2014)	Edge of deep slope (2014)
	
	
	

Method: 1m^2 quadrat
Location: Western edge (No. 193)

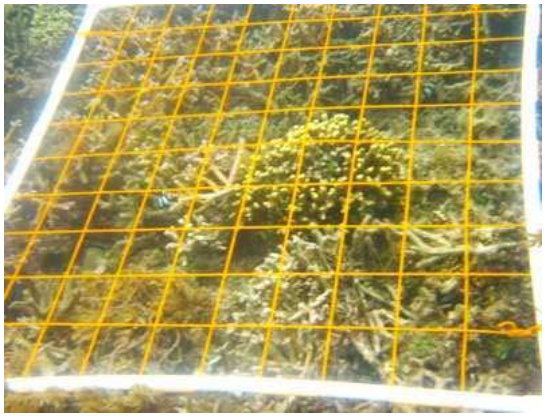
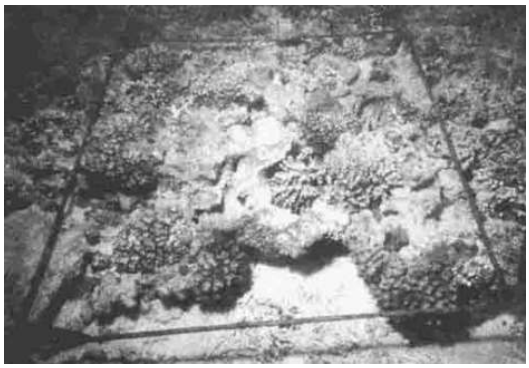
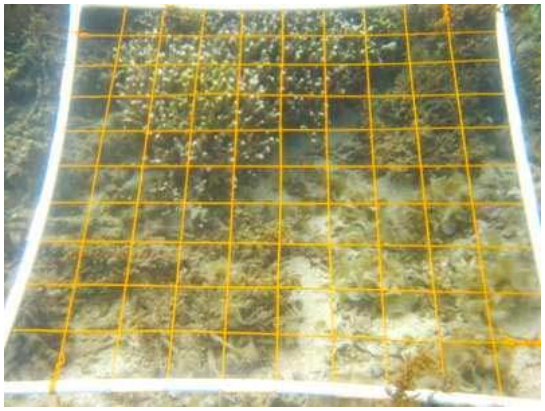
Figure 3.6 Photographs of Palolo Deep

Figure 3.7 shows the comparison of coral status between two surveys conducted in 1994 (*Lovell* E) and 2014 at eastern edge.

These quadrates were not set in the exact location of the 1994 surveys. Site 1 in 1994 is approximately 200m north of the eastern marker where the 2014 photographs were taken. However, the area is very homogenous and the photos are thought to be representative.

Coral type and cover appeared similar in both survey periods, although colonies seemed larger and more mature in 2014.

There was a marked increased in algal cover by 2014, with a large influx of *Padina* and *Sargassum* algae which may reflect either increased eutrophication, or a decrease in herbivorous animals, or both.

1994	2014
	
	
	

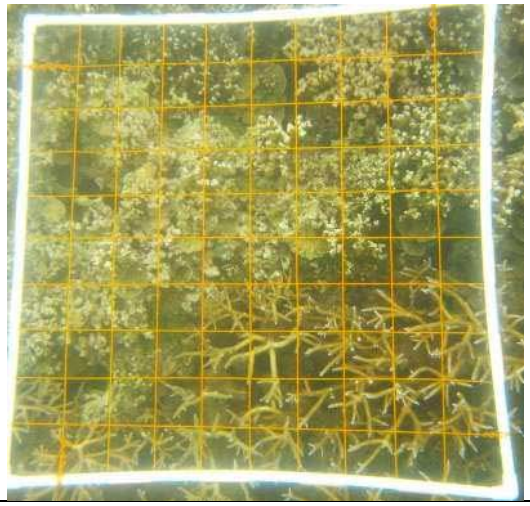
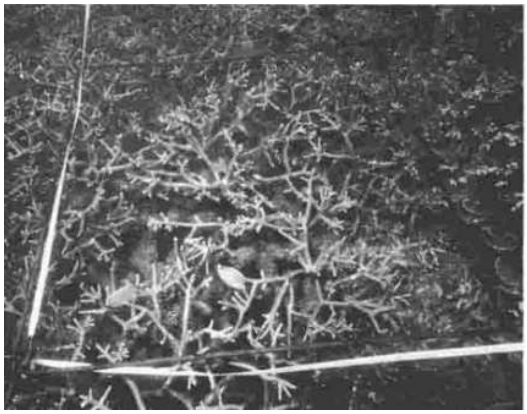
Method: 1m^2 quadrat
Location: Eastern edge (No. 195) in 2014
Sate 1 in 1994 (*Lovell*, E, 1994)

Figure 3.7 Comparison of the coral status between 1994 and 2014

Figure 3.8 shows the comparison of coral status between two surveys conducted in 1994 (*Lovell* E) and 2014 at southern edge.

These quadrates were not set in the exact location of the 1994 surveys. Site 2 in 1994 is

approximately 200m north of the marker where the 2014 photographs were taken. However, the area is very homogenous and the photos are thought to be representative. Coral type and cover appeared similar in both survey periods, although colonies seemed larger and more mature in 2014. In 2014 there was a heavier percentage of algae, but this was that created by damsel fish farms rather than the large areas of *Padina* and *Sargassum* algae seen on the flats.

1994	2014
	
	
	

Method: 1m^2 quadrate
Location: Southern edge (No. 195) in 2014
Sate 2 in 1994 (*Lovell*, E, 1994)

Figure 3.8 Comparison of the coral status between 1994 and 2014

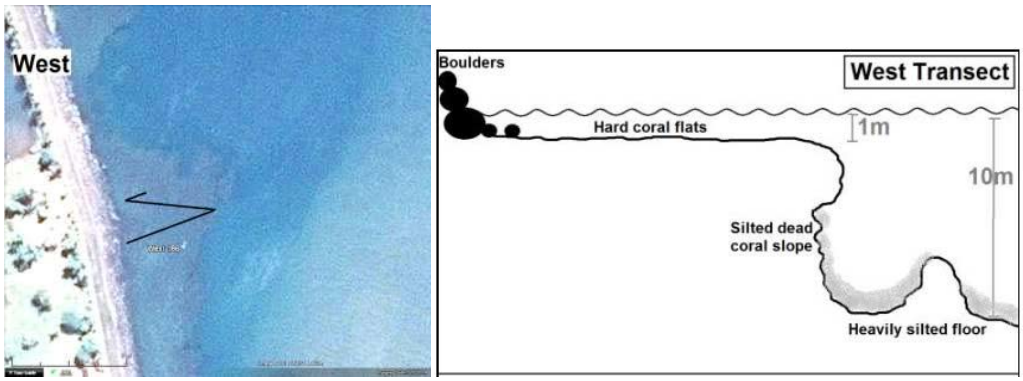
(3) Transect survey site (West)

Figure 3.9 show the survey line of transect survey and reef profile.

The reef top drops off into deeper water at about 80m from shore. The 100m West transect runs from shore to reef edge and back towards shore, staying within the reef flat habitat, at an average depth of 1.2 m (on a falling tide).

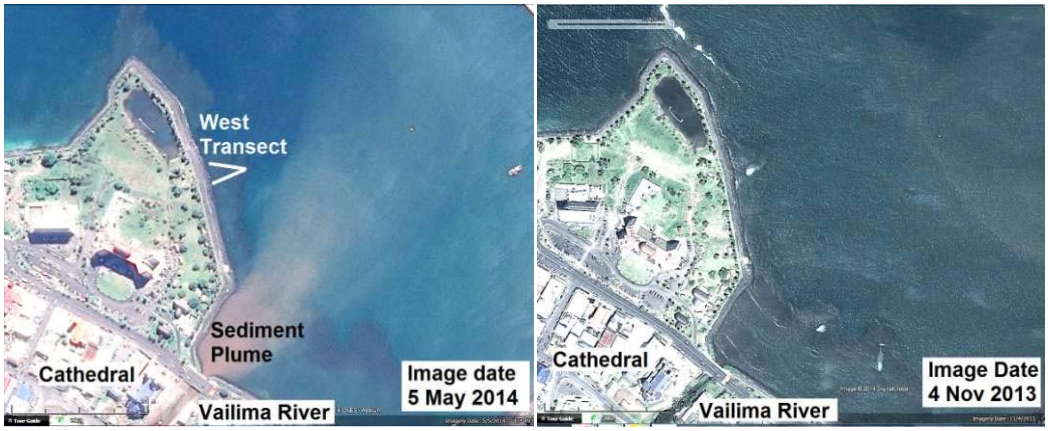
The profile starts with shallow reef flat extending about 80m from shore, with many small hard coral colonies, dropping to a heavily sedimentation slope and floor at 10m depth. This sedimentation seems to be caused by the Vailima River which enters the sea near the Cathedral. The Google image (see Figure 3.10) shows a large plume of dark area from the river mouth in May 2014, while the area cannot be seen in November 2013. This suggests turbid water flow into the area. At the time of the survey in 2014, construction work of river bed improvement was being carried out at the upstream of the Vailima River.

Figure 3.9 show the survey line of transect survey and reef profile.



Source: Google Earth Image

Figure 3.9 Transect survey line and reef profile (West)



Source: Google Earth Image

Figure 3.10 Sediment plumes from river

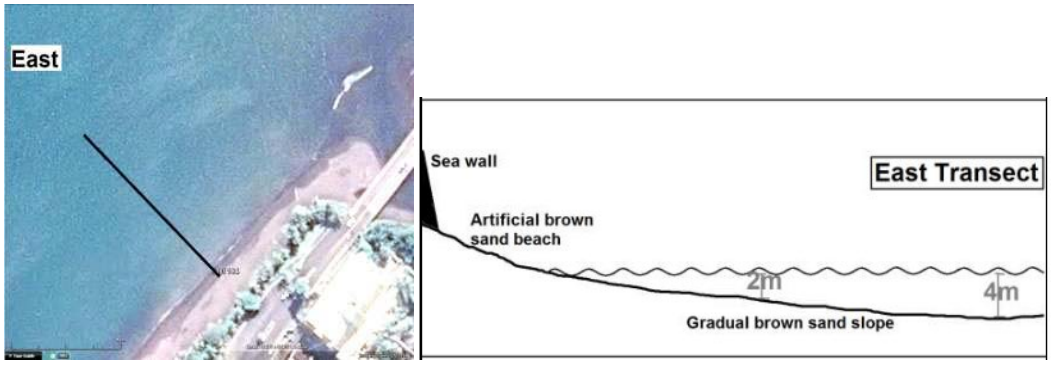
(4) Transect survey site (East)

Source: Google Earth Image

Figure 3.11 show the survey line of transect survey and reef profile.

Brown sand beach extends out to sea, sloping gradually. According to the interview with SPREP, the beach has recently been artificially created, using sand dredged from other sections of the bay, and is currently a featureless brown sand slope. The 100m East transect starts at the high tide mark and extends straight out from shore, reaching a depth of 4m.

The site is highly influenced by sedimentation from the Vaisicano River which enters the sea near Aggie Grey's hotel.



Source: Google Earth Image

Figure 3.11 Transect survey line and reef profile (East)

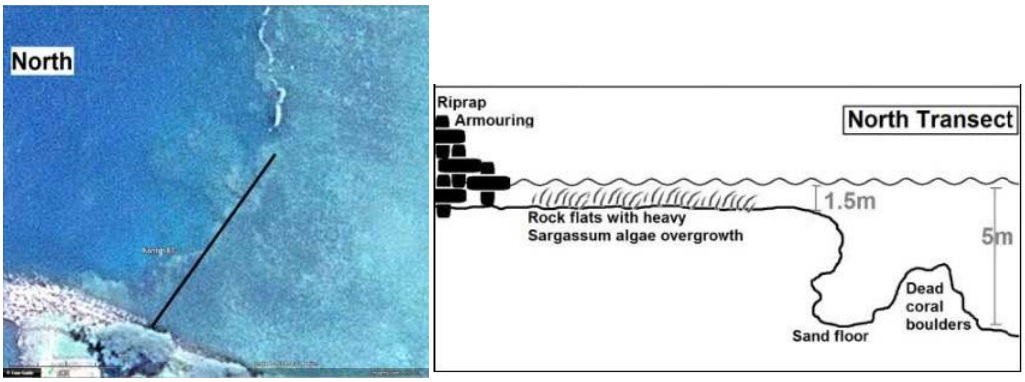
(5) Transect survey site (North)

Source: Google Earth Image

Figure 3.12 show the survey line of transect survey and reef profile.

The reef flats extend out northwards from the armored Port breakwater, dropping off to the side. The 100m North Transects was run out along the reef flat with dead coral at an average depth of 1.5m on a falling tide with a very heavy overgrowth of *Sargassum* algae. At the side of the reef it drops to a 5m sand and rubble floor with largely dead coral boulders and outcrops..

The site is 250m from the western boundary of the Palolo Deep Marine Reserve.



Source: Google Earth Image

Figure 3.12 Transect survey line and reef profile (North)

3.2.2 Benthic cover

(1) Composition of benthic cover

Using the Australian Institute of Marine Science (AIMS) life form categories, benthic type was recorded every 50 centimeters along a 100 meter long line transect at three sites.

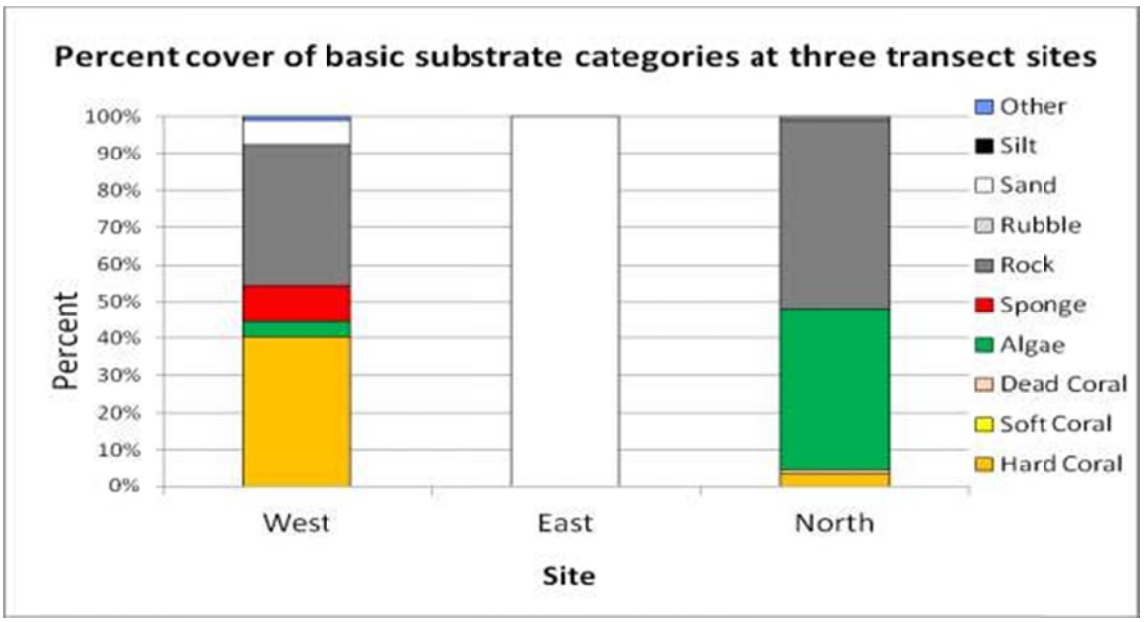


Figure 3.13 Benthic cover at three transect sites

The West transect had 40% hard coral cover 5% macro-algae & 45% dead coral rock and sand. There was 10% cover of an encrusting sponge, probably a *Dysidea* species. Figure 3.14 shows the condition of the West transect survey line.

Figure 3.14 Condition of transect survey line (West)

The East transect was, as has already been observed, 100% brown sand.
Figure 3.15 shows the condition of the transect East survey line.

Figure 3.15 Condition of transect survey line (East)

Figure 3.16 shows the condition of the North transect survey line.
The North transect was 51% bare reef substrate (rock) with 44% algal cover.
There were a few small hard coral colonies (4% cover) in gaps in the algae.

Figure 3.16 Condition of transect survey line (North)

(2) Coral

Figure 3.17 shows coral coverage and its composition at each transect survey line. The only area with significant coral cover was the West transect, near Government Buildings, which had many small coral colonies on the shallow reef top. The predominant corals were Digitate *Acropora* and Submassive *Pocillopora* species. A grey encrusting sponge, and a few patches of encrusting green tunicates were found overgrowing corals closer to shore.

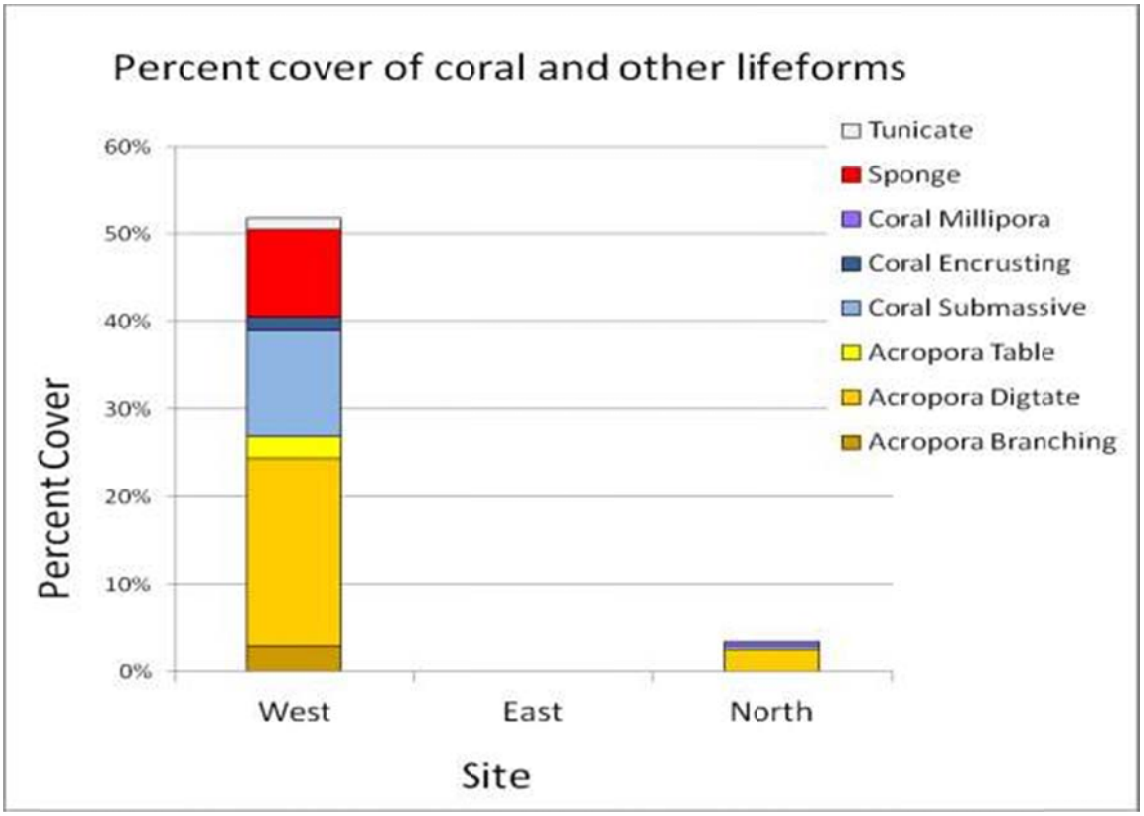
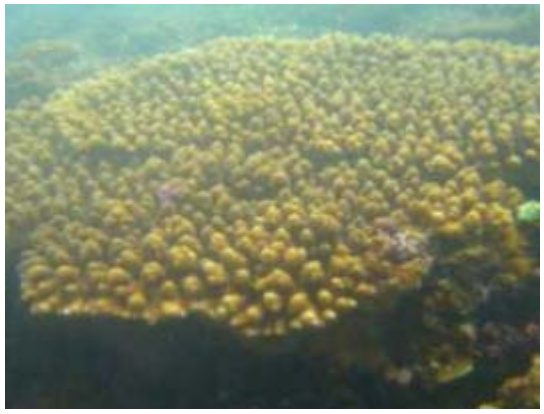


Figure 3.17 Coral coverage and its composition

Table 3.3 Sessile Invertebrates identified during surveys

Phylla	Group	Species	
		Common name	***Scientific name***
Coelenterata	Millipora	Encrusting Fire coral	*Millipora spp*
	Scleractinia	Massive (boulder) coral	*Porites spp,* poss *P. solida or lobata*
	Hard corals	Star boulder coral	*Diploastrea heliopora*
		Submassive coral	*Pocillopora damicornis*
			Pocillopora verrucosa
			Pocillopora meandris
			Pocillopora eyedouxi
		Encrusting coral	*Montipora spumosa*
			Favites spp
			Galaxea fascularis
		Table coral	*Acropora hyacinthus*
			Acropora poss *A. gemmifera* or *A. retusa* (uncommon)
		Branching staghorn	*Acropora formosa*
			Acropora loripes
		Digitate coral	*Acropora humilis*
Urochordata	Ascidiacea	Colonial tunicate	Possibly *Tridemnum spp*
Porifera	Sponges	Encrusting sponge	Possibly *Dysidea herbacea*



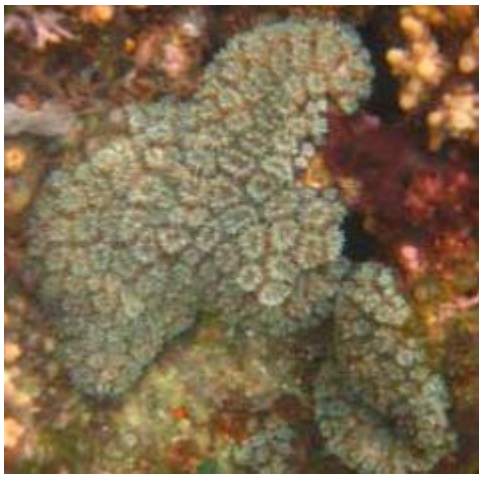
Tabulate Acropora
poss *A. gemmifera* (common)
or *A. retusa* (uncommon)

Tabulate Acropora *Acropora hyacinthus*

Digitate Acropora *Acropora*

Digitate Acropora

Digitate Acropora



Encrusting coral *Galaxea fascularis*

Figure 3.18 Photographs of hard corals

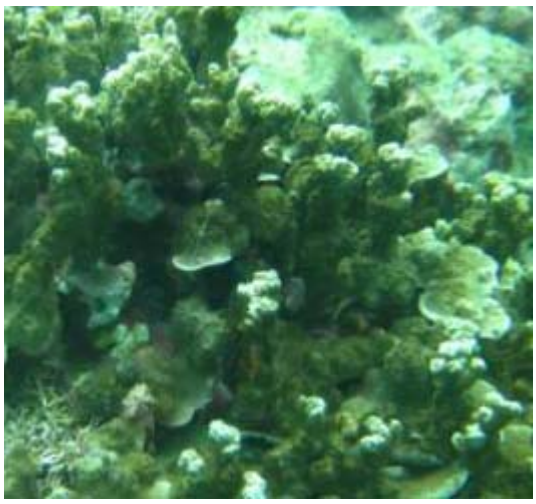
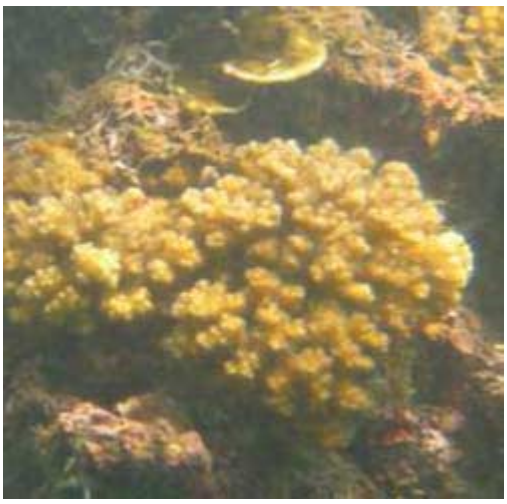
	
Massive coral *Porites spp, poss P. solida or lobata*	Encrusting Fire coral *Millipora*
	
Submassive coral *Monitpora spumosa*	Submassive coral *Pocillopora damicornis*
	
Submassive coral *Pocillopora verrucosa*	Submassive coral Poss *Pocillopora meandrina* or *P eyedouxi*

Figure 3.19 Photographs of hard corals

No temperature-related coral bleaching was seen. One Crown of Thorns coral-eating starfish was seen and on a few *Acropora* and *Pocillopora* species of hard coral. There were aggregations of coral predacious “Drupe” snails. Patches of invasive sponges and tunicates were seen on the western transect, possibly indicative of increasing nutrient levels. The largest adverse impact on coral health in the area appears to be heavy sedimentation and poor water quality as described in Section 3.2.1 (3) at Page 33.
Figure 3.20 shows coral damages by biological causes and Figure 3.21 shows coral damages by sedimentation at West transect site.

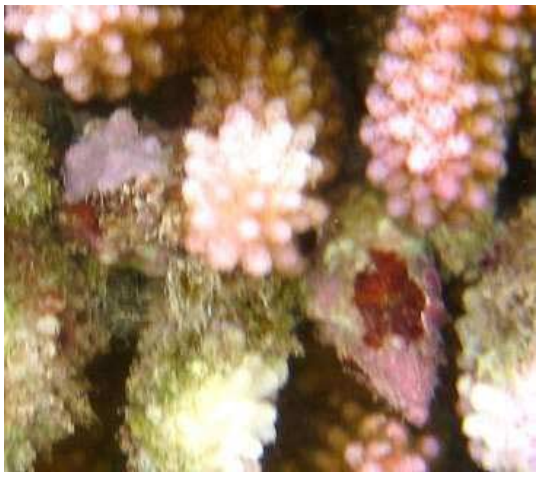
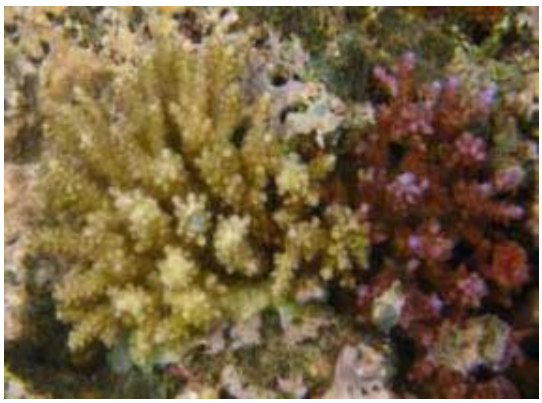
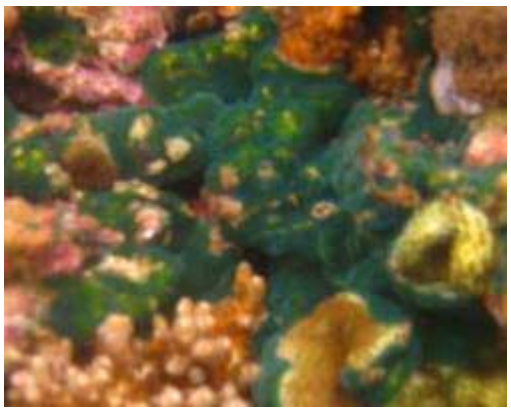
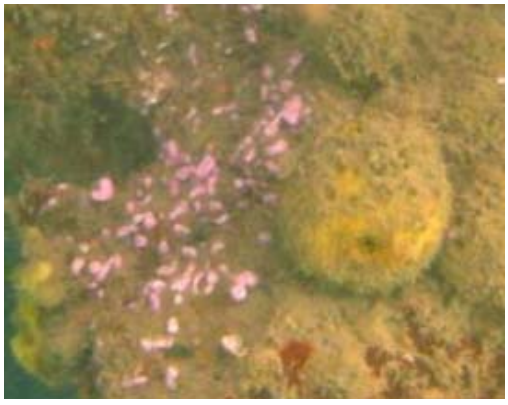
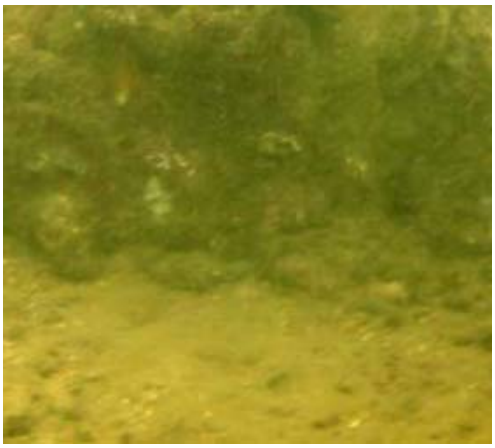
	
Corallivorous snails *Drupella conus*	Crown of Thorns star eating coral at Palolo Deep
	
Dead patch on *Pocillopora* coral colony caused by *Drupella* predation	Dead *Acropora* coral (left), living coral (right), probably due to Drupella predation
	
Encrusting Sponge, probably *Dysidea spp*	Encrusting Tunicate, possibly *Tridemnum spp*

Figure 3.20 Photographs of coral damage

	
Deep, soft sediment 10m deep on the sea bed off the West transect, near the Government Buildings	Dead corals covered in silt at 6m deep on the reef slope off the West transect, near the Government Buildings
	
Halimedes algae covered in silt at 8m deep on the reef slope off the West transect, near the Government Buildings	Sponge covered in silt at 6m deep on the reef slope off the West transect, near the Government Buildings
	
Sedimented reef at 4m deep at water sample site E, within the sediment plume*	Sedimented sea floor at 5m deep at water sample site E, within the sediment plume*

*: Refer to Figure 3.10 for the sediment plume.

Figure 3.21 Photographs of coral damage caused by sedimentation (West transect)

(3) Macro-alga

Macro-Algae are a normal component of reefs, particularly of fringing reef flats, but large or unusual overgrowths can be an indication of overfishing of grazing fish and other animals, and/or of nutrient enrichment such as farm or urban sewerage run off. The large cover of *Sargassum* on the North Transect is strongly suggestive of both these factors, and overfishing in particular, as far less Algae is found closer to Palolo Deep Marine Reserve where there is a large population of grazing Parrot and Surgeonfish.

Blue-Green Algae (*Cyanobacter*) can be an indication of land-based eutrophication. It was not found on the shallow reef transects, but clumps occurred on the reef floor of the North Transect, possibly indicating nutrients in settling sediments coming from the port.

Figure 3.22 shows coverage of macro-alga, Table 3.4 lists macro-alga identified during the survey and Figure 3.23 shows photographs of macro algae, respectively.

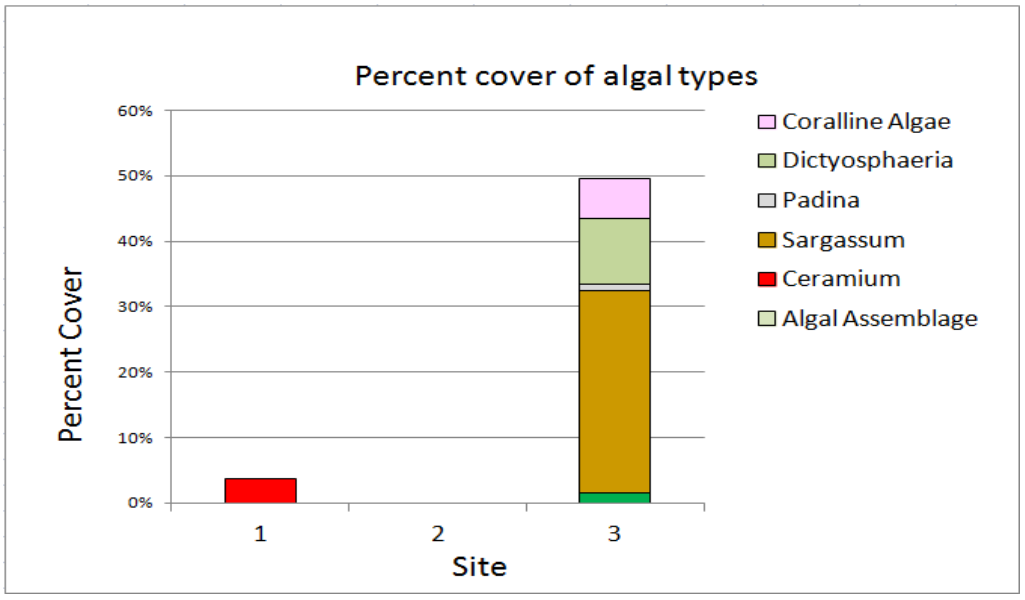


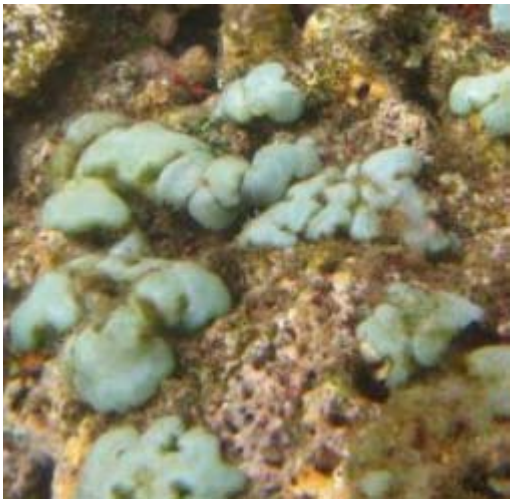
Figure 3.22 Coverage of macro-alga at three transect survey line

Table 3.4 List of macro-alga identified during the survey

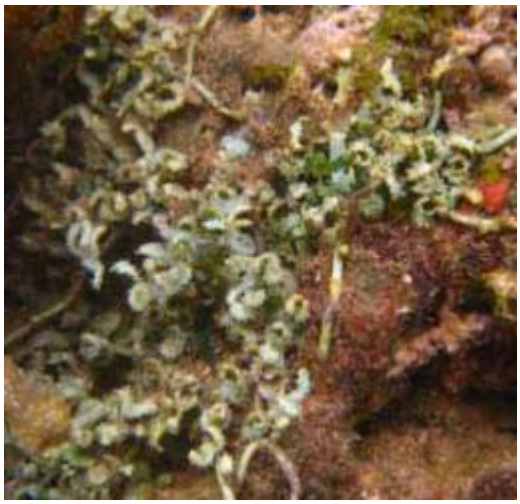
Group		Species	Where seen
Chlorophyta	Green Algae	*Halimedes spp*	North transect
		Dictyosphaeria versluysii	North transect
		Caurlerpa serrulats f. spiralis	North transect
Rhodophyta	Red Algae	*Ceramium spp*	West transect
Phaeophyta	Brown Algae	*Sargassum spp* poss *S. cristaefolium*	North transect
		Padina spp. poss *P Sanctae.crucis* and *P. melemele*	North transect
Cyanobacter	Blue-green Algae	Red filamentous, poss *Phormium spp*	North transect

Sargassum spp poss *S. cristaefolium*

Padina spp. poss *P Sanctae.crucis* and *P. melemele*



Dictyosphaeria versluysii | *Ceramium spp*



Caurlerpa serrulats f. spiralis

Cyanobacter, poss *Phormium spp*

Figure 3.23 Photographs of Macro Algae

(4) Macro invertebrates

Very few invertebrates of any fisheries importance were seen, indicating regular subsistence level collection, particularly on the Northern reef. The two Sea Cucumber species found were of low commercial value, and the only Giant Clam was a juvenile about 5cm long. *Linckia* Starfish are not collected for food and were more common.

Two coral damaging species were found on the West Transect, *Drupe* snails and Crown of Thorns Starfish (see Figure 3.24).

Crown of Thorns Star

Acanthaster planci

Blue Sea Star

Linckia laevigata

Juvenile Giant Clam

Tridacna maxima

Figure 3.24 Photographs of invertebrates

(5) Fish

Figure 3.25 shows key fish density.

Over 70% more key fish of local fisheries importance were seen on the North transect than on the West. No fish at all were seen on the East transect. No groupers were seen anywhere and only a single sweetlips, species that are targeted by spear-fishers.

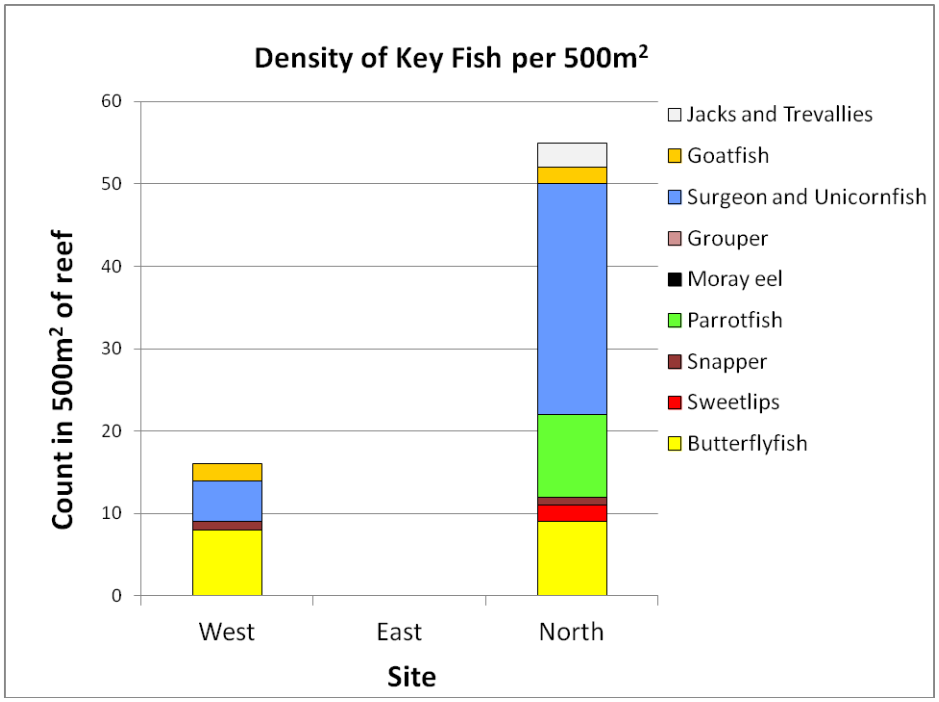


Figure 3.25 Bar chart of Key Fish Density at the three transect sites

Surveys of all fish species, not just targeted species, showed 43% more fish and 63% more species of fish on the North site than the West (no fish on the East Transect). The North transect had both higher species diversity and fish numbers, particularly of those fish targeted by local fishing practices, than the West reef transect (see Figure 3.26).

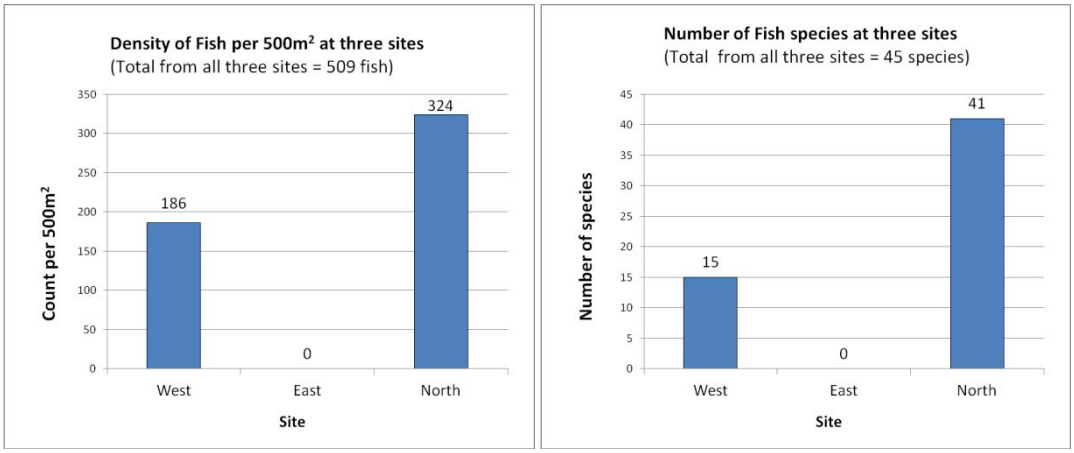


Figure 3.26 Bar Charts of number of all fish & number of all fish species seen during surveys

Figure 3.27 shows the size of fish at each transect site.

The fish seen on the West transect were very small, all 10cm long or below, and most below 5 cm long. Most of the fish seen on the North transect were between 6 and 10 cm long, with a few between 11 and 20cm. The only fish over 20cm long was a single Small-tooth Jobfish (Snapper family) seen on the reef edge on the North transect.

As shown in Figure 3.28, most of the species seen were *Pomacentridae* (Damselfish), *Labridae* (Wrasse), *Chaetodontidae* (Butterflyfish) and *Acanthuridae* (Surgeonfish). Of these, only the Surgeonfish are of local fisheries importance, the other three groups being made up of small fish not targeted by fishers and not taken by spear-fishing. The pattern of species richness is typical of over fished reefs.

No species of national or international conservation significance were found, and no species from the IUCN Red List were seen.

One species of local interest was found, but the sighting is unconfirmed: The small damsel fish known as the Blueline Demoiselle *Chrysiptera caeruloelineata* may have been found in a dark color phase previously only reported from Rowley Shoals in Australia. A better photograph is needed for confirmation.

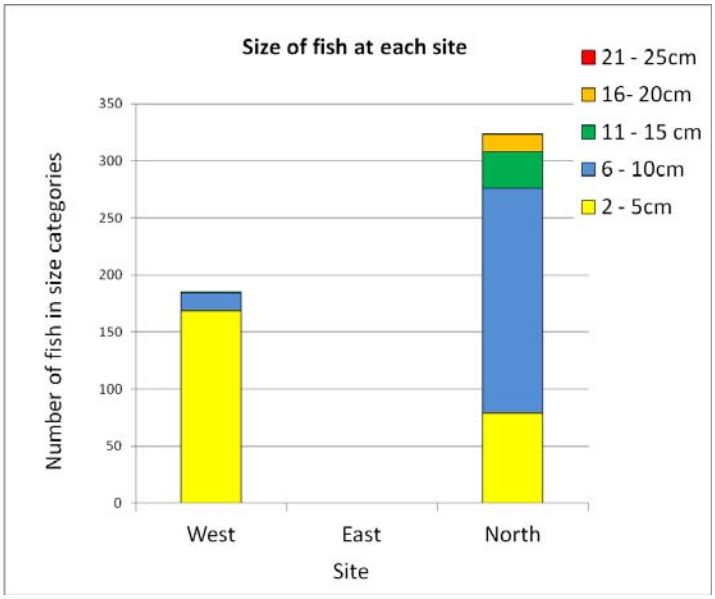


Figure 3.27 Bar chart of sizes of fish at the three transect sites (in size categories)

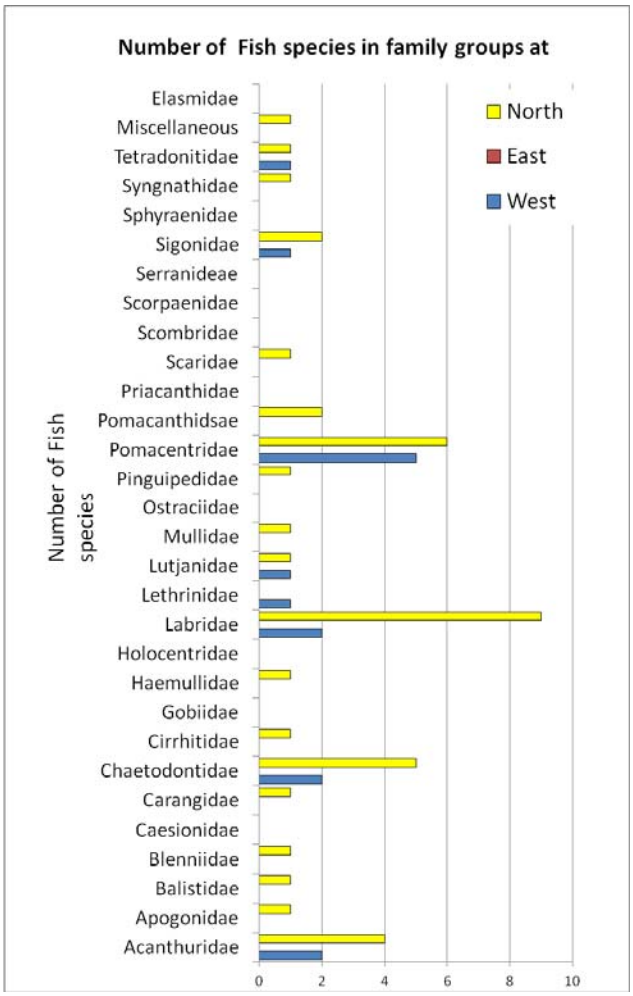
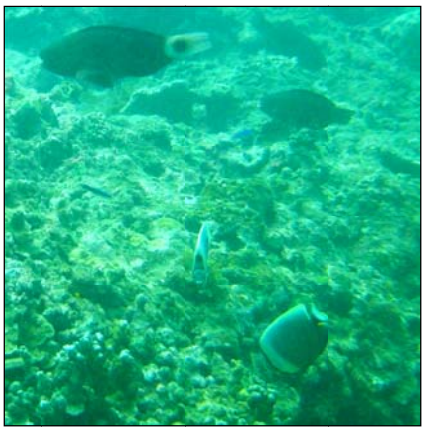


Figure 3.28 Bar chart of fish families seen at the three transect sites

Table 3.5 Fish species seen during surveys

English Name	Samoan name	*Scientific name*	*Notes*
Twospot bristletooth	Ponepone	*Ctenochaetus binotatus*	
Convict surgeon	Manini	*Acanthurus triostegus*	
Striped surgeon	Alogo	*Acanthurus lineatus*	
Whitespotted surgeon	Maogo	*Acanthurus guttatus*	
Orangespine unicorn	Umelei	*Naso lituratus*	
Fivelined cardinal	Fu tusiloloa	*Cheilodipterus quinquelineatus*	
Orangestriped trigger	Sumu aimaunu	*Balistapus undulatus*	
Scaleeating fangblenny	Mano'o	*Plagiotremus tapienosoma*	
Bluefin trevally	Malauli apamoana	*Caranx melampygus*	
Redfin butterfly	Tifitifi manifi	*Chaetodon lunulatus*	
Reticulated butterfly	Tifitifi maono	*Chaetodon reticulatus*	
Saddled butterfly	Tifitifi tuauli	*Chaetodon ephippium*	
Speckled butterfly	Tifitifi muamai	*Chaetodon citrinellus*	
Vagabond butterfly	Tifitifi matapua'a	*Chaetodon vagabundus*	
Arceye hawk	Lausiva	*Paracirrhites arcatus*	
Oriental sweetlips	Mutumutu	*Plectrorhinchus orientalis*	
Bluestreak cleaner wrasse	Sagale mo'otai	*Labroides dimidiatus*	
Bird wrasse	Gutusi'u	*Gomphosus varius*	
Blackedge thicklip wrasse	Sugale laugutu	*Hemigymnus melapterus*	
Checkerboard wrasse	Sugale a'au	*Halichoeres hortulanus*	
Dusky wrasse	Sugale lalafi	*Halichoeres marginata*	
Floral wrasse	Lalafi matapua'a	*Cheilinus chlorourus*	
Redshoulder wrasse	Lape a'au	*Stethojulis bandanensis*	
Sixbar wrasse	Sugale a'au	*Thalassoma hardwicke*	
Slingjaw wrasse	Si'umutu	*Epibulus insidiator*	
Surge wrasse	Patagaloa	*Thalassoma purpureum*	
Thumbprint emperor	Filoa vai	*Lethrinus harak*	
Smalltooth jobfish	Palu aloalo	*Aphareus furca*	
Multibarred goat	Matulau	*Parupeneus multifasciatus*	
Speckled sandperch	Ta'uto	*Parapercis hexophtalma*	
Ambon chromis	Tu'u'u palevai	*Chromis amboinensis*	
Blueline demoiselle	Tu'u'u	*Chrysiptera caeruloelineata*	
Blueline demoiselle - dark "Rowley shoals" variation*			*To be confirmed
Dusky gregory	Tu'u'moi	*Stegastes nigricans*	
South seas devil		*Chrysiptera taupou*	
Surge demoiselle – blue phase	Tu'u'u tulisegasega	*Chrysiptera leucopoma*	
Surge demoiselle – brown phase	Tu'u'u alamu	*Chrysiptera leucopoma*	
Banded sergeant	Mutu	*Abudefduf septemfasciatus*	
Lemonpeel angel	Tu'u'u sama	*Centropyge flavissimus*	
Regal angel	Tu'u'u moana	*Pygoplites diacanthus*	
Bullethead parrot	Fuga gutumu	*Scarus sordidus*	
Goldspotted rabbit	Io	*Siganus punctatus*	
Scribbled rabbit	Anefe and Pa'ulu	*Siganus spinus*	Traditionally

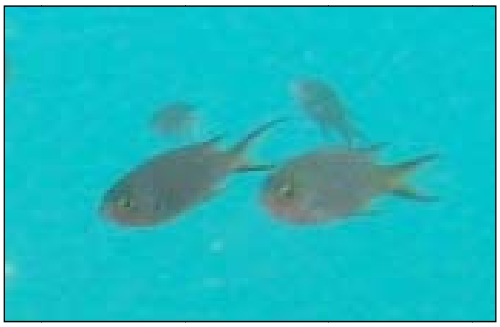
English Name	Samoan name	*Scientific name*	*Notes*
			significant
Scribbled pipefish	n/a	*Corythoichthys intestinalis*	
Spotted toby	Sue mimi	*Canthigaster solandri*	
Sweeper	Manifi	*Pempheris spp*	



Bullethead Parrotfish & Reticulated Butterflyfish

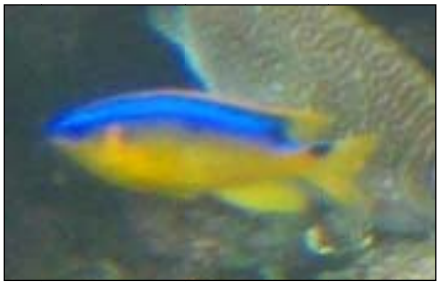
Scribbled Rabbitfish *Siganus spinus*

2-spot Bristletooth (Surgeonfish), Multibar Goatfish and Striped Surgeonfish

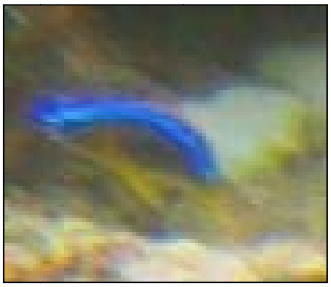


Ambon Chromis *Chromis amboinensis*

Scribbled pipefish *Corythoichthys intestinalis*



Surge demoiselle *Chrysiptera leucopoma*



Blueline demoiselle? *Chrysiptera caeruloelineata?*

This is a very poor picture and identification cannot be confirmed, see note on page 27

Table 3.6 Photographs of fish seen during surveys

3.2.3 Fishing status around the project site

Interviews of key personnel at the Department of Fisheries and the Secretariat of the South Pacific Regional Environment Program confirmed the information given by local fishermen and vendors at the Fishermen's Wharf market.

There are no official marine protected areas within the Apia Bay. And there is no officially permitted fishing within the bay. Alias (local catamarans) fish at night well outside the bay and offshore of the reefs. Local spear-fishermen operate at night on reef tops and slopes away from the bay.

However, informal recreational and small-scale artisanal fishing does take place within the bay: netting around both river mouths, spear-fishing on the West reef and rod fishing in front of the Vaisigano River was observed and reported to be frequent.

On Saturday nights local youths night fish using spears on the reef flat outside the breakwater and up to the edge of the Paolo Deep, probably encroaching into the reserve but not into the deep itself.

Figure 3.29 shows photographs of local fishing,

Table 3.7 shows fish species caught by net fishermen and Figure 3.30 shows Photographs of fish caught by net fishermen, respectively.

"Alia": 9.0m long aluminum catamaran vessels introduced to Samoa in the 1970's to enable indigenous fishers to take part in deep-water bottom fishing and trolling around Fish Attraction Devices (FADs), troll nightly outside Apia Bay.

Their catch, as well as that brought in by night spear fishers from surrounding reefs, is brought into the Apia Fishermen's Wharf market every morning. One spear fisher said he swam off the reef edge for 4 hours that night.

Net fishing: Every morning (on falling tides) of the survey, one dugout canoe with two fishermen from an inland community were seen setting nets across the mouths of the rivers flowing into Apia Bay.

After 2 hours, nets were pulled in and a mixed catch of Mangrove Crabs and Juvenile pelagic and reef fish was taken. Fishers reported that they would sell their catch to Chinese Restaurants.

Line and Spear Fishing: On two out of the four days of the survey period, local fishers were seen either snorkeling with spears, or line fishing, in the shallow waters inside Apia Bay. This is a popular recreation for many local people.

Local sources reported that night spear fishing is practiced every Saturday night on the reef immediately north of the port breakwater, for fish to eat and present at family and church functions on a Sunday.

Figure 3.29 Photographs of local fishing observed during surveys

Table 3.7 Fish species caught by net fishers

English Name	Samoan name	*Scientific name*	Notes
(Net-fishing in front of creek near Cathedral in Apia Bay)			
Coachwhip Trevally		*Carangoides oblongus*	Juveniles 25 – 30cm
Sixfeeler Threadfin		*Polydactus sexfilis*	
Narrow-barred Spanish Mackerel (Walu)		*Scomberomorus commerson*	Juveniles 25 – 30cm **ICUN Red List: Near Threatened**
Acute-jawed Mullet	‘anae	*Neomyxus leuciscus*	
Green Mangrove Crab	Pa’alimago	*Scylla paramamosian*	

Green Mangrove Crab *Scylla paramamosian*

Fish catch

Juvenile Coach-Whip Trevally

Carangoides oblongus

Sixfeeler Threadfin

Polydactus sexfilis

Juvenile Narrow-barred Spanish Mackerel (Walu) *Scomberomorus commerson*

ICUN Red List: Near Threatened

These fish are not commonly seen at this size, usually caught as adults off deep water drop offs.

Their presence here indicates an important juvenile estuarine habitat

Figure 3.30 Photographs of fish caught by net fishermen in Vailima estuary inside Apia Bay

3.3 Discussion

3.3.1 Habitat type

The mouths of the two rivers flowing into the bay, the Vailima and Vaisigano Rivers, have been severely modified from natural river courses into urban canals which frequently cause sediment plumes into the bay. However, fishing catches from these river mouths show that they are still integral to the marine ecosystem, being used as juvenile habitat by important marine fish such as Spanish Mackerel and Trevallies.

The marine habitats within the Apia Bay range from shallow reef flats with relatively high coral cover along the western seawall, to brown sand slopes in the centre, and drifts of deep silt along the eastern port boundaries. The entire area is badly affected by land-based sedimentation. Seawalls and breakwaters have been built on top of what were once probably healthy reef and mangrove areas.

Immediately outside the port, north of the breakwater, the reef is mostly dead rock with high levels of algal overgrowth, probably indicative of a combination of nutrient enrichment (sewage etc) and overfishing of herbivorous fish and invertebrate animals. The only healthy coral ecosystem seen was inside the Palolo Deep Marine Reserve, 250m east of the edge of the reef.

3.3.2 Benthic cover

The highest amount of living coral inside the bay was on the shallow reefs of the western coast, where 40% hard coral cover was found, even though water turbidity was high due to the sediment plume from the Vailima River. This percentage would be considered High coral cover within the Ministry of Agriculture and Fisheries' Village Fisheries Reserves analysis (*Samoa State of Environment report 2013*).

It is likely that sediments do not settle on the reef top due to wave action. At greater depths the reef was badly affected by sedimentation, and most coral was dead.

10% cover of an overgrowing sponge and a small amount of an encrusting tunicate suggest that nutrient levels (possibly from sewage) may be rising in the area, and could adversely impact coral health in the future.

The area between the two rivers has recently had an artificial beach constructed on it, and the marine habitat is currently featureless brown sand.

In contrast the section outside the bay, immediately north of the port breakwater, had less than 4% living coral, but more than 40% algae, mostly large fields of the brown algae *Sargassum* with some patches of *Padina*. This was also seen inside the Palolo Deep Marine Reserve, where past surveys in 1994 reported only trace amounts of brown algae. This increase in brown algae could be the result of two main changes since 1994: an

increase in nutrient levels in the water, and a decrease in herbivorous animals that would normally graze on such algae.
Increased nutrient levels could be related to an increasing urban population with inadequate sewage treatment, agricultural fertilizers and cattle waste carried down rivers into the bay, or to pollution from sources in the port.
Decrease in herbivores is probably due to over fishing and overharvesting of invertebrates such as Sea Urchins and Sea Cucumbers.
All reef areas in Samoa appear to be experiencing downwards trends in coral cover over time. (*Samoa State of Environment report 2013*).

3.3.3 Macro-invertebrates

Very few Macro-invertebrates of any fisheries importance were found, a probable result of long-term over harvesting and sedimentation. Two destructive species were seen, in low densities: the Crown of Thorns Starfish, which has been causing widespread coral damage in Samoa for several years but is now apparently dropping off in number, and the Drupella snail, which was thought to be responsible for most of the recent coral death seen.

3.3.4 Fish

Fish observed on the reef during surveys were small species of no fisheries or conservation importance, and were found in low densities. Patterns of fish families suggest that these reefs have been over fished for a long period of time.
One species of local interest was found, but the sighting is unconfirmed: the small damsel fish known as the Blueline Demoiselle *Chrysiptera caeruloelineata* may have been found in a dark color phase previously only reported from Rowley Shoals in Australia. A better photograph is needed for confirmation.
The only IUCN Red-listed fish found within the bay were juvenile Spanish Mackerel caught by net-fishers in the Vailima River mouth (refer to Table 3.8 for the IUCN Red list fish species). Their presence emphasizes that, even in a degraded state, these rivers are important components of the marine ecosystem, and as a juvenile habitat for a near-threatened species, their condition should be better controlled.
All other species of interest or IUCN Red-listing were caught well away from Apia Bay.

Table 3.8 IUCN Red List Fish Species for Samoa

Table 19: IUCN Red Listed Marine Fish Species of Samoa

Species #	Scientific name	English name	Samoan name	Threat category	Population Trend
1	Cheilinus undulatus	Humphead Wrasse	Malatea	Endangered	Decreasing
2	Epinephelus lanceolatus	Giant Grouper	Ata'ata-uli	Vulnerable	Decreasing
3	Nebrius ferrugineus	Nurse shark	Malie	Vulnerable	Decreasing
4	Negaprion acutidens	Lemon shark	Naiufi	Vulnerable	Decreasing
5	Rhicodon typus	Whale shark	Faaeme	Vulnerable	Decreasing
6	Rhyncobatus djiddensis	Guitarfish	No Samoan name	Vulnerable	Not known
7	Sphoeroides pachygaster	Puffer fish	Sue	Vulnerable	Not known
8	Bolbometopan muricatum	Bumphead Parrot Fish	Galo	Vulnerable	Decreasing
9	Stegostama fasciatum	Zebra Shark	Malie	Vulnerable	Decreasing
10	Carcharhinus longimanus	White Tip Shark	Malie Aloalo	Vulnerable	Decreasing
11	Carcharhinus limbatus	Black TipShark	Malie Aloalo	Vulnerable	Not known
12	Plectropomus areolatus	Polkadot Cod	Ata'ata-utu	Vulnerable	Decreasing
13	Plectropomus laevis	Blacksaddled Coral Grouper	Ata'ata-utu	Vulnerable	Decreasing

Source: Based on CI-Pacific Islands Programme, MNRE and SPREP. 2010. Priority Sites for Conservation in Samoa: Key Biodiversity Areas. Apia, Samoa.

3.3.5 Fishing status around the Apia Bay

Apia Bay is not itself a focus of commercial or large scale artisanal fishing, with the Alia boats based at the Fishermen's wharf heading out to deep seas outside the reefs, and the artisanal reef fishermen spear fishing off the reef slopes outside villages away from Apia. Small scale artisanal and recreational fishing is commonly carried out around and between the two river estuaries, and on the reef flats outside the port, north of the breakwater. All fishing appears to be done by ethnically indigenous Samoans, and most seems to be night fishing, which has frequently been shown to be an unsustainable practice.

The only Marine Protected Area in the immediate vicinity is the Paolo Deep Marine Reserve, formed in1974. This reserve is north east of the port breakwater, and starts only 250m from the reef edge. Although not literally within the bay area, it is close enough that port development could easily impact the sensitive coral habitats of the "Deep" itself, as sediments and pollution would be likely to collect in the lagoon. At this time the corals of the deep lagoon appear to be as or more healthy than they were in 1994, but algal growth and overfishing on the flats have resulted vast *Sargassum* meadows on the shallow reef, showing that the area is vulnerable to local impacts.

Palolo Deep reef flats, and the outer reef flats on the west side of the bay channel, are important locations for coral and invertebrate collection, used as a nursery site for village based reef restoration projects by the Department of Fisheries. Damage to these reef

stocks would have significant impacts on these Community Based Fisheries Management Programs (CBFMP) projects across Samoa.
No areas of traditional cultural significance were identified.

4 Conclusion

There are two rivers flow into Apia Bay and influence to the water quality by the river water flow is dominant in the bay. Total Coliforms is high due to untreated/overflowed sewage water from the rivers. And turbidity (Suspended Solid) is high near the river mouths. However, there is no particular negative value that port activity causes And negative impact to water quality in Apia Bay by port operation at moment is not seen.

Two parameters in bottom sediment, Chromium and Nickel, exceeded the ANZECC 2000 trigger values. The cause of the exceedance might be natural occurrence enhanced by river water flow. Some parameters shows the cause by port operation, but the concentrations are within ANZECC 2000 trigger values. Since dredging activity is not planned in this project, significant disturbance of bottom sediment, which leads to elution of harmful substances from bottom sediment into the water, will not be caused. So that major impact by the substances in bottom sediment cannot be considered. However, incase maintenance dredging would be planned in the future, further study of sediment quality and countermeasure to avoid elution of harmful substances into the water environment shall be considered.

The marine ecosystems of Apia Bay have been significantly changed and negatively impacted, but not yet completely destroyed. Sea walls enclose the entire bay and have cut off most land/sea connectivity, making it impossible for turtles or land crabs to utilize the area for breeding.
The rivers discharge highly turbid water into the bay, but still function as a juvenile habitat for important reef fish. The reefs within the bay have been damaged by excessive sedimentation, although they still bear some living corals, especially in shallow waters.
There are no protected areas within the bay, but the Palolo Deep Marine Reserve is very close to the northern port breakwater, and could easily be impacted by poorly designed development in that area. The reserve is important to local tourism and as a stock reservoir for Dept of Fisheries reef restoration projects across the country.
No organized fishing goes on within the bay, but recreational and small scale artisanal fishing is carried out in all shallow areas, particularly at the weekends.
No Critically Endangered or Endangered marine life, or species of conservation significance were found in the bay except for juvenile Spanish Mackerel (ICUN Red List Near Threatened status) caught from the Vailima River mouth.
Apia Bay has, overall, a damaged and limited, but still functioning marine ecosystem. The overall ecological value of the shallow reef habitats is less than other reefs in the larger area,

particularly when compared to the neighboring Palolo Deep marine reserve, but the river mouths and deeper reefs include juvenile habitat for some important fisheries species.

5 References and Bibliography

Ah-Leong Samuelu, J. and Sapatu, M. 2007
Status of Coral Reefs in Samoa
Fisheries Division Ministry of Agriculture and Fisheries

Allen, G., Steene, R., Humann, P., DeLoach, N 2003
Reef Fish Identification, Tropical Pacific
New World Publications ISBN 1 878348 36 1

Colin, P. L. and Arneson, C. 1995
Tropical Pacific Invertebrates
Coral Reef Press ISBN 0 9645625 0 2

Fisheries Division 2013
Annual Report 2012-2013
Ministry of Agriculture and Fisheries

Food and Agriculture Organization of the United Nations 2009
National Fishery Sector Overview – Samoa
Fishery and Aquaculture Profiles

Gillett, R. 2011
Samoa pp 188 – 200
In Fisheries of the Pacific Islands: Regional and National Information
FAO Regional Office for Asia and the Pacific, Bangkok, Thailand
RAP publication 2011/03, 279 pages

Gosliner T.M., Bebrens, D.W., Williams, G.C 1996
Coral Reef Animals of the Indo Pacific
Sea Challengers ISBN 0 930118 21 9

Goldin, M.R
Field Guide to the Samoan Archipelago: Fish, Wildlife, and Protected Areas
The Bess Press, Honolulu, Hawai'i ISBN 1-57306-111-5

Kelly, R

The Coral Finder Indo Pacific
The Australian Coral Reef Society ISBN 978 0 646 52326 2

Littler D.S. and Littler M.M
South Pacific Reef Plants
Off-shore Graphics Inc ISBN 0 9678901 9 5

Lovell, E.R and Toloa, F 1994
Palolo Deep National Marine Reserve: a survey, inventory and information report
SPREP report and study number 84 ISBN 982-04-0111-9

Ministry of Natural Resources and Environment 2013
Samoa 2013 State of the Environment Report
Government of Samoa

Tiitii, U., Sharp, M. and Ah-Leong J 2014
Samoa Socioeconomic Fisheries report 2011/2012
Fisheries Division, Ministry of Agriculture and Fisheries, Apia, Samoa

Veron, J.E.N 2000
Corals of the World: Volumes 1, 2 and 3
Australian Institute of Marine Science ISBN: 0 642 32236 8; 0 642 32237 6; and 0 642 32238 4

Naito, R., Nakamura, Y., Urase, T., June 2008
Relationship between sediment quality and benthic macrofauna in Japanese ports and harbors -Technical Notes of the Port and Airport Research Institute No. 1174-
Independent Administrative Institution, Port and Airport Research Institute, Japan

Supplement A Photographs of the survey sites

Photograph 1: View from Site A.

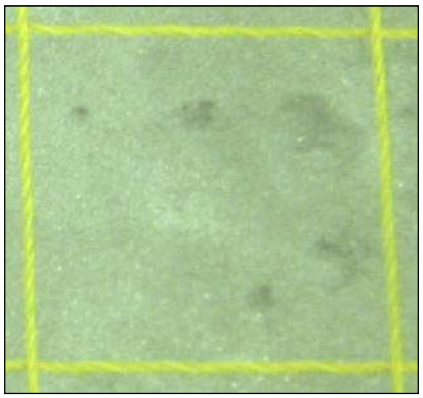
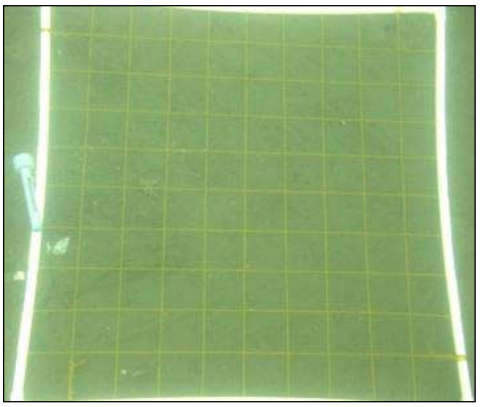
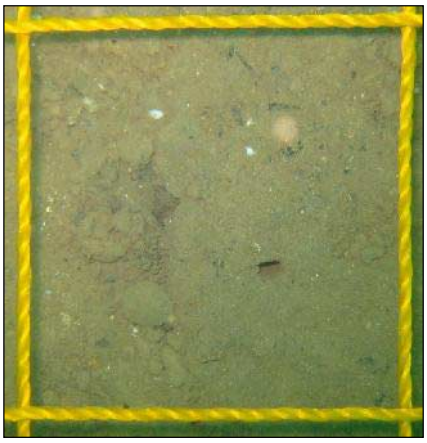
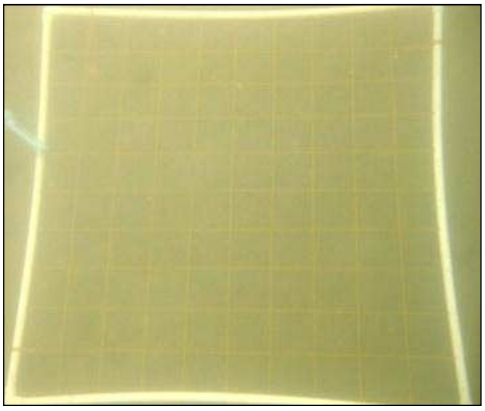
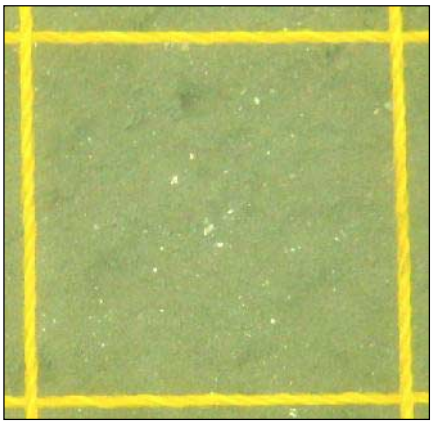
Photograph 2: View from Site B.

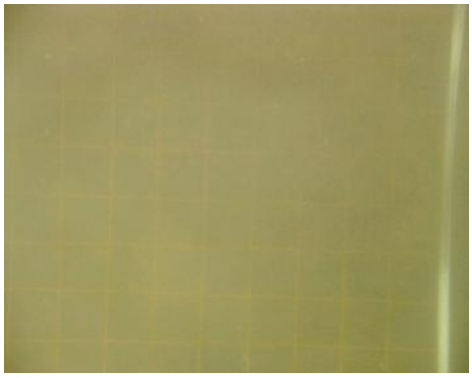
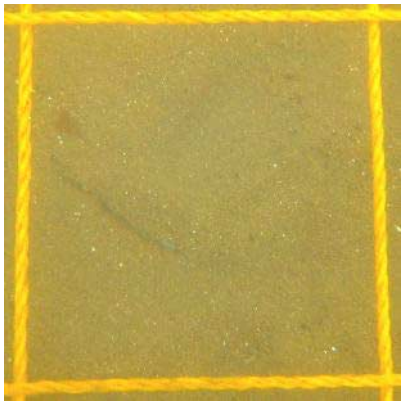
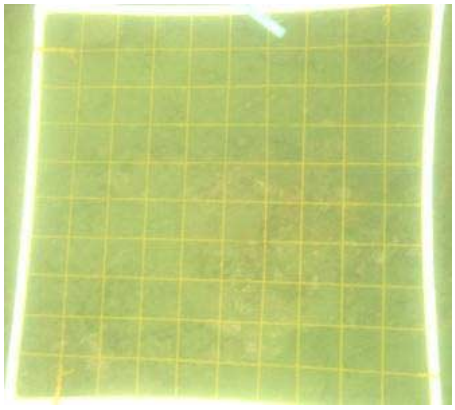
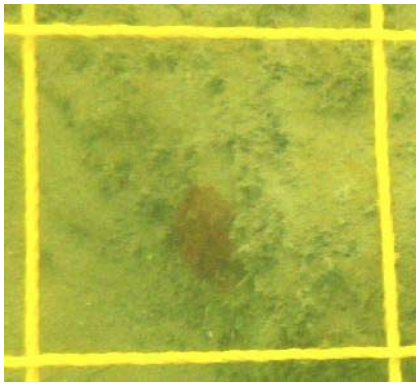
Photograph 3: View from Site C.

Photograph 4: View to Site D situated in front of the river mouth on the right hand side.

Photograph 5: View from Site E.

Underwater photographs of the seabed at each site

1m^2 quadrat	**100cm^2 section**
	
Site A (Mid channel): Brown sand, Turbidity <6 NTU	
	
Site B (Near wharf): Soft deep mud, Turbidity < 6 NTU	
	
Site C (Marina entrance): mixed sand, mud and shell fragments, Turbidity < 6 NTU	

	
Site D (Vaisigano River outlet): Brown sand, Turbidity < 6 NTU	
1m^2 quadrat	**100cm^2 section**
	
Site E (Vailima River outlet): Dead coral with thin layer of fine land-based mud and silt, Turbidity 20 NTU	

（1） 説明用スライド

Project for Enhancement of Safety of Apia Port in the Independent State of Samoa

Project Outlines

December 2014

Japan International Cooperation Agency (JICA)
Oriental Consultants Global Co., Ltd.

Project Purpose

Enhancement of Safety of Apia Port

Main Subjects of the Project are Enhancement of

1. **Ship berthing & mooring safety,**
2. **Cargo handling operation & passenger traffic safety, and**
3. **Ship maneuvering safety.**

2

Project Component

1. Enhancement of Ship berthing & mooring safety

Facility	Improvement
Wharf	Extension of new wharf
Mooring Facility	Construction of mooring dolphin
Fender System	Installation of new fenders

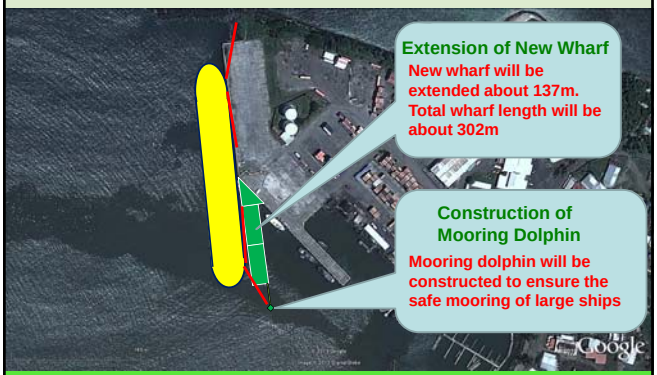
3

Wharf & Mooring Facilities: Present Conditions

Subject: Ship berthing and mooring safety is not enough due to luck of berth length against the ship length.

4

Wharf & Mooring Facilities: Improvement



Ship berthing and mooring safety will be enhanced.

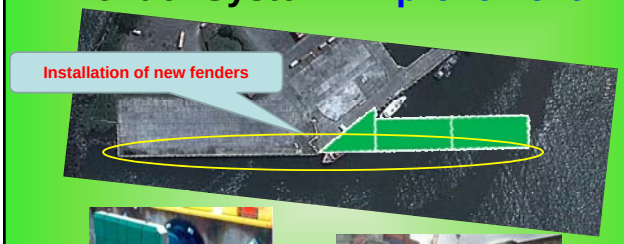
5

Fender System: Present Conditions

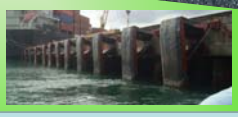
Subject: Ship berthing is not safe due to luck of fendar system.

6

Fender System: Improvement



Fender Image Photo



Fender Installation Image

Safety of ship berthing will be increased.

7

Project Component

2. To Enhance Cargo handling & passenger safety

Facility	Improvement
Container Yard	Rehabilitation
Passenger Walkway	Separation from cargo handling flow lines
Oil Tank	Safety enhancement by SPA
Access Road	Rehabilitation by SPA

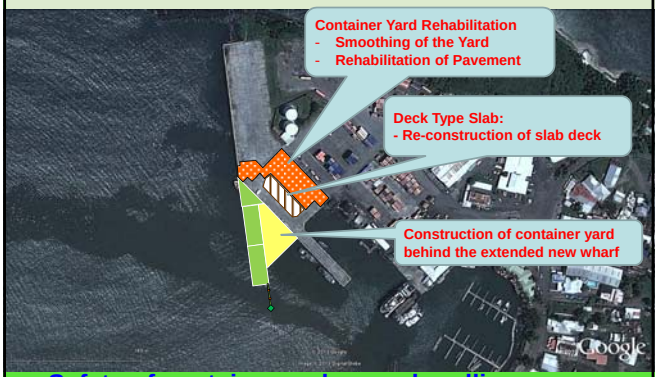
8

Container Yard: Present Conditions

Subject: Container yard is not safe for container and cargo handling operations.

9

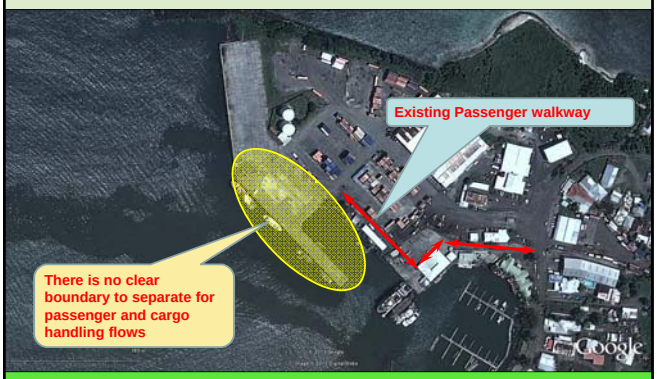
Container Yard: Improvement



Safety of container and cargo handling operations will be increased.

10

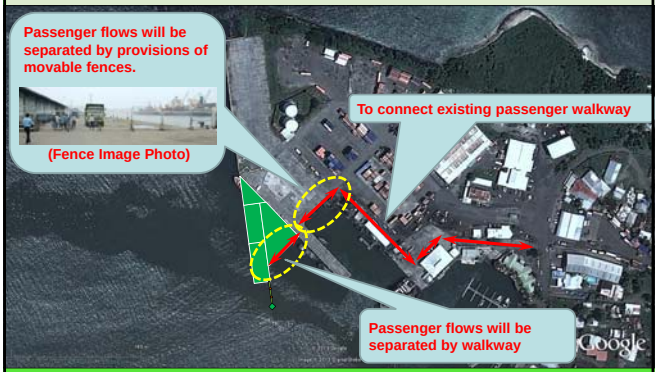
Passenger Walkway: Present Conditions



Subject: Passengers and cargo flows are congested and unsafe during the cruiser ship entering.

11

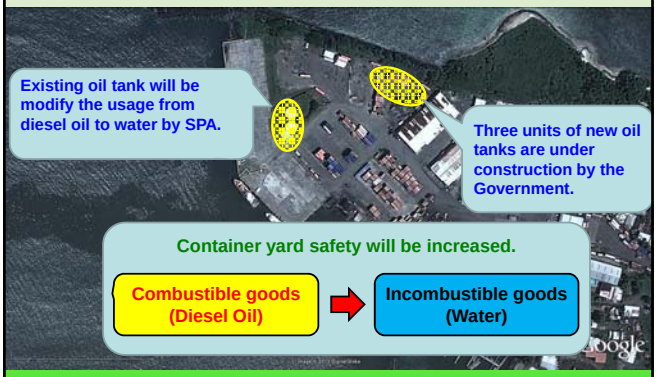
Passenger Walkway: Improvement



Passenger and cargo flow lines will be separated.

12

Oil Tank: Safety Enhancement by SPA



Container yard safety will be improved.

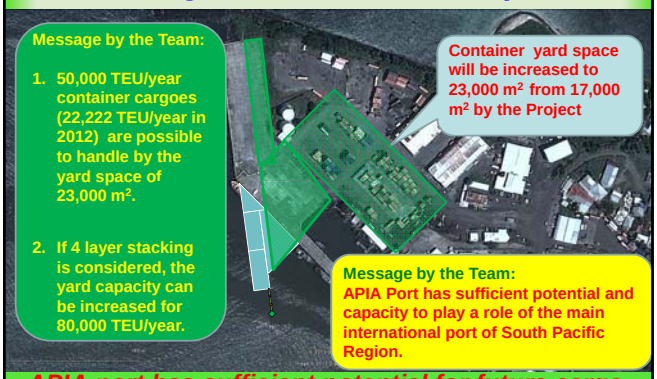
13

Access Road: Rehabilitation by SPA

Smooth and safety port access will be enhanced.

14

Message: Container Yard Space



APIA port has sufficient potential for future cargo demands in the region!

15

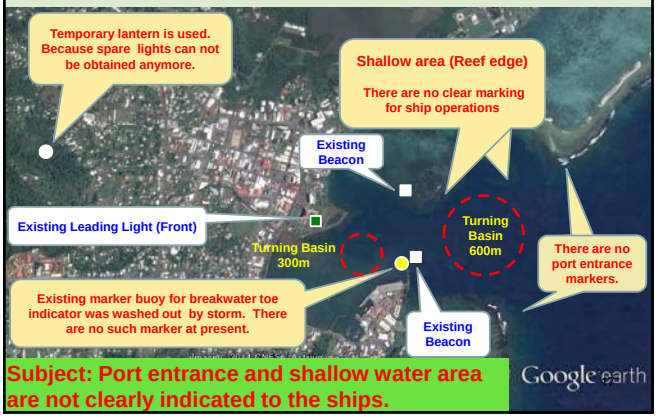
Project Component

3. To Enhance Ship maneuvering safety

Facility	Improvement
Navigation Aids	Rehabilitation & Upgrade
Tug Boats	Rehabilitation

16

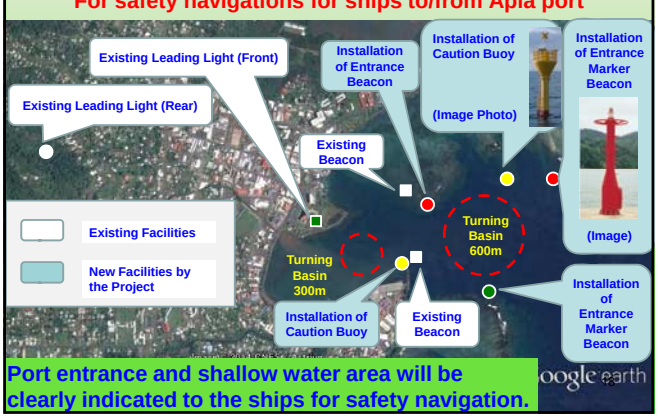
Navigation Aids: Present Conditions



Subject: Port entrance and shallow water area are not clearly indicated to the ships.

Navigation Aids: Improvement

For safety navigations for ships to/from Apia port



Port entrance and shallow water area will be clearly indicated to the ships for safety navigation.

Navigation Aids(Leading Lights): Present Conditions & Improvement

19

Leading Lights: Improvement

For safety navigations for ships to/from Apia port

Ship navigation safety will be enhanced.

Tug Boats: Rehabilitation

Item	Present Conditions	Rehabilitations
Upper Deck	Heavily corroded.	Will be repaired
Bulwark	Heavily damaged.	Will be repaired
Navigation Equipment	Radar, GPS and Compass are not functioned	New devices will be installed.
Engines	Good/Fair	Will be maintained
Others	Fair / Bad	Will be repaired

Safety vessel maneuvering will be increased.

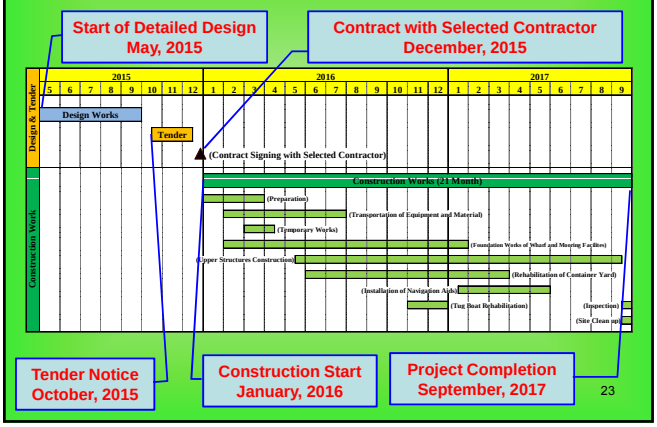
21

Temporary Yard during Construction Period

Stakeholders understanding and cooperation are requested.

22

Expected Project Schedule



23

Project for Enhancement of Safety of Apia Port in the Independent State of Samoa

Environmental and Social Consideration

Construction Method
Wharf Extension


1. Pile foundation:
   Steel pipe pile driving by pile hammer
2. Beam and Slab:
   Construction by reinforcement concrete, re-bar installation and concrete casting

25

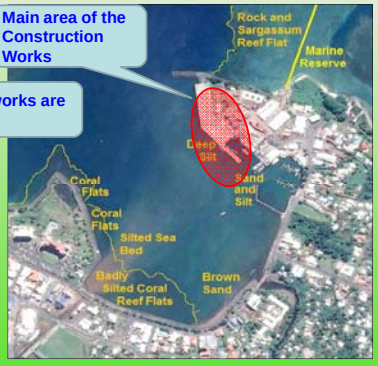
Construction Method
Rehabilitation of Container Yard




1. Demolition and removal of damaged part:
   Damaged part concrete demolish by breaker
2. Re-construction:
   Construction by reinforcement concrete, re-bar installation and concrete casting

26

Major Ecosystem



Consideration not to violate those ecosystems will be paid during the construction.

27

Main Impact

- Noise and Vibration of Pile Driving

- Traffic flow of dump truck and concrete mixer truck


- Dust by Demolition Work

28

Mitigation Measures
Noise and Vibrations of Pile Driving

Consideration not to violate the noise and vibration standard levels will be paid during the construction.

29

Mitigation Measures

- Traffic flow of dump truck and concrete mixer truck


- Traffic will be controlled not to harm the livelihood

30

Mitigation Measures

Dust by Demolition Work

- **Regular Water Spraying**
- **Monitoring**

31

Thank You Very Much

32

（2）　住民説明　現地新聞報道

LOCAL

Matautu wharf extension plan

"Today there are big ships from overseas that cannot dock at our wharf and the idea behind the project is to make the wharf bigger so that we can accommodate the ships"

PLANNING AHEAD: S.P.A Manager Commercial and Marketing Division Galuvao Uili Isara and General Manager Tufuga Fagaloa Tufuga.

Lanuola Tupufia

A plan to make Matautu wharf bigger has been revealed.

The project is being driven by the government with the hope to attract bigger ships to dock in Apia.

The project is expected to start in January 2016. It will be funded by a partnership between the government and the Japan International Corporation Agency (J.I.C.A).

During a public consultation held at the Elisa Hotel on Friday, the Samoa Ports Authority (S.P.A) General Manager, Tufuga Fagaloa Tufuga, announced the plan.

Tufuga said the plan is to improve Samoa's wharf so that it can compete with some of the biggest ports in the Pacific.

Safety, he said, is paramount.

"That is one of the main reasons for the extension," said Tufuga. "It is to enhance the ship berthing and mooring safety."

"Today there are big ships from overseas that cannot dock at our wharf and the idea behind the project is to make the wharf bigger so that we can accommodate the ships."

"The initiative is also positive for tourism so that we can host big cruise ships and have more tourists."

Tufuga said the project will also provide employment for the locals.

He added that the consultation enables the Authority to hear about the concerns and take them into consideration.

S.P.A Manager Commercial and Marketing Division, Galuvao Uili Isara said at the moment, the wharf can only accommodate a ship the size of 180 meters long.

The extension will stretch the wharf to 300 meters long, said Galuvao.

The Manager declined to say how much the extension works will cost.

"It is not finalised because at this stage we are consulting and have yet to do the designing of the extension," said Galuvao.

The project is expected to finish in 2017.

Interview Survey Results on Port Safety of Apia Port

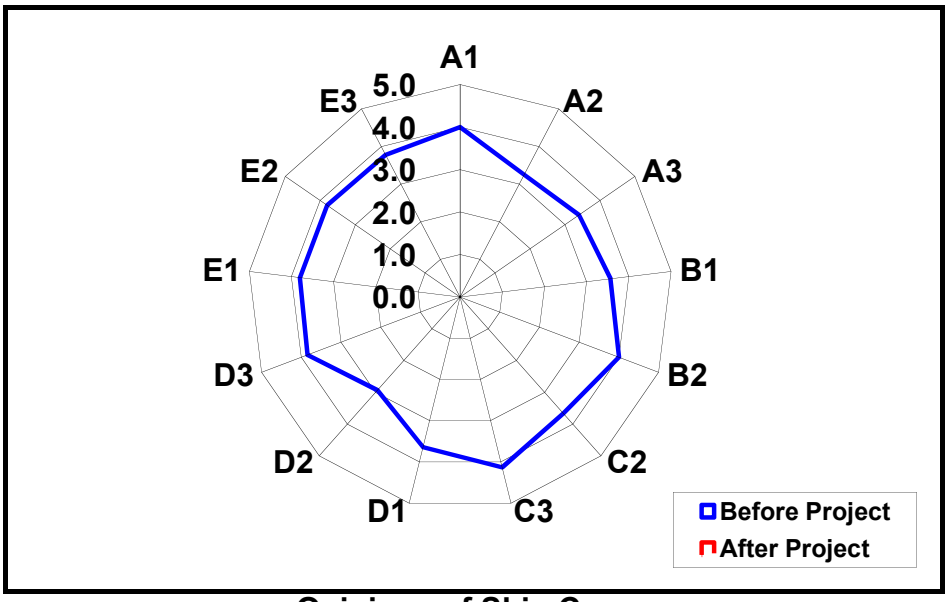
Interview to Ship Crews

				Before the Project																			After the Project					
Interview Number				1	2	3	4	5	6	7-a	8	9	10	11	12	13	7-b	14	15	16	17			1	2	3			
Ship Name				MV. Southern Lily	PB. Matua	MV. Captain Tasan	MV. Olomana	Telapa 18	Yu Hussiang Maru	Papuan Chief	Coral Islander II	Cap Tapaga	Chang Hang Fei Yue	Amsterdam	Tropical Islander	Highland Chief	Papuan Chief	Polynesia	Mad Geo Chan	LPG/C Victorie	Friesland	Average	Number of Effective Answers					Average	Number of Effective Answers
Survey Date				2014																								
				7/17	7/23	7/24	7/28	7/29	7/30	8/1	8/2	8/2	NA	NA	NA	NA	NA	NA	NA	NA	NA								
Sect	No.		Questions	Score																				Score					
1	1		Position in the Ship																										
		a	Captain	1	1	1	1	1		1					1				1	1			9						
		b	Chief (First) Officer																				0						
		c	Second Officer				1						1				1				1		4						
		d	Others								1			1		1							3						
	2		Ship Category																										
		a	Container ship	1		1	1			1					1		1	1					7						
		b	General Cargo Ship													1							1						
		c	Oil/Gas Tanker										1							1			2						
		d	Cruise Ship											1					1				2						
		e	others		1			1			1										1		4						
A			Navigation Aids																										
	1		Leading Light Conditions	3	4	3	3	3	NA	3	3	NA	5	5	5	5	3	4	5	5	5	4.0	16						
	2		Entrance Marker Bouys Conditions	1	3	1	3	3	NA	1	3	NA	5	5	3	5	3	1	5	5	5	3.3	16						
	3		Conditions of Other Navigation Bouys	2	NA	5	3	3	NA	1	2	NA	5	5	2	3	2	3	5	5	5	3.4	15						
B			Tug Boats																										
	1		Tug Boats Power	2.5	NA	3	3	3	NA	3	2	NA	5	3	4	5	3	3	5	4	5	3.6	15						
	2		Safety of Present Tug Boats Attends	3	NA	4	3	5	NA	3	3	NA	5	5	5	5	3	3	3	5	5	4.0	15						
C			Turning Basin / Port Basin																										
	2		Width of the turning basin	3	NA	5	3	4	NA	1	2	NA	4	4	4	5	3	2	5	5	5	3.7	15						
	3		Water depth of port bathin	3	NA	5	3	3	NA	4	4	NA	5	5	5	5	2	3	5	5	5	4.1	15						
D			Berthing and Mooring Facilities																										
	1		Wharf Length of Wharf	3	NA	4	3	5	NA	4	1	NA	5	2	3	5	2	4	5	NA	5	3.6	14						
	2		Fender System of Wharf	1	2	2	3	2	NA	1	2	NA	4	5	4	3	4	3	3	NA	5	2.9	15						
	3		Mooring Bitts / Bollard of Wharf	1	NA	5	3	5	NA	1	4	NA	5	4	NA	5	4	3	5	NA	5	3.8	13						
E			Cargo Handling / Passenger Flows																										
	1		Flency of Cargo Loading / Unloading Operation	3	NA	4	3	NA	NA	3	3	NA	5	4	NA	5	NA	3	NA	NA	5	3.8	10						
	2		Safety of Cargo Handling Operations	3	NA	4	3	NA	NA	3	3	NA	5	4	NA	5	NA	3	NA	NA	5	3.8	10						
	3		Carefullness of Cargo Handling	3	NA	4	3	NA	NA	NA	3	NA	4	4	NA	5	NA	3	NA	NA	5	3.8	9						
Ship Size			L.O.A (m)	142.7	44.0	144.0	116.0	53.5	92.0	158.1	160.7	157.0	185.0	238.0	160.7	158.1	158.1	161.1	103.0	86.0	79.0	128.8	18						
			Breath (m)	22.6	9.6	22.6	16.6	8.8	14.0	22.0	25.0	12.8	32.8	32.0	25.0	22.0	22.0	25.0	14.5	16.0	15.0	19.1	18						
			Max.Df. (m)	8.2	2.8	8.1	6.2	3.9	4.9	8.0	9.2	9.3	12.0	8.1	NA	8.0	7.2	9.4	4.0	6.2	9.0	6.8	17						
			Ton (GT / DWT)	9,648 GT	450 GT	9,422 GT	5,025 GT	577 GT	2,713 GT	10,350 GT	17,111 GT	12,029 GT	25,781 GT	62,735 GT	18,174 GT	13,669 DWT	10,350 GT	15,636 GT	3,984 GT	3,759 GT	2,437 GT								

Interview Survey Results on Port Safety of Apia Port

Interview to Ship Crews

				Before the Project								After the Project					
Interview Number				1	2	3	4	5	6			1	2	3			
Firm Name				Betham Brothers Enterprises Ltd.	Polinesia Shipping Services Ltd.	AMA SAMOA LTD.	Government of Tokelau	PFL SAMOA	Transam Samoa Ltd.	Avr	Number of Effective Answers					Avr	Number of Effective Answers
Survey Date				2014													
				7/21	7/21	7/22	7/22	7/23	7/24								
Sect	No.		Questions	Score								Score					
1	1		Business Category														
		a	Shipping Firm	1				1			2						
		b	Forwarder	1		1					2						
		c	Terminal Operator	1							1						
		d	Shipping Agent	1	1			1	1		4						
		e	Others	1			1	1	1		4						
	2		Ship category														
		a	Container ship	1	1	1	1	1	1		6						
		b	Post/Mail								0						
		c	Courier					1			1						
		d	Passengers				1				1						
		e	others								0						
A			Container Yard Conditions														
	1		Pavement Condition	3	5	1	3	2	3	2.8	6						
	2		Space for Safety Handling Operation	1	5	1	2	2	2.5	2.3	6						
B			Wharf														
	1		Width for Safety Handling Operation	5	4	3	3	3	4	3.7	6						
	2		Length for Safety Handling Operation	1	5	4	2	2	4	3.0	6						
C			Cargo handling operations and Cruiser Ship Passengers														
	1		Safety of the Passenger Flows	3	5	4	3	4	3	3.7	6						
	2		Separation from Cargo Handling	3	4	3	4	2	2	3.0	6						



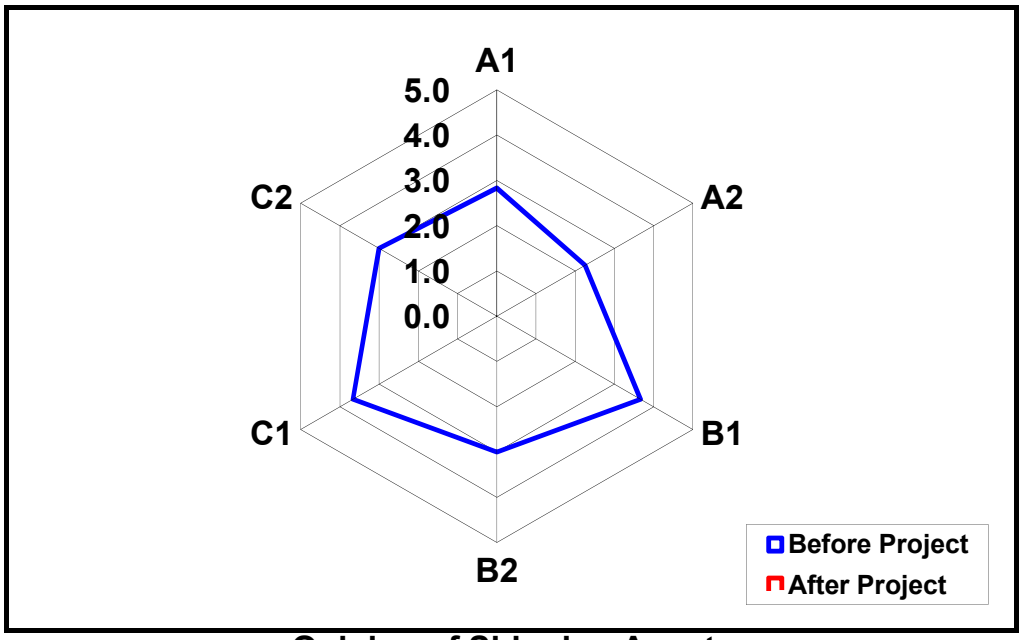
Opinions of Ship Crews
on the Present Conditions of Port Safety of Apia Port

Questions, Scoring System and Obtained Average Scores

No.	Questions	Scoring System			Obtained Average Score	
		1	3	5	Before Project	After Project
A1	Navigation Aids: Leading Light Conditions	Not enough	Acceptable	Well enough	4.0	
A2	Navigation Aids: Entrance Marker Conditions	Not enough	Acceptable	Well enough	3.3	
A3	Navigation Aids: Conditions of other Navigation Aids	Not enough	Acceptable	Well enough	3.4	
B1	Tug Boats: Tug Boat Powers	Not enough	Acceptable	Well enough	3.6	
B2	Tug Boats: Safety of Present Tug Boats Attends	Un Safe	Acceptable	Safe	4.0	
C2	Turnign Basin: Width	Not enough	Acceptable	Sufficient enough	3.7	
C3	Turing Basin: Water Depth	Not enough	Acceptable	Excellent	4.1	
D1	Wharf: Length	Not enough	Acceptable	Well enough	3.6	
D2	Wharf: Fender System	Not enough	Acceptable	Well enough	2.9	
D3	Wharf: Mooring Bits	Not enough	Acceptable	Well enough	3.8	
E1	Cargo Handling: Fluency	Not enough	Acceptable	Well enough	3.8	
E2	Cargo Handling: Safety	Danger	Average	Safe	3.8	
E3	Cargo Handling: Carefullness	Bad	Average	Good	3.8	

Data Source: JICA Survey Team / SPA

Opinions of Ship Crews
on the Present Conditions of Port Safety of Apia Port



Opinion of Shipping Agents
on the Present Conditions of Port Safety of Apia Port

Questions, Scoring System and Obtained Average Scores

No.	unloading operations?	Scoring System			Obtained Average Score	
		1	3	5	Before Project	After Project
A1	Container Yard: Pavement Conditions	Not enough	Acceptable	Well enough	2.8	
A2	Container Yard: Space for Safety Cargo Handling	Not enough	Acceptable	Well enough	2.3	
B1	Wharf: Width for Safety Cargo Handling	Not enough	Acceptable	Well enough	3.7	
B2	Wharf: Length for Safety Cargo Handling	Not enough	Acceptable	Well enough	3.0	
C1	Passenger Flow: Safety of the Passenger Flows	Danger	Average	Safe	3.7	
C2	Passenger Flow: Separation from Cargo Handling	Not separated	Fairly separated	Separated	3.0	

Data Source: JICA Survey Team As August 4th (2014) Survey

Opinions of Shipping Agents
on the Present Conditions of Safety of Apia Port