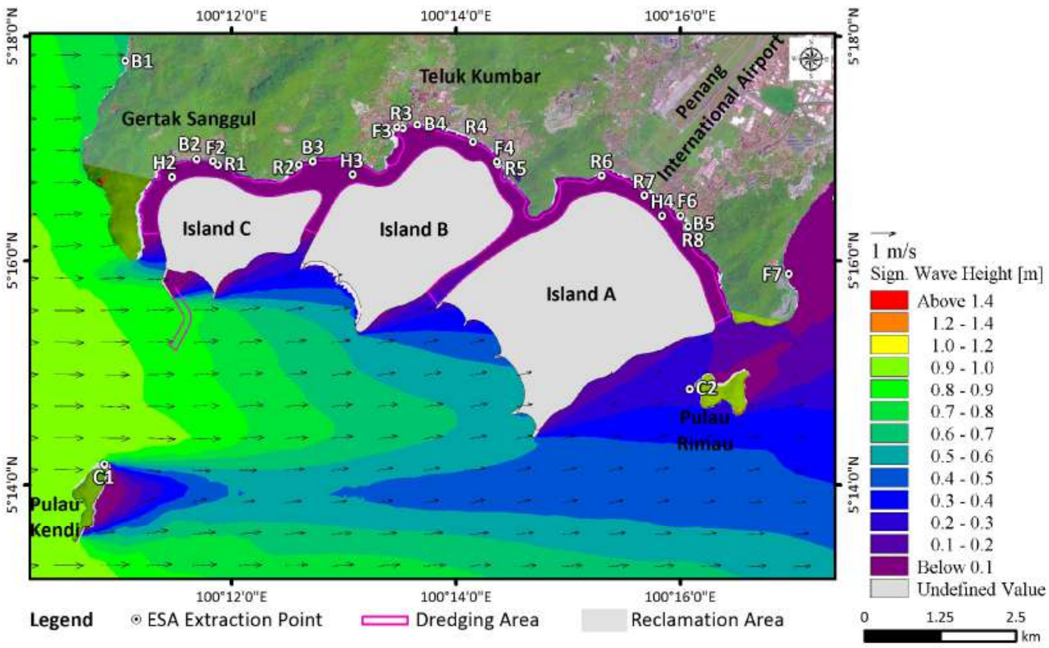
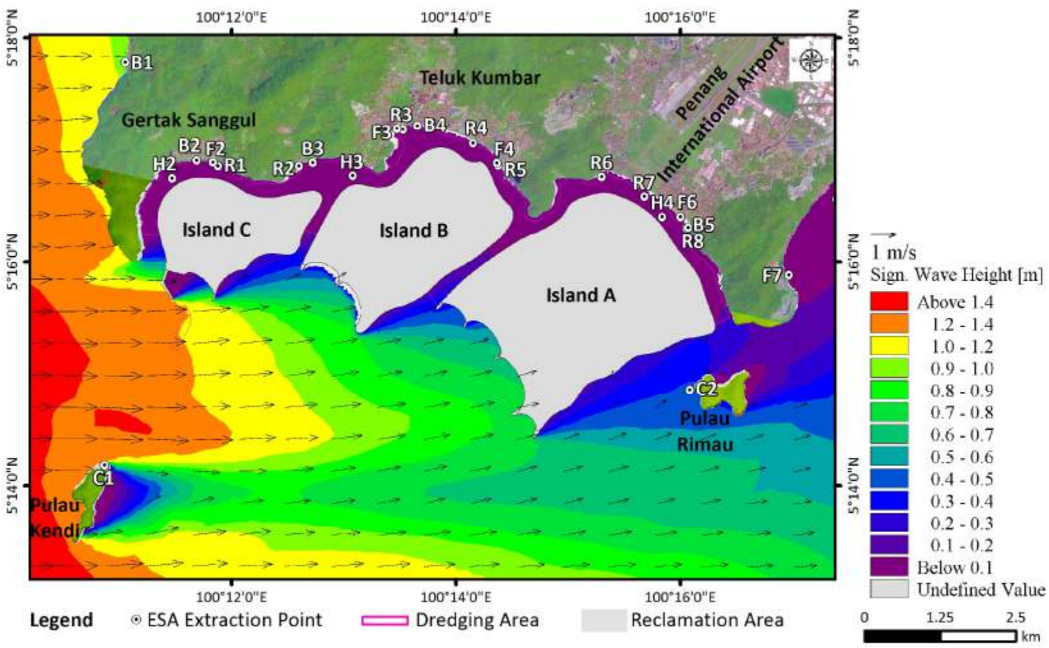
d) Scenario 4

The modelling results of the 1 in 1 year and 1 in 60 years return period events under Scenario 4 for the dominant wave direction are shown in F7.38. Meanwhile, the differences in wave heights for the dominant waves, as compared to those in the existing conditions, are shown in F7.39. Comparisons of the predominant wave heights at the ESAs between the baseline and Scenario 4 are tabulated in T7.20.

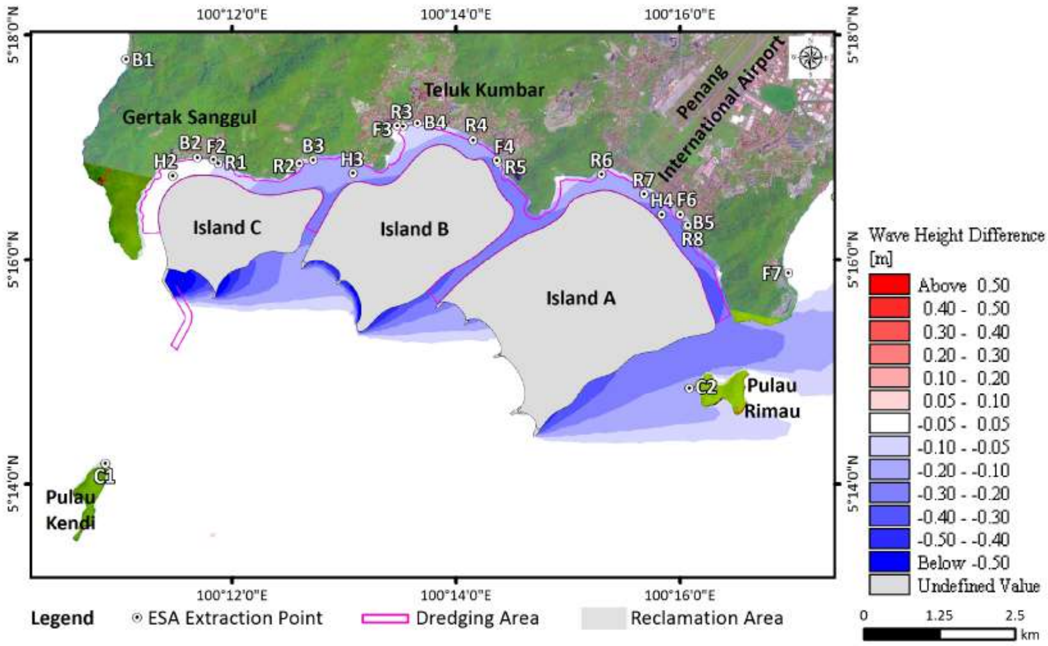


a) 1 in 1 year return period event: H_{m0} = 1.0 m, T_p = 5.5 s

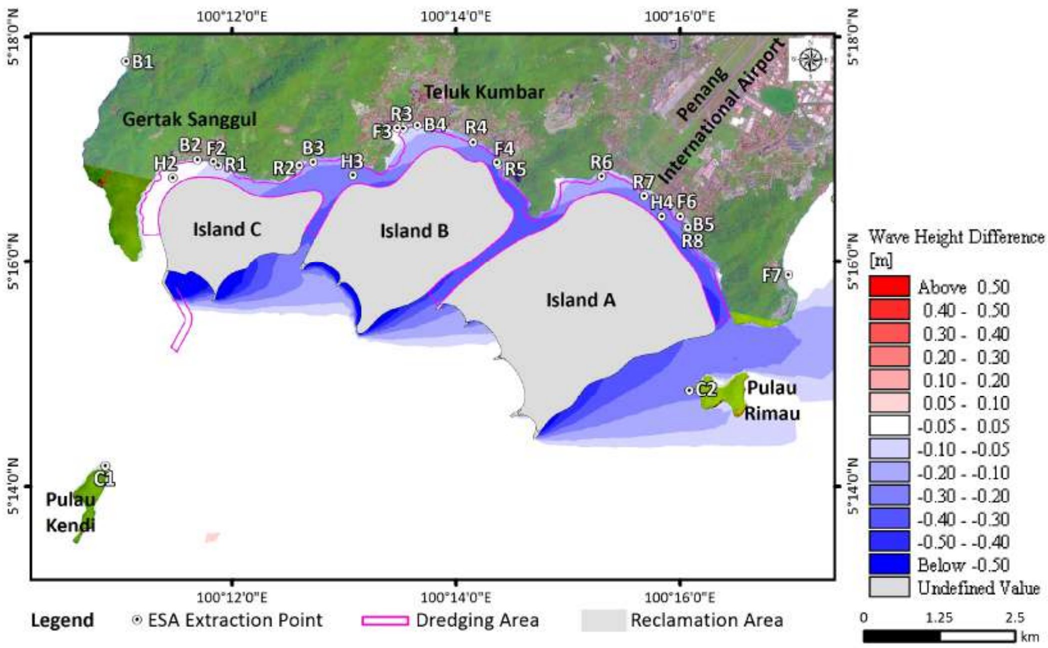


b) 1 in 60 year return period event: H_{m0} = 1.5 m, T_p = 6.0 s

F7.38 Significant wave heights; Scenario 4 condition; MWD = 270°N



a) 1 in 1 year return period event: H_{m0} = 1.0 m, T_p = 5.5 s



b) 1 in 60 year return period event: H_{m0} = 1.5 m, T_p = 6.0 s

F7.39 Wave height difference; Scenario 4 vs. existing condition; MWD = 270°N

T7.20 Comparison of the predominant wave heights at the ESAs between baseline condition and Scenario 4

Point	Location	Baseline Condition		Scenario 1						Remarks
				1 in 1 year			1 in 60 year			
		1 in 1 year (m)	1 in 60 year (m)	Value (m)	Difference (m)	Difference (%)	Value (m)	Difference (m)	Difference (%)	
R1	Sungai Gertak Sanggul	0.05	0.07	0.00	-0.05	-100	0.01	-0.06	-86	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
R2	Sungai Gemuruh	0.13	0.18	0.00	-0.13	-100	0.00	-0.18	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
R3	Sungai Teluk Kumbar	0.04	0.05	0.00	-0.04	-100	0.00	-0.05	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
R4	Sungai Mati	0.13	0.18	0.00	-0.13	-100	0.00	-0.18	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
R5	Sungai Batu	0.15	0.19	0.00	-0.15	-100	0.00	-0.19	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
R6	Sungai Bayan Lepas	0.11	0.14	0.00	-0.11	-100	0.00	-0.14	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
R7	Bayan Lepas Main Drain	0.16	0.21	0.00	-0.16	-100	0.00	-0.21	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
R8	Sungai Ikan Mati	0.13	0.15	0.00	-0.13	-100	0.00	-0.15	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8.*
C1	Pulau Kendi	0.78	1.15	0.78	0.00	0	1.15	0.00	0	Insignificant impact
C2	Pulau Rimau	0.47	0.63	0.29	-0.18	-38	0.41	-0.22	-35	Decrease in wave height may cause detrimental impact to corals. Refer to *Section 7.5.1.*

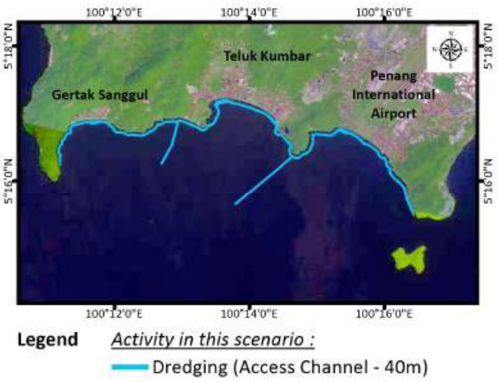
T7.20 Comparison of the predominant wave heights at the ESAs between baseline condition and Scenario 4 (cont'd)

Point	Location	Baseline Condition		Scenario 1						Remarks
				1 in 1 year			1 in 60 year			
		1 in 1 year (m)	1 in 60 year (m)	Value (m)	Difference (m)	Difference (%)	Value (m)	Difference (m)	Difference (%)	
H1	Sungai Pulau Betung	0.17	0.22	0.17	0.00	0	0.22	0.00	0	Insignificant impact
H2	Gertak Sanggul	0.03	0.04	0.01	-0.02	-67	0.02	-0.02	-50	Insignificant impact
H3	Teluk Kumbar	0.18	0.25	0.01	-0.17	-94	0.01	-0.24	-96	Insignificant impact
H4	Permatang Damar Laut	0.22	0.28	0.00	-0.22	-100	0.01	-0.27	-96	Insignificant impact
A1	Pulau Betung	0.58	0.80	0.58	0.00	0	0.80	0.00	0	Insignificant impact
A2	Sungai Pulau Betung	-	-	-	-	-	-	-	-	Insignificant impact
A3	Batu Maung	0.02	0.03	0.02	0.00	0	0.03	0.00	0	Insignificant impact
F1	Sungai Pulau Betung	-	-	-	-	-	-	-	-	No data (upstream location)
F2	Gertak Sanggul	0.05	0.06	0.00	-0.05	-100	0.01	-0.05	-83	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8*.
F3	Teluk Kumbar	0.02	0.02	0.00	-0.02	-100	0.00	-0.02	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8*.
F4	Sungai Batu	0.19	0.26	0.00	-0.19	-100	0.00	-0.26	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8*.
F5	Permatang Tepi Laut	-	-	-	-	-	-	-	-	No data (upstream location)
F6	Permatang Damar Laut	0.11	0.13	0.00	-0.11	-100	0.00	-0.13	-100	Decrease in wave height may induce sedimentation. Refer to *Section 7.3.8*.
F7	Teluk Tempoyak Besar	0.03	0.04	0.02	-0.01	-33	0.04	0.00	0	Insignificant impact
F8	Teluk Tempoyak Kecil	0.02	0.03	0.02	0.00	0	0.03	0.00	0	Insignificant impact
F9	Batu Maung	0.02	0.02	0.02	0.00	0	0.02	0.00	0	Insignificant impact
F10	Sri Jerjak	0.01	0.02	0.01	0.00	0	0.02	0.00	0	Insignificant impact

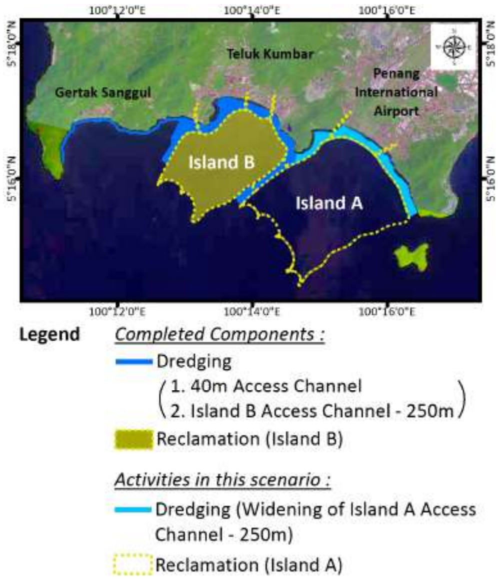
7.3.7.3 Overall Findings for Waves

Potential impact on wave height due to the presence of the proposed development was assessed by determining the differences in wave height before and after the development. Based on the simulation results, there are mainly reductions in wave height in all scenarios. There are some slight increases in the access channel along the existing foreshore where the reclaimed island is yet to be built. This attenuation of wave energy may cause increased sedimentation and reduction in flushing rate, which in turn will affect water quality within the dredged channel. However, the impacts on sedimentation and water quality will be addressed separately in the following subsections. As for wave heights, the changes are generally localised for all scenarios of the proposed development. Potential impacts on wave heights in each of the development scenarios are described below (T7.21).

T7.21 Summary of potential impacts on wave heights for all scenarios

Scenario	Findings
Scenario 1 	There are marginal localised changes in wave height in Scenario 1 with respect to the existing condition for both 1 in 1 year and 1 in 60 years return period events. There are small reductions in wave height of up to 0.2 m, near the beach enhancement sites, due to the shallower foreshore. Such reductions are mainly for waves from the 180 and 210°N. Changes are relatively small for waves propagating from 240 and 270°N reaching the foreshore. Slight increase in wave height of up to 0.2 m is predicted within the dredged channel for waves coming from the 180 and 210°N.
Scenario 2 	■ *1 in 1 year return period event* – Localised reductions in wave height of up to about 0.4 m can be observed along the sheltered edges of Island B, mainly in the dredged channels and the area offshore of the coastline of Permatang Damar Laut. It is predicted that there will be reductions in waves coming from 210 and 240°N in the area offshore of the coastline of Permatang Damar Laut by up to 0.3 m. These changes may affect the littoral transport rates along the coastline of Permatang Damar Laut. The results also show that the wave height reduces at the artificial beaches on the proposed reclaimed island. The reduction is due to shallower water and the sheltering effect provided by the headlands. ■ *1 in 60 year return period event* – The changes in wave height are very similar to those of the 1 in 1 year event. The reductions in wave height are mostly localised and up to 0.4 m. In cases where waves are propagating from 180 and 210°N, the reduction in wave height between Island B and the coastline of Teluk Kumbar is about 0.5 m.

T7.21 Summary of potential impacts on wave heights for all scenarios (cont'd)

Scenario	Findings
Scenario 3  	■ *1 in 1 year return period event* – In the two-island scenario, the reduction in wave height is again localised, mostly within the dredged channels and the beaches on the proposed reclaimed islands. The magnitude of the reductions is between 0.2 and 0.4 m. In the case of waves propagating from 270°N, wave reduction of up to 0.3 m extends to Pulau Rimau. This is due to the protruding headland of Island A. ■ *1 in 60 year return period event* – The differences in wave heights are very similar to the 1 in 1 year return period event, i.e. localised and mostly within the dredged channels and the artificial beaches on the proposed reclaimed islands, and are of similar magnitude of up to 0.5 m. Similar extent of reduction in wave height near Pulau Rimau is observed, with a magnitude of 0.3 m.
Scenario 4  	■ *1 in 1 year return period event* – Similar to Scenario 3, the reduction in wave height of up to 0.5 m is mainly observed within the dredged channels and the artificial beaches of the reclaimed islands in cases where the waves are propagating from 180 and 210°N. For waves coming from 240°N, reduction in wave height is observed off the southern coastline of Island C. Such reduction is extended to the southwestern edge of Island B in the case of waves propagating from 270°N. In this case, the reduction in wave height near Pulau Rimau is similar to that of Scenario 3. The marina basin is sheltered from waves by its breakwaters, which are intended for exactly this purpose. ■ *1 in 60 year return period event* – Reductions in wave heights are observed in areas similar to the 1 in 1 year return period event. The magnitude of reduction is however slightly higher, up to 0.6 m. The reduction in wave height near Pulau Rimau is up to 0.3 m, mainly due to the protruding headland of Island A.

There is generally a decrease in wave heights for all scenarios. An increase in wave heights occurs at the outlets of Sungai Gertak Sanggul, Sungai Batu, Sungai Bayan Lepas and Bayan Lepas Main Drain. The wave height increase is up to 0.07 to 0.11 m for waves with return period of 1 in 1 year and 1 in 60 years respectively. However, the decrease of wave heights occurs at these river outlets with the presence of the reclaimed islands upon the implementation of each construction phase.

7.3.8 Sedimentation and Erosion

As mentioned in *Section 7.3.5 - Currents*, changes in the existing hydrodynamics regime caused by the proposed development will ultimately alter the sedimentation and erosion rate around the Project site. Sediment transport modelling using MIKE 21 Mud Transport ("MT") module was used to evaluate erosion and sedimentation within the study area for impact assessment.

7.3.8.1 Simulation Model

MIKE 21 MT is a two-dimensional mud transport model that uses output from the hydrodynamic model, MIKE 21 HD. MIKE 21 MT is used to study transport, deposition, erosion, dispersion and consolidation of cohesive sediments under the influence of tides and currents. This model is capable in resolving horizontal spatial variations of water depths.

Simulations for the sediment transport modelling with the climatic conditions include pure tide, Northeast Monsoon and Southwest Monsoon conditions. The model is simulated for one month for all climatic conditions to ensure that an equilibrium state is reached. The sedimentation pattern developed for the last two weeks of the simulation period in these climatic conditions is extrapolated for the respective monsoon duration and combined to obtain annual sedimentation rates.

Wave forcing is included in the sediment transport modelling with a simulated wave field generated with 0.6 m wave height at the boundary from 225^{o}N, to represent the nearshore wave condition from southwesterly wave direction. Sediment discharge from the rivers was taken into account in the simulations to assess the contribution of river discharge to the sedimentation along the shoreline.

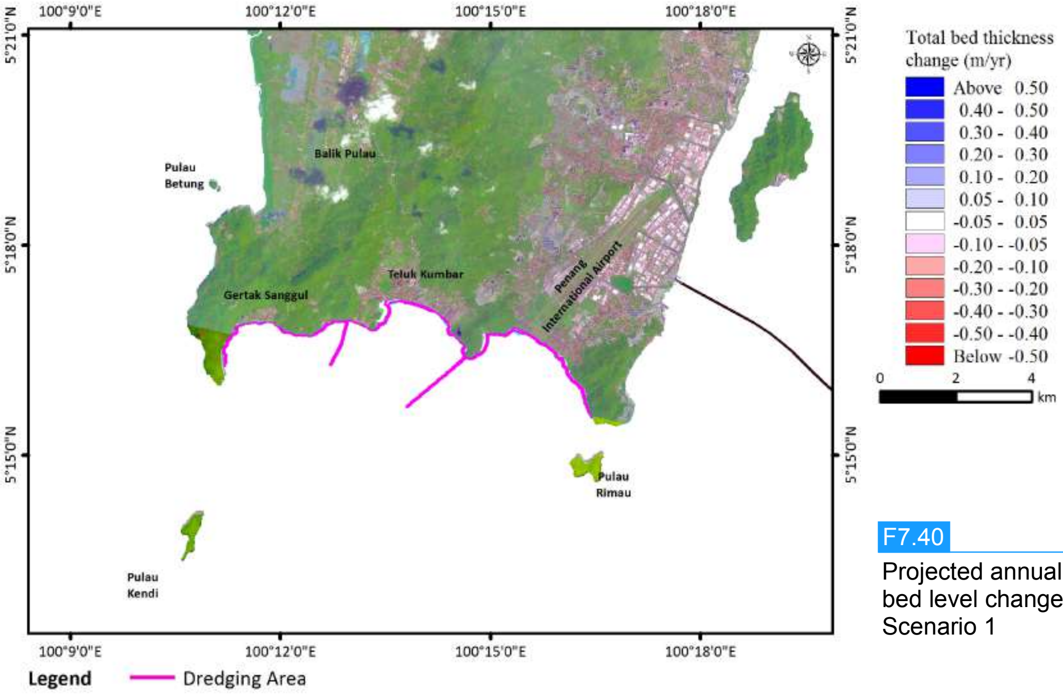
7.3.8.2 Impact Assessment

a) Scenario 1

The projected annual sedimentation and erosion rates for Scenario 1 are shown in F7.40. There is no significant change in the bed level after the development.

Localised sedimentation of up to 0.1 m/year is observed in the access channels at the outlets of Sungai Teluk Kumbar, Sungai Batu and Sungai Bayan Lepas. Localised erosion up to 0.1 m/year is predicted on the foreshore of Teluk Kumbar and Permatang Damar Laut, where the beaches are raised by 1 m as part of the beach enhancement works.

T7.22 shows the projected average sedimentation and erosion rate at ESAs for Scenario 1.



F7.40
Projected annual bed level change for Scenario 1

T7.22 Projected average sedimentation and erosion rate at the ESAs for Scenario 1

Point	Location	Average Sedimentation Rate (m/year)	Remarks
R1	Sungai Gertak Sanggul	0.02	Insignificant impact
R2	Sungai Gemuruh	0.00	Insignificant impact
R3	Sungai Teluk Kumbar	0.00	Insignificant impact
R4	Sungai Mati	0.00	Insignificant impact
R5	Sungai Batu	0.00	Insignificant impact
R6	Sungai Bayan Lepas	0.00	Insignificant impact
R7	Bayan Lepas Main Drain	0.00	Insignificant impact
R8	Sungai Ikan Mati	-0.03	Insignificant impact
C1	Pulau Kendi	0.00	Insignificant impact
C2	Pulau Rimau	0.00	Insignificant impact
H1	Sungai Pulau Betung	0.00	Insignificant impact
H2	Gertak Sanggul	0.00	Insignificant impact
H3	Teluk Kumbar	0.00	Insignificant impact
H4	Permatang Damar Laut	0.00	Insignificant impact
A1	Pulau Betung	0.00	Insignificant impact
A2	Sungai Pulau Betung	-	No data (upstream location)
A3	Batu Maung	0.00	Insignificant impact
F1	Sungai Pulau Betung	-	No data (upstream location)
F2	Gertak Sanggul	0.01	Insignificant impact
F3	Teluk Kumbar	0.00	Insignificant impact
F4	Sungai Batu	0.01	Insignificant impact
F5	Permatang Tepi Laut	-	No data (upstream location)
F6	Permatang Damar Laut	0.00	Insignificant impact

T7.22 Projected average sedimentation and erosion rate at the ESAs for Scenario 1

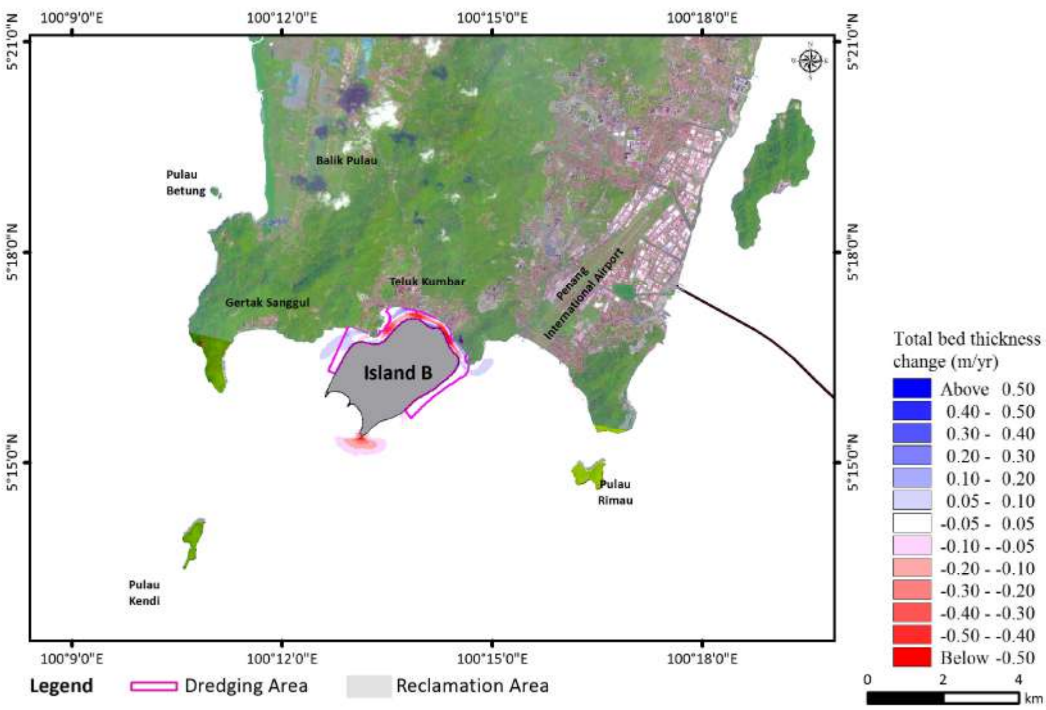
Point	Location	Average Sedimentation Rate (m/year)	Remarks
F7	Teluk Tempoyak Besar	0.00	Insignificant impact
F8	Teluk Tempoyak Kecil	0.00	Insignificant impact
F9	Batu Maung	0.00	Insignificant impact
F10	Sri Jerjak	0.00	Insignificant impact
B1	Pantai Pasir Panjang	0.00	Insignificant impact
B2	Pantai Gertak Sanggul	0.00	Insignificant impact
B3	Pantai Tanjung Asam	0.00	Insignificant impact
B4	Pantai Nelayan	0.00	Insignificant impact
B5	Pantai Bakar Kapor	0.00	Insignificant impact

b) Scenario 2

The projected annual sedimentation and erosion rates for Scenario 2 are shown in F7.41. The projected annual bed level changes are mostly in close proximity to the proposed Island B. The highest erosion rate occurs at the southern-most headland of the reclaimed island with an average erosion rate of up to 0.5 m/year. Erosion is also predicted in most part of the dredged channel between Island B and the frontage of Teluk Kumbar, with an average rate of up to 0.5 m/year. The erosion does not appear to extend to the beaches of Teluk Kumbar.

Sedimentation is observed in the bay between Island B and Teluk Pasir Belanda and near Tanjung Chut, i.e. of up to 0.1 m/year.

T7.23 shows the projected average sedimentation and erosion rates at ESAs for Scenario 2.



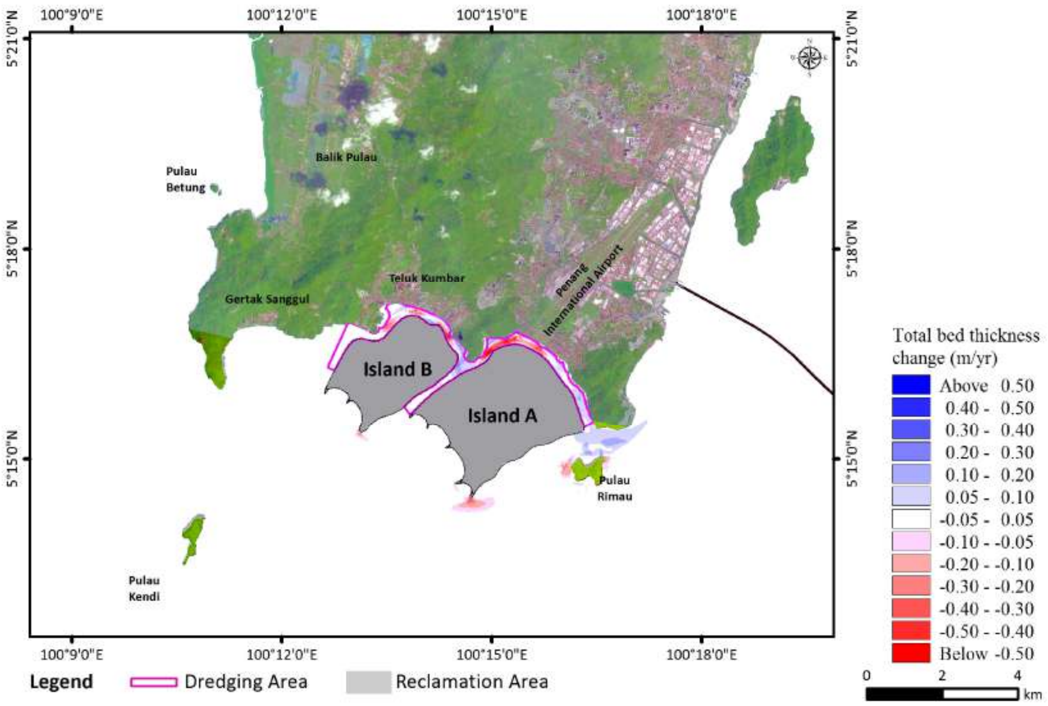
F7.41 Projected annual bed level change for Scenario 2

T7.23 Projected average sedimentation and erosion rate at the ESAs for Scenario 2

Point	Location	Average Sedimentation Rate (m/year)	Remarks
R1	Sungai Gertak Sanggul	0.01	Insignificant impact
R2	Sungai Gemuruh	0.00	Insignificant impact
R3	Sungai Teluk Kumbar	0.00	Insignificant impact
R4	Sungai Mati	0.02	Insignificant impact
R5	Sungai Batu	0.15	Significant sedimentation, thus mitigation measure is required
R6	Sungai Bayan Lepas	0.00	Insignificant impact
R7	Bayan Lepas Main Drain	0.00	Insignificant impact
R8	Sungai Ikan Mati	-0.03	Insignificant impact
C1	Pulau Kendi	0.00	Insignificant impact
C2	Pulau Rimau	0.00	Insignificant impact
H1	Sungai Pulau Betung	0.00	Insignificant impact
H2	Gertak Sanggul	0.00	Insignificant impact
H3	Teluk Kumbar	-0.03	Insignificant impact
H4	Permatang Damar Laut	0.00	Insignificant impact
A1	Pulau Betung	0.00	Insignificant impact
A2	Sungai Pulau Betung	-	No data (upstream location)
A3	Batu Maung	0.00	Insignificant impact
F1	Sungai Pulau Betung	-	No data (upstream location)
F2	Gertak Sanggul	0.01	Insignificant impact
F3	Teluk Kumbar	0.00	Insignificant impact
F4	Sungai Batu	0.14	Significant sedimentation, thus mitigation measure is required
F5	Permatang Tepi Laut	-	No data (upstream location)
F6	Permatang Damar Laut	0.00	Insignificant impact
F7	Teluk Tempoyak Besar	0.00	Insignificant impact
F8	Teluk Tempoyak Kecil	0.00	Insignificant impact
F9	Batu Maung	0.00	Insignificant impact
F10	Sri Jerjak	0.00	Insignificant impact
B1	Pantai Pasir Panjang	0.00	Insignificant impact
B2	Pantai Gertak Sanggul	0.00	Insignificant impact
B3	Pantai Tanjung Asam	0.00	Insignificant impact
B4	Pantai Nelayan	0.00	Insignificant impact
B5	Pantai Bakar Kapor	0.00	Insignificant impact

c) Scenario 3

The projected annual sedimentation and erosion rates for Scenario 3 are shown in F7.42. With Island A, it appears that the extent and erosion rates in the channel between Island B and the existing foreshore of Teluk Kumbar previously observed in Scenario 2 is reduced to 0.4 m/year in Scenario 3 due to lower current speeds.



F7.42 Projected annual bed level change for Scenario 3

The simulation results also show that there will be erosion of up to 0.5 m/year in the western half of the channel between Island A and the existing foreshore of Permatang Damar Laut. The eastern half of the channel is predicted to experience sedimentation of up to 0.1 m/year. The sedimentation is predicted to extend to between Tanjung Teluk Tempoyak and Pulau Rimau, i.e. up to 0.2 m/year.

Erosion is predicted at the southern-most headland of Island A with an average erosion rate of up to about 0.4 m/year. The erosion rates at the southern-most headland of Island B is reduced from about 0.5 m/year in Scenario 2 to about 0.3 m/year in Scenario 3.

The area off the western coastline of Pulau Rimau is predicted to experience erosion rates of up to 0.2 m/year.

T7.24 shows the projected average sedimentation and erosion rate at ESAs for Scenario 3.

T7.24 Projected average sedimentation and erosion rate at the ESAs for Scenario 3

Point	Location	Average Sedimentation Rate (m/yr)	Remarks
R1	Sungai Gertak Sanggul	0.02	Insignificant impact
R2	Sungai Gemuruh	0.00	Insignificant impact
R3	Sungai Teluk Kumbar	0.00	Insignificant impact
R4	Sungai Mati	0.03	Insignificant impact
R5	Sungai Batu	0.14	Significant sedimentation, thus mitigation measure is required
R6	Sungai Bayan Lepas	-0.10	Significant erosion, thus mitigation measure is required
R7	Bayan Lepas Main Drain	-0.34	Significant erosion, thus mitigation measure is required
R8	Sungai Ikan Mati	-0.03	Insignificant impact
C1	Pulau Kendi	0.00	Insignificant impact
C2	Pulau Rimau	0.00	Insignificant impact
H1	Sungai Pulau Betung	0.00	Insignificant impact
H2	Gertak Sanggul	0.00	Insignificant impact
H3	Teluk Kumbar	0.01	Insignificant impact
H4	Permatang Damar Laut	0.00	Insignificant impact
A1	Pulau Betung	0.00	Insignificant impact
A2	Sungai Pulau Betung	-	No data (upstream location)
A3	Batu Maung	0.00	Insignificant impact
F1	Sungai Pulau Betung	-	No data (upstream location)
F2	Gertak Sanggul	0.01	Insignificant impact
F3	Teluk Kumbar	0.00	Insignificant impact
F4	Sungai Batu	0.10	Significant sedimentation, thus mitigation measure is required
F5	Permatang Tepi Laut	-	No data (upstream location)
F6	Permatang Damar Laut	0.00	Insignificant impact
F7	Teluk Tempoyak Besar	0.00	Insignificant impact
F8	Teluk Tempoyak Kecil	0.00	Insignificant impact
F9	Batu Maung	0.00	Insignificant impact
F10	Sri Jerjak	0.00	Insignificant impact
B1	Pantai Pasir Panjang	0.00	Insignificant impact
B2	Pantai Gertak Sanggul	0.00	Insignificant impact
B3	Pantai Tanjung Asam	0.00	Insignificant impact
B4	Pantai Nelayan	0.00	Insignificant impact
B5	Pantai Bakar Kapor	0.00	Insignificant impact

d) Scenario 4

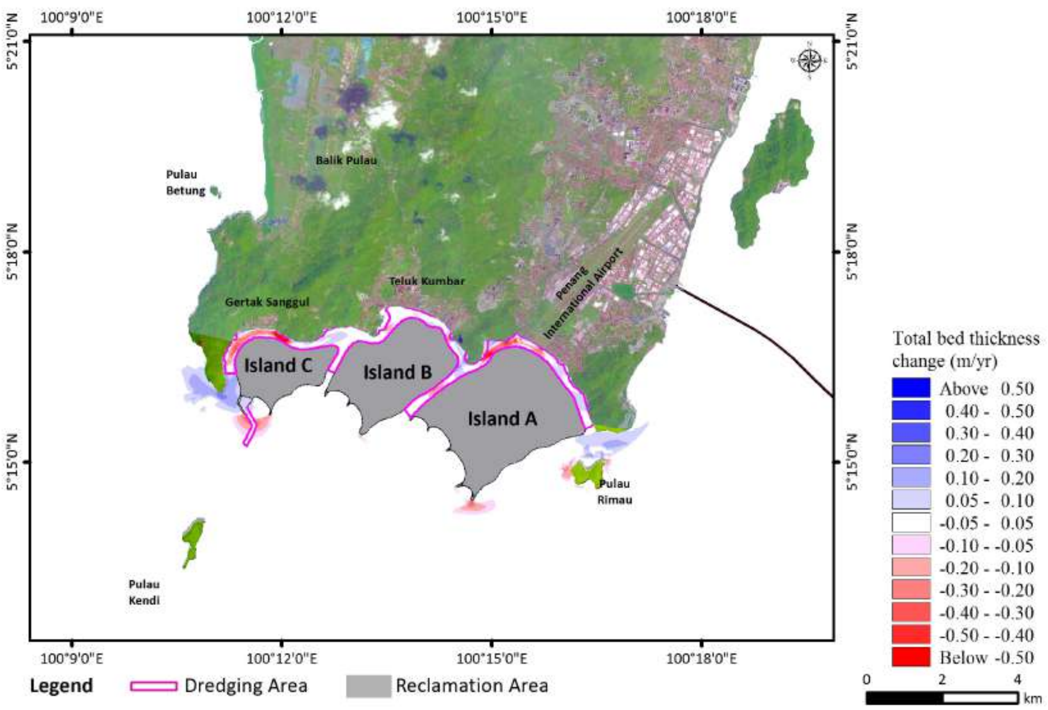
The projected annual sedimentation and erosion rates for Scenario 4 are shown in F7.43.

The presence of Island C appears to reduce the sedimentation and erosion in the dredged channel between Island B and the frontage of Teluk Kumbar, as compared to Scenario 3. Erosion at the southern-most headland of Island B is reduced to about 0.1 m/year for Scenario 4 due to the sheltering effect provided by Island C. The projected annual bed level change near Pulau Rimau is similar to that of Scenario 3, with an average sedimentation and erosion rate of up to 0.2 m/year.

The channel between Island C and the coastline of Kampung Gertak Sanggul is predicted to experience erosion. The erosion rate is up to 0.6 m/year near the rocky headland of Tanjung Gemuruh. Sedimentation of up to 0.1 m/year is observed in Teluk Pasir Belanda.

The marina basin is expected to experience sedimentation of up to 0.1 m/year. Erosion of up to 0.3 m/year is observed offshore of Island C, where the current speeds are higher at the breakwaters of the marina. There is an increase in projected annual bed level changes at the headland of Tanjung Gertak Sanggul of up to 0.2 m/year due to a reduction in current speed with the presence of Island C and the marina breakwater.

T7.25 shows the projected average sedimentation and erosion rates at ESAs for Scenario 1.



F7.43 Projected annual bed level change for Scenario 4

T7.25 Projected average sedimentation and erosion rate at the ESAs for Scenario 4

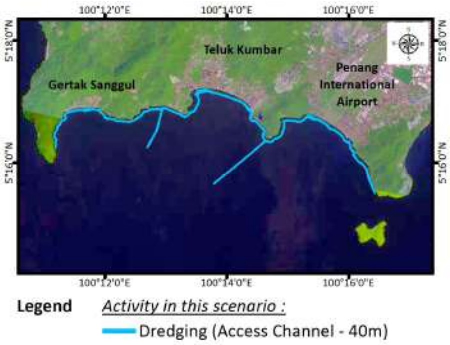
Point	Location	Average Sedimentation Rate (m/year)	Remarks
R1	Sungai Gertak Sanggul	0.14	Significant sedimentation, thus mitigation measure is required
R2	Sungai Gemuruh	0.00	Insignificant impact
R3	Sungai Teluk Kumbar	0.00	Insignificant impact
R4	Sungai Mati	0.01	Insignificant impact
R5	Sungai Batu	0.06	Significant sedimentation, thus mitigation measure is required
R6	Sungai Bayan Lepas	-0.10	Significant erosion, thus mitigation measure is required
R7	Bayan Lepas Main Drain	-0.26	Significant erosion, thus mitigation measure is required
R8	Sungai Ikan Mati	-0.03	Insignificant impact
C1	Pulau Kendi	0.00	Insignificant impact
C2	Pulau Rimau	0.00	Insignificant impact
H1	Sungai Pulau Betung	0.00	Insignificant impact
H2	Gertak Sanggul	-0.08	Insignificant impact
H3	Teluk Kumbar	0.02	Insignificant impact
H4	Permatang Damar Laut	0.00	Insignificant impact
A1	Pulau Betung	0.00	Insignificant impact
A2	Sungai Pulau Betung	-	No data (upstream location)
A3	Batu Maung	0.00	Insignificant impact
F1	Sungai Pulau Betung	-	No data (upstream location)
F2	Gertak Sanggul	0.14	Significant sedimentation, thus mitigation measure is required
F3	Teluk Kumbar	0.00	Insignificant impact
F4	Sungai Batu	0.04	Significant sedimentation, thus mitigation measure is required
F5	Permatang Tepi Laut	-	No data (upstream location)
F6	Permatang Damar Laut	0.00	Insignificant impact
F7	Teluk Tempoyak Besar	0.00	Insignificant impact
F8	Teluk Tempoyak Kecil	0.00	Insignificant impact
F9	Batu Maung	0.00	Insignificant impact
F10	Sri Jerjak	0.00	Insignificant impact
B1	Pantai Pasir Panjang	0.00	Insignificant impact
B2	Pantai Gertak Sanggul	0.00	Insignificant impact
B3	Pantai Tanjung Asam	0.00	Insignificant impact
B4	Pantai Nelayan	0.00	Insignificant impact
B5	Pantai Bakar Kapor	0.00	Insignificant impact

7.3.8.3 Overall Findings for Sedimentation and Erosion

Results of the sediment transport modelling simulations suggest that changes in the sediment transport regime are mostly localised within the Project site between Tanjung Teluk Tempoyak and Tanjung Gertak Sanggul in Scenarios 1 and 2. In Scenarios 3 and 4, changes around Pulau Rimau of up to 0.2 m/year are observed in addition to the changes within the Project site.

Sedimentation is expected in the channel between the reclaimed islands and the existing coastline of Penang Potential impacts on sediment transport in each of the development scenarios are described below (T7.26). It should be noted that the changes in seabed levels are expected to reduce over time as the seabed adjusts itself towards an equilibrium state. Erosion in the dredged channel does not affect the existing shoreline as the results show that the ‘erosion’ happens mostly at the rock outcrops that constrict the flow and thus increase the flow speed.

T7.26 Summary of potential impacts on sediment transport for all scenarios

Scenario	Findings
Scenario 1  	There is insignificant change in the bed level except for localised sedimentation up to about 0.1 m/year at the outlets of Sungai Teluk Kumbar, Sungai Batu and Sungai Bayan Lepas due to the increased water depth. There is also localised erosion of up to 0.1 m/year predicted on the beaches where beach enhancement works are predicted. There are insignificant changes at the ESAs. Periodic monitoring survey and maintenance dredging is recommended to ensure the access channel is navigable for fishing boats.
Scenario 2  	There will be a likely reduction in bed level of up to about 0.5 m/year in the dredged channel between Island B and the existing foreshore of Teluk Kumbar due to the higher speed arising from the constricted current flow. The model results show that the reduction in bed level is within the dredged channel and close to the proposed reclaimed island. As such, the island’s edge protection needs to be designed to withstand such current speeds as well as incorporating scour protection. There is a reduction in sea bed level near the western end of Teluk Pak Pajuh and the eastern coastline of Tanjung Bongkok. The coastlines at these locations are however fronted by rock outcrops and thus would not be affected. Localised erosion of up to 0.5 m/year is observed near the southern-most artificial headland of Island B. The erosion is due to the increase in current speed induced by the headland which protrudes perpendicularly into the current flow direction. The design of the artificial headlands shall incorporate protection against toe scour. Sedimentation of up to 0.1 m/year was observed in the channel along the western edge of Island B, where there is a reduction in current speed. This requires periodic monitoring survey and potentially maintenance dredging to ensure that the channels are kept navigable for the local fishing communities. There are insignificant changes at the ESAs, except for the outlet of Sungai Batu that is predicted to experience a sedimentation rate of about 0.15 m/year. The sedimentation rate within the dredged channels is predicted to be approximately 70,000 m^3/year. Periodic monitoring survey and maintenance dredging are recommended to mitigate sedimentation in the dredged channel.

T7.26 Summary of potential impacts on sediment transport for all scenarios (cont'd)

Scenario	Findings
Scenario 3 	There is localised erosion with an average rate of up to 0.5 m/year observed in the western half of the dredged channel between Island A and Permatang Damar Laut's frontage, whilst the eastern half of the channel is predicted to experience sedimentation of up to 0.1 m/year. Reduction in sea bed level is predicted mainly within the dredged channel close to the island's edges. It is therefore recommended that the island's edge protection design incorporates scour protection. There are reductions in sea bed level near the eastern coastline of Tanjung Chut and to the west of Sungai Bayan Lepas which are rocky coastlines. It is therefore considered that there is no erosion risk on the existing coastline. Maintenance dredging is probably required to ensure the channel is navigable. Erosion of up to 0.4 m/year is observed at the southern-most headland of Island A. The design of the artificial headland of Island A is recommended to incorporate scour protection. Sedimentation of 0.1 m/year is predicted at Tanjung Teluk Tempoyak due to reduction in current speed with the presence of Island A. However, the sedimentation is not expected to have an impact to the navigation given the existing seabed level is about -8 m CD. Erosion rate of up to 0.2 m/year is predicted along the eastern and western coastlines of Pulau Rimau, where corals exist. These coastlines are however found to be rocky and the corals are on the rocks, based on field observations made in the Project's EIA study. It is therefore considered that there will be no impact on the corals. Insignificant changes are predicted at the ESAs, apart from at the outlets of Sungai Bayan Lepas and Bayan Lepas Main Drain, where erosion is predicted up to 0.1 and 0.3 m/year respectively. The erosion, however, is not expected to cause negative impact as there would be less maintenance dredging requirement. The sedimentation rate within the dredged channels is predicted to be approximately 125,000 m^3/year.

T7.26 Summary of potential impacts on sediment transport for all scenarios (cont'd)

Scenario	Findings
Scenario 4 	The channel between Island C and the coastline of Kampung Gertak Sanggul is predicted to experience erosion. The erosion rate is up to 0.6 m/year near the coastline of Tanjung Gemuruh which is mostly rocky. Although the predicted erosion is within the dredged channel, it is recommended that Island C's edge protection design incorporate scour protection. Sedimentation of up to 0.1 m/year is observed in the channel along Teluk Pasir Belanda. Periodic monitoring survey is recommended to ensure the channel is navigable for the local fishing communities and maintenance dredging is to be carried out as and when required. There is localised erosion up to 0.3 m/year near Island C's marina breakwaters. As such, the design of the breakwaters needs to incorporate protection against toe scour. Sedimentation of up to 0.1 m/year is expected within the marina basin, where periodic monitoring survey and maintenance dredging can be done for safe berthing of recreational boats. As the marina's northern breakwater protrudes further into the current flow path than the headland of Tanjung Gertak Sanggul, sedimentation rate of up to 0.2 m/year at the headland is predicted. Given that the existing seabed level in this area is deeper than -9 m CD, sedimentation is not expected to have an impact on the safe navigation of the fishing boats. There are insignificant changes at the ESAs, except for the outlet of Sungai Gertak Sanggul, where a sedimentation rate of about 0.1 m/year is predicted. Periodic monitoring survey and maintenance dredging are recommended. The annual sedimentation rate within the dredged channels is predicted to be approximately 150,000 m^3.

7.3.9 Sediment Spill Dispersion

One of the major environmental considerations for activities related to land reclamation and dredging work is on the dispersion of sediment plume. Land reclamation works will introduce fine material from the fill material (sand) while dredging will disturb the bed material, causing clay, silt and sand to be dispersed in the water column. These would increase the suspended sediments and the spatial distribution of the TSS would cause turbid water around the Project area. If unmitigated, this condition may affect various sensitive receptors.

The impact of sediment dispersion has been investigated using sediment plume modelling. The purpose of the sediment dispersion modelling is to determine the spatial and temporal concentrations of the spilled suspended sediment as well as the eventual fate of the suspended sediment. These would help inform the assessment of potential impact on marine biology, water quality and other sensitive receptors in the vicinity of the Project site.

7.3.9.1 Simulation Model

MIKE 21 Mud Transport (MT) module has been used for the sediment dispersion modelling simulations. The sediment dispersion model interacts with the hydrodynamics model to simulate the dispersion of the suspended sediment under the climatic conditions described in *Section 7.3*.

The sediment plume dispersion model is initially set up for the reclamation and dredging work activities described in *Chapter 5: Project Description* without any mitigation measures to represent the worst-case scenario. In the event that the modelling results show there is an exceedance of the tolerable limits of the suspended sediment concentration at the ESAs, mitigation measures are proposed in which the mitigated condition will be re-simulated in the model. A simulation period coinciding with a full spring-neap cycle is used.

7.3.9.2 Sediment Spill Budget

For the purpose of this study, a daily sediment spill rate is established, which is incorporated as an input for the simulation. The daily sediment spill rates for each CSD undertaking dredging works and each THSD off-loading reclamation material are 1,283 tonnes and 952 tonnes respectively as derived in *Section 5.4.4* and *Section 5.4.5,* respectively.

It is planned to have two Cutter Suction Dredgers (CSD) undertaking dredging works in all scenarios while reclamation works will deploy four Trailing Suction Hopper Dredgers (TSHD). It is noted that although there are a number of TSHDs working in each scenario, there will only be one THSD and one discharge point at a time, as the TSHD will be scheduled to pump the reclamation material ashore one after another. T7.27 summarises the total daily sediment spill budget for each of the development scenario without any mitigation measures.

T7.27 Number of CSDs and THSDs and total daily sediment spill budget in each scenario

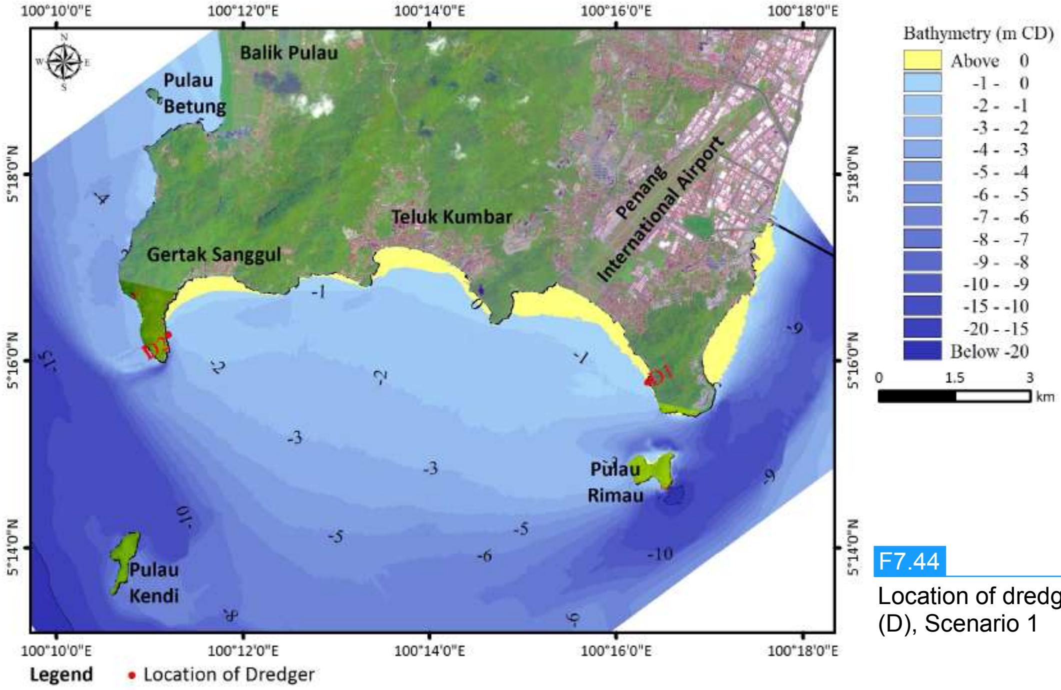
Descriptions	Scenario 1	Scenario 2	Scenario 3	Scenario 4
No. of CSD	2	2	2	2
Daily spill budget from dredging activities	2,566 tonnes	2,566 tonnes	2,566 tonnes	2,566 tonnes
No. of TSHD	-	4	4	2
Daily spill budget from reclamation activities	-	3,808 tonnes	3,808 tonnes	1,904 tonnes
Total daily spill budget	2,566 tonnes	6,374 tonnes	6,374 tonnes	4,470 tonnes

7.3.9.3 Impact Assessment

The dispersal of sediment plume that will cause an elevated level of TSS concentration will not only affect the marine water quality but also the ESAs located surrounding the Project site. The magnitude of impacts affecting said ESAs are closely related with the extent of the plume dispersant. For brevity of the impact assessment discussion, these two aspects will be discussed in two different sections. This section will only focus on the extent of plume dispersant while the impacts on each identified ESA will be discussed in the following subsections.

a) Scenario 1

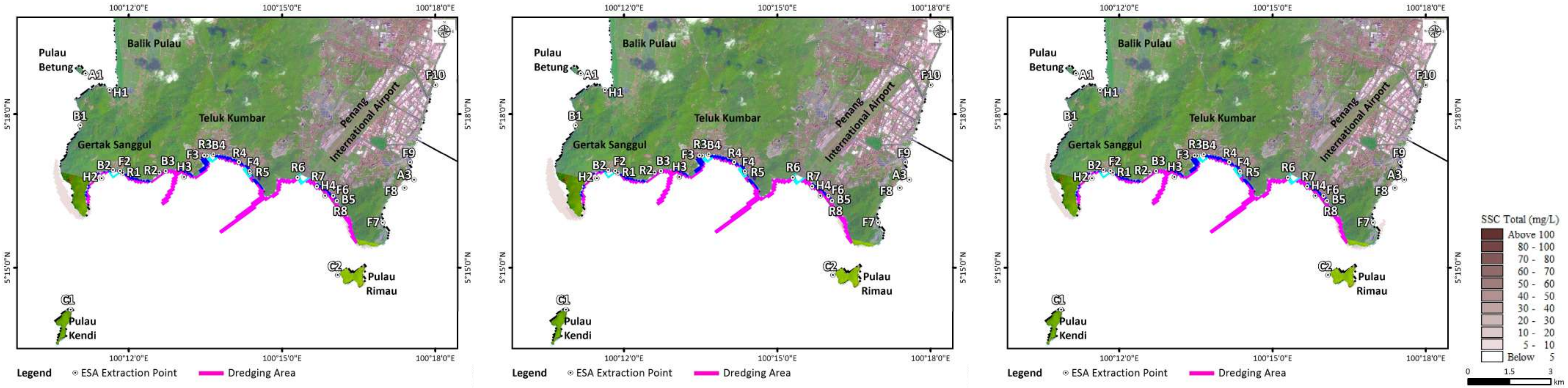
The dredging works are initially simulated with two dredgers working at the same time. One dredger is dredging at the -2 m CD seabed contour near Tanjung Gertak Sanggul and the other at -2 m CD contour near Tanjung Teluk Tempoyak, as shown in F7.44. These two locations are selected as the current speeds are higher and they are the nearest to Pulau Kendi and Pulau Rimau (implying a worst-case scenario).



F7.44
Location of dredgers (D), Scenario 1

The mean and maximum excess suspended sediment concentrations for the different climatic conditions due to the dredging works in Scenario 1 are shown in F7.45 and F7.46. From the results, the Southwest Monsoon condition represents the worst-case condition in terms of the extent of sediment spill dispersion. F7.46 shows that the maximum suspended sediment concentration at the aquaculture farms at Batu Maung and Pulau Betung is up to 20 mg/L. The figure also shows that the excess suspended sediment concentrations at Pulau Kendi and the water extraction point for the hatchery near Sungai Pulau Betung are below 5 mg/L.

The maximum excess suspended sediment concentration exceeds 10 mg/L at Pulau Rimau. Further analysis are therefore required on the percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations required to ascertain the level of impact at Pulau Rimau. The results of the analysis are presented in F7.47 and F7.48. These figures show that the percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations is less than 5% at both Pulau Rimau and Pulau Kendi. F7.49 shows that the sedimentation rates of suspended sediment at both Pulau Rimau and Pulau Kendi are less than 1 mm over 14 days.

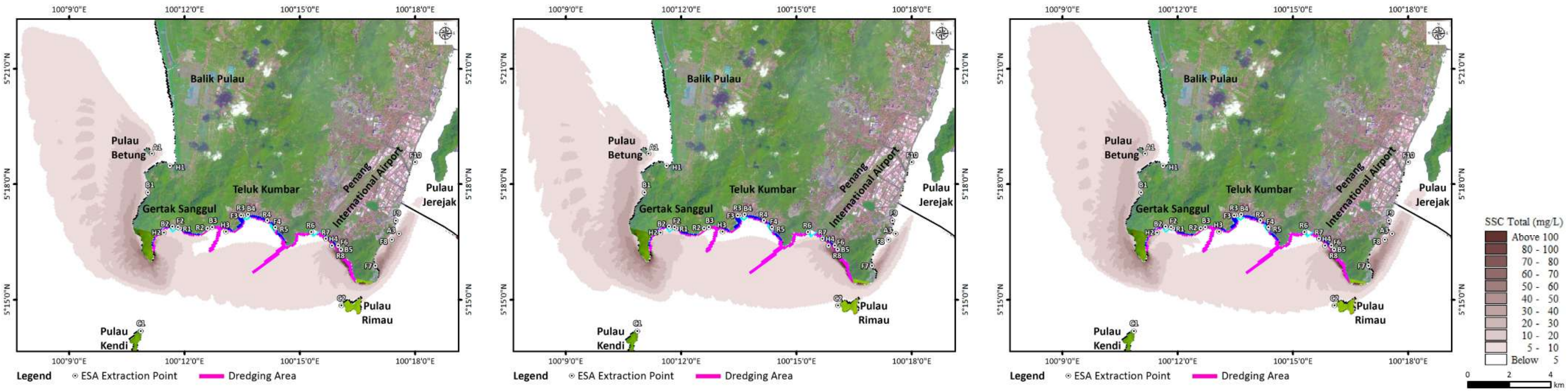


a) Pure tide condition

b) Northeast Monsoon condition

c) Southwest Monsoon condition

F7.45 Mean excess suspended sediment concentration for Scenario 1, unmitigated condition



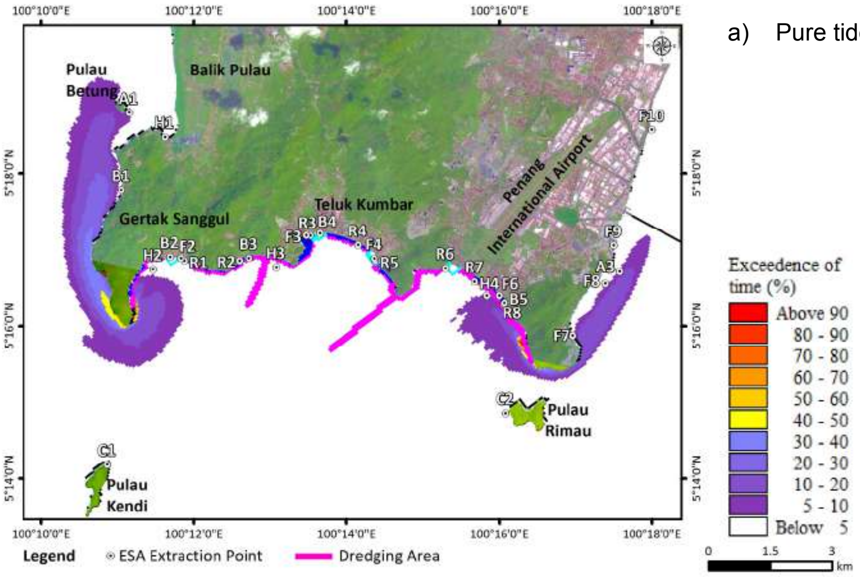
a) Pure tide condition

b) Northeast Monsoon condition

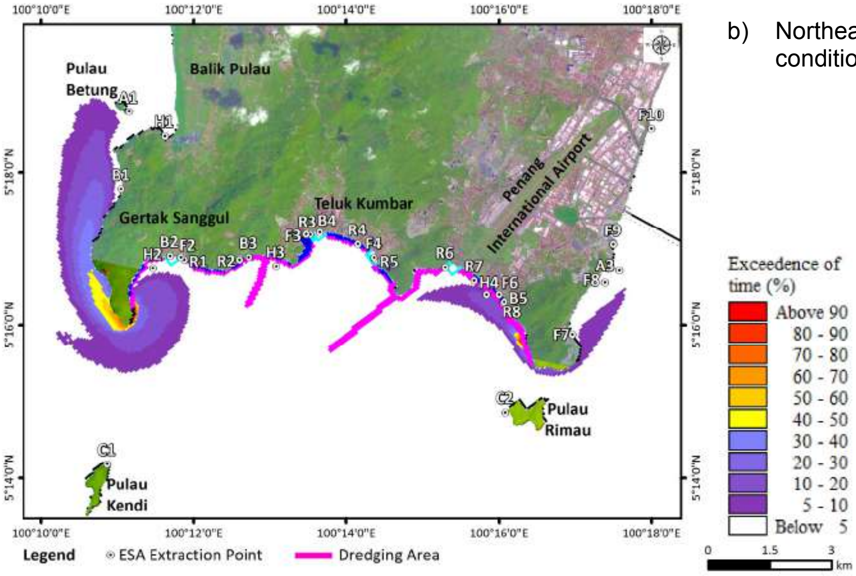
c) Southwest Monsoon condition

F7.46 Maximum excess suspended sediment concentration for Scenario 1, unmitigated condition

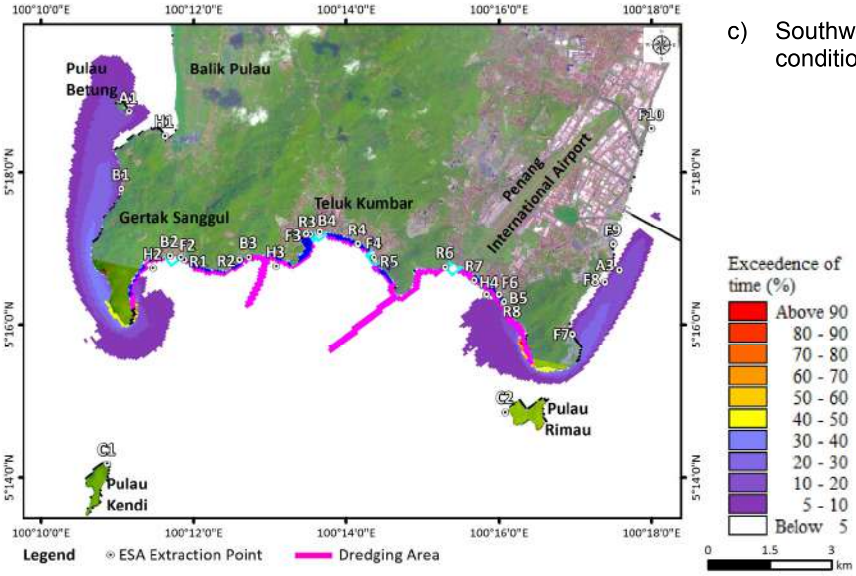
a) Pure tide condition



b) Northeast Monsoon condition

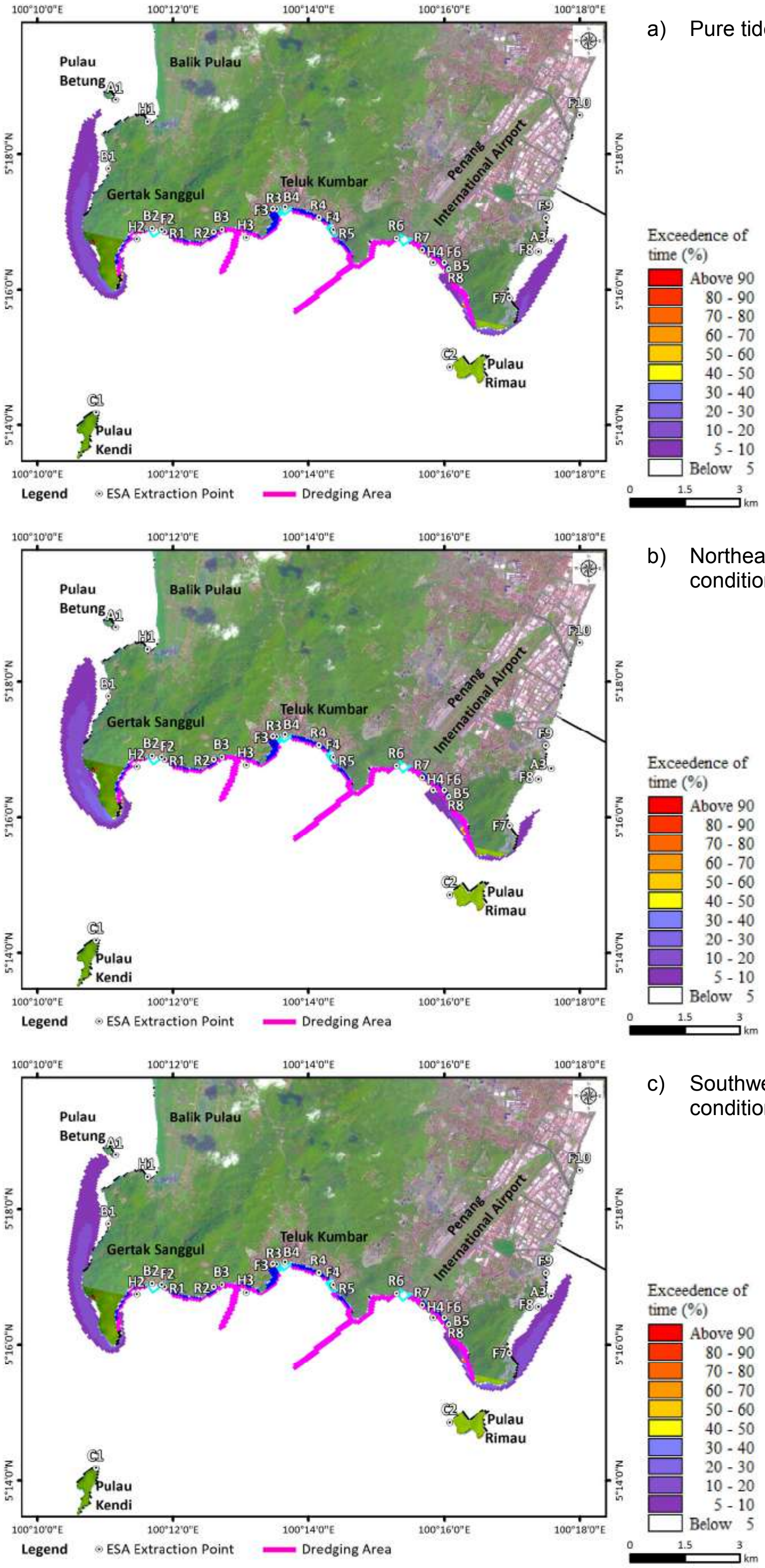


c) Southwest Monsoon condition



F7.47

Percentage of time exceedance of suspended sediment concentration above 5 mg/L for Scenario 1, unmitigated condition



a) Pure tide condition

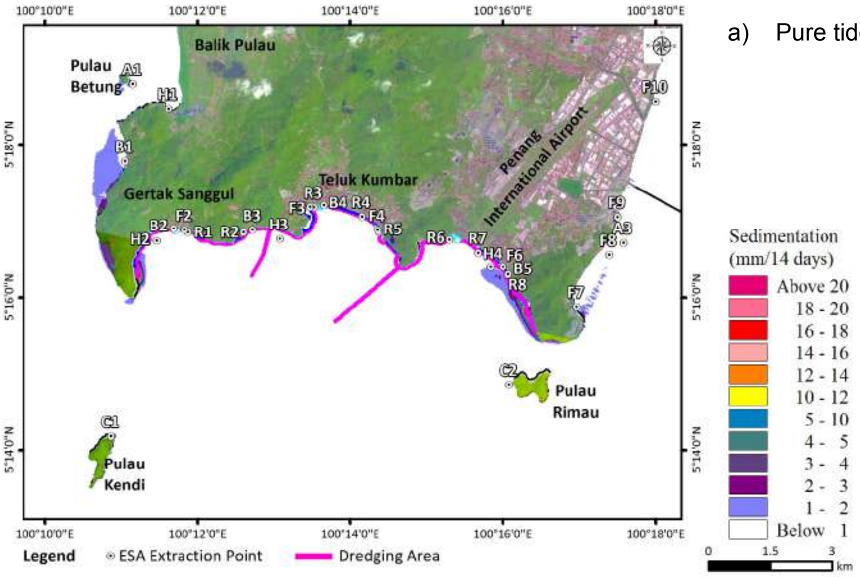
b) Northeast Monsoon condition

c) Southwest Monsoon condition

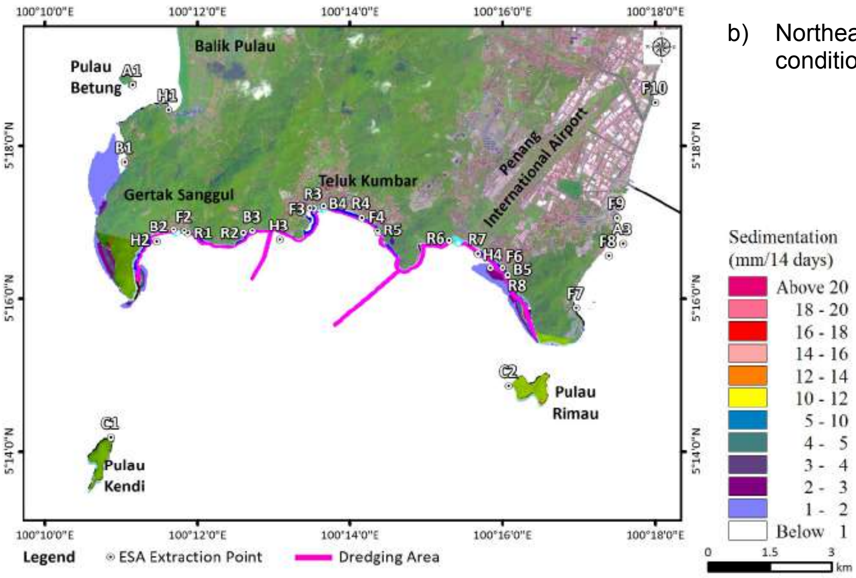
F7.48

Percentage of time exceedance of suspended sediment concentration above 10 mg/L for Scenario 1, unmitigated condition

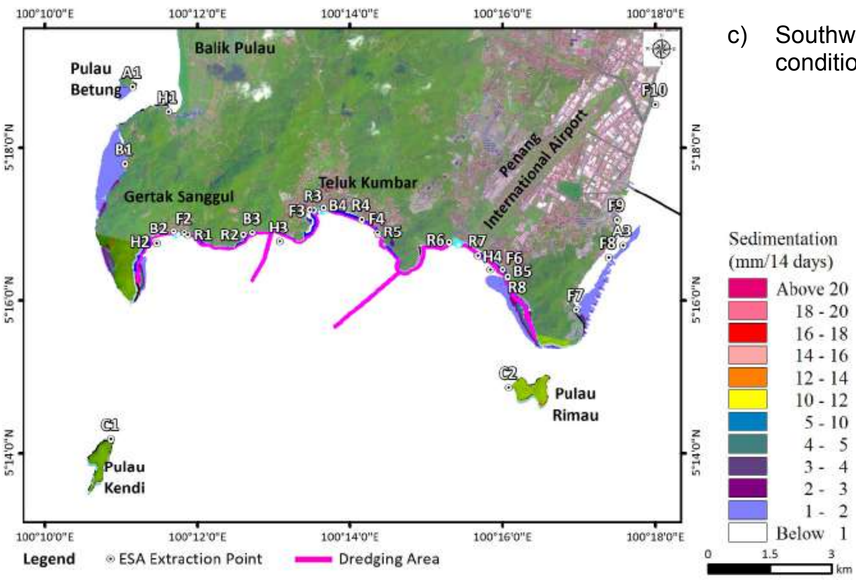
a) Pure tide condition



b) Northeast Monsoon condition



c) Southwest Monsoon condition



F7.49 Sedimentation of suspended sediment for Scenario 1, unmitigated condition

Mean and maximum excess suspended concentration levels were extracted at the ESAs point, as presented in T7.28.

T7.28 Mean and maximum excess suspended concentration at the ESAs for Scenario 1

Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
R1	Sungai Gertak Sanggul	0	4	Insignificant impact
R2	Sungai Gemuruh	0	1	Insignificant impact
R3	Sungai Teluk Kumbar	0	0	Insignificant impact
R4	Sungai Mati	0	0	Insignificant impact
R5	Sungai Batu	0	0	Insignificant impact
R6	Sungai Bayan Lepas	0	0	Insignificant impact
R7	Bayan Lepas Main Drain	0	1	Insignificant impact
R8	Sungai Ikan Mati	1	15	Insignificant impact
C1	Pulau Kendi	0	0	Insignificant impact
C2	Pulau Rimau	0	2	Insignificant impact
H1	Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	1	3	Insignificant impact
H3	Teluk Kumbar	0	1	Insignificant impact
H4	Permatang Damar Laut	1	9	Insignificant impact
A1	Pulau Betung	1	7	Insignificant impact
A2	Sungai Pulau Betung	-	-	No data (upstream location)
A3	Batu Maung	1	14	Insignificant impact
F1	Sungai Pulau Betung	-	-	No data (upstream location)
F2	Gertak Sanggul	0	1	Insignificant impact
F3	Teluk Kumbar	0	0	Insignificant impact
F4	Sungai Batu	0	0	Insignificant impact
F5	Permatang Tepi Laut	-	-	No data (upstream location)
F6	Permatang Damar Laut	1	17	Insignificant impact
F7	Teluk Tempoyak Besar	0	13	Insignificant impact
F8	Teluk Tempoyak Kecil	0	10	Insignificant impact
F9	Batu Maung	0	0	Insignificant impact
F10	Sri Jerjak	0	0	Insignificant impact

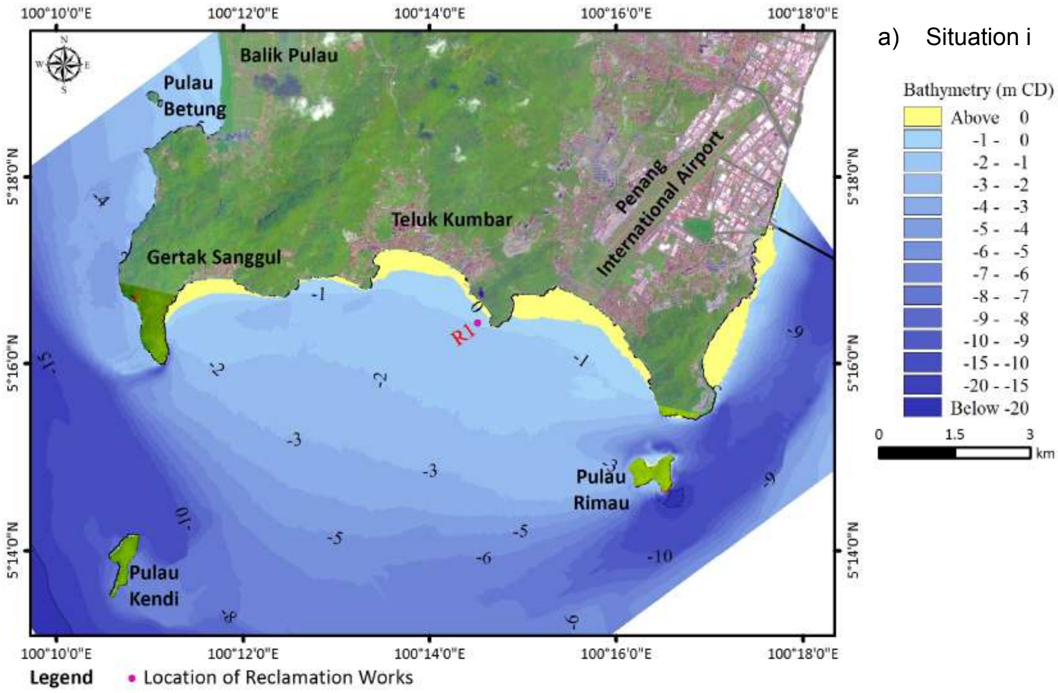
b) Scenario 2

As described in *Chapter 5: Project Description*, the reclamation works will start with the placing of reclamation material within the proposed rock bund. A sand bund will then be constructed. The rock and sand bunds constructed will enclose the reclamation area, within which the reclamation material will be offloaded. It is considered that the initial placing of fill material (sand) over the footprint of the proposed rock bund, without any containment, will present the worst-case scenario for the sediment spill dispersion modelling.

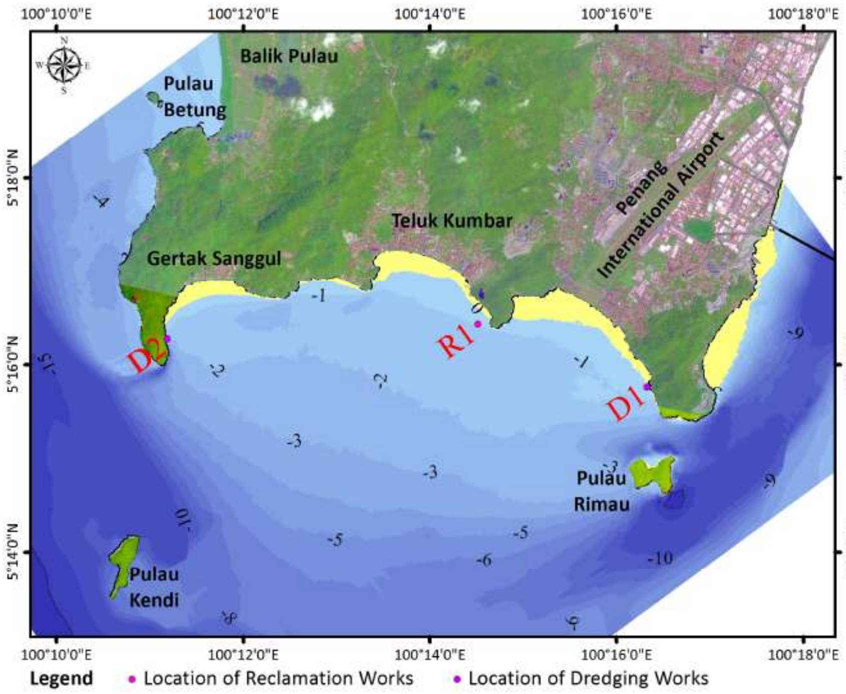
The reclamation and dredging works will be done simultaneously during this scenario. As such, placement of the dredgers and the location of reclamation activities are imperative in determining the stage of work that will cause the highest impact magnitude.

Several dredgers placement and reclamation activities location in relation to the progress of the development have been considered, which can be described as follows:

i) Reclamation of Scenario 2 from the inshore end of Island B (F7.50a);
ii) Dredging of Scenario 1 and reclamation of Scenario 2 (inshore end) running simultaneously (F7.50b); and
iii) Reclamation at the outermost end of Island B and dredging of access channel running simultaneously (F7.50c).



a) Situation i

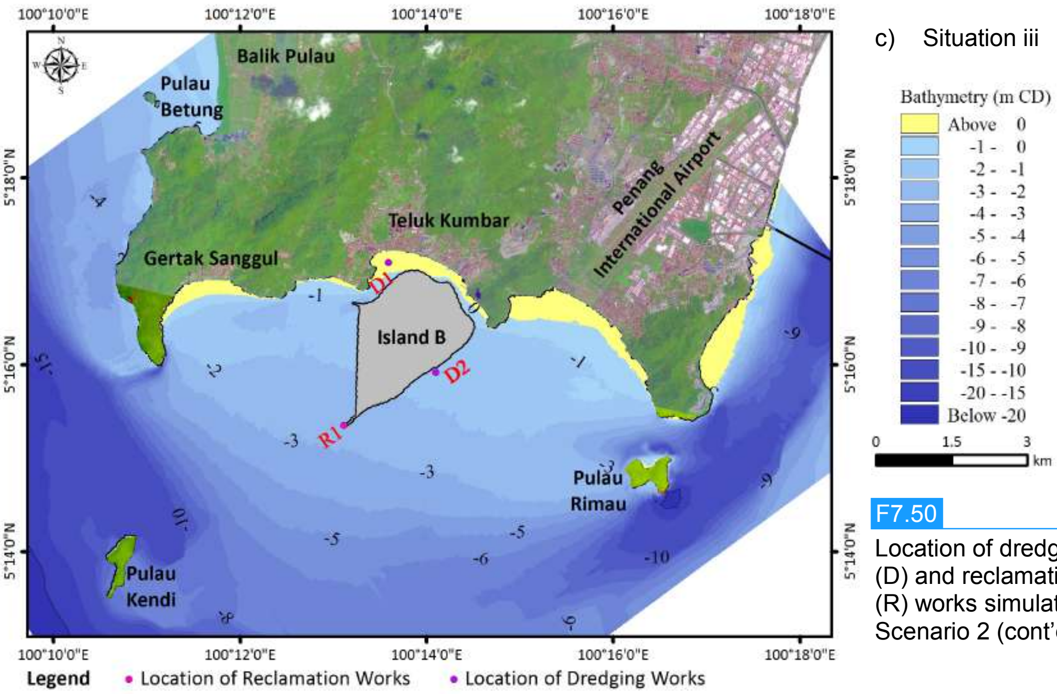


b) Situation ii

F7.50

Location of dredging (D) and reclamation (R) works simulated, Scenario 2

c) Situation iii



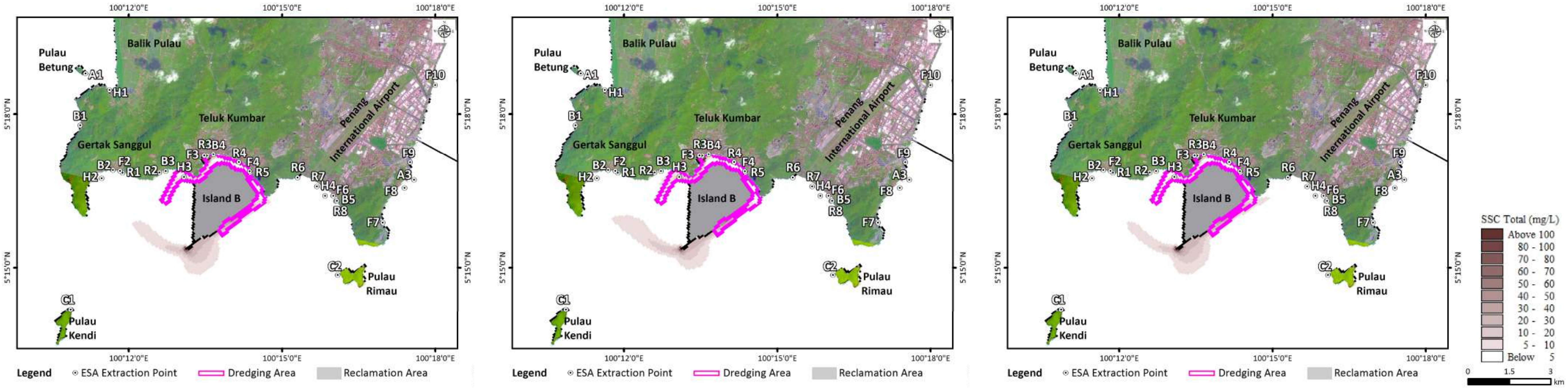
F7.50

Location of dredging (D) and reclamation (R) works simulated, Scenario 2 (cont'd)

From the simulation results, the worst case to be considered in the impact assessment is determined to be *Situation iii* where the fast currents at the outer end of the reclamation cause the furthest dispersant of sediment plume. For *Situations i* and *ii* where the reclamation is placed at the inshore end, the extent of sediment plume is less as the current speed is slower. As such, impact assessment for Scenario 2 is based on the later stage of the reclamation where the active working area is at the outermost end of Island B.

F7.51 and F7.52 show the mean and maximum excess suspended sediment concentration for Scenario 2 for different climatic conditions respectively. F7.52 shows that the maximum suspended sediment concentrations extends further northwest than Pulau Betung, especially in the Southwest Monsoon conditions, but are reasonably distant from the aquaculture farms. The water abstraction point for the hatchery near Sungai Pulau Betung is not affected.

The percentages of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations are presented in F7.53 and F7.54, respectively. Meanwhile, F7.55 shows that the sedimentation rates of suspended sediment at Pulau Rimau and Pulau Kendi do not exceed 1 mm over 14 days.

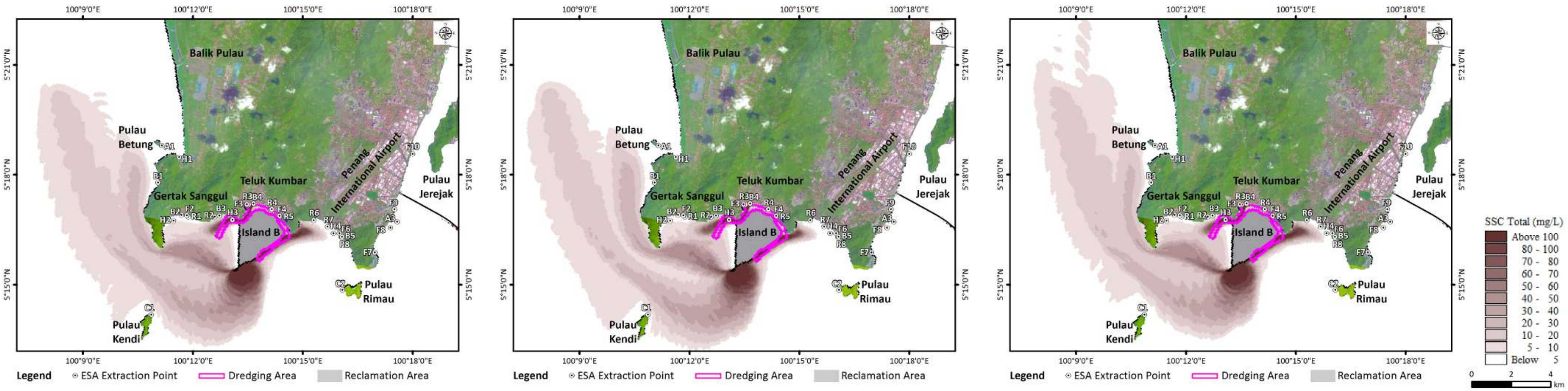


a) Pure tide condition

b) Northeast Monsoon condition

c) Southwest Monsoon condition

F7.51 Mean excess suspended sediment concentration for Scenario 2, unmitigated condition



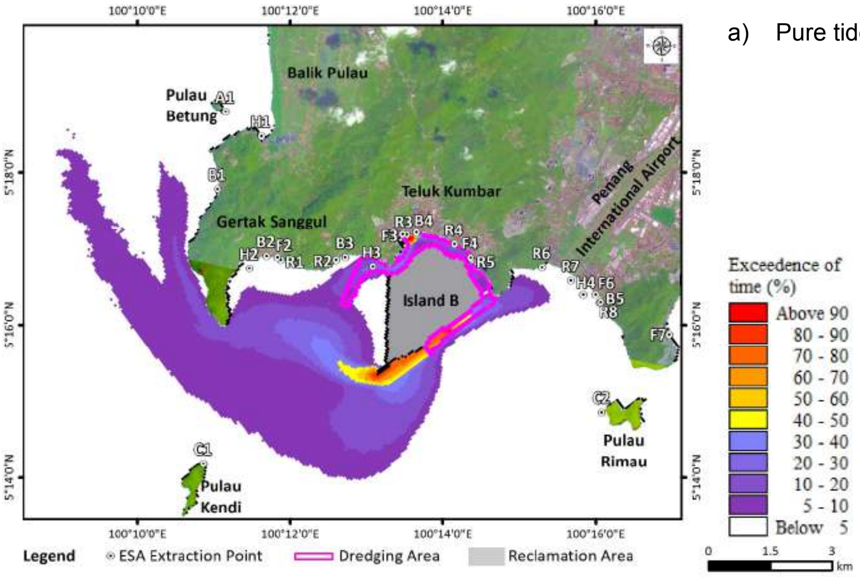
a) Pure tide condition

b) Northeast Monsoon condition

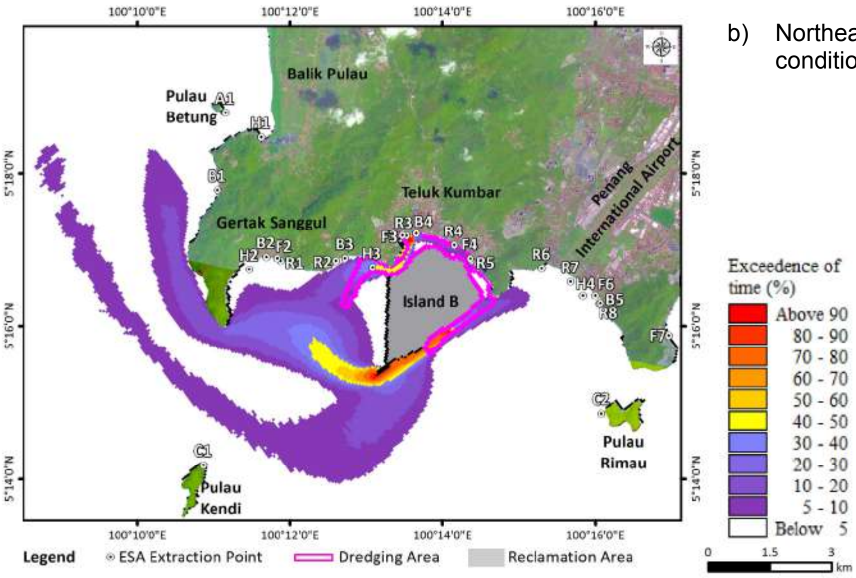
c) Southwest Monsoon condition

F7.52 Maximum excess suspended sediment concentration for Scenario 2, unmitigated condition

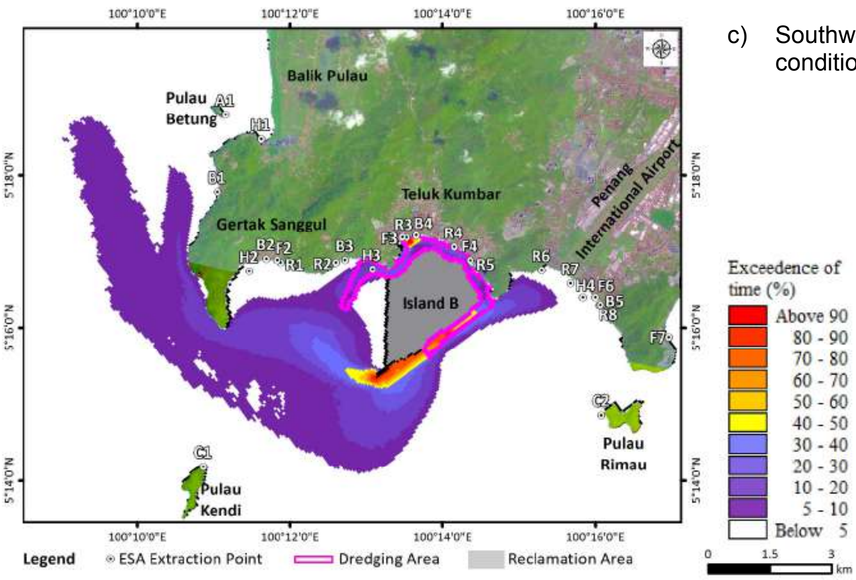
a) Pure tide condition



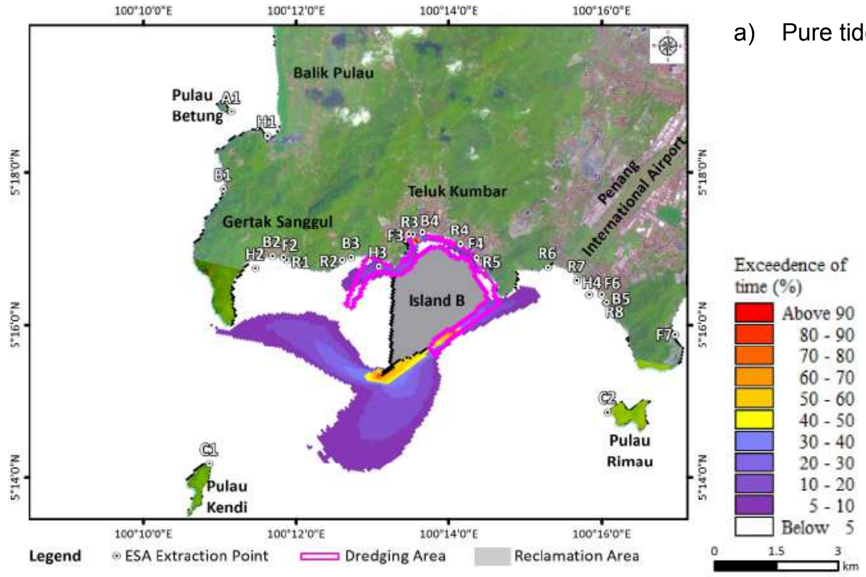
b) Northeast Monsoon condition



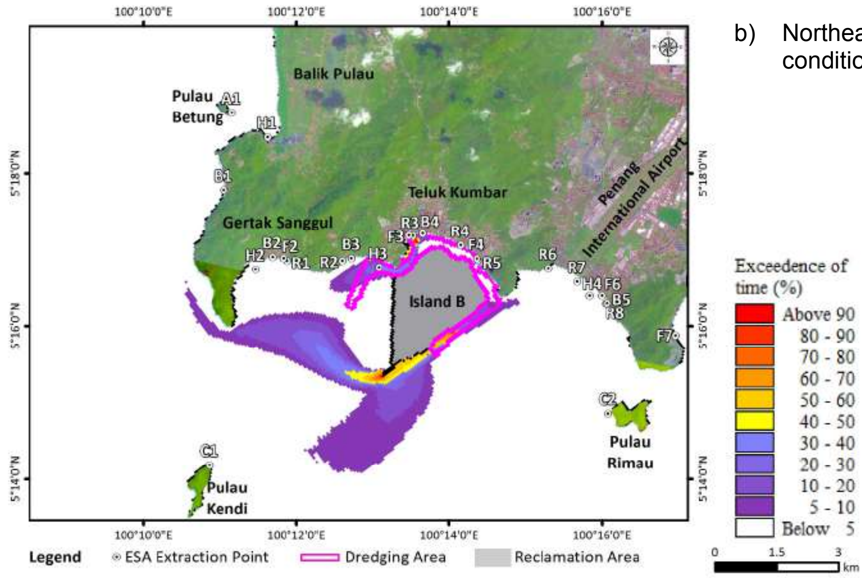
c) Southwest Monsoon condition



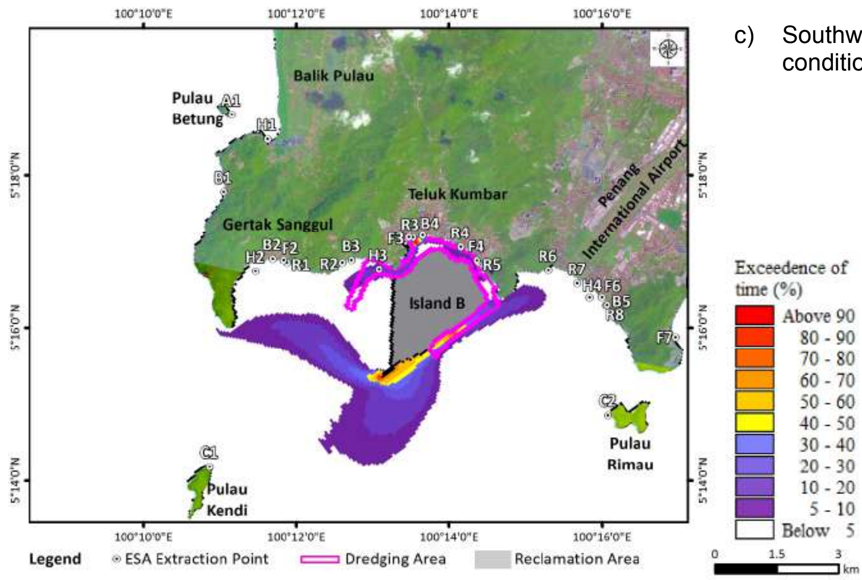
F7.53
Percentage of time exceedance of suspended sediment concentration above 5 mg/L for Scenario 2, unmitigated condition



a) Pure tide condition

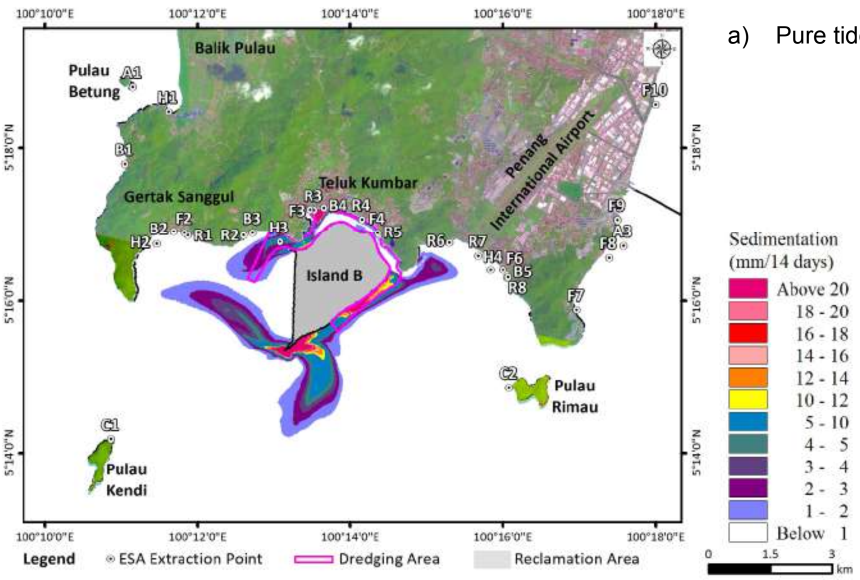


b) Northeast Monsoon condition

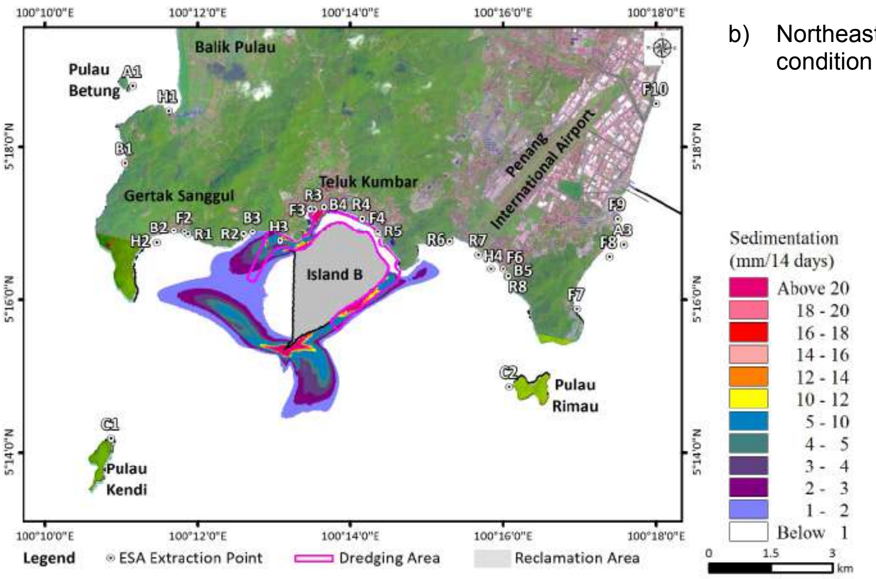


c) Southwest Monsoon condition

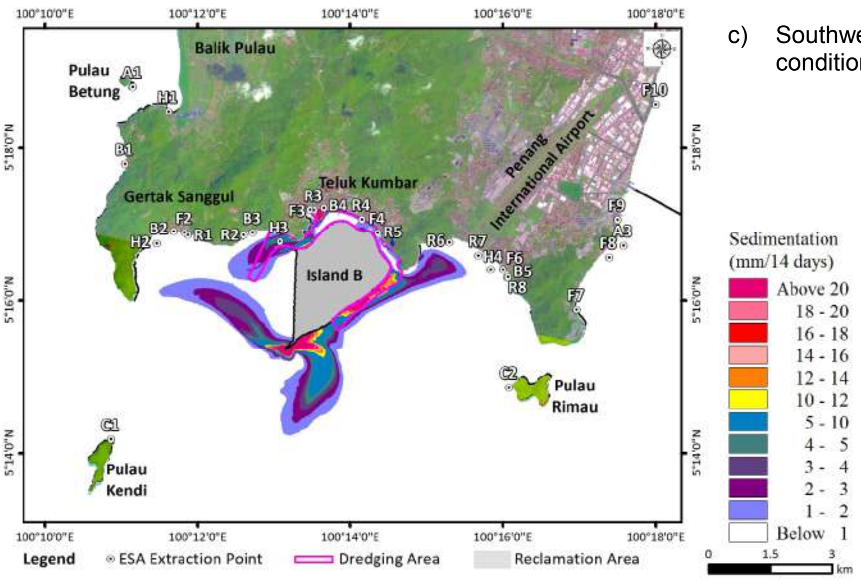
F7.54
Percentage of time exceedance of suspended sediment concentration above 10 mg/L for Scenario 2, unmitigated condition



a) Pure tide condition



b) Northeast Monsoon condition



c) Southwest Monsoon condition

F7.55

Sedimentation of suspended sediment for Scenario 2, unmitigated condition

Mean and maximum excess suspended concentration levels were extracted at the ESAs point, which is presented in T7.29.

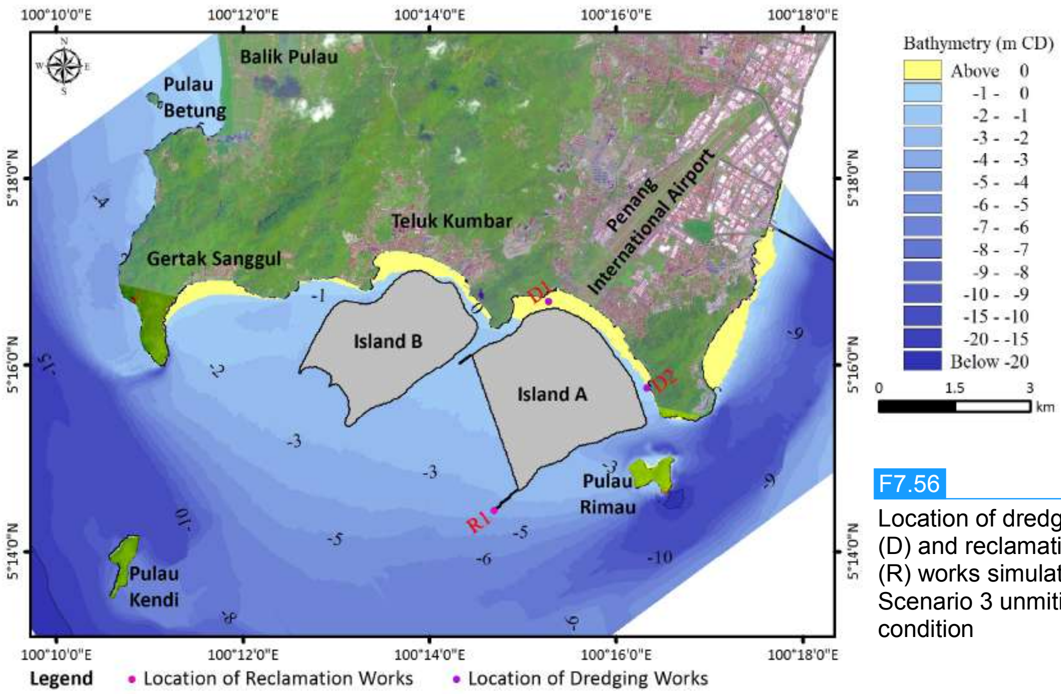
T7.29 Mean and maximum excess suspended concentration at the ESAs for Scenario 2

Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
R1	Sungai Gertak Sanggul	0	2	Insignificant impact
R2	Sungai Gemuruh	1	13	Insignificant impact
R3	Sungai Teluk Kumbar	2	11	Insignificant impact
R4	Sungai Mati	2	28	Insignificant impact
R5	Sungai Batu	2	45	Insignificant impact
R6	Sungai Bayan Lepas	0	1	Insignificant impact
R7	Bayan Lepas Main Drain	0	0	Insignificant impact
R8	Sungai Ikan Mati	0	0	Insignificant impact
C1	Pulau Kendi	0	1	Insignificant impact
C2	Pulau Rimau	0	0	Insignificant impact
H1	Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	117	High TSS level will affect the existing filtration system, thus mitigation measure is required
H4	Permatang Damar Laut	0	0	Insignificant impact
A1	Pulau Betung	0	2	Insignificant impact
A2	Sungai Pulau Betung	-	-	No data (upstream location)
A3	Batu Maung	0	0	Insignificant impact
F1	Sungai Pulau Betung	-	-	No data (upstream location)
F2	Gertak Sanggul	0	1	Insignificant impact
F3	Teluk Kumbar	4	19	Insignificant impact
F4	Sungai Batu	3	54	Insignificant impact
F5	Permatang Tepi Laut	-	-	No data (upstream location)
F6	Permatang Damar Laut	0	0	Insignificant impact
F7	Teluk Tempoyak Besar	0	0	Insignificant impact
F8	Teluk Tempoyak Kecil	0	0	Insignificant impact
F9	Batu Maung	0	0	Insignificant impact
F10	Sri Jerjak	0	0	Insignificant impact

c) Scenario 3

Findings from Scenario 2 have demonstrated that the reclamation works within the Project site do not result in significant level of excess suspended sediment concentrations at the ESAs. This is because the current speeds are lower at the inner ends of the reclaimed islands. It is therefore considered not necessary to simulate the reclamation works at the inner end of Island A in Scenario 3.

Instead, the sediment spill dispersion model for Scenario 3 simulates placement of the initial reclamation layer without containment at the outer-most end of Island A. At the same time, dredging works are carried out by two dredgers working simultaneously. One dredger is dredging between Island A and the existing foreshore and the other one is dredging the access channel near Tanjung Teluk Tempoyak at -2 m CD. F7.56 shows the locations of the dredging and reclamation activities for Scenario 3.

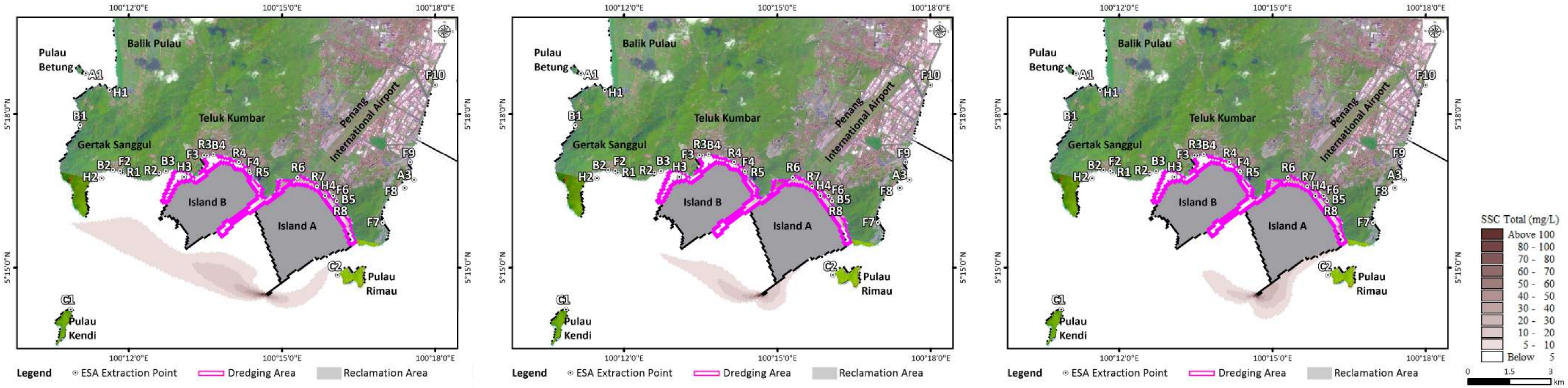


F7.56
Location of dredging (D) and reclamation (R) works simulated, Scenario 3 unmitigated condition

It is noted that although the reclamation works in Scenario 4 are planned to start while the dredging works in Scenario 3 are being carried out, the reclamation works in Scenario 4 will start from the inner end of Island C instead of the outer end. As such, the reclamation location considered for Island A is still considered the worst case as it is at the outer end of Island A where there are fast currents.

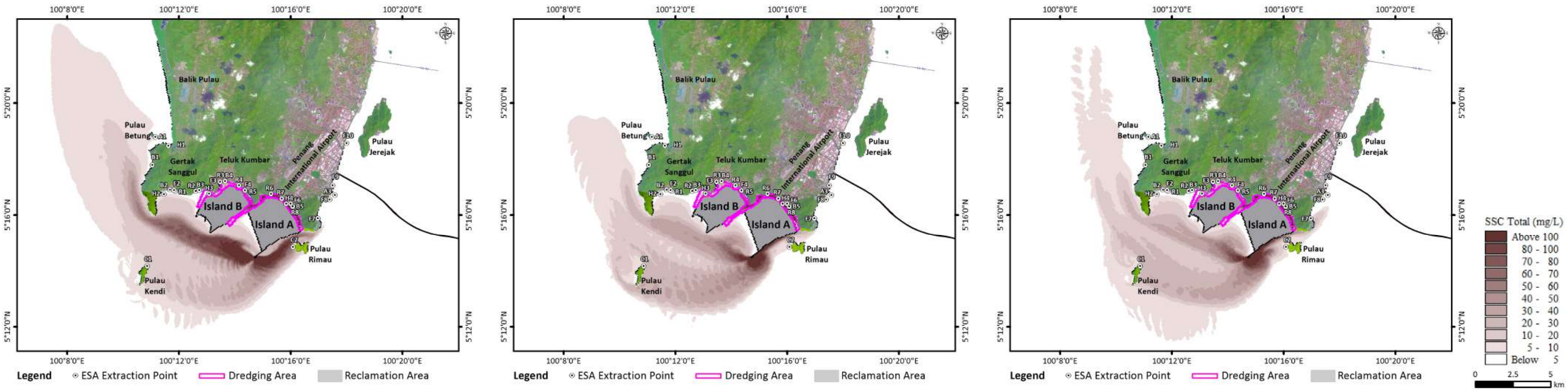
F7.57 and F7.58 show the mean and maximum excess suspended sediment concentrations for Scenario 3, unmitigated condition, for different climatic conditions respectively. The pure-tide condition appears to be the worst-case condition, in terms of the extent and level of suspended sediment concentration, especially near Pulau Rimau. From the figures, the excess suspended sediment concentration appears to be primarily arising from the reclamation activities as the dredging locations are relatively sheltered. The reclamation location is at a very fast current area.

The results show that the maximum excess suspended sediment concentration at Pulau Betung is up to 10 mg/L and less than 5 mg/L at Batu Maung. There are therefore no impacts to the aquaculture farms in these areas. Likewise, the water abstraction point for the hatchery near Sungai Pulau Betung is not affected. The maximum excess suspended sediment concentration at Pulau Kendi and Pulau Rimau appears high, especially at the latter. F7.59 and F7.60 show the percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations respectively. F7.61 shows the sedimentation rates of suspended sediment at Pulau Kendi are less than 1 mm over 14 days.



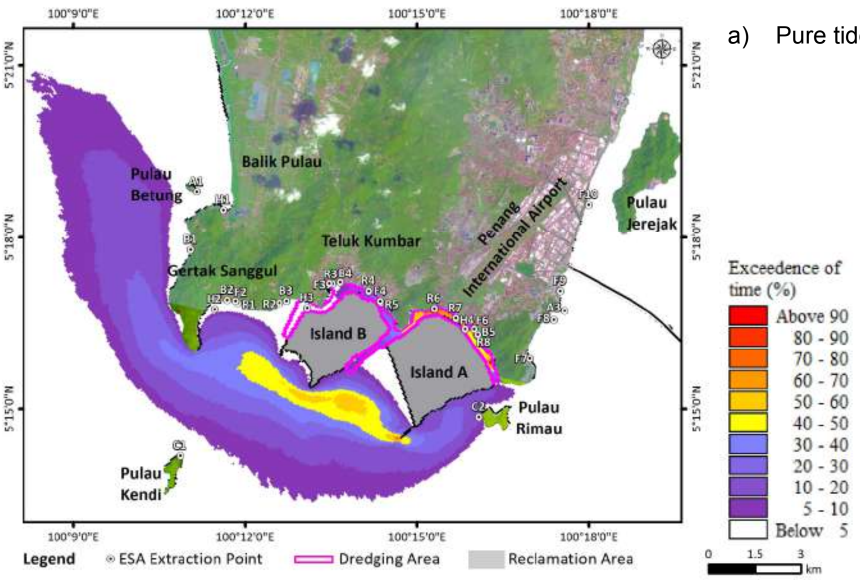
a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

F7.57 Mean excess suspended sediment concentration for Scenario 3, unmitigated condition

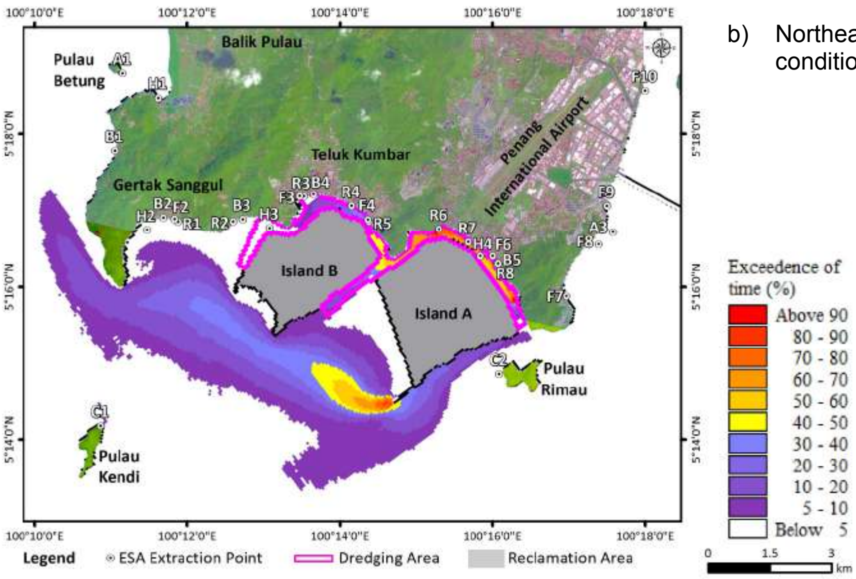


a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

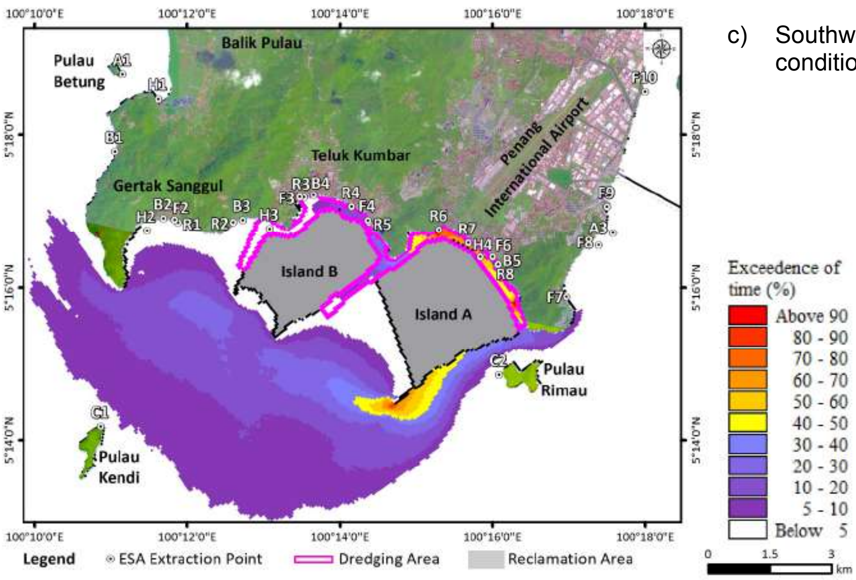
F7.58 Maximum excess suspended sediment concentration for Scenario 3, unmitigated condition



a) Pure tide condition



b) Northeast Monsoon condition

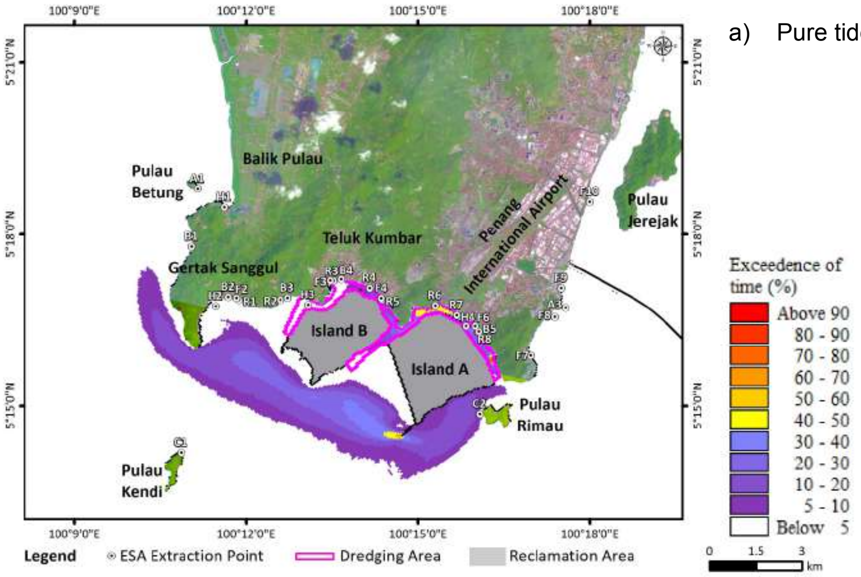


c) Southwest Monsoon condition

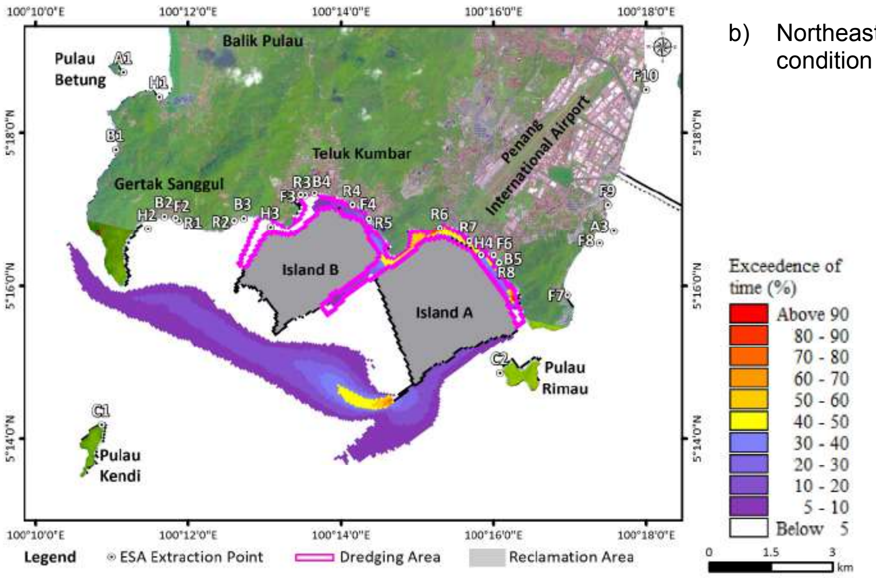
F7.59

Percentage of time exceedance of suspended sediment concentration above 5 mg/L for Scenario 3, unmitigated condition

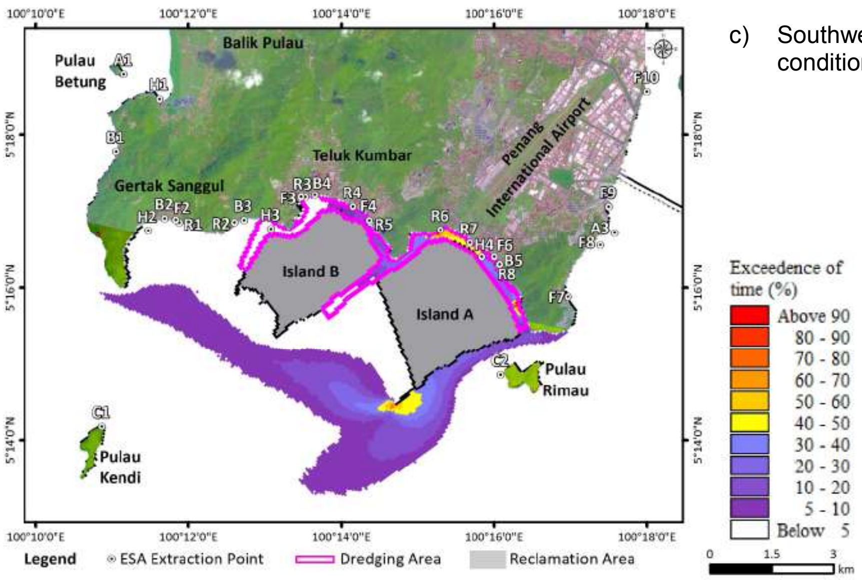
a) Pure tide condition



b) Northeast Monsoon condition

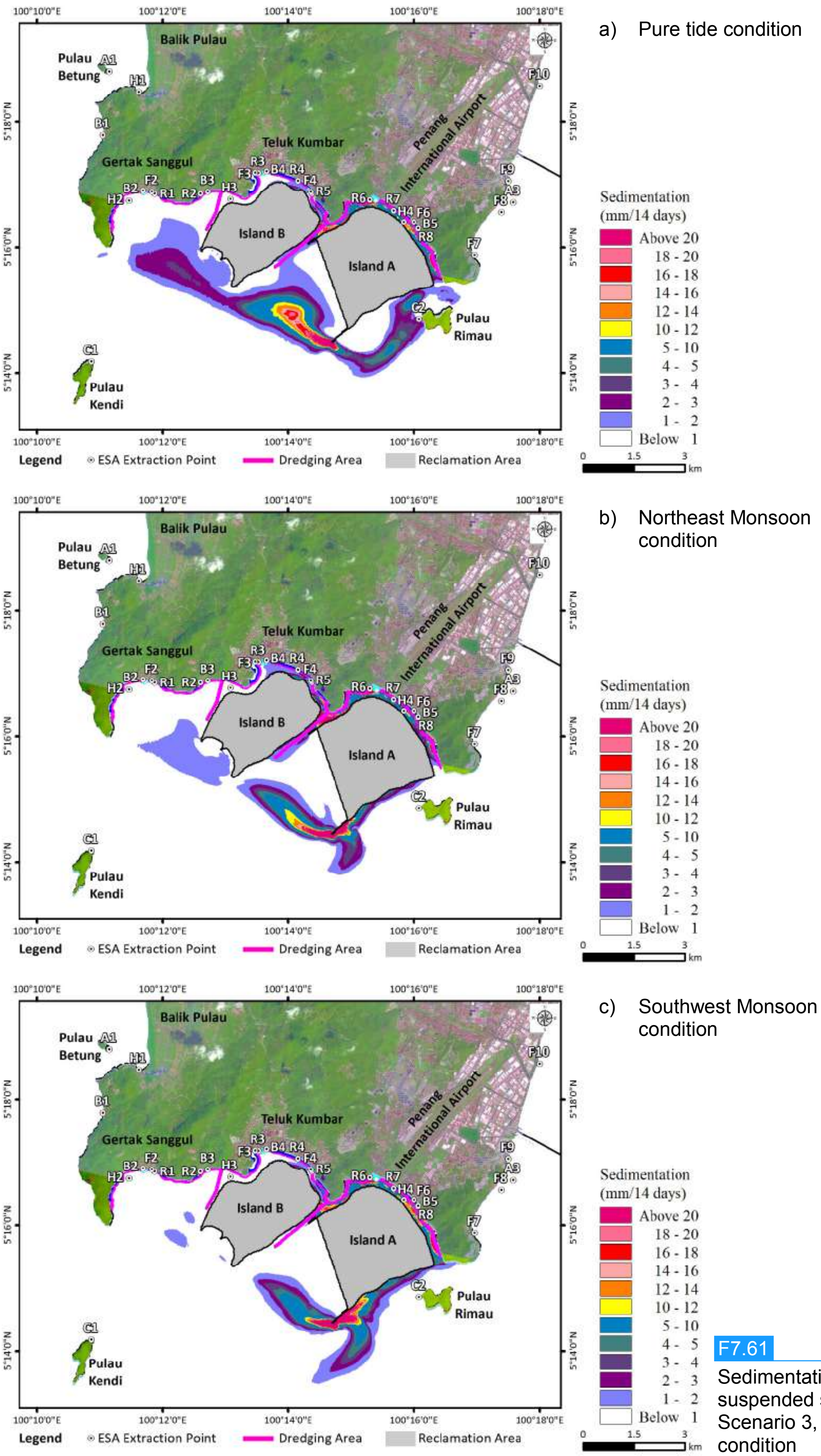


c) Southwest Monsoon condition



F7.60

Percentage of time exceedance of suspended sediment concentration above 10 mg/L for Scenario 3, unmitigated condition



F7.61

Sedimentation of suspended sediment for Scenario 3, unmitigated condition

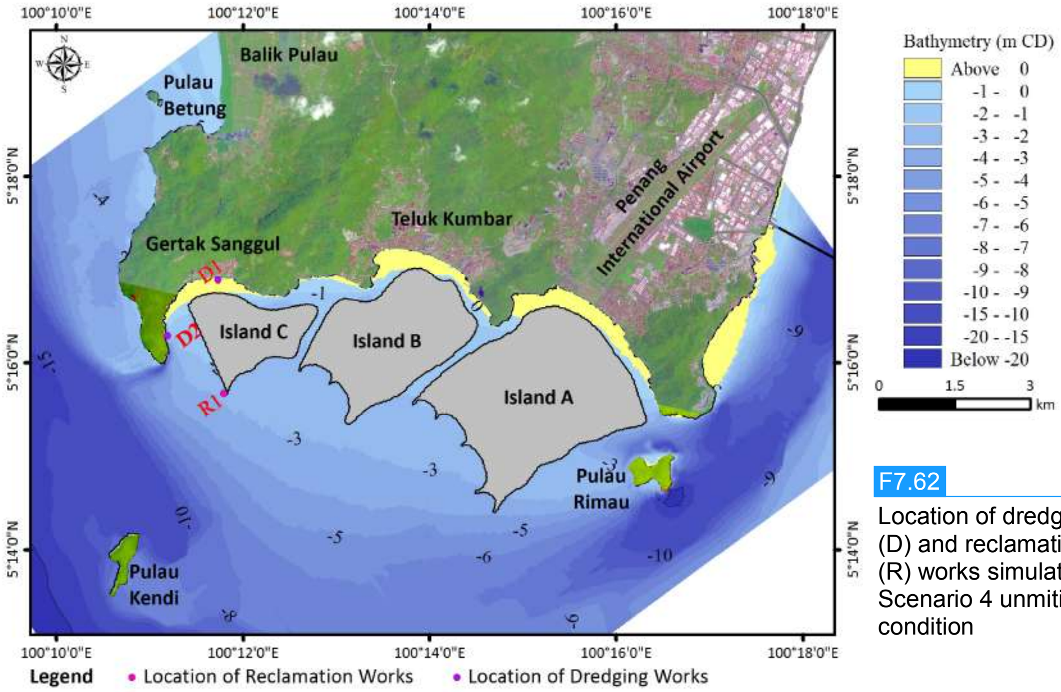
Mean and maximum excess suspended concentration levels were extracted at the ESAs points, which are presented in T7.30.

T7.30 Mean and maximum excess suspended concentration at the ESAs for Scenario 3

Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
R1	Sungai Gertak Sanggul	0	3	Insignificant impact
R2	Sungai Gemuruh	0	1	Insignificant impact
R3	Sungai Teluk Kumbar	1	29	Insignificant impact
R4	Sungai Mati	1	12	Insignificant impact
R5	Sungai Batu	3	25	Insignificant impact
R6	Sungai Bayan Lepas	26	244	Turbid water may cause aesthetic impact
R7	Bayan Lepas Main Drain	26	315	Turbid water may cause aesthetic impact
R8	Sungai Ikan Mati	13	226	Turbid water may cause aesthetic impact
C1	Pulau Kendi	1	5	Insignificant impact
C2	Pulau Rimau	2	47	High TSS level may cause stress to the corals. Refer to *Section 7.5.1*.
H1	Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	7	Insignificant impact
H4	Permatang Damar Laut	19	241	High TSS level will affect the existing filtration system, thus mitigation measure is required
A1	Pulau Betung	0	4	Insignificant impact
A2	Sungai Pulau Betung	-	-	No data (upstream location)
A3	Batu Maung	0	0	Insignificant impact
F1	Sungai Pulau Betung	-	-	No data (upstream location)
F2	Gertak Sanggul	0	2	Insignificant impact
F3	Teluk Kumbar	0	2	Insignificant impact
F4	Sungai Batu	4	35	Insignificant impact
F5	Permatang Tepi Laut	-	-	No data (upstream location)
F6	Permatang Damar Laut	17	271	Turbid water may cause aesthetic impact
F7	Teluk Tempoyak Besar	0	1	Insignificant impact
F8	Teluk Tempoyak Kecil	0	0	Insignificant impact
F9	Batu Maung	0	0	Insignificant impact
F10	Sri Jerjak	0	0	Insignificant impact

d) Scenario 4

Similar to Scenarios 2 and 3, the activities simulated in Scenario 4 are placement of an initial reclamation layer without containment at the outer-most end of Island C as well as two dredgers working at the same time. The simulated activities are shown in F7.62.



F7.62

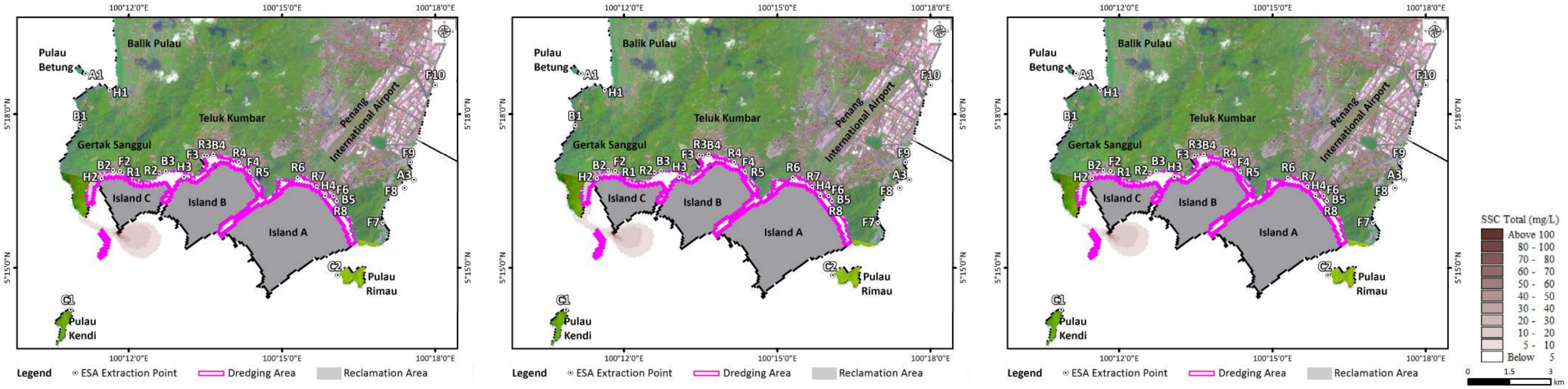
Location of dredging (D) and reclamation (R) works simulated, Scenario 4 unmitigated condition

F7.63 and F7.64 show mean and maximum excess suspended sediment concentrations for Scenario 4, unmitigated condition for different climatic conditions respectively. The pure-tide condition appears to be the worst-case condition, in terms of the extent and level of suspended sediment concentration. The extent of maximum excess suspended sediment concentration is similar to that of the dredging works near Tanjung Gertak Sanggul in Scenario 1, albeit slightly smaller. The excess suspended sediment arising from the dredging and reclamation activities does not extend to the east of Island B.

F7.64 shows that the maximum suspended sediment concentration at Pulau Betung is less than 20 mg/L, thus lower than the tolerable limit of 80 mg/L for aquaculture. The maximum suspended sediment concentration at the water abstraction point near Pulau Betung is less than 5 mg/L.

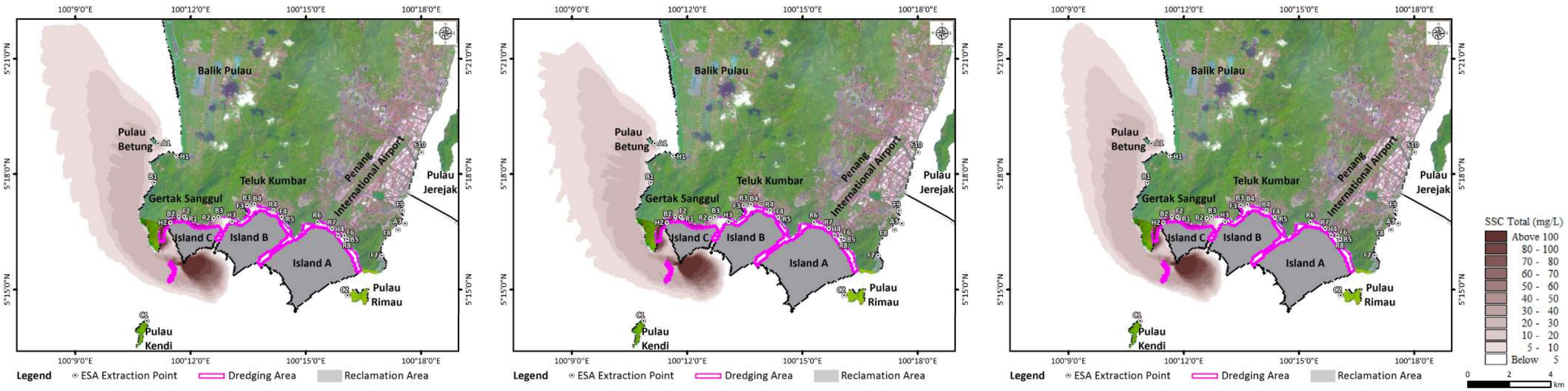
The percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations are presented in F7.65 and F7.66 respectively. These figures show that the tolerable limits for coral reefs are not exceeded at Pulau Kendi and Pulau Rimau. F7.67 shows the sedimentation rates of suspended sediment at Pulau Rimau and Pulau Kendi do not exceed 1 mm over 14 days.

Considering the results from the sediment spill dispersion modelling simulations for the dredging and reclamation activities in Scenario 4, there is no exceedance of tolerable limits of excess suspended sediment concentrations at the ESAs considered.



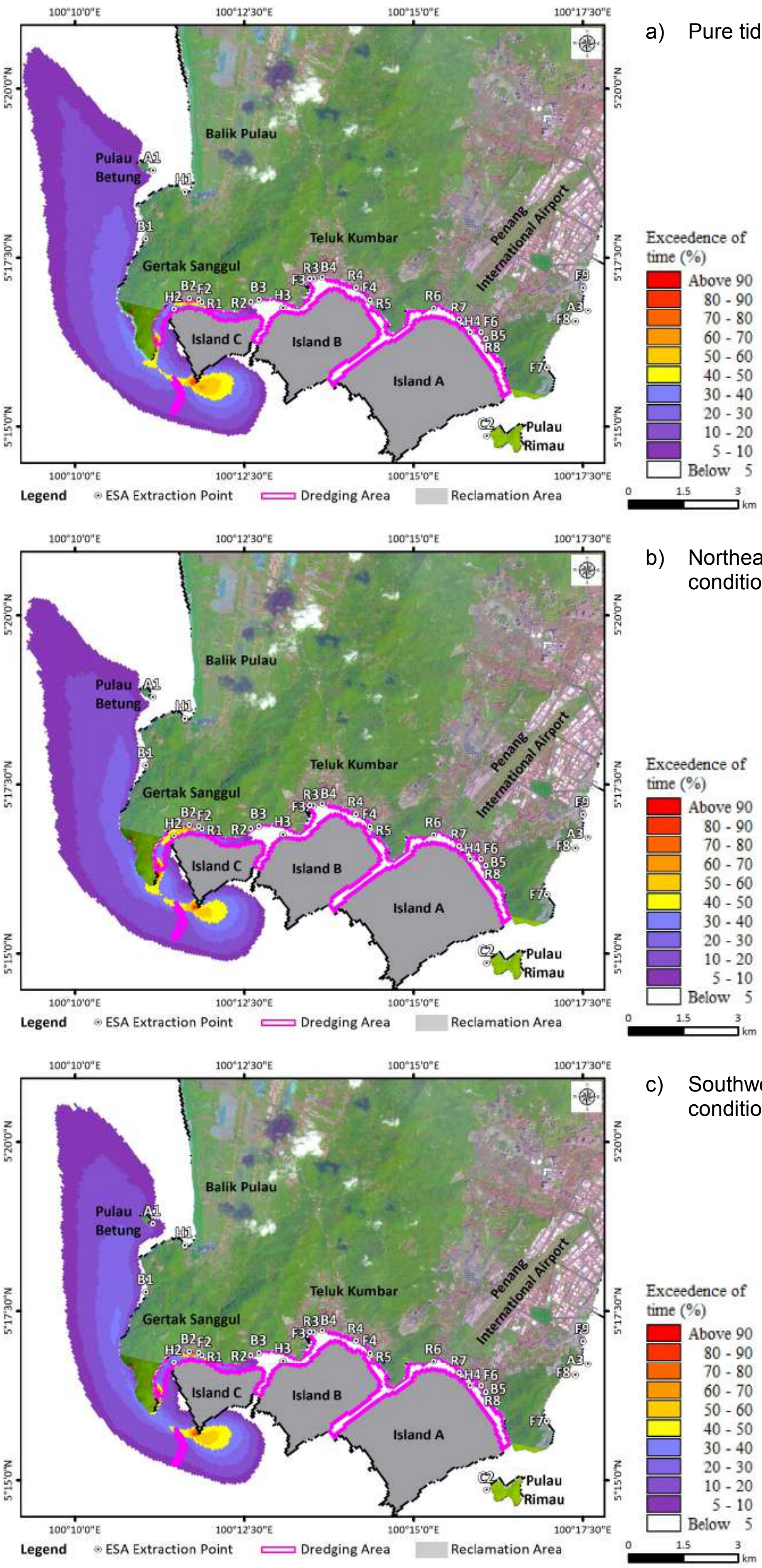
a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

F7.63 Mean excess suspended sediment concentration for Scenario 4, unmitigated condition



a) Pure tide condition b) Northeast Monsoon condition c) Southwest Monsoon condition

F7.64 Maximum excess suspended sediment concentration for Scenario 4, unmitigated condition



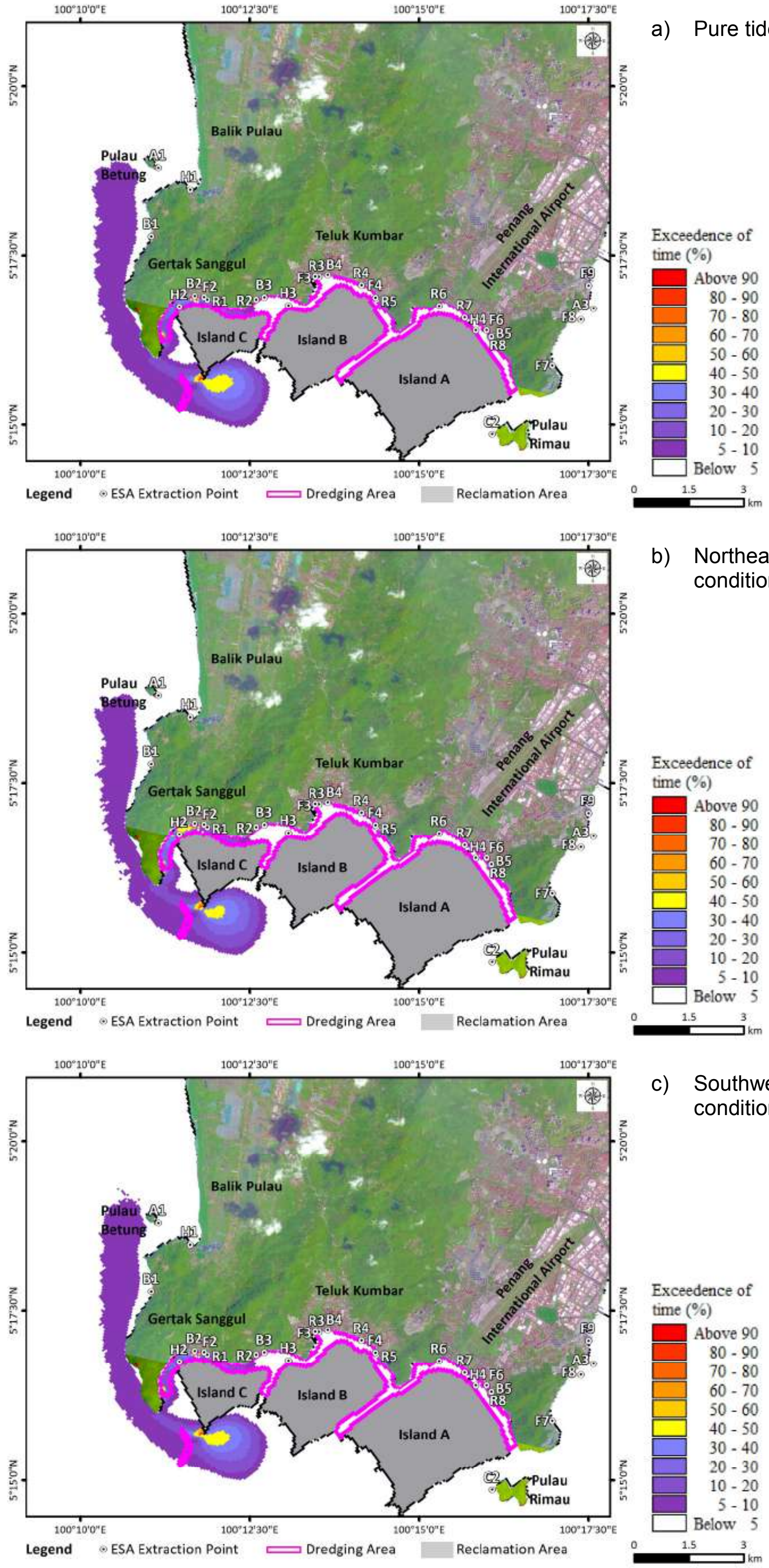
a) Pure tide condition

b) Northeast Monsoon condition

c) Southwest Monsoon condition

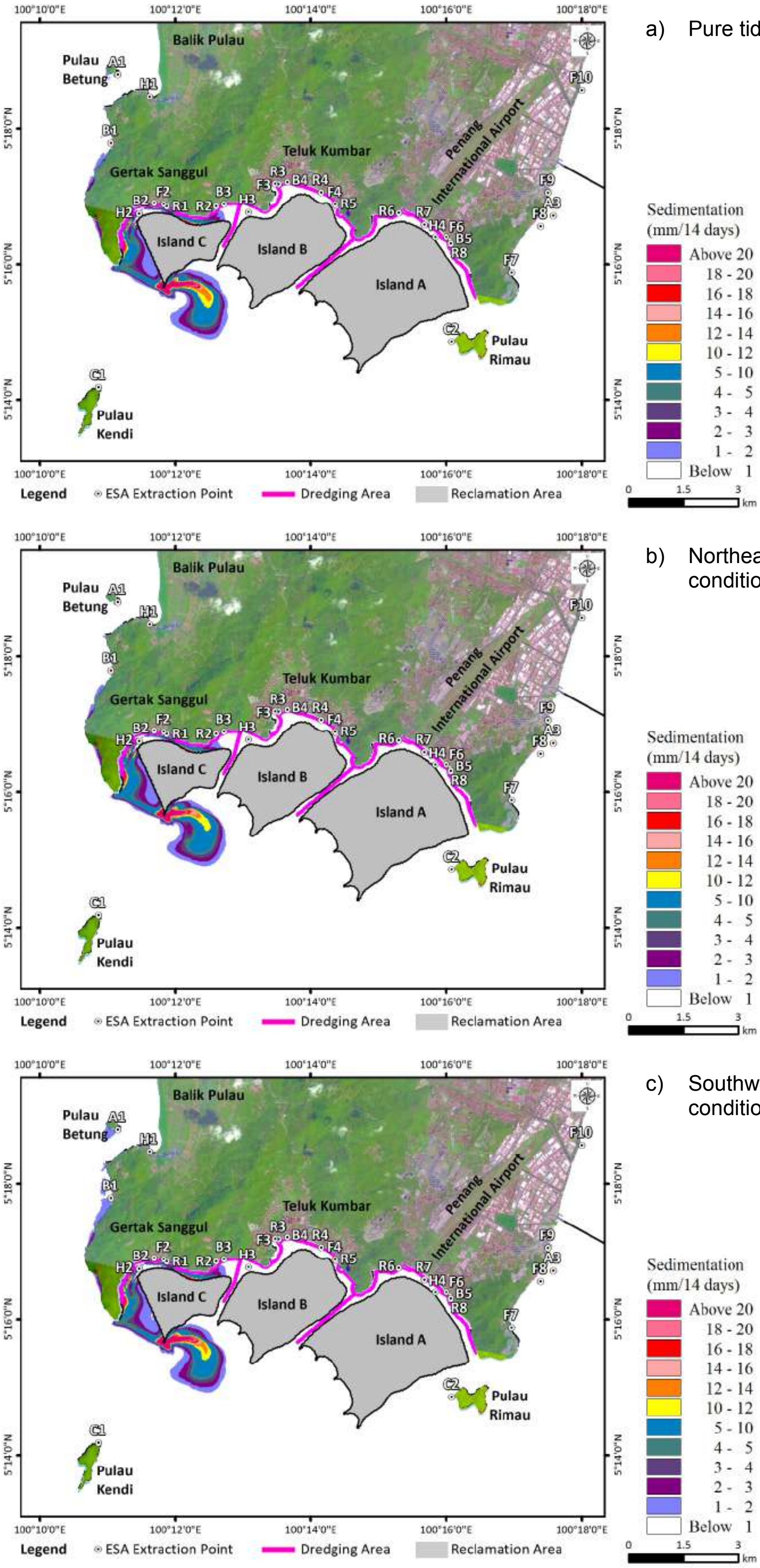
F7.65

Percentage of time exceedance of suspended sediment concentration above 5 mg/L for Scenario 4, unmitigated condition



F7.66

Percentage of time exceedance of suspended sediment concentration above 10 mg/L for Scenario 4, unmitigated condition



a) Pure tide condition

b) Northeast Monsoon condition

c) Southwest Monsoon condition

F7.67

Sedimentation of suspended sediment for Scenario 4, unmitigated condition

Mean and maximum excess suspended concentration levels were extracted at the ESAs' point, as presented in T7.31.

T7.31 Mean and maximum excess suspended concentration at the ESAs for Scenario 4

Point	Location	Excess Suspended Sediment Concentration (mg/L)		Remarks
		Mean	Max	
R1	Sungai Gertak Sanggul	21	366	Turbid water may cause aesthetic impact
R2	Sungai Gemuruh	0	3	Insignificant impact
R3	Sungai Teluk Kumbar	0	0	Insignificant impact
R4	Sungai Mati	0	0	Insignificant impact
R5	Sungai Batu	0	0	Insignificant impact
R6	Sungai Bayan Lepas	0	0	Insignificant impact
R7	Bayan Lepas Main Drain	0	0	Insignificant impact
R8	Sungai Ikan Mati	0	0	Insignificant impact
C1	Pulau Kendi	0	0	Insignificant impact
C2	Pulau Rimau	0	0	Insignificant impact
H1	Sungai Pulau Betung	0	0	Insignificant Impact
H2	Gertak Sanggul	23	305	High TSS level will affect the existing filtration system, thus mitigation measure is required
H3	Teluk Kumbar	0	0	Insignificant impact
H4	Permatang Damar Laut	0	0	Insignificant impact
A1	Pulau Betung	1	9	Insignificant impact
A2	Sungai Pulau Betung	-	-	No data (upstream location)
A3	Batu Maung	0	0	Insignificant impact
F1	Sungai Pulau Betung	-	-	No data (upstream location)
F2	Gertak Sanggul	36	542	Turbid water may cause aesthetic impact
F3	Teluk Kumbar	0	0	Insignificant impact
F4	Sungai Batu	0	0	Insignificant impact
F5	Permatang Tepi Laut	-	-	No data (upstream location)
F6	Permatang Damar Laut	0	0	Insignificant impact
F7	Teluk Tempoyak Besar	0	0	Insignificant impact
F8	Teluk Tempoyak Kecil	0	0	Insignificant impact
F9	Batu Maung	0	0	Insignificant impact
F10	Sri Jerjak	0	0	Insignificant impact

7.3.9.4 Overall Findings for Sediment Spill Dispersion

Sediment spill dispersion modelling simulations have been undertaken to assess the potential temporary impact on the ESAs within and in close proximity to the Project site, namely coral reefs at Pulau Rimau and Pulau Kendi, aquaculture farms in Batu Maung and Pulau Betung as well as water abstraction points of the hatcheries within the Project site and near Sungai Pulau Betung.

The model simulates the dredging and/or reclamation activities in all development scenarios. The worst case locations for the dredging and/or reclamation, in terms of high current speeds that would disperse the excess suspended sediment arising from these activities, have been used in the model simulations. The placement of a layer of sandy bedding material has been used to represent the reclamation works as it is considered the 'worst case' for sediment spill dispersion.

The sediment spill dispersion modelling results show that the maximum excess suspended sediment concentration associated with the dredging and reclamation works in all development scenarios are below the tolerable limits at the aquaculture farms in Batu Maung and Pulau Betung, as well as the water abstraction point for the hatchery near Sungai Pulau Betung. The abstraction points for the hatcheries within the Project site will be affected in all scenarios, and thus an upgrade to the filtration systems of the hatcheries will be required.

The modelling results show that the dredging works for the dredged channels as well as the reclamation works of Islands B and C do not result in exceedance of tolerable limits of the excess suspended sediment concentrations at the coral reefs at Pulau Kendi and Pulau Rimau. The placement of the sandy bedding material for the rock bund along the southeastern edge of Island A in Scenario 3, however, is predicted to have an impact to the coral reefs at Pulau Rimau.

The sediment dispersion modelling forms part of the impact assessment on the coral reefs around Pulau Rimau. Based on the outcome of the hydraulic studies as well as the ecological assessment, it is recommended that the coral reefs along the western coastline of Pulau Rimau, i.e. those facing Island A, are to be fully traded off. The Project Proponent is committed to implement an offset programme that includes installation of artificial reefs and provision of grants of financial support for research related to coral reefs.

7.4 Impacts on Water Quality

One of the key issues that need to be handled delicately on this Project is the impact on water quality. Land reclamation and dredging can be very detrimental to water quality if they are not managed properly. Impacts arising from land reclamation and dredging can be considered as short-term impacts as these will cease once the reclamation and dredging works end after the development is completed.

However, the presence of newly-reclaimed islands will instigate a more serious problem as the impact will be extensive and permanent. For the proposed Project, the issue on water quality is very delicate as there are several rivers that can be classified as polluted discharging into the proposed development site.

7.4.1 Land Reclamation and Dredging

One of the major sources of impact to water quality by land reclamation and dredging activities is sediment plume which has been discussed extensively in *Section 7.3.5*. For land reclamation, sediment plume generation is mainly related to sand filling work. Activities that do not involve sand filling, such as construction of rock bund or revetment, will not generate significant level of sediment plume. It should be noted that the movement of vessels may also produce visible plume trailing in their wake, as illustrated in F7.68. This generally occurs at an area where the draft is relatively shallow and the seabed is made up of soft, muddy material. However, plume generated from the vessels' movement is mostly localised and does not significantly disperse over a large area.

F7.68
Sediment plume generated by vessel movement

As for dredging, the source for sediment dispersion may come from the material loosened by the cutter head which will be dispersed by the current over to the surrounding area. Meanwhile, the dredged material from the dredger will be filled into a barge via pipeline for disposal. During the filling process, significant sediment plume will be generated from the overflow.

a) Pre-dredging

The construction of workers' quarters and an access road will involve land-clearing works. The area to be cleared for the workers' quarters is approximately 4 acres while the access road is approximately 1 km in length. This activity will generate biomass that need to be managed and disposed properly. The exposed topsoil will cause surface erosion that will transport sediment to nearby waterbodies.

After the workers' quarters are completed, it is projected that a workers' base will be set up within or nearby the Project area. Workers residing within the base will generate significant amounts of solid waste, organic waste and wastewater. Sewage and greywater generated from the toilets and/or kitchen may cause elevated levels of BOD, *E. coli* and nutrients within the surrounding water if discharged untreated. Taking into account the existing water quality, these will further exacerbate the problem and may cause health problems not only to the workers but also to the neighbouring communities. Solid and organic waste, if not managed properly, may produce leachate that can lead to surface and groundwater pollution. Garbage and food waste will attract strays, pests and scavenger animals such as rats, crows, dogs and cats.

Normally, a stockpile and storage facilities will be constructed together with the workers' base. Spillage and runoff contamination from the stockpile and storage area will introduce pollutants to the surrounding water body.

b) Scenario 1

For this scenario, a total of 2.2 million m^3 of material will be dredged. As the location of the dredging is very near to the coastline, it is expected that the plume generated will affect the operation of hatcheries located at Gertak Sanggul, Teluk Kumbar and Permatang Damar Laut that source their water for operation via intake pipes located near the coastline, which is also located near the dredging area. A high level of TSS will cause operational problems to the hatcheries as the current filtration system utilized by the hatcheries functions according to the existing TSS level of around 10 to 20 mg/L. Details of the impact on hatchery operations will be further discussed in *Section 7.6.1 - Hatcheries*.

c) Scenario 2

Scenario 2 involves the creation of Island B and the dredging of channel surrounding Island B. As such, the main source of pollution on water quality will be the land reclamation and dredging activities that will cause high TSS level to the surrounding waters. A total of 93.8 million m^3 of sand will be used for Island B reclamation while the material to be dredged is approximately 1.6 million m^3.

Based on the sediment plume simulation, no sensitive receptors will be affected during this stage other than hatcheries at Teluk Kumbar. This is expected as the land reclamation and dredging activities will be conducted within the immediate vicinity of hatcheries at Teluk Kumbar. The maximum excess SSC level projected during this scenario is over 100 mg/L, which will render the marine water unsuitable for hatchery operation without additional treatment.

In addition to sediment plume, vessels deployed for the work is another potential source of water pollution. During this scenario, more vessels will be operating within the Project area as the actual reclamation work has commenced. Some vessels will store fuel, oil, grease and chemicals on board for operation and maintenance purposes. Spillage of these materials can happen, whether accidental or otherwise. Oil spill presents a significant contamination risk to the water surrounding the Project area. Depending on the currents and wind movement, the oil slick may disperse over a large area as well as reaching Penang's southern coastline, impacting a myriad of receptors.

Some of the vessels will have toilet and kitchen facilities for the crew staying on board. Direct discharge of wastewater, greywater and other solid waste into the sea is detrimental to water quality if done in large quantity.

Ballast water and bilges generated from the vessels usually contain significant levels of pollutants, in which oil is the most common contaminant. According to Environmental Quality (Scheduled Waste) Regulation 2005, a mixture of water and oil such as ballast water is classified as Scheduled Waste. These contaminants will be introduced into the environment if the ballast water and bilges are not handled correctly as per the prevailing regulations.

It is expected that the number of workers residing at the quarters will increase. Correspondingly, the number of waste produced by the workers will also grow.

d) Scenario 3

The situation for this scenario will be similar with Scenario 2, where the land reclamation and dredging activities at Island A will cause high TSS level to the surrounding area while the vessels and machineries used will present a risk of pollution from oil, chemicals, wastewater, etc. The difference is that the impact will more prominently occur at the area of Permatang Damar Laut (Island A) instead of Teluk Kumbar (Island B). More importantly, the reclamation of Island A is located near to Pulau Rimau. As such, degradation of water quality during this period will affect the coral reefs at Pulau Rimau. Impact on water quality to corals at Pulau Rimau is further discussed in *Section 7.5.1 – Coral Reefs*.

e) Scenario 4

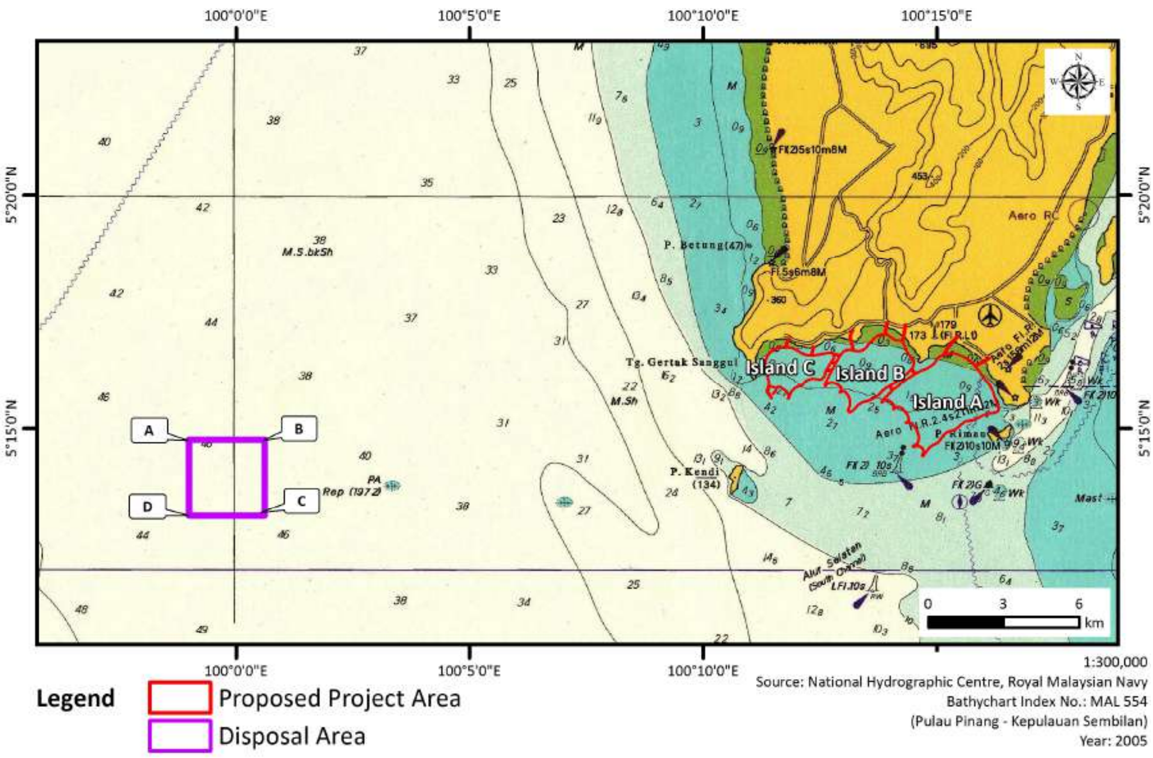
The situation for this scenario will be similar with the previous two scenarios, where the land reclamation and dredging activities will cause high TSS level to the surrounding area while the vessels and machineries used present a risk of pollution from oil, chemicals, wastewater, etc. However, the impact during this period will be more prominently felt at the western side of the study area, namely Gertak Sanggul and Pulau Betung. Correspondingly, the sensitive receptors that will be affected are those located at Gertak Sanggul i.e. hatcheries. The impact on hatcheries will be discussed in the following section as mentioned previously.

7.4.2 Disposal of Dredged Material

The material produced by the dredging activities will be disposed of at a designated disposal area as shown in F7.69 while the coordinates are as tabulated in T7.32. The disposal will be conducted by using hopper barges that will be pulled by tugboats to the disposal area located approximately 15 nautical miles (28 km) away from the Project area. Dredging activities will be conducted for all development scenarios. Thus the disposal of dredged material will occur over the whole period of the Project.

T7.32 Coordinates of the designated disposal area

Point	Longitude	Latitude
A	99° 58' 59.2"E	5° 14' 45.6"N
B	100° 00' 36.6"E	5° 14' 45.6"N
C	100° 00' 36.7"E	5° 13' 08.0"N
D	99° 58' 59.3"E	5° 13' 07.9"N



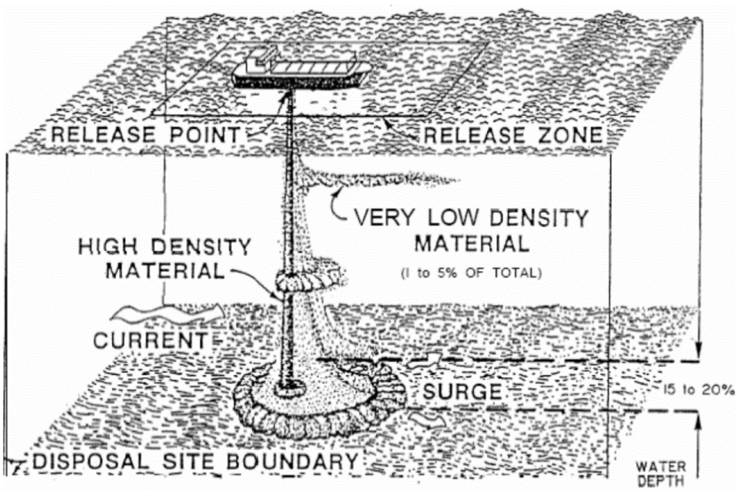
F7.69 Location of the designated disposal area

The process of dredged material disposal can be detrimental to the environment if done unsystematically and improperly. Careful consideration must be taken and proper procedures for disposal are to be followed at all times. In order to ensure the disposal process creates minimal impact on the environment, the recommended guidelines formulated by the Department of Environment (DOE) regarding the disposal site and method of disposing must be strictly followed, as listed in T7.33.

T7.33 DOE guidelines for disposal of dredged material

Activity	Guidelines
On the disposal site	The depth shall be more than 20 m deep
	The location must be reasonably distant from sensitive areas
	The location must not be within fishing grounds, coral reefs and artificial reefs
On the method of disposing the dredged material	While disposing the dredged materials at the designated site, the vessel must be in continuous motion at the speed of 1 to 2 knots
	The materials being disposed should spread out within a reasonable distance of the designated area
	No point disposal is allowed
	Dispersion modelling should be carried out to indicate the vertical and horizontal movements of the materials being disposed

Disposal of the dredged material is not expected to generate significant plume. The reason for this is because the dumping of dredged material generally occurs underneath the transport vessel. During the dumping process, most of the material is caught within a vertical density current. Near the seabed, this current transforms into a horizontal one, influenced by the direction of the tidal current and the seabed slope (Malherbe 1991; Van Parijs *et al.*, 2002). Most of the dredged material will be deposited on the seabed whereby only the very low density material, which consists of less than 5% of the total material will be suspended in the water column and dispersed by currents. F7.70 illustrates the behaviour of dredged material during the dumping process.



F7.70 Behaviour of dredged material during dumping (Elsaeed 1991)

In addition, taking into account the location of the disposal site and its depth which is over 40 m, it is expected that sediment plume will not affect any sensitive receptors surrounding the area. As such, no mitigation measure is proposed for this activity.

On the other hand, leakage may occur to barges carrying dredged material to the disposal site. Sediment plume will be generated along the transportation route which causes the impact to be dispersed over a long stretch of area. Overfilling of barges also may cause spillage of dredged material along the way to the disposal site. Poorly-maintained barges and an incompetent crew may cause short dumping incidence to occur during transportation.

It should be noted that the disposal area proposed to be used for this Project is a new dumping area yet to be gazetted. As such, the Project Proponent is required to conduct a separate EIA study for approval.

7.4.3 Post-reclamation

The presence of new landmass in the form of the three islands is expected to significantly influence the flushing capacity of waters surrounding the Project site. Currently, there are eight main rivers and drains that discharge its water along Penang southern coastline. The river and marine water quality data collected during this study showed there was nutrient elevation (NH_3-N, NO_3-N and phosphate). While there is insufficient information in order to accurately determine the origin of the nutrients, it is undeniable the polluted rivers in the region remains a major contributor.

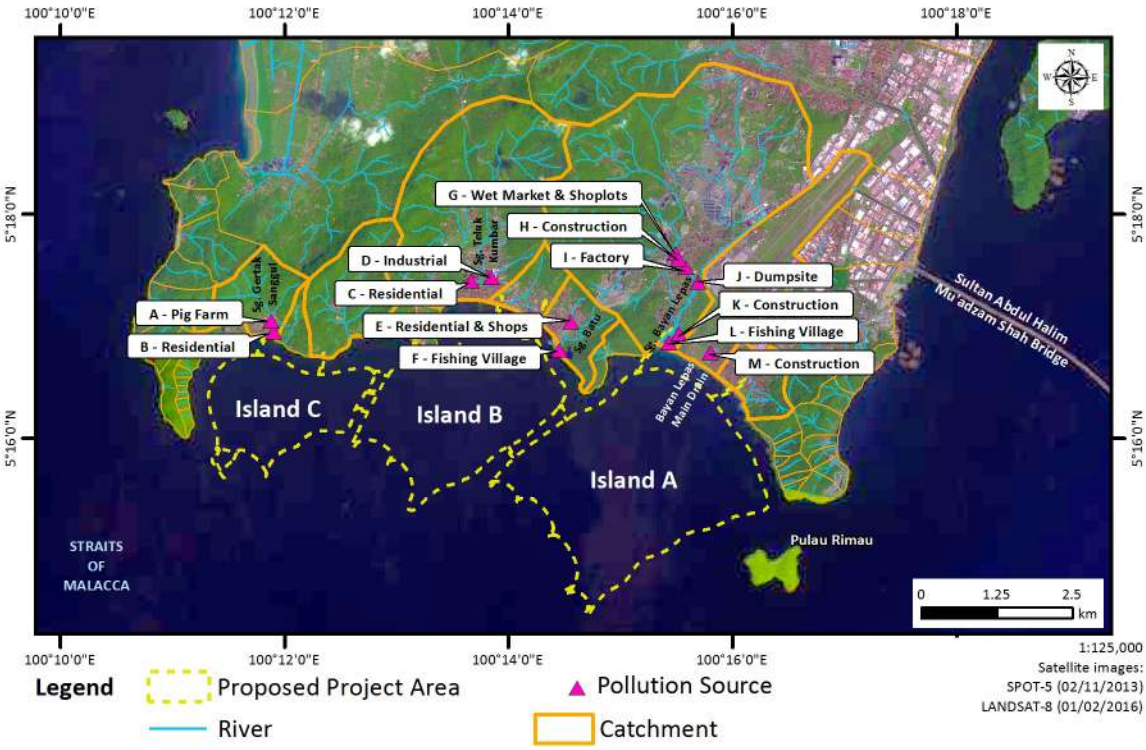
Based on the preliminary pollution source study, which is done concurrently with this EIA study, the major pollution sources (F7.71) and the current river conditions (T7.34) include the following:

a) Construction sites;
b) Factories;
c) Residential dwellings;
d) Shoplots;
e) Dumpsites;
f) Sewage treatment plants (IWK); and
g) Cottage industries (e.g. pig farms).

T7.34 Summary of river conditions

River	Catchment Area (km^2)	Major Pollutant Sources	Debris	Water Quality
Bayan Lepas main drain	3.0	Construction sites	Minimal debris issue	Class III
Sungai Bayan Lepas	7.4	Construction sites Shoplots Factories Dumpsite Fishing village	Household debris along river bank Construction waste	Class III
Sungai Batu	1.2	Residential Fishing village	Vegetation Household debris	Class III
Sungak Teluk Kumbar	7.1	Residential Factories	Vegetation Household debris (localised)	Class IV
Sungai Gertak Sanggul	1.3	Residential Pig farms	Vegetation Minimal debris issue	Class IV

Note: Water quality for each river was classified based on DOE's water quality index (WQI) classification.



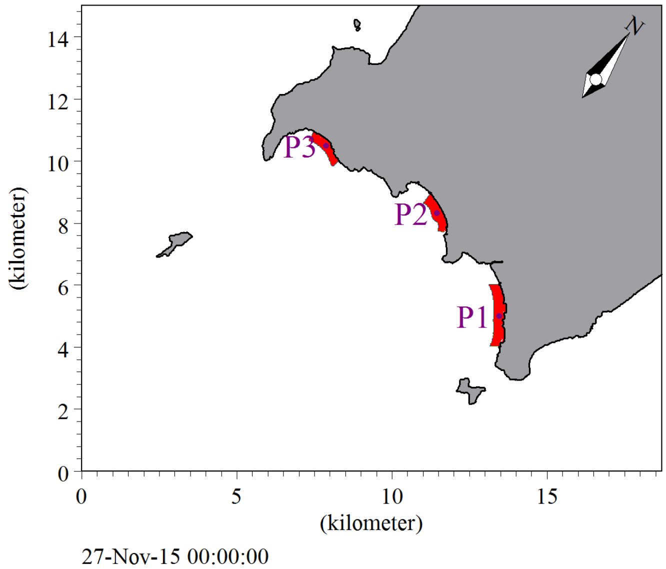
F7.71 Major pollution sources

This may be a cause for concern, as the flushing of pollutants could be disrupted by the presence of the islands. In fact, there is even potential for accumulation along the navigation channel if the water becomes stagnant (e.g. intertidal). Build-up of nutrients, such as NH_3-N, NO_3-N and phosphate presents the risk of algae blooms and even eutrophication (F7.72), with nitrogen species being the limiting nutrient for marine environments. This potential impact needs to be mitigated by ensuring the hydrodynamics of the region are not impeded due to the presence of the islands.

F7.72 Example of red tide occurrence in Benguela, Angola

The potential impact of the proposed development within the Project area with regard to water quality (flushing) has been assessed using MIKE 21 Advection-Dispersion (AD) module. The assessment has been undertaken by comparing the flushing capacities associated with the existing and "with Project" conditions. Generally, a good flushing capacity contributes to good water quality.

The flushing capacity has been assessed by determining the duration required to reduce the concentration of a tracer by half, known as the retention time (T_{50}). The assessment has been undertaken for spring and neap periods for pure tide, Northeast Monsoon and Southwest Monsoon conditions. As an indication, the T_{50} must not be more than two days to avoid severe water quality issues. It shall be kept to less than one day if the waterways are to be used for recreational purposes. The location of the tracers placed during the simulation for all scenarios are illustrated in F7.73. The corresponding rivers along the tracer point are shown in T7.35.



F7.73 Locations of tracers

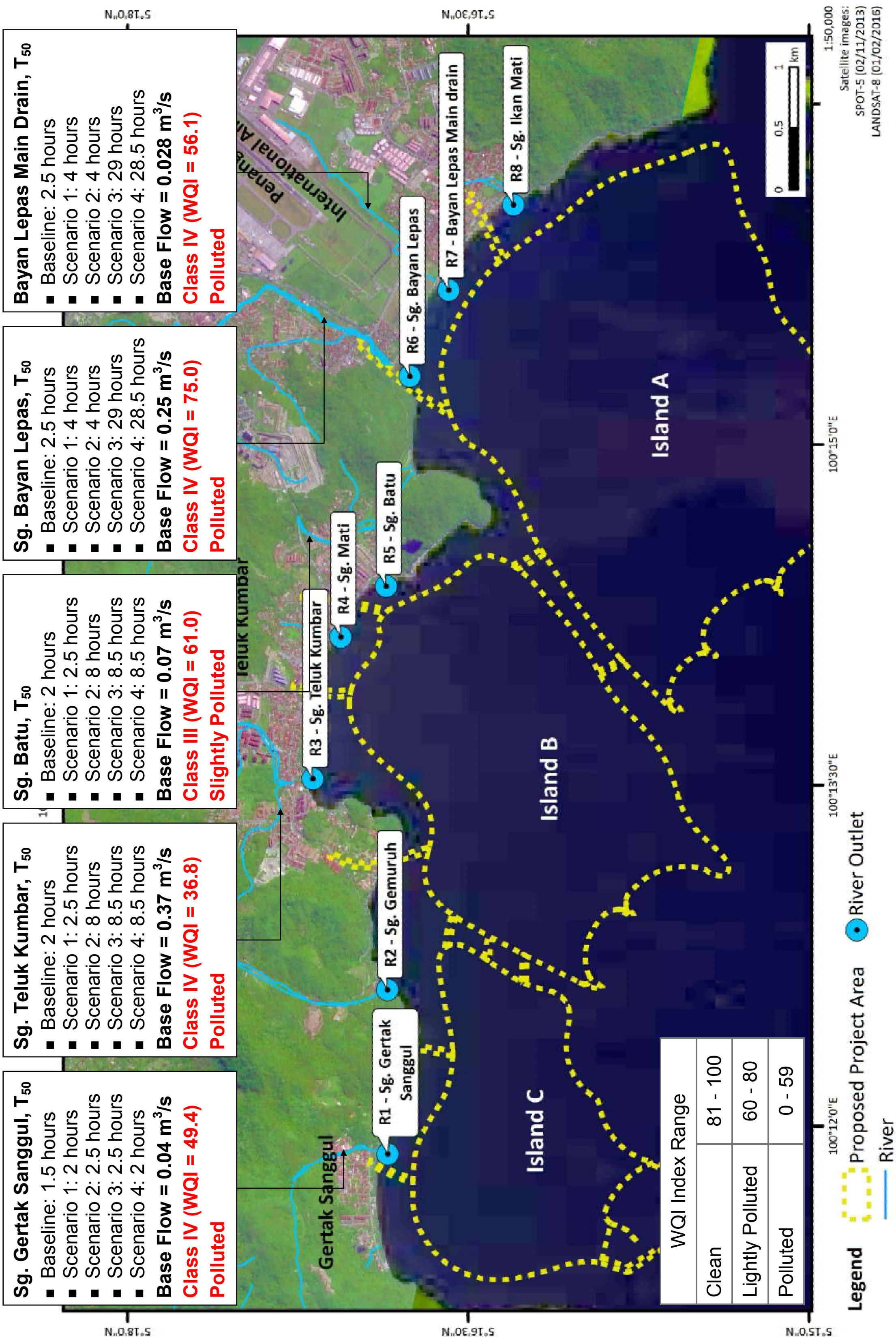
T7.35 Tracer point and the corresponding river

Tracer Point	Corresponding River
P1	Bayan Lepas Main Drain
	Sungai Bayan Lepas
P2	Sungai Batu
	Sungai Teluk Kumbar
P3	Sungai Gertak Sanggul

T7.36 shows the time required to reduce tracer concentration by 50%, T_{50}, under the pure tide and monsoonal conditions in the existing condition and "with Project" scenarios. Meanwhile, the required T_{50} during the worst case scenario (neap period and pure tide) was presented spatially according to each corresponding river in F7.74.

T7.36 Summary of the T_{50} for pure tide, Northeast and Southwest Monsoon conditions

Scenarios		T_{50} (hours)					
		Spring			Neap		
		P1	P2	P3	P1	P2	P3
Pure tide condition	Existing condition	2.5	3.0	2.0	2.5	2.0	1.5
	Scenario 1	2.5	3.5	2.5	4.0	2.5	2.0
	Scenario 2	2.5	3.5	2.5	4.0	8.0	2.5
	Scenario 3	2.0	11.5	2.5	29.0	8.5	2.5
	Scenario 4	2.0	11.0	4.5	28.5	8.5	2.0
Northeast Monsoon condition	Existing condition	2.5	3.0	2.5	3.5	2.5	2.0
	Scenario 1	2.5	3.5	3.0	3.5	4.0	3.5
	Scenario 2	2.5	3.5	3.5	3.5	6.0	3.5
	Scenario 3	2.5	7.5	3.5	4.0	19.0	3.5
	Scenario 4	2.5	8.0	5.0	4.0	19.0	8.5
Southwest Monsoon condition	Existing condition	3.0	3.5	2.5	3.0	2.5	2.0
	Scenario 1	3.0	4.0	3.0	4.5	3.0	2.5
	Scenario 2	3.0	4.0	3.0	4.5	9.0	2.5
	Scenario 3	3.0	11.5	3.0	23.0	9.5	2.5
	Scenario 4	2.5	11.5	5.0	23.5	10.0	9.5



F7.74 Summary of T_{50} at each river outlet during worst-case scenario (neap period and pure tide)

The results show that, in general, the T_{50} associated with the "with Project" scenarios are higher than the existing condition, but are less than 48 hours. This presents good flushing capacity if the existing water quality is clean.

It is noted that T_{50} is more than 24 hours at P1 (Sungai Bayan Lepas and Bayan Lepas Main Drain) for the pure tide condition during neap period in Scenarios 3 and 4. The T_{50} is 29 and 28.5 hours from the start of the simulation in Scenarios 3 and 4, respectively. Both are slightly over a day. The results also show that in Scenario 3 and 4, monsoonal winds will significantly reduce the T_{50} at P1 during neap tide.

Meanwhile, the retention time at P2 (Sungai Batu and Sungai Teluk Kumbar) will worsen from the existing 2 hours to 8 hours after the completion of Island A, and further worsen to 8.5 hours after the completion of Island B. While the retention time does not exceed 24 hours, the impact is still significant as the rivers that discharge into this area, namely Sungai Batu and Sungai Teluk Kumbar, are polluted and can be categorised as Class III and Class IV respectively.

It would have been preferable to conduct a dynamic water quality modelling exercise to ascertain the long-term impacts of the development towards water quality. However, due to large coverage area and lack of long-term hydrodynamic data, constructing a model with an acceptable level of confidence was not plausible at this juncture. Developing a model with minimal or no flushing on the other hand, would merely be an academic exercise which could not be substantiated.

Because of this, the focus was placed on mitigating the potential sources of the nutrient, which in this case, were the mainland sources that empty into the river as well as those of the coastline. This way, the risk of future nutrient elevation can be circumvented.

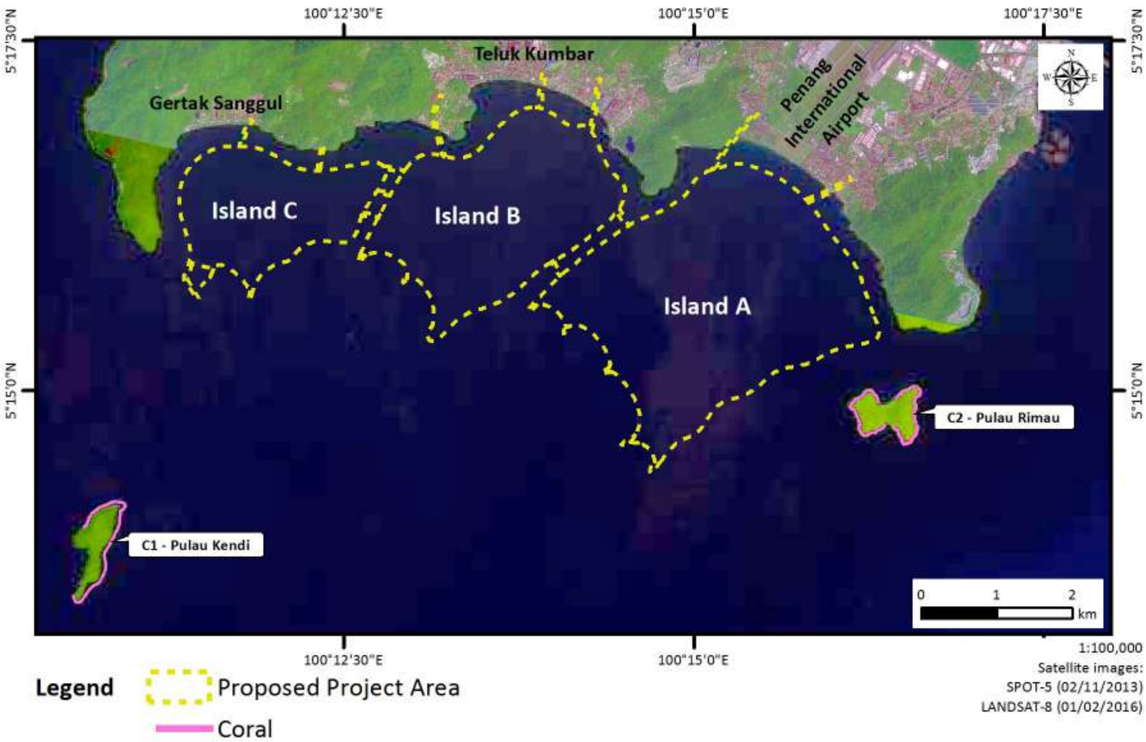
Another factor that contributes into the deterioration of water quality is the reduction in wave heights within the access channel. As discussed in *Section 7.3.7 – Waves*, some locations will experience a total deficit in wave heights after the reclamation is completed. Wave action is one of the factors that aides in the mixing and flushing of a water column and when this energy is removed, the flushing capacity will be affected.

7.5 Impacts on Environmentally Sensitive Areas

Each stage of the dredging and land reclamation works will cause changes to the environmental condition status quo. These changes may cause additional stress or pressure which then will materialize as negative impacts on the ESAs.

7.5.1 Coral Reefs

Pulau Rimau and Pulau Kendi hold an established network of coral reefs surrounding the rocky outcrops of these islands. Although both islands are located nearby to each other, the nature of coral reefs at Pulau Kendi and Pulau Rimau is different. At Pulau Kendi, the coral reefs are mostly hard coral reef, with some soft coral, whereas the coral reefs at Pulau Rimau are largely gorgonians. F7.75 shows the stretch where coral was observed at both islands.



F7.75 Location of coral reefs at Pulau Kedi and Pulau Rimau

7.5.1.1 Land Reclamation and Dredging

The major impact arising from the reclamation process on the coral reefs would be turbidity and sedimentation. These two factors create shading caused by a decrease in ambient lighting as well as sediment cover on the coral's surface. Suspended sediments block sunlight from reaching the zooxanthellae, thus decreasing food availability and consequently leading to mortality (Bak, 1978; Miller, 1999; Masalu, 2000). The growth forms of many corals are focused on trapping light and thus are not optimized for sediment-shedding (Stafford-Smith, 1993; Sanders and Baron-Szabo, 2005). In addition, sedimentation also creates problem of costly energy spent by the corals due to mucus production, sediment clearance and also impaired feeding (Erftemeijer *et al*., 2012).

Though some corals can grow and survive in turbid waters, they however experience more stressful conditions compared to the clear water conditions. It has been demonstrated that increased turbidity and siltation in the coastal zone are potential causes of coral reef degradation (Terney Pradeep Kumara, 2010). High sedimentation does not necessarily lead to mortality, but it could still have sub-lethal effects i.e. reduced growth, lower calcification rates and reduced productivity, bleaching, increased susceptibility to disease, physical damage to coral tissue and reef structures (breaking and abrasion), and reduced regeneration from tissue damage (Erftemeijer *et al*., 2012). The coral re-colonization is also expected to be restricted if high sedimentation occurs (Masalu, 2000; Miller, 1999; Delbeek and Sprung, 1994). Thus, this could lead to changes in reef community structure i.e. a decrease in density, diversity and coral cover, and will shift towards the dominances of non-coral species, such as sponges and algae.

The tolerance limit of the corals for the total suspended matter is widely ranged as it depends on the species, grain size, and geographic regions. The report by Erftemeijer *et al.* (2012) indicated that most soft corals and massive corals are relatively sensitive to turbidity. On the other hand, laminar, plating and tabular corals as well as some morphologically variable corals are relatively tolerant. It is also indicated that the diameter of the coral's calyx is not correlated with their sensitivity towards turbidity. Some of the species that are well adapted to turbid waters include *Leptastrea*, Montipora, Pectinia, Porites (Dikou and Van Woesik, 2006), and *Turbinaria* (Stoddart and Stoddart, 2005) as well as the Gorgonians (Fabricius and Dommisse, 2000).

Grain size can also affect the tolerance limit of the corals, as fine sediments would only reduce the light penetration into the water bodies, whereas coarser particles may cause scouring and abrasion of coral tissue (PIANC, 2010). Geographic regions also play an important part in determining the tolerance limit of turbidity of the corals. For example, in the Great Barrier Reef of Australia, the threshold level of corals is 3.3 mg/L (Bell, 1990), as the area is not subject to any stresses from human activities. However, the threshold level is higher in marginal reefs in turbid near-shore area, such as in Magnetic Island (75 to 120 mg/L; Mapstone *et al*., 1989) and Cape Tribulation (100 to 260 mg/L; Hopley *et al*., 1993), both in Great Barrier Reef, Australia. Therefore, it is important to note that the threshold level for the reefs is a case-to-case basis, which will take into account the surrounding environment conditions as well as the severity of impact on the reefs. Currently only 10% of the coral species has been studied for their response towards the sediment disturbance, which still indicates poor understanding of the relationship between sediment stress and response of most corals.

For the purpose of this study, the tolerable limits of excess suspended sediment and sedimentation rate respectively established in PIANC Report No. 108-2010 "Dredging and port construction around coral reefs" has been used. Although the limits are related to hard coral reefs, they are adopted for both coral reefs as they are more conservative, in the absence of published tolerable limits for soft corals.

T7.37 and T7.38 show the tolerable limits of excess suspended sediment and sedimentation rate published in the PIANC report respectively. These tolerable limits for coral habitats constitute a conservative indicator of the potential stresses that can be added on other natural receptors. For the assessment of the sediment plume dispersion results, tolerable limits associated with the "Slight impact" category have been adopted.

Based on the sediment spill dispersion findings presented in *Section 7.3.9* above, the tolerable limits for the percentage of time exceedance for 5 and 10 mg/L excess suspended sediment concentrations are less than 5% at both Pulau Rimau and Pulau Kendi for Scenarios 1, 2 and 4, which mean that the tolerable limit are not exceeded. However, for Scenario 3, it is expected that limits will exceed up to 20% at Pulau Rimau once the reclamation works move closer to the island.

As for sedimentation caused by the dispersed sediment, the highest level recorded is at Pulau Rimau during Scenario 3, with a rate that exceed 3 mm over 14 days, which is over the tolerable limit for "Slight Impact".

Apart from sediment plume directly attributed to land reclamation and dredging activities, another potential impact arising from the reclamation Project on the coral reefs is the movement of boats and barges carrying materials into the reclamation site, particularly in the area of Pulau Rimau. The movement can potentially create wake that could affect the coral reefs, though currently there is no study on the impact of boat and barges wake onto the coral reefs. However, the wake is known to disturb the water circulation and alter tidal patterns that can disrupt the reef's nutrient supply (Asplund, 2000). The wake of the boats and barges are also known to induce turbidity, which is known to be detrimental to the corals.

In summary, the coral reef at Pulau Kendi is projected to be unaffected during the land reclamation and dredging works because the extent of sediment plume does not reach this location. However, the construction of perimeter bund at Island A will cause impact to coral reef at Pulau Rimau. It is assumed that only corals located at the west of Pulau Rimau will be greatly affected. Meanwhile, coral located at the east is expected to be sheltered. Thus, the loss of corals at Pulau Rimau is considered as partial trade-off.

T7.37 Impact severity categories for suspended sediment concentration

Category	Definition	Description
No impact	Excess suspended sediment concentration (SSC) > 5 mg/L for less than 1% of the time	Changes are significantly below physical detection level and below the reliability of numerical models, so that no change to the quality or functionality of the receptor will occur.
Slight impact	■ Excess SSC > 5 mg/L for less than 10% of the time ■ Excess SSC > 10 mg/L for less than 1% of the time	Changes can be resolved by numerical models, but are difficult to detect in the field as they are associated with changes that cause stress, not mortality, to marine ecosystems. Slight impacts may be recoverable once the stress factor has been removed.
Minor impact	■ Excess SSC > 5 mg/L for less than 20% of the time ■ Excess SSC > 10 mg/L for less than 5% of the time	Changes can be resolved by numerical models and are likely to be detected in the field as localised mortalities, but to spatial scale that is unlikely to have any secondary consequences.
Moderate impact	■ Excess SSC > 10 mg/L for less than 20% of the time ■ Excess SSC > 5 mg/L for more than 20% of the time	Changes can be resolved by numerical models and are detectable in the field. Moderate impacts are expected to be locally significant.
Major impact	■ Excess SSC > 25 mg/L for more than 5% of the time ■ Excess SSC > 10 mg/L for more than 20% of the time	Changes are detectable in the field and are likely to be related to complete habitat loss. Major impacts are likely to have secondary influences on other ecosystems.

T7.38 Impact severity categories for sedimentation

Category	Definition	Description
No impact	Sedimentation < 0.05 /m^2/day	<1.7 mm/14 days
Slight impact	Sedimentation < 0.1 kg/m^2/day	<3.5 mm/14 days
Minor impact	Sedimentation < 0.2 kg/m^2/day	<7 mm/14 days
Moderate impact	Sedimentation < 0.5 kg/m^2/day	<17.5 mm/14 days
Major impact	Sedimentation > 0.5 kg/m^2/day	>17.5 mm/14 days

7.5.1.2 Post-reclamation

Coral is known to be a very sensitive organism that can only survive within specific physical and biological environmental variables. Any changes in the status quo will cause stresses on the coral, which may lead to a bleaching event. Corals can survive and recover from a bleaching event if the stress is not severe and the environmental conditions return to normal quickly. However, if the algae loss is prolonged and the stress continues, coral eventually dies.

The presence of new landmass will change the existing coastal regime near the coral reefs of Pulau Kendi and Pulau Rimau. Based on the hydrodynamic findings discussed in *Section 7.3.5 - Currents*, there will be changes on current speed near Pulau Rimau and Pulau Kendi. For Pulau Kendi, the impacts are very small and can be considered as negligible (less than 3% change) due to the fact that the island is located some distant away from the proposed Project. However, massive current speed changes are projected to occur at Pulau Rimau after the completion of Island A (Scenario 3). The mean current speed is reduced by 0.1 m/s to the north and south of the island; increased by 0.15 m/s to the west of the island; and increased by 0.05 m/s to the east of the Pulau Rimau. The maximum current speed is reduced by up to 0.2 m/s to the north of the island and increased by 0.4 m/s to the west of the island. These changes are permanent.

Correspondingly, the impacts on coral reefs caused by changes in other parameters only occur at Pulau Rimau and will started after the completion Island A (Scenario 3).

The variation in current speed is expected to cause alteration in the existing sedimentation and erosion rate. Generally, reduction in current speed will induce sedimentation and vice versa. Unlike sedimentation that is caused by settling sediment plume originating from the land reclamation and dredging activities, this is a long-term occurrence as one of the components of the overall coastal morphology. After Island A is completed, the changes in the eastern side of Pulau Rimau will experience erosion at a rate of 0.01 m/yr.

Another important parameter that determines the wellbeing of coral is wave action. Waves, along with tides, drive the water flow rate around the coral reefs. Sufficient exchange of water is vital in maintaining a healthy coral population. On the other hand, too much wave energy may cause heavy pounding that inflicts physical damage to the corals. The changes in wave condition at Pulau Rimau and Pulau Kendi have been discussed in *Section 7.3.7 - Waves*. In general, the protruding headland of Island A (Scenario 3) causes a reduction in wave height of up to 0.3 m at Pulau Rimau for the predominant wave direction (270^{o}N). This condition is expected to affect the water mixing surrounding the coral sites at Pulau Rimau. This impact can be further exacerbated because the marine water quality within the vicinity of the Project site may deteriorate after the completion of the Project.

As explained in *Section 7.4.3*, the newly-formed islands will affect the flushing capacity for waters surrounding the Project site. Currently, all main rivers that are discharging along the south coast of Penang Island can be categorized as “Slightly Polluted” to “Polluted” according to DOE’s WQI classification. The deterioration of water quality usually involves the buildup of nutrients such as BOD, nitrate and phosphate.

Nutrient enrichment can shift species composition of the coral community, where larger and slow-growing organisms that thrive in nutrient-poor waters are replaced by smaller and rapidly growing species (Bell, 1992; Done, 1992; Birkeland, 1988). The inclusion of significant additional levels of phosphate in the coral area would potentially affect the growth. High phosphate levels can lead to algal blooms, decreasing sunlight penetration that can reduce coral growth (Mohammed *et al*., 1995). Phosphate enrichment also contributes overgrowth by filamentous algae as well as inhibits precipitation of calcium carbonate from seawater (Kleypas *et al*., 1999).

The major changes in flushing capacity occur after the completion of Island A. It should be noted that the deterioration of water quality is expected to occur mainly in the flushing channel. Whether the extent of water pollution will reach the vicinity of Pulau Rimau and at what magnitude cannot be deduced at this moment without a more detailed simulation on water quality.

Nevertheless, it is deduced that once the reclamation of Island A is completed, there will be significant impact to the coral reefs at Pulau Rimau. Meanwhile, the coral reefs at Pulau Kendi is in general unaffected because of its distant location. These permanent impacts may hamper the recovery of coral reefs that would be affected during the reclamation of Island A. As such, the loss of coral reefs at Pulau Rimau is considered as partial trade-off.

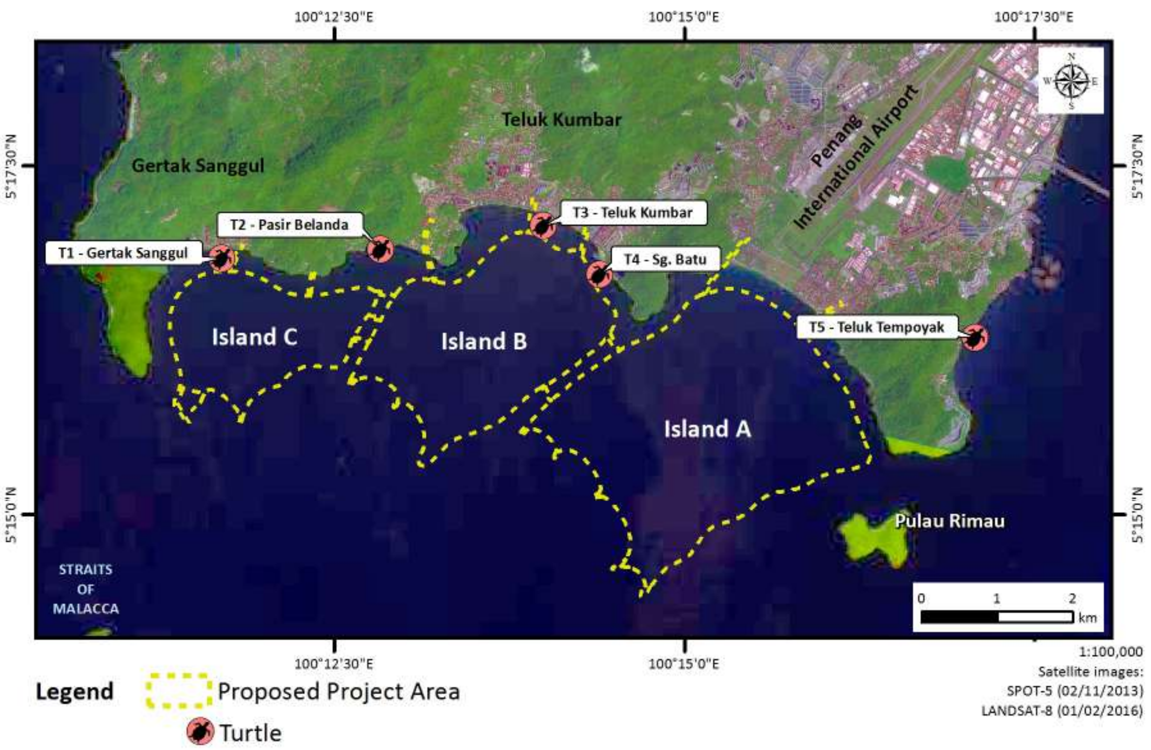
7.5.2 Turtle Nesting Area

There are several turtle nesting sites identified along the south coast of Penang Island. T7.39 and F7.76 identify the stretch of beaches where turtle nestings have been recorded in the past. Two species have been reported to nest within the study area, namely Green Turtle and Olive Ridley Turtle. Artificial lightings from developments in Teluk Kumbar are known to discourage female turtles from nesting. Once the land reclamation and dredging works commence, disturbance by lights and noises from the vessels will worsen the situation and the south coast of Penang Island will become an unfavourable site for turtle landing.

T7.39 Turtle nesting sites

Point	Beach Name
T1	Gertak Sanggul
T2	Pasir Belanda
T3	Teluk Kumbar
T4	Sungai Batu (Pantai Medan)
T5	Teluk Tempoyak

More pressingly, once the reclamation is completed, the new landmass will become a huge physical obstruction to the nesting beaches. Turtles are known to land only at the same stretch of beach for nesting. With these new obstacles in place, it is safe to assume that any turtles intending to nest at the south coast of Penang Island will not reach the landing site. As such, this ESA is considered as a trade-off.



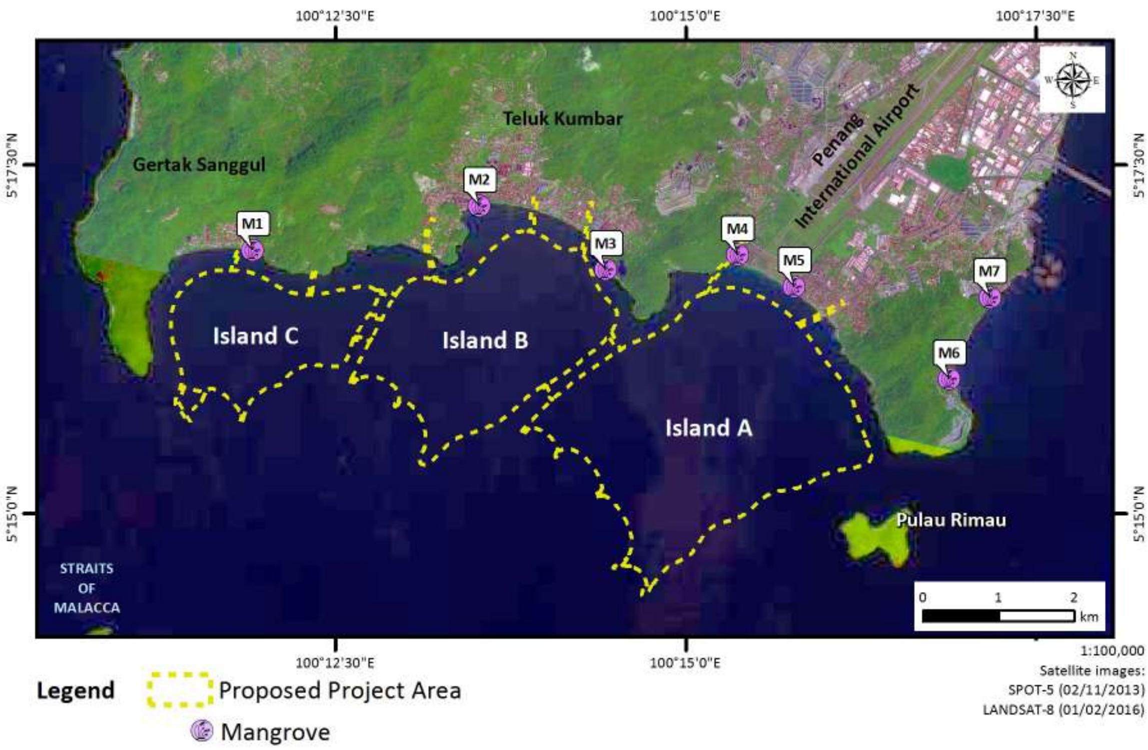
F7.76 Turtle nesting sites at the south coast of Penang Island

7.5.3 Mangrove

While there are no significant mangrove forests found surrounding the Project area, some small patches of mangroves can still be observed mainly in the rivers nearby the Project site, as shown in T7.40 and F7.77. Although the mangroves appear to be less dense, taking into account the importance of mangroves in nearshore marine ecosystem, the impacts on mangroves is still evaluated and discussed in this subsection.

T7.40 Locations of mangrove patches

Point	Location of Mangrove
M1	Sungai Gertak Sanggul
M2	Sungai Teluk Kumbar
M3	Sungai Batu
M4	Sungai Bayan Lepas
M5	Bayan Lepas Main Drain
M6	Teluk Tempoyak Besar
M7	Teluk Tempoyak Kecil



F7.77 Mangroves observed nearby the Project site

7.5.3.1 Land Reclamation and Dredging

Mangroves are known to be very tolerant towards the range of suspended sediment loads that may be generated from dredging and reclamation activities (Doorn-Groen and Foster, 2007). According to Thampanya *et al*. (2002), the mangroves that are sensitive towards sedimentation are those with pneumatophore root (e.g. *Avicennia* sp.), though they are highly unlikely to be stressed, except when the sedimentation reach levels from 10 cm up to 30 cm for a prolonged period. The seedlings, however, are susceptible to sedimentation as the lenticels, which carry out the gas exchange may be blocked by sediment (Thampanya *et al*., 2002). On the other hand, erosion may cause destabilization of the river bank, which in turn will uproot the mangroves trees.

Based on the hydraulic simulation results, no significant sedimentation and erosion is projected to occur at the mangroves area. As such, it is expected that the mangrove will not be affected during the course of Project implementation.

7.5.3.2 Post-reclamation

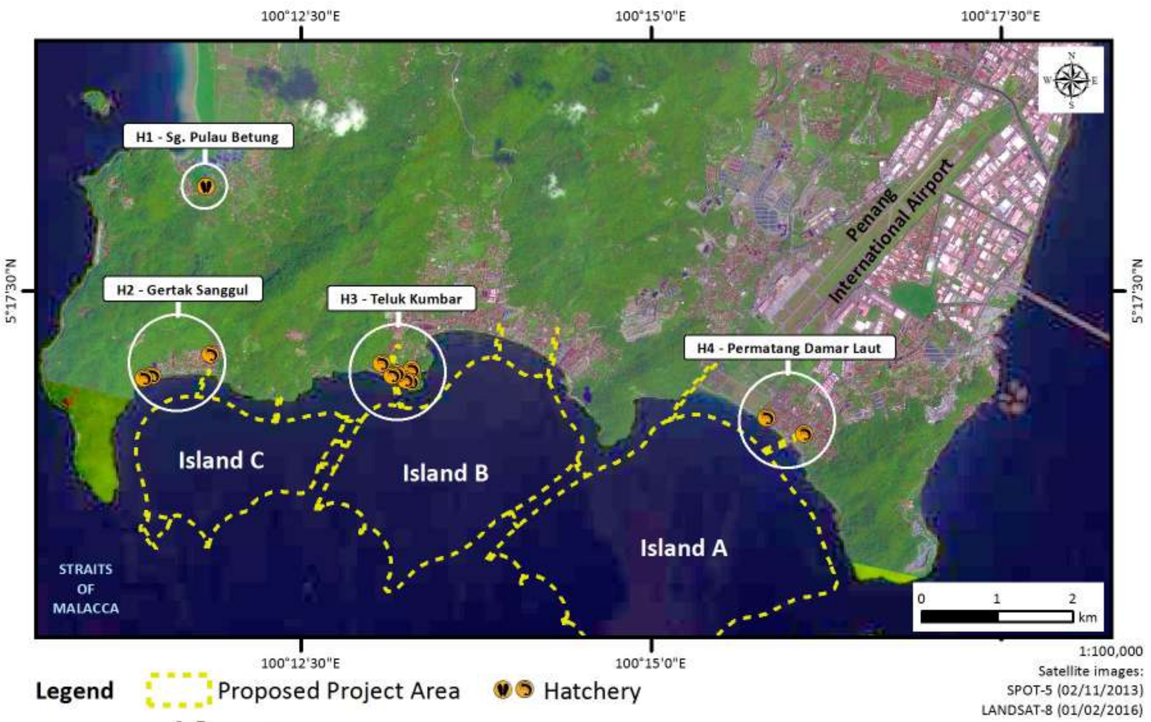
The proposed Project does not directly affect the mangroves due to its location. Nonetheless, the presence of three newly-reclaimed islands is expected to change the current flow at the study area. The increase in current flow may affect the mangrove negatively if erosion occurs along the riverbank populated by the mangroves. However, the hydraulic simulation results show that there will be no change in sedimentation and erosion rate at the mangrove area. Thus no impact is expected to occur.

7.6 Impacts on Fishing Industry

The proposed Project is situated in an area that has an active fishing industry, substantiated by clusters of hatchery and aquaculture operations as well as various fishing villages and jetties dotting along the coastline. The hatchery and aquaculture operations are especially noted to be significant in sizes and value. The produce are sold in local market as well as exported to Singapore and Hong Kong. As for fishermen within the study area, although they are mostly made up of small-scale, artisanal fishermen, it is still a vital source of livelihood for some of the local population.

7.6.1 Hatcheries

At the moment, there are four main clusters of hatchery operations located adjacent to the proposed Project site, as shown in F7.78. Hatcheries operations are very much dependent on the quality of sea water obtained via the intake. As different hatcheries operator adopt different types of treatment systems, the existing treatment system of all the hatcheries will be assessed and discuss with respective hatcheries operator to determine forms of upgrade preferred. The hatcheries' current treatment systems work on a baseline value of 10 to 15 mg/L of suspended solid during the high tides. An increase in sediment levels at the water intake points means there will be a need to upgrade the filtration systems of the hatcheries.



F7.78 Locations of hatchery operations

7.6.1.1 Land Reclamation and Dredging

As the water intake points of the hatcheries are located about 5 to 100 m from the shoreline, it is considered for the intake to be affected, especially during dredging activities. Dredging activities will be conducted for all development scenarios. Impacts to the hatcheries during the Project implementation stage can be gauged using extracted data from the sediment spill dispersion simulation.

a) Scenario 1

As detailed out in T7.41, the extracted data shows that all hatcheries will not be significantly affected during Scenario 1. However, this is not entirely accurate as dredging will be carried out directly at the location of water intake points for hatcheries at Gertak Sanggul, Teluk Kumbar and Permatang Damar Laut. Logically, these hatcheries may be impacted from the sediment plume dispersion. This situation was not reflected in the simulation because of model limitation i.e. the location of dredgers established in the model.

Nevertheless, it is reasonable to assume that the hatcheries at these locations may be impacted during this scenario. The high TSS level introduced by the dredging activities may cause additional loading to the current filtration system used by the hatcheries.

T7.41 Excess suspended sediment concentration level at the hatcheries for Scenario 1

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	1	3	Insignificant impact
H3	Teluk Kumbar	0	1	Insignificant impact
H4	Permatang Damar Laut	1	9	Insignificant impact

b) Scenario 2

The activities during this Scenario is conducted adjacent to Teluk Kumbar. Thus, the impact will be primarily felt by hatcheries located at Teluk Kumbar. This is reflected in the simulation model whereby there will be a significant increase in TSS level as shown in T7.42.

T7.42 Excess suspended sediment concentration level at the hatcheries for Scenario 2

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	117	High TSS level will affect the existing filtration system, thus mitigation measure is required
H4	Permatang Damar Laut	0	0	Insignificant impact

After Island B is completed, the flushing capacity at Teluk Kumbar will increase from the existing 2 hours to 8 hours. Conservatively, it can be assumed that the water quality within the access channel of Island B where the intake pipe is currently located will deteriorate. The increase in nutrient and other pollutants in the marine water may render it to be unsuitable for hatcheries operation without extensive treatment.

Other hatcheries are expected not to be significantly affected during this scenario.

c) Scenario 3

During this scenario, the excess suspended sediment concentration does not increase significantly at all water intake locations as shown in T7.43. Nevertheless, the presence of Islands A and B will significantly alter the flushing capacity at Teluk Kumbar and Permatang Damar Laut area in which the retention time has increased to 8.5 hours and 29 hours respectively. This condition is expected to cause deterioration in water quality, especially at Permatang Damar Laut area, that may affect the hatchery operations.

T7.43 Excess suspended sediment concentration level at the hatcheries for Scenario 3

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	0	1	Insignificant impact
H3	Teluk Kumbar	0	7	Insignificant impact
H4	Permatang Damar Laut	19	241	High TSS level will affect the existing filtration system, thus mitigation measure is required

d) Scenario 4

For this scenario, the excess suspended sediment concentration recorded is very low at all locations as tabulated in T7.44. Thus the impact is deemed insignificant. However, there is a slight increase in retention time at Gertak Sanggul, from 1.5 hours to 2 hours. It is expected that this slight increase will not significantly alter the existing water quality at Gertak Sanggul, and thus, no impact to the hatcheries located within this area.

T7.44 Excess suspended sediment concentration level at the hatcheries for Scenario 4

Point	Location	Excess Suspended Sediment Concentration		Remarks
		Mean	Max	
H1	Near Sungai Pulau Betung	0	0	Insignificant impact
H2	Gertak Sanggul	23	305	High TSS level will affect the existing filtration system, thus mitigation measure is required
H3	Teluk Kumbar	0	0	Insignificant impact
H4	Permatang Damar Laut	0	0	Insignificant impact

7.6.1.2 Post-reclamation

After the reclamation is completed, it is expected that the level of TSS in the marine water will return within the normal range of baseline condition. However, the presence of three adjacent new islands will affect the flushing capacity, which in turn will cause significant degradation of water quality within the access channel, notably at Permatang Damar Laut and Teluk Kumbar area. At the moment, the locations of water intake point for all the hatcheries are located in the proposed access channel. As such, the water available for intake is of lower quality and may require further treatment.

7.6.2 Cage Cultures

There are significant numbers of marine fish cage culture operations at Batu Maung and Pulau Betong that could potentially be affected by the proposed Project. The main impact on aquaculture would come from potential deterioration of water quality. An increase in TSS and turbidity levels will cause additional stress on fishes reared in the aquaculture farms.

Theoretically, the response of cultured fish to adverse environmental conditions would be the same as that of wild fish. The initial response of fish would be to move away from the area of adverse environmental conditions. However, caged fish are not in a position to migrate from their culture site, irrespective of the environmental conditions, and are forced to put up with such adverse conditions. Generally, a greater incidence of disease infestation and/or slower growth could be expected. Known occurrences of mass fish mortality in cage aquacultures caused by high level of TSS have been reported in Malaysia. For cage cultures, the tolerable limit for TSS adopted is 80 mg/L. This is in line with the recommended in Water Quality Standards for Aquaculture in Malaysia (Liong, 1984).

The larvae and eggs are more vulnerable to lower concentrations of TSS as compared to juveniles and adults (Engell-Sørensen and Skyt, 2002), particularly in larvae where their gills are sensitive to clogging. In addition, the duration of exposure is also more critical when the fishes are persistently exposed to the TSS for prolonged period compared to being exposed to high level of suspended sediments for a short time (Berry *et al.*, 2003). Being exposed for longer periods would cause sub-lethal effects i.e. increased respiration rate due to the gills being clogged, hence depleting oxygen, as well as reduced feeding rates which indirectly lead to slower growth. Mortality would likely occur afterwards.

Higher concentration could cause the solids to deposit on the nets, thus becoming substrates for the growth of fouling organisms that would prevent proper water circulation. Higher concentrations could cause the solids to deposit on the nets, thus becoming substrates for the growth of fouling organisms that would prevent proper water circulation. The presence of suspended solids could also be related to disease such as “fin-rot” that is caused by Mycobacteria (Herbert and Merkens, 1961, Herbert and Richards, 1963).

T7.45 shows the projected mean and maximum excess SSC brought about by the proposed Project at the aquaculture farms for all development scenarios. Based on the table, the increase in mean excess SSC is negligible while the highest increase in maximum excess SSC is recorded at Batu Maung for Scenario 1 (14 mg/L). With these minimal changes, it is deduced that the impact to aquaculture operations caused by the proposed development is insignificant.

T7.45 Excess SSC level at the hatcheries for Scenario 1

Point	Location	Excess Suspended Sediment Concentration (mg/L)								Remarks
		Scenario 1		Scenario 2		Scenario 3		Scenario 4		
		Mean	Max	Mean	Max	Mean	Max	Mean	Max	
A1	Pulau Betung	1	7	0	2	0	4	1	9	Insignificant impact
A2	Sungai Pulau Betung	-	-	-	-	-	-	-	-	No data (upstream location)
A3	Batu Maung	1	14	0	0	0	0	0	0	Insignificant impact

7.6.3 Marine Capture Fisheries

The impact brought about by the proposed Project would be most felt by artisanal fishermen operating from the various landing points fronting the Project area. As for commercial fishing vessels, such as trawlers and Tuna Long-lines, particularly at Batu Maung, the loss of fishing grounds at the proposed Project site is not expected to affect their operation and catch since they fish further ashore. Therefore, the focus of this section is on the coastal fishermen.

It should be noted that the impact on fishermen and fisheries is relatively similar during the Project implementation phase and after the reclamation is completed (post-reclamation). As such, the impact components for both setting are discussed together under each section.

7.6.3.1 Loss of Fishing Ground

Fishing activities are undertaken within the mudflat area that is the target of the proposed reclamation. The area is a fishing ground for the fishermen from Sungai Batu, Permatang Damar Laut, Permatang Tepi Laut, Teluk Kumbar and Gertak Sanggul, which front the proposed reclamation site. Artisanal fishermen largely fish for crab (300 to 500 m) and shrimp (500 m and beyond) in the foreshore and near shore areas that are to be reclaimed.

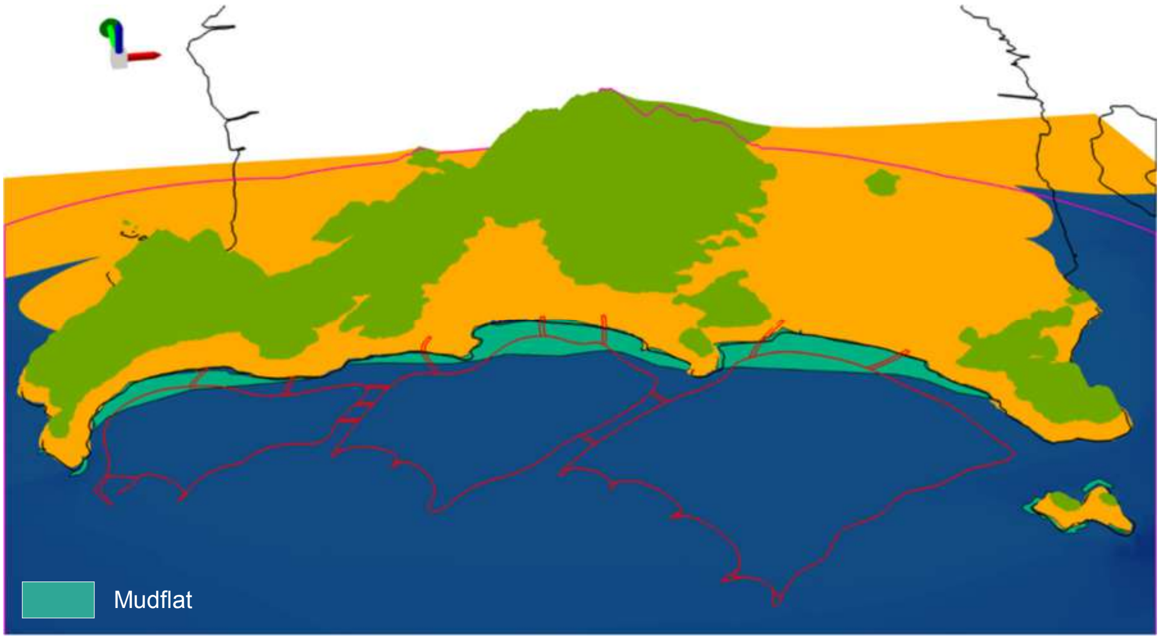
During the Project implementation stage, this fishery is expected to be affected and, to some extent will be lost, with the implementation of the project. This can potentially lead to decrease in fish landings and directly affect the income and livelihood of fishermen fishing in the area. The marine capture fishery is thus expected to be affected and this can potentially lead to overall decrease in fish landings.

After the reclamation is completed, the fishermen that are involved in crab and shrimp fishing will permanently lose a stretch of their fishing grounds at the reclamation footprint. Therefore, the fishing activities are likely to be shifted and concentrated at other areas such as off Pulau Kendi and Berting or other further area including Sri Jerjak, Batu Maung, Teluk Tempoyak Kechil and Besar as well as Pulau Betong, whereby fishermen from other fish landing points already been fishing at these areas. This would lead to increase the intensity of the fishing activities in these adjacent grounds.

The impact of the loss on the fishing economy in particular is difficult to assess on a quantitative basis. Fishermen are, by nature, opportunistic and will seek out other grounds to sustain their catch. Without accurate resource data, however, it is not possible to establish the extent to which these grounds would compensate for the loss in catch that will accompany the reduction in fishing area. What is clear, however, is the fishermen would have to move further out to fish, leading to increased operational cost, particularly fuel, which in turn will affect their productivity.

7.6.3.2 Loss of Fish Nursery Ground

Mudflats are highly productive areas and although may be relatively low in biological diversity, they support a high biomass of micro and infaunal organisms and support large fin and shellfish stocks due to the sediment being rich in organic content. Some footprints of the reclamation area cover intertidal mudflat area, as illustrated in F7.79, which can be considered as resulting in total loss.



F7.79 Mudflat area covered by the reclamation footprint

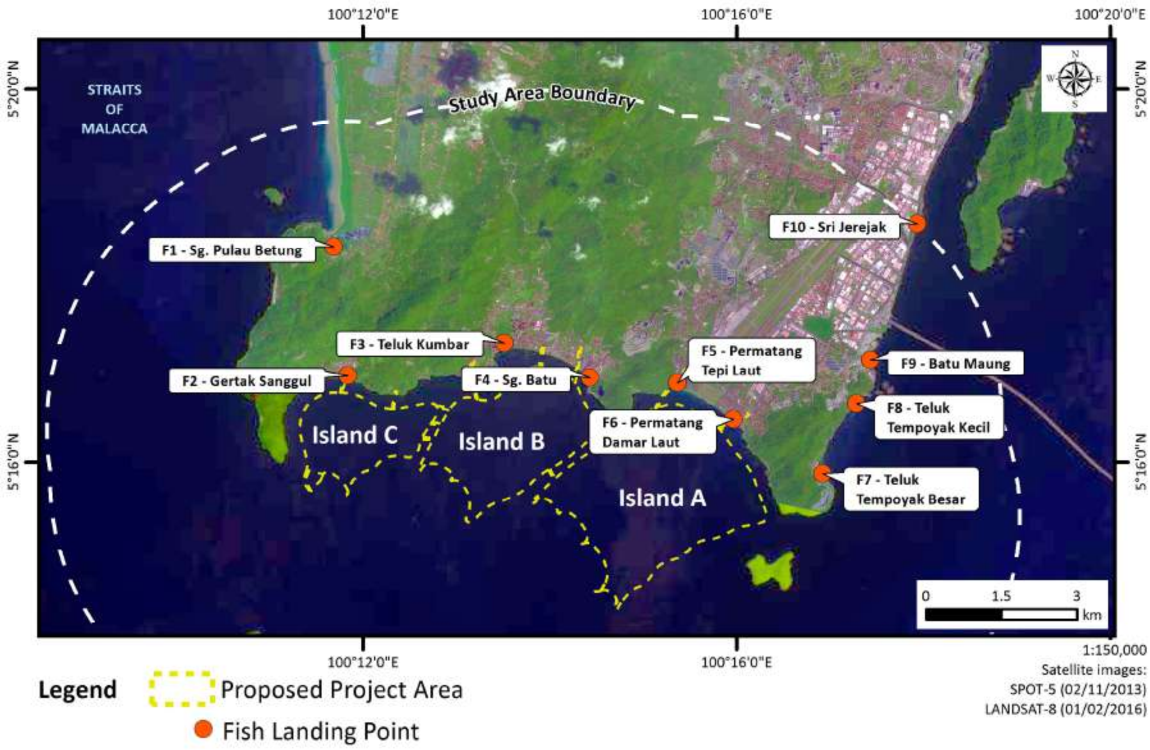
It is pertinent to note that coastal shallows and intertidal zones are where the land and the sea meet. When artificially separated, nutrients from the land can no longer flow into coastal waters, threatening crabs, shrimp, clams and other organisms, which rely on this source of food. This has an impact on the ocean food chain and the fishing industry.

To be concise, collectively the intertidal/mudflat habitat is of great importance to large numbers of invertebrates and fish, supporting complex estuarine food webs and provide nursery and feeding grounds to large numbers of fish species. Hence, they are important to the local fishery economy.

These services are likely to be compromised to an extent by the proposed reclamation. Again, the extent to which this is likely to occur would depend on scope of the reclamation that is to be carried out. It should be noted that once the reclamation has taken place, the mudflats that are reclaimed and dredged would be lost.

7.6.3.3 Fish Landing Points

Typical of an area where there is a substantial fishing industry, there are numerous fishermen jetties and facilities located along the coastline. Fishermen jetty is an important structure normally used by these fishermen to unload their catch as well as providing a space to berth their boats. Ten landing points were identified that are susceptible to the impacts caused by the proposed Project, as illustrated in F7.80. Considerable increase in wave heights and/or current speeds may affect manoeuvring of the boats while sedimentation occurrence may cause the water depth to be shallow, thus requiring regular maintenance dredging.



F7.80 Fish landing points within the study area

a) Current Speed

Hydraulic simulation for current speed is discussed extensively in *Section 7.3.5*. The result shows that there will be a considerable increase in current speed for the fish-landing point at Permatang Damar Laut and Sungai Batu. It is expected that manoeuvring of the boats will be slightly difficult because of this condition, especially for boats equipped with low-powered engines (less than 19 horsepower). Based on the survey conducted with local fishermen within the study area, boats with less than 19 horsepower engine made up approximately 3% of the total boats commonly used, mainly found at Batu Maung, Gertak Sanggul and Pulau Betung. As such, the increase in current speed at fish landing points is expected not to cause any significant impact to the fishermen.

b) Wave

Based on the result of wave heights simulation discussed extensively in *Section 7.3.7*, there is no significant increase in wave heights at all fish-landing points. Thus, it is deduced that the impact of wave height difference brought by the proposed Project will be insignificant.

c) Sedimentation and Erosion

T7.46 shows the rate of sedimentation or erosion that is expected to occur at the fish landing points. Based on the result, all locations will not be affected except for Gertak Sanggul and Sungai Batu whereby significant sedimentation is expected to occur. If unmitigated, water depth at these landing points will become shallower, which in turn will cause access difficulties for fishing boats.

T7.46 Sedimentation rate at fish landing points for all scenarios

Point	Location	Average Sedimentation Rate (m/year)				Remarks
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	
F1	Sungai Pulau Betung	-	-	-	-	No data (upstream location)
F2	Gertak Sanggul	0.01	0.01	0.01	0.14	Significant sedimentation, thus mitigation measure is required
F3	Teluk Kumbar	0.00	0.00	0.00	0.00	Insignificant impact
F4	Sungai Batu	0.01	0.14	0.10	0.04	Significant sedimentation, thus mitigation measure is required.
F5	Permatang Tepi Laut	-	-	-	-	No data (upstream location)
F6	Permatang Damar Laut	0.00	0.00	0.00	0.00	Insignificant impact
F7	Teluk Tempoyak Besar	0.00	0.00	0.00	0.00	Insignificant impact
F8	Teluk Tempoyak Kecil	0.00	0.00	0.00	0.00	Insignificant impact
F9	Batu Maung	0.00	0.00	0.00	0.00	Insignificant impact
F10	Sri Jerjak	0.00	0.00	0.00	0.00	Insignificant impact

7.7 Impacts on Marine Biology

Marine biology is an important component that is interconnected with the fishing industry. The study area comprises ecologically important habitats, namely mudflat, coral reefs, mangrove and coastal waters which support important marine fauna such as fish, macrobenthos and plankton. Therefore, should any component of the complex marine ecosystems be disturbed by the implementation of the proposed Project, the fishing industry may be affected.

7.7.1 Land Reclamation and Dredging

The various activities associated with the proposed island reclamation at the Project site will invariably bring about environmental impacts on different aspects of the marine environment and consequently on the immediate coastal environment as well as fisheries and aquaculture activities. The nature and intensity of these impacts would depend on the extent, intensity and timing of the activities and can be of a short or long-term nature.

7.7.1.1 Loss of Foreshore Area and Mudflat

Dredging activities will cause disturbance and removal of benthic infauna and alteration of the substance upon which colonization depends. This will in turn affect its stability as a fish or shellfish food habitat. However, this impact can be considered as temporary whereby if the remnant substrate is identical to the surficial sediment, disturbance is unlikely to be permanent and the extraction area will be recolonised. However, the time scale will vary depending on the nature and location of the deposit.

Muddy seabed can be found at certain sections of the proposed Project area, thus making it a potentially important forage base for marine organisms, especially commercially important fish species. It is likely that both primary and secondary productivity at the area would be quite high. However, increased suspended solids in the water column due to reclamation activities may inhibit light penetration, thus limiting the primary productivity of the immediate aquatic environment in the vicinity of the Project area. Nevertheless, this is considered a short-term impact and localised within the source.

7.7.1.2 Fish Fauna

Certain fish species are susceptible to high levels of silt in the water, which can abrade and clog their gills causing severe haemorrhaging, osmotic imbalance and respiratory difficulties (Redding and Midlen, 1991; Hodgson, 1994; EPA, 1976). Abrasion by particles may remove the protective coating of mucus and increase the susceptibility of fish to disease (Everhart and Duchrow, 1970).

In addition, high levels of suspended sediments lead to light reduction and visual impairment. Thus, fish may have difficulty seeing prey (Bouma, 1976) while mating and territorial behaviour patterns which are highly dependent on visual cues (Thresher, 1984) would be disrupted by turbid water conditions. This would result in a reduced reproductive rate that would eventually reduce the abundance and diversity of fish. Crustaceans such as shrimps and molluscs (gastropod and bivalves), which have limited mobility, would be most affected. This, in turn, would reduce the abundance of these organisms.

Unfortunately, little is known about the absolute sediment tolerance thresholds of most commercial fish species. For each organism, injury will occur above a different threshold concentration of suspended sediments and also vary among the different life stages (egg, larva, juvenile and adult). The younger stages of the fish would be most vulnerable and sensitive to this effect (Hodgson, 1994).

Besides the likelihood of distinctly possible fish kills, the immediate impact on fisheries would be the migration of fishes and free-swimming or mobile aquatic fauna to safer or less disturbed areas (generally deeper waters) as a natural response to changes in the marine environment (Wildish and Power,1985; Pennekamp and Quaak, 1990). This would in a way lead to a reduction of catches for fishermen operating in the affected area.

7.7.1.3 Plankton

Primary and secondary productivity are important indicators of the available forage base for marine planktivorous organisms. These organisms, in turn, play an important part in the marine food web (Chong *et al*., 1990). Many commercially important pelagic fish species are, in fact, directly dependent on primary and secondary producers. The impacts of plankton populations are not restricted to a specific area and relate closely with primary and secondary productivity along the entire coastline.

The extent of primary and secondary productivity in a given environment is dependent on a number of factors including light levels, nutrient levels, temperature and favourable hydrographic conditions (Alongi and Cristoffersen, 1992). Under local conditions, where light intensity and duration are constant throughout the country, nutrient levels primarily mediate plankton densities.

Turbidity is a major factor mediating primary productivity in marine waters (Pequegnat, 1978). A significant increase in turbidity levels would therefore retard primary production and, by extension, the rest of the marine food web. Decreasing availability of food due to reduced photosynthesis (Pequegnat, 1978) would likely induce migration of herbivorous organisms out of the area to search for food. Hence, the action will continue to disrupt the food-web in the area by depriving food for the higher trophic, causing imbalance to the community there.

7.7.1.4 Macrobenthos

Sediment communities have been found to play a critical role in the food chain for the marine organism (Chong *et al.*, 1990). Benthic macrofauna are also one of the most important food sources for marine demersal fish (Sasekumar, 1984; Sasekumar *et al.*, 1984; Erfetemeyer *et al.*, 1989). Thus, the loss of macrobenthic fauna at and adjacent to the site would clearly impact on fish fauna currently found there. Sediment communities relate closely with primary and secondary productivity along the entire coastline. Therefore, direct effects of constructions works on these organisms and disturbance to the seabed communities can also deleteriously affect organisms on higher trophic levels in adjacent areas by depriving them of food.

Crustaceans such as shrimps and molluscs (gastropod and bivalves), which have limited mobility and are largely dependent upon for food and shelter on the foreshore area, would be seriously affected due to reclamation and dredging activities. This, in turn, would reduce the abundance of these organisms. In addition, a study by Ingle (1952), recorded that high levels of suspended sediments have been shown to kill bivalves. Other impacts arise from the disturbance of seabed are the destruction of spawning areas and smothering or suffocation of sessile organisms in the area (Pennekamp and Quaak, 1990).

7.7.2 Transportation and Disposal of Dredged Material

Constant marine traffic movement (tug boats and barges) transporting fill material may disturb the aquatic communities along the transportation route. Oil discharge or leakages from the vessels may pollute the pelagic and benthic ecosystems. It could also increase the possibility of accidents at sea with further adverse consequences to the marine life. Spillage of fill material could result in increased water turbidity.

Settlement of sediment from the disposed materials will have a serious impact on the habitat of the benthic communities as the sediments will smother the communities at the sea bottom. However, this is a short-term impact. The benthic communities will eventually recover and recolonise the area.

7.7.3 Post-reclamation

7.7.3.1 Loss of Mudflat Area

The nature of reclamation is such that it is expected to lead to an irreversible change in the area to be developed. The original physical, biological resources and productivity prevailing at the proposed Project area would largely be lost permanently, particularly the coastal mudflats and its associated flora and fauna. Losses of such magnitude are likely to be key drivers of declines in biodiversity and ecosystem services in the intertidal zone of the region. Though there is a buffer zone (approximately 250 m of access channel) between the mainland and reclaimed area, it would not be able to compensate for a much larger portion of the foreshore area (4,500 acres) that is expected to be totally eliminated.

7.8 Impacts on Marine Traffic and Navigation

Land reclamation and dredging activities for this Project will involve a big number of vessels ranging from dredgers, barges, tug boats and pontoons. These vessels will operate within an area where there is a high concentration of fishermen boats as the coastline adjacent to the Project site housed a number of fishing villages and bases. In addition, there are also several boat operators catering for the recreational fishing trip. These operators were located at Pantai Sri Jerjak, Batu Maung, and Pulau Betong. It is projected that the fishermen, as the prominent marine user of the area, will be the most affected group in terms of marine traffic and navigation.

7.8.1 Land Reclamation and Dredging

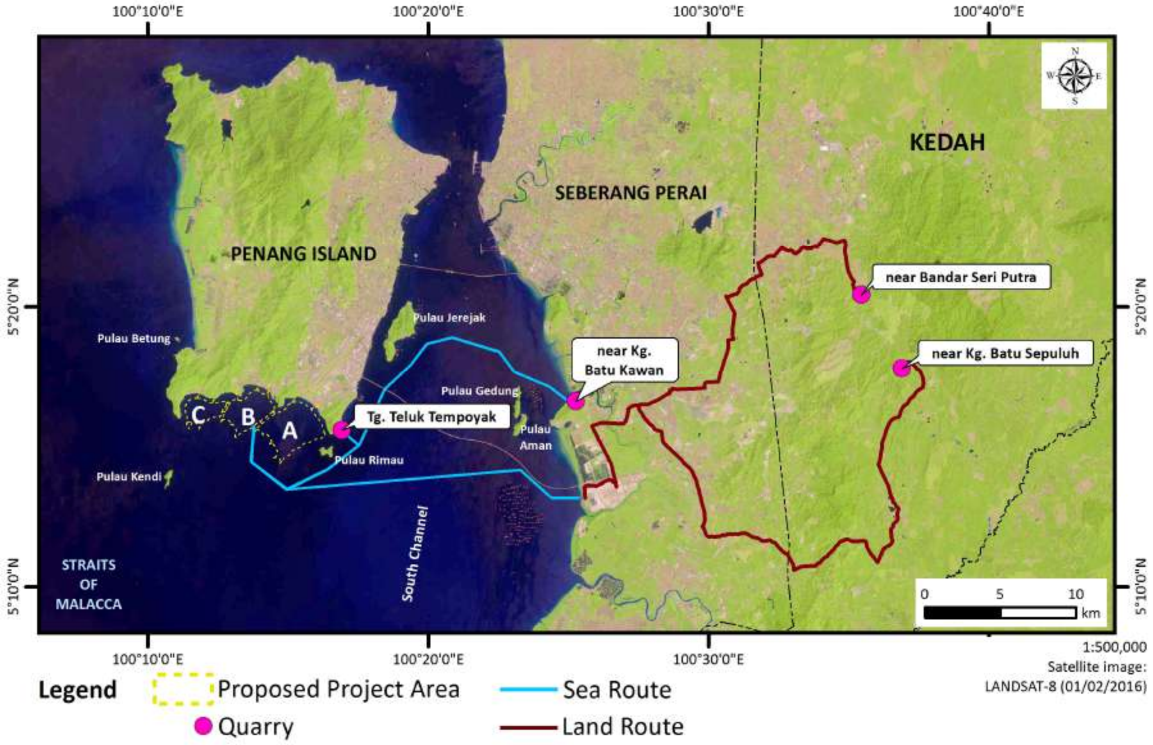
The proposed Project will cause a considerable increase in marine traffic within the vicinity of the Project site. Furthermore, vessels involved in the Project such as tugboats, barges and TSHDs are significantly larger in size compared to the existing marine traffic users which are mostly made up of fishermen and rental boats.

The movement of the fishing vessels will be restricted during the land reclamation and dredging periods. It is expected that lighted buoys will be deployed around the Project site to mark the designated working area. For safety reasons, this area is considered off-limit to the fishermen boats. If possible, the fishermen shall be requested to use assigned routes for travelling in and out of their villages/bases. However, by doing so, the daily commute of these fishermen will become longer, thus incurring additional fuel costs. On the other hand, the risk of collision between the fishermen and the working vessels will be greatly reduced.

The Project area is located within an area where fishermen looking for prawns regularly cast their net. If they continue to do so during the implementation of the Project, their nets may be entangled with the work vessels. During the process of casting their net, the mobility of the fishermen boats is limited. This situation presents a significant risk of collision between the work vessels and these boats.

Once dredging and land reclamation start, the Project site will be interspersed with fixed and movable structures such as pipelines, silt curtains and rock bunds. These structures present a safety risk for fishermen and other marine users, especially at night.

The Project location is also situated adjacent to the South Channel of the Penang Port. Based on the location of the proposed disposal ground and sand source, it is expected that the additional traffic caused by the land reclamation and dredging activities will not affect the marine navigation within South Channel. Transportation of rocks from the quarry in Juru will directly cross the South Channel, as illustrated in F7.81. But looking into the low traffic volume for the South Channel (approximately 20 to 30 vessel calls per year), it can be deduced that the impact will be insignificant.



F7.81 Rock barges route to the Project site

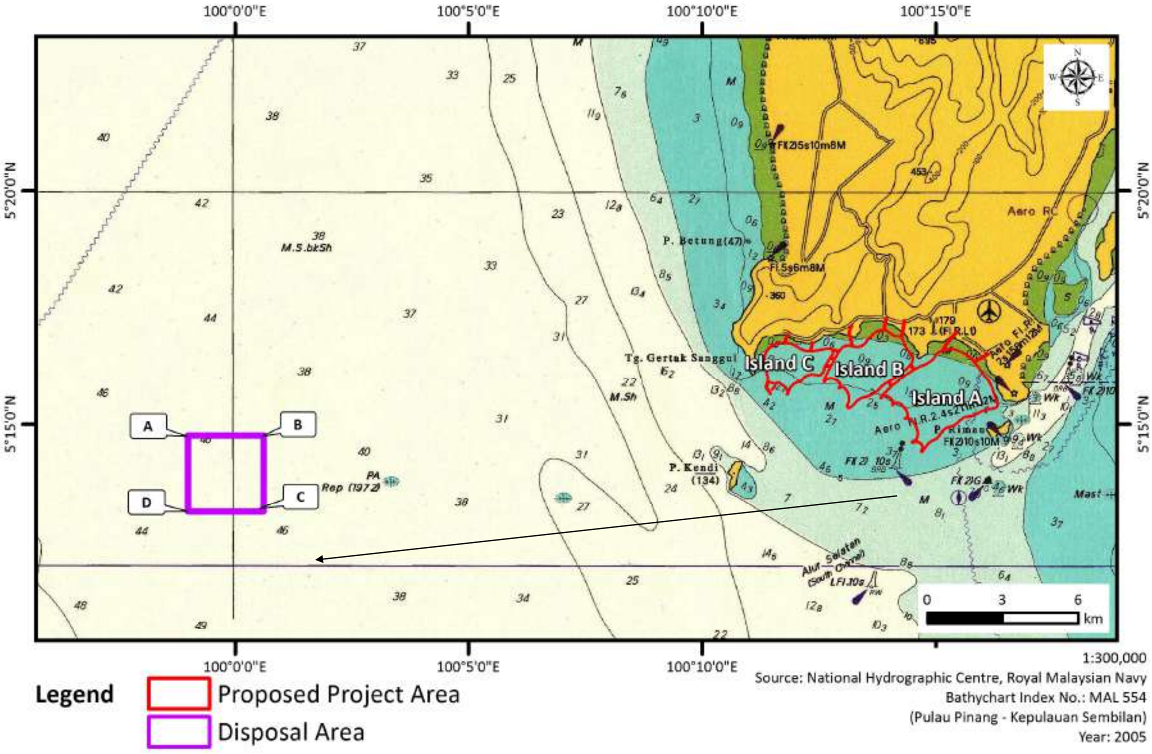
7.8.2 Transportation and Disposal of Dredged Material

The movement of barges carrying dredged material to the designated disposal area will travel along the route as shown in F7.82. The route to the dumping area will go nearby Pulau Kendi, which is a popular ground for fishermen and recreational fishing activities. The constant movement of barges will present collision risk between the work vessels and fishermen/angler boats, especially at night.

7.8.3 Post-reclamation

As mentioned previously, post-reclamation refers to a stage when the reclamation and dredging are completed, but no topside development is undertaken yet. As such, no discernible impact to marine traffic and navigation is expected during this stage.

Later, once the topside development commences, a marina will be built on Island C. The presence of marina will bring about additional marine traffic into the Project area. In order to accurately assess the impacts from this additional traffic, it is advisable for a Marine Risk Assessment (MRA) to be conducted. Findings from the MRA study can be included in the EIA to be conducted during the topside development stage.



F7.82 Transportation route to the designated dumping area

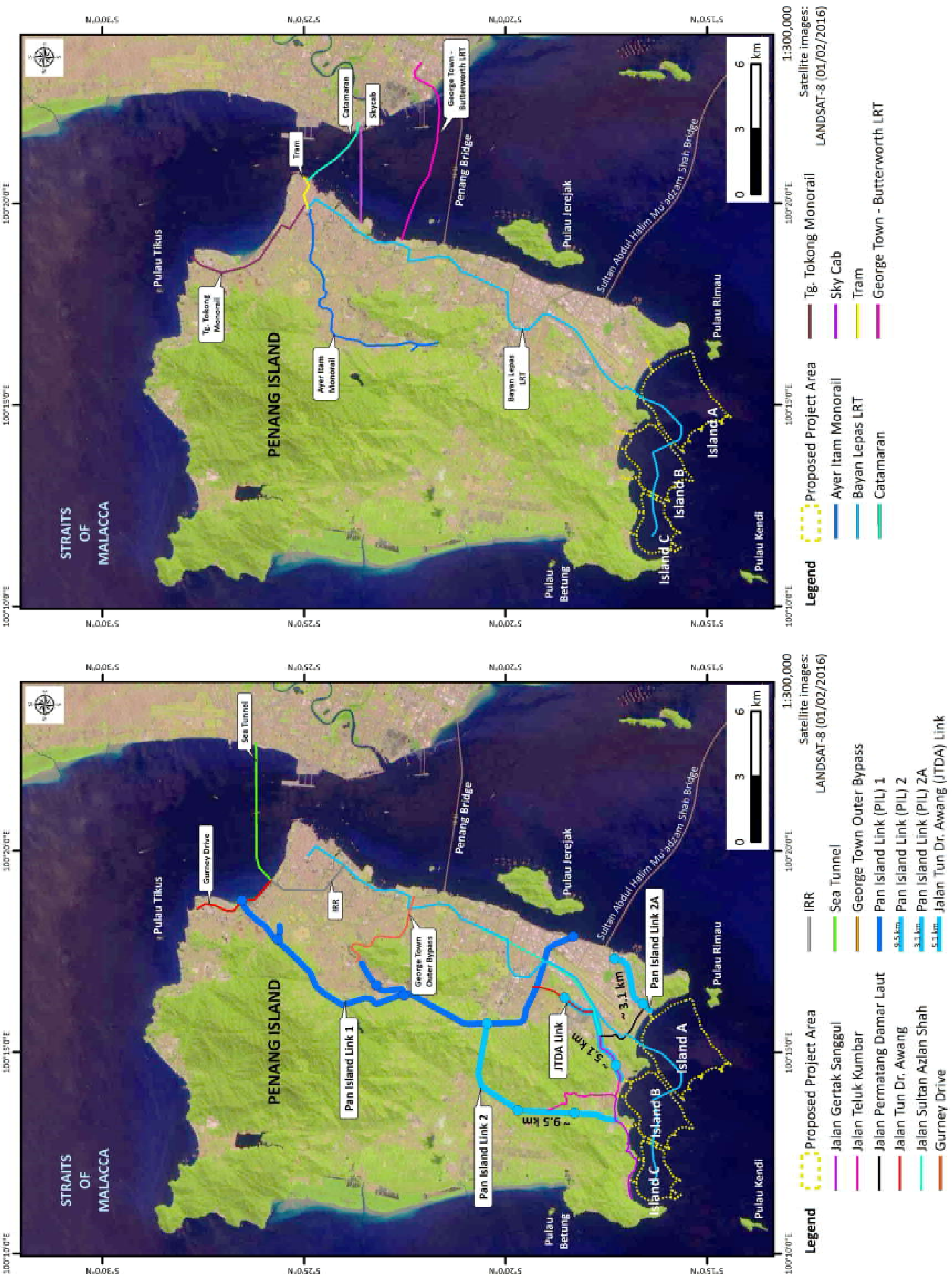
7.9 Traffic Impact Assessment (TIA)

Although this EIA study primarily focuses on the dredging and land reclamation related activities, some aspects that are related with topside development stage also need to be taken into account in order to get a better understanding on the overall impact of the proposed development to the surroundings. Land traffic is one of the relevant component of said aspects, thus an impact assessment study on land traffic was conducted whereby the findings will be discussed in the following sections.

7.9.1 Penang South Reclamation Transport Network

The development is proposed to be served by an extension to the proposed Bayan Lepas LRT line and an internal tram system. There will be three main highway connections from the development (shown in light blue in the diagram on the left below), providing grade-separated access to the wider expressway network, namely: Pan Island Link 2 (PIL 2), PIL 2A and Jalan Tun Dr. Awang Link (JTDA). In addition, there will be six (6) secondary accesses and upgrading to the existing roads (Jalan Teluk Kumbar, Jalan Permatang Damar Laut and Jalan Gertak Sanggul). The proposed transport network for PSR is shown in F7.83.

F7.83 Proposed transportation network for PSR



7.9.2 Methodology

7.9.2.1 Passenger Car Unit (PCU) Conversion Factors

For the purposes of assessing the capacity of the road network, each vehicle classification is converted into PCUs to reflect the amount of road capacity they use in relation to a standard car. The conversion unit from vehicles to PCUs for the observed classes of vehicles were based on the values provided by REAM which are summarized in T6.26 in *Chapter 6: Existing Environment*.

7.9.2.2 Definition of Peak Period

The peak hour periods were determined by analyzing the hourly traffic flows at all junctions within the study area. Based on analysis of the traffic flow data collected, the peak hours are found to occur during the following periods:

a) AM peak: 0730 – 0830 hours; and
b) PM peak: 1730 – 1830 hours.

7.9.2.3 Forecast of Future Traffic

Travel demand forecasting for the study is estimated by taking into consideration of the proposed development up to the future horizon when PSR development is fully matured. This involves making estimation of future growth in traffic demand due to socioeconomic indicators as well as land use changes. Estimation of development traffic uses the Highway Planning Unit Trip Generation Manual (2010).

The trips during the AM and PM peak periods are derived based on the land use in each of the parcels within the islands. The demand is distributed to areas both within the PSR development and to areas on Penang Island and the mainland based on a calibrated gravity model. The estimated trip generation for the proposed development is shown in T7.47.

The surrounding developments are also predicted to have their contributions towards the trips generated and attracted to the development site. This is known as background growth and the growth rate for said background growth has been identified and included in the assessment.

T7.47 Estimated trip generation (PCUs/hour)

Peak Period	Island	Car	Motorcycle	Truck	Bus	Total
AM	A	18,931	4,007	6,295	2,154	31,387
	B	20,653	2,672	4,061	662	28,049
	C	7,649	1,156	2,053	374	11,232
	Total	**47,234**	**7,837**	**12,408**	**3,189**	**70,669**
PM	A	16,452	3,066	5,482	1,768	26,768
	B	23,109	2,729	4,057	387	30,282
	C	8,716	1,315	1,836	191	12,057
	Total	**48,276**	**7,109**	**11,376**	**2,346**	**69,107**

7.9.2.4 Scenario Definitions of TIA

The following scenarios have been assessed for the traffic impact assessment which are explained as follows:

a) *Without Development* - This scenario includes all proposed external transport infrastructure outlined in T7.48, other key developments within the study area without the proposed PSR development
b) *With Development* - This scenario includes all proposed internal and external transport infrastructure outlined in T7.48 including PIL and the connections between PIL and the proposed PSR development. Mitigation measures proposed to alleviate the traffic impacts generated by the proposed development is also incorporated.

T7.48 Proposed external transport infrastructure

Projects		Without Development	With Development
Rail	LRT Bayan Lepas	✓	✓
	LRT Bayan Lepas (extension to PSR)		✓
	Monorail AI+TB	✓	✓
	BRT	✓	✓
	Crossing LRT	✓	✓
	Mainland monorail	✓	✓
	Georgetown tram	✓	✓
Bus	Rationalisation of bus routes at rail corridor	✓	✓
	Feeder bus system	✓	✓
PSR Highway	PIL1	✓	✓
	PIL2		✓
	PIL2A		✓
	Jalan Tun Dr. Awang (JTDA) elevated road		✓
Other public transportation	Sky Cab	✓	✓
Policy	Increased private vehicle charging - existing areas	✓	✓
	Increased private vehicle charging - PSR		✓
	Fuel price	✓	✓
PSR	PSR Development traffic		✓
Government committed highways	Penang Third Crossing - Sea Tunnel	✓	✓
	Georgetown Inner Ring Road (IRR)	✓	✓
	Georgetown Outer Bypass (GTOB)	✓	✓
	North Coast Pair Road (NCPR) (Zenith Section)	✓	✓
	North Coast Pair Road (NPCR) (SRSC Section)	✓	✓
	Gurney Expressway	✓	✓
	Connecting road between NCPR and Gurney Expressway	✓	✓
	Ayer Itam Pair Road (at Bukit Kukus)	✓	✓
	Tun Dr. Lim Chong Eu Elevated Expressway	✓	✓
	General road widening in Teluk Kumbar	✓	✓
	Batu Maung flyover	✓	✓
	Macallum U-turn and road improvement	✓	✓

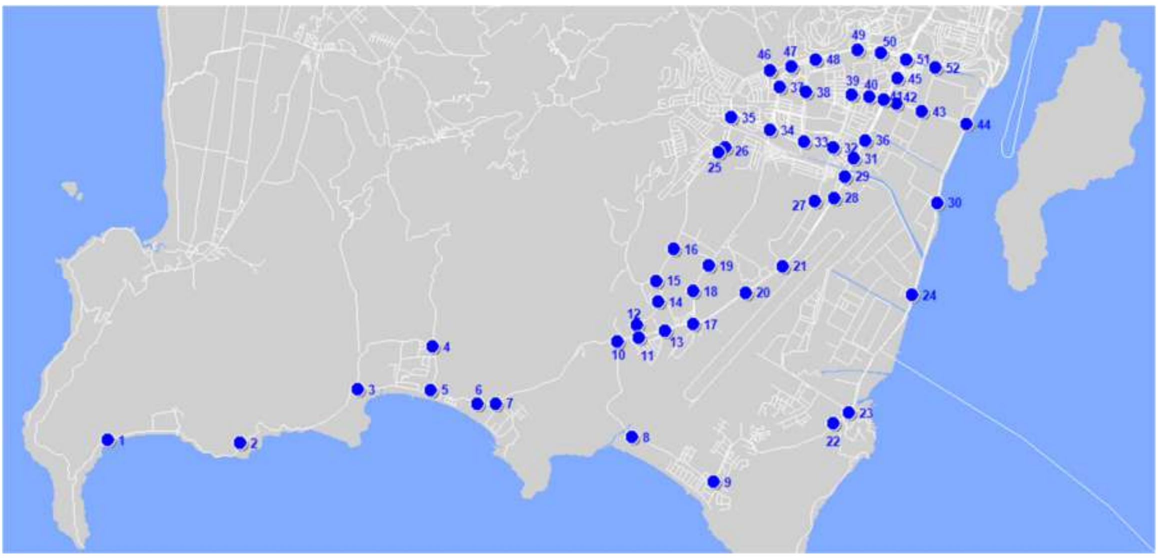
T7.48 Proposed external transport infrastructure

Projects		Without Development	With Development
Government committed highways	The Lights - Connector roads and internal roads	✓	✓
	Jalan Pisang/Jalan Zoo road improvement	✓	✓
	Jalan Bukit Gambir/Jalan Tun Dr. Awang junction improvement	✓	✓
	FIZ contraflow system at Hilir Sungai Kluang 4	✓	✓
	Jalan Bayan Lepas/Jalan Teluk Kumbar/Jalan Permatang Damar Laut junction improvement	✓	✓
	Jalan Sultan Azlan Shah road improvement	✓	✓
	Jalan Kampung Batak road improvement	✓	✓
	Jalan Sultan Azlan Shah improvement at Batu Uban	✓	✓
	NSE link road	✓	✓

7.9.2.5 Traffic Performance

The road network within the study area is characterised by a dense road network and junctions. These junctions are either signalised or unsignalised and are pinch points that are the controlling factor in determining effective traffic throughput and ultimately the capacity of the road network. As such, the impact assessment will look into the performance of the junctions.

The junctions envisaged to be impacted by the proposed PSR development, shown in F7.84 and T7.49, were assessed using the SIDRA 6.1 junction analysis software. The program assesses the operational performance of the junctions based on inputs relating to the layout and geometry of the junction and the observed traffic volumes. The key performance indicator for junction is the controlled delay(s). For both signalized and unsignalized junctions, the Level of Service (LoS) relates to the delay experienced by traffic at the junctions (T6.26 in *Chapter 6: Existing Environment* shows the relationship between delay and the LoS).



F7.84 Locations of junctions simulated in the study

T7.49

Details of junctions simulated in the study

Junction	Description
1	From PSR Island C to Jalan Gertak Sanggul
2	From PSR Island C to Jalan Gertak Sanggul
3	Jalan Gertak Sanggul - P235
4	Jalan Teluk Kumbar - P235
5	Jalan Teluk Kumbar - Jalan Gertak Sanggul
6	From PSR Island B to Jalan Teluk Kumbar
7	Jalan Teluk Kumbar - Jalan Sungai Batu
8	From PSR Island A to Jalan Permatang Damar Laut (at western airport boundary)
9	From PSR Island A to Jalan Permatang Damar Laut (at Lorong Permatang Damar Laut)
10	Jalan Permatang Damar Laut - Jalan Teluk Kumbar
11	Jalan Bayan Lepas - Jalan Dato’ Ismail Hashim
12	Jalan Dato Ismail Hashim -Jalan Dato’ Ismail Hashim
13	Jalan Bayan Lepas - Jalan Garuda
14	Jalan Mahkamah - Jalan Dato’ Ismail Hashim
15	Persiaran Kelicap - Jalan Dato’ Ismail Hashim
16	Pintasan Kelicap 1 - Jalan Rajawali and Jalan Dato Ismail Hashim
17	Jalan Sultan Azlan Shah - Jalan Tun Dr. Awang
18	Jalan Tun Dr. Awang - Persiaran Rajawali
19	Jalan Tun Dr. Awang Double U-turn
20	Jalan Sungai Tiram 1 and Jalan Sultan Azlan Shah
21	Jalan Sultan Azlan Shah/Lorong Sungai Tiram 1
22	Jalan Permatang Damar Laut - Jalan Teluk Tempoyak
23	Jalan Permatang Damar Laut - Jalan Batu Maung
24	Tun Dr. Lim Chong Eu Highway -Hilir Sungai Kluang 1
25	Jalan Kenari - Jalan Dato’ Ismail Hashim
26	Lebuh Sungai Ara 1 - Jalan Dato’ Ismail Hashim
27	Jalan Mayang Pasir - Lebuh Sungai Tiram 1
28	Jalan Tokong Ular - Jalan Sultan Azlan Shah
29	Jalan Sultan Azlan Shah - Jalan Tokong Ular
30	Kampung Jawa Highway - Tun Dr. Lim Chong Eu Highway
31	Jalan Tengah - Jalan Sultan Azlan Shah
32	Jalan Tengah - Jalan Mayang Pasir
33	Jalan Tengah - Persiaran Mahsuri
34	Jalan Tun Dr Awang - Jalan Bayan-Jalan Tengah
35	Jalan Dato’ Ismail Hashim - Jalan Bayan
36	Kampung Jawa Highway - Jalan Sultan Azlan Shah
37	Jalan Tun Dr. Awang - Jalan Mahsuri
38	Jalan Mahsuri - Persiaran Mahsuri
39	Jalan Mayang Pasir - Jalan Mahsuri
40	Jalan Mahsuri - Jalan Nibung
41	Jalan Mahsuri – Jalan Kampung Jawa and Jalan Sultan Azlan Shah
42	Jalan Kampung Jawa - Lorong Kampung Jawa

Junction	Description
43	Jalan Kampung Jawa - Lebuh Kampung Jawa
44	Jalan Kampung Jawa - Tun Dr. Lim Chong Eu Highway
45	Jalan Bahagia - Jalan Sultan Azlan Shah
46	Jalan Dato Ismail Hashim - Jalan Paya Terubong
47	Jalan Tun Dr Awang - Jalan Dato' Ismail Hashim
48	Persiaran Bukit Jambul - Jalan Tun Dr. Awang
49	Jalan Bukit Gambir - Jalan Tun Dr. Awang
50	Jalan Tun Dr Awang - Jalan Kampung Relau
51	Jalan Tun Dr Awang – Sungai Nibong Highway - Jalan Sultan Azlan Shah
52	Sungai Nibong Highway - Lebuh Kampung Jawa

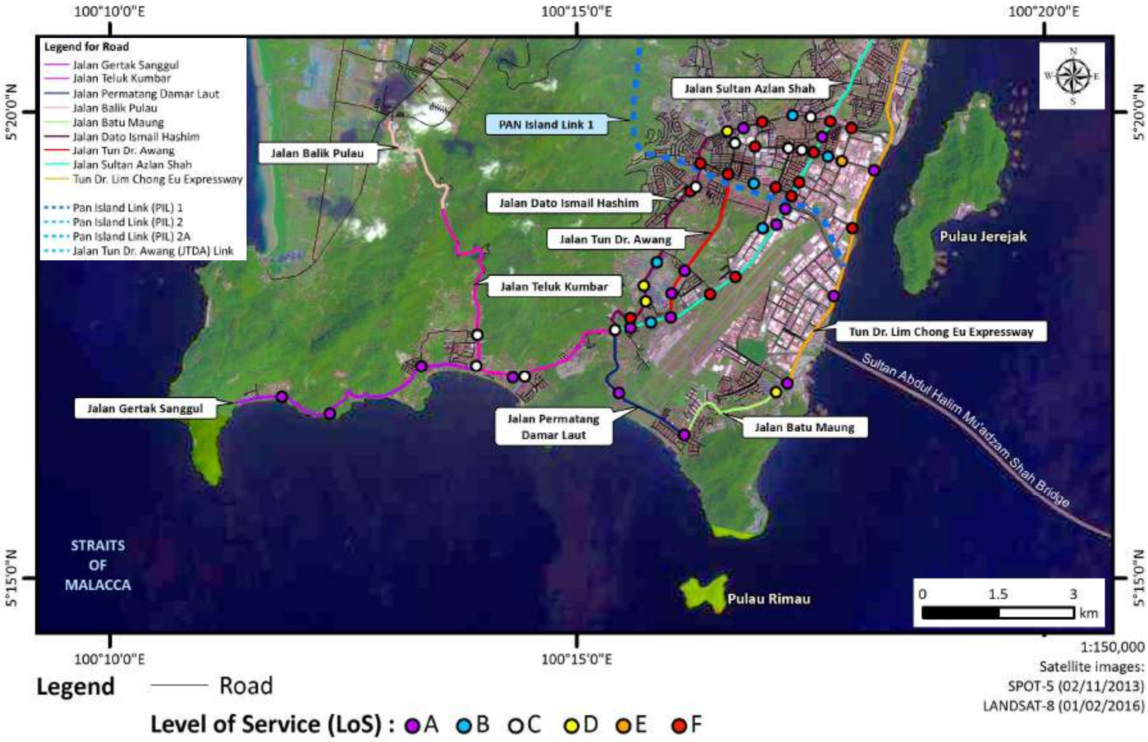
T7.49
Details of junctions simulated in the study (cont'd)

7.9.3 Overall Findings for Traffic

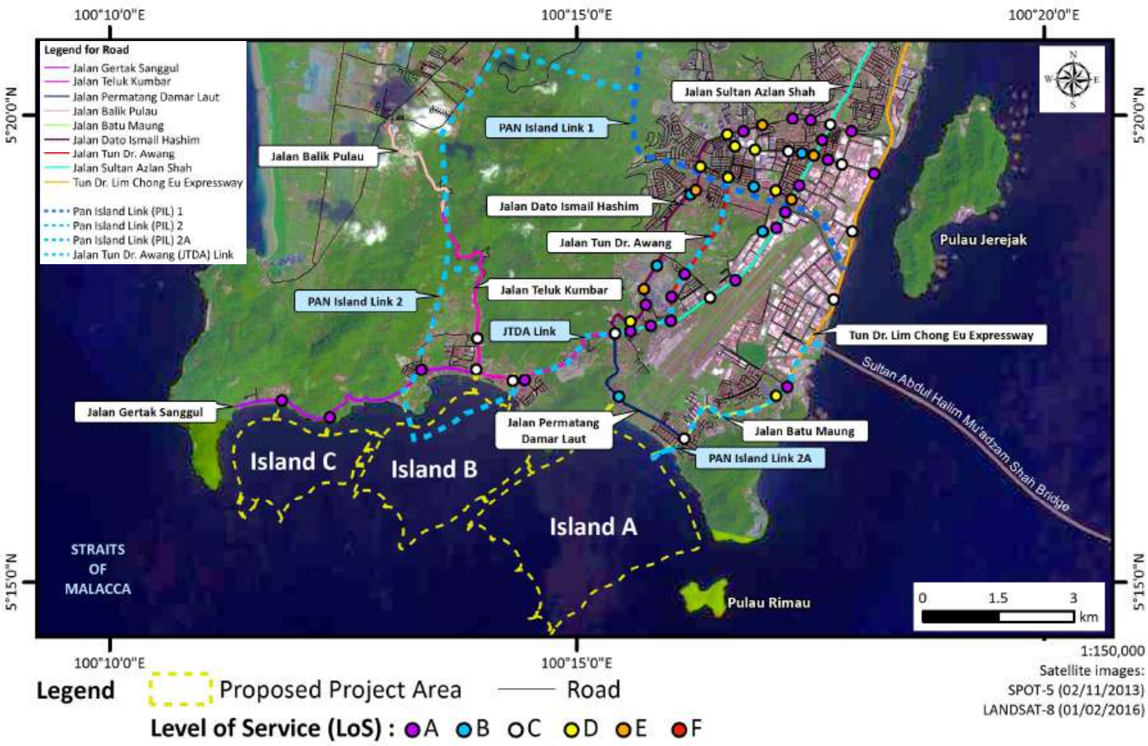
F7.85 and F7.86 shows the comparison of junction performance between the Without and With Development scenario while T7.50 summarised the junction counts according to the LoS. Details on the performance for each junctions simulated in the study is given in T7.51. The results shown that With Development scenario, which includes the Bayan Lepas LRT extension to PSR, PIL2, PIL2A and JTDA, bring about a sharp reduction (100%) in the number of junctions operating at LoS F. There are also increase in number of junctions performing at LoS A, B and C. Thus, in general, it can be deduced that there is an improvement in traffic condition as the proposed development also include a number of new external connection as well as upgrading of the existing roads at Jalan Teluk Kumbar, Jalan Permatang Damar Laut and Jalan Gertak Sanggul.

Level of Service (LoS)	Junction Count			
	AM		PM	
	Without Development	With Development	Without Development	With Development
A	17	22	15	20
B	6	6	5	7
C	9	11	8	8
D	4	8	4	10
E	1	5	3	7
F	15	0	17	0

T7.50
Junction counts according to the LoS

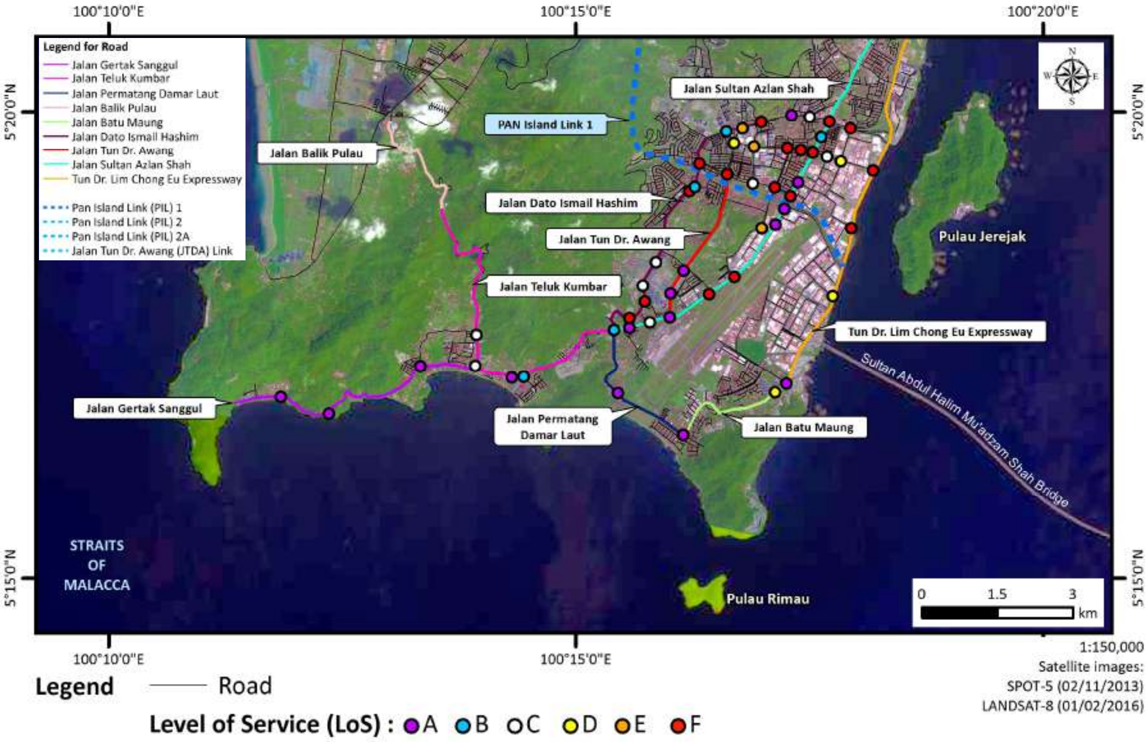


a) Without development

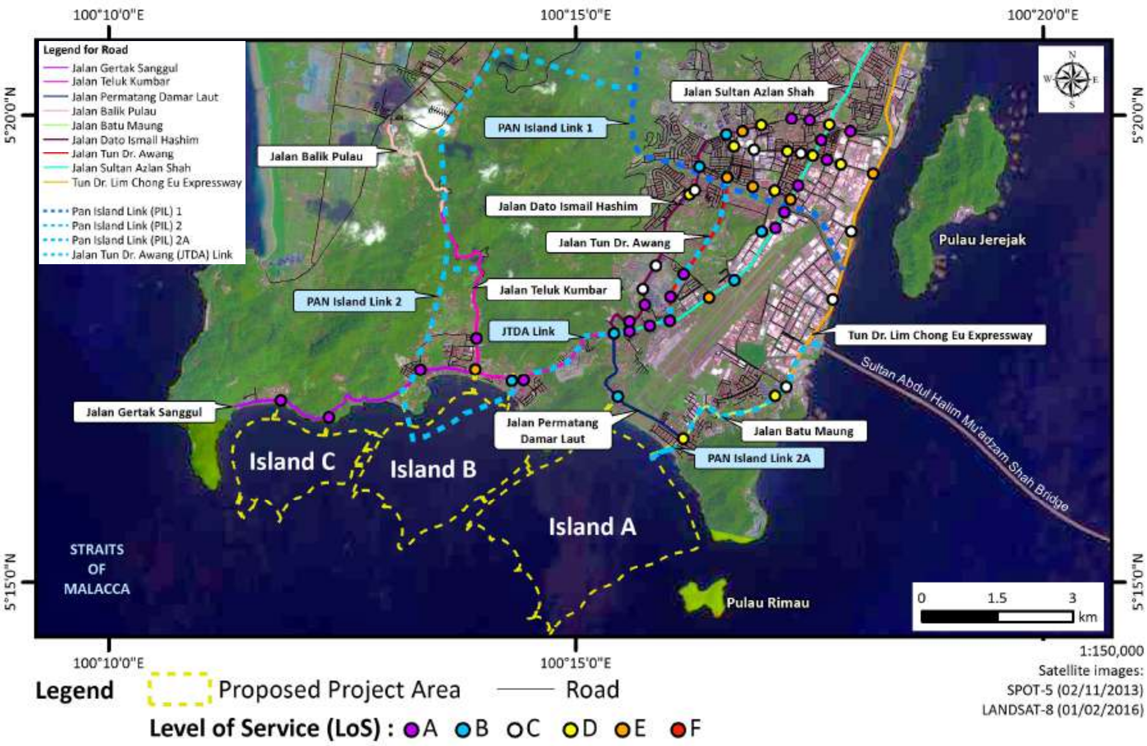


b) With development

F7.85 Junction performance comparison for AM traffic: Without vs. With development



a) Without development



b) With development

F7.86 Junction performance comparison for PM traffic: Without vs. With development

T7.51 Performance of simulated junctions

Junction	Description	AM		PM	
		Without Development	With Development	Without Development	With Development
1	From PSR Island C to Jalan Gertak Sanggul	A	A	A	A
2	From PSR Island C to Jalan Gertak Sanggul	A	A	A	A
3	Jalan Gertak Sanggul - P235	A	A	A	A
4	Jalan Teluk Kumbar - P235	C	C	C	A
5	Jalan Teluk Kumbar - Jalan Gertak Sanggul	C	C	C	E
6	From PSR Island B to Jalan Teluk Kumbar	A	C	A	B
7	Jalan Teluk Kumbar - Jalan Sungai Batu	C	A	B	A
8	From PSR Island A to Jalan Permatang Damar Laut (at western airport boundary)	A	B	A	B
9	From PSR Island A to Jalan Permatang Damar Laut (at Lorong Permatang Damar Laut)	A	C	A	D
10	Jalan Permatang Damar Laut - Jalan Teluk Kumbar	C	C	B	B
11	Jalan Bayan Lepas - Jalan Dato' Ismail Hashim	A	A	A	A
12	Jalan Dato Ismail Hashim -Jalan Dato' Ismail Hashim	F	D	F	A
13	Jalan Bayan Lepas - Jalan Garuda	B	A	C	A
14	Jalan Mahkamah - Jalan Dato' Ismail Hashim	D	A	F	A
15	Persiaran Kelicap - Jalan Dato' Ismail Hashim	D	E	C	C
16	Pintasan Kelicap 1 - Jalan Rajawali and Jalan Dato' Ismail Hashim	B	B	C	C
17	Jalan Sultan Azlan Shah - Jalan Tun Dr. Awang	A	A	A	A
18	Jalan Tun Dr. Awang - Persiaran Rajawali	A	A	A	A
19	Jalan Tun Dr. Awang Double U-turn	A	A	A	A
20	Jalan Sungai Tiram 1 and Jalan Sultan Azlan Shah	F	C	F	E
21	Jalan Sultan Azlan Shah/Lorong Sungai Tiram 1	F	A	F	B
22	Jalan Permatang Damar Laut - Jalan Teluk Tempoyak	D	D	D	D
23	Jalan Permatang Damar Laut - Jalan Batu Maung	A	A	A	C
24	Tun Dr. Lim Chong Eu Highway -Hilir Sungai Kluang 1	A	C	D	C
25	Jalan Kenari - Jalan Dato' Ismail Hashim	F	B	F	D
26	Lebuh Sungai Ara 1 - Jalan Dato' Ismail Hashim	C	E	B	C
27	Jalan Mayang Pasir - Lebuh Sungai Tiram 1	B	B	E	B
28	Jalan Tokong Ular - Jalan Sultan Azlan Shah	A	A	A	A
29	Jalan Sultan Azlan Shah - Jalan Tokong Ular	A	A	A	A
30	Kampung Jawa Highway - Tun Dr. Lim Chong Eu Highway	F	C	F	C
31	Jalan Tengah - Jalan Sultan Azlan Shah	F	E	F	E
32	Jalan Tengah - Jalan Mayang Pasir	F	D	F	D
33	Jalan Tengah - Persiaran Mahsuri	B	B	C	E
34	Jalan Tun Dr Awang - Jalan Bayan-Jalan Tengah	F	D	F	E
35	Jalan Dato' Ismail Hashim - Jalan Bayan	F	D	F	B
36	Kampung Jawa Highway - Jalan Sultan Azlan Shah	F	A	A	A
37	Jalan Tun Dr. Awang - Jalan Mahsuri	C	D	D	D

T7.51 Performance of simulated junctions (cont'd)

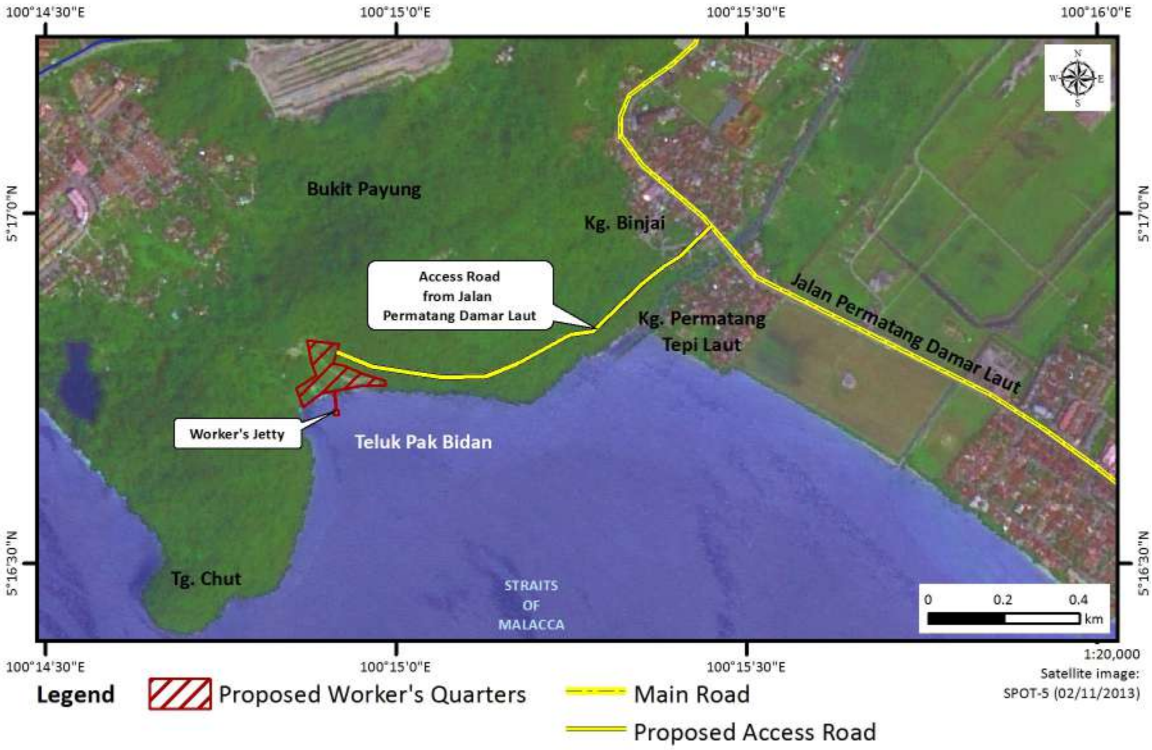
Junction	Description	AM		PM	
		Without Development	With Development	Without Development	With Development
38	Jalan Mahsuri - Persiaran Mahsuri	F	D	E	C
39	Jalan Mayang Pasir - Jalan Mahsuri	C	C	F	D
40	Jalan Mahsuri - Jalan Nibung	C	B	F	C
41	Jalan Mahsuri – Jalan Kampung Jawa and Jalan Sultan Azlan Shah	F	E	F	D
42	Jalan Kampung Jawa - Lorong Kampung Jawa	B	A	C	A
43	Jalan Kampung Jawa - Lebuh Kampung Jawa	E	C	D	D
44	Jalan Kampung Jawa - Tun Dr. Lim Chong Eu Highway	A	A	F	E
45	Jalan Bahagia - Jalan Sultan Azlan Shah	A	A	B	A
46	Jalan Dato Ismail Hashim - Jalan Paya Terubong	D	D	B	B
47	Jalan Tun Dr Awang - Jalan Dato' Ismail Hashim	A	A	E	E
48	Persiaran Bukit Jambul - Jalan Tun Dr. Awang	F	E	F	D
49	Jalan Bukit Gambir - Jalan Tun Dr. Awang	B	A	A	A
50	Jalan Tun Dr Awang - Jalan Kampung Relau	C	A	C	A
51	Jalan Tun Dr Awang – Sungai Nibong Highway - Jalan Sultan Azlan Shah	F	C	F	D
52	Sungai Nibong Highway - Lebuh Kampung Jawa	F	A	F	A

7.10 Noise

Noise pollution will be temporary impacts as it will only be generated during the Project implementation stages. After all work is completed (post-reclamation), the impact of noise pollution will cease. Among all activities that will be carried out over the course of Project implementation, the construction of workers' quarters (Pre-dredging Phase) and rock perimeter bund are expected to emit a significant level of noise. Impact of noise pollution is also related with the working hours of the proposed Project. Noise emitted from the work will be more noticeable at night because of the quieter background.

7.10.3.1 Pre-dredging

The construction of workers' quarters during this phase will involve heavy machineries and lorries movement that usually emit a high level of noise. However, the noise impact from this activity is projected to be insignificant as the construction site is located away from residential areas (approximately 400 m) and the area is surrounded by hilly terrain and lush vegetation which will act as an effective sound buffer, as shown in F7.87. In addition, it is expected that the construction activities will only be conducted during day time; thus the impact of noise during this phase is manageable and will not cause significant impact.



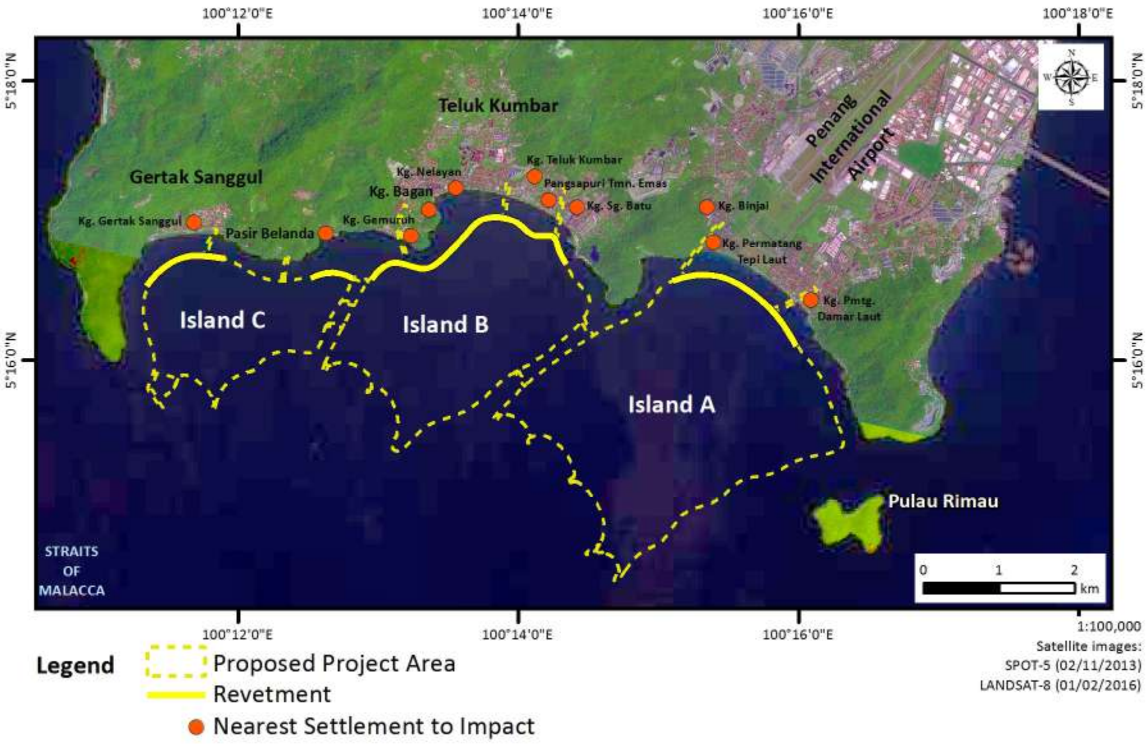
F7.87 Proposed location of workers' quarters

7.10.3.2 Land Reclamation

Normally, dredging operations emit minimal noise so the impact on noise pollution from dredging is expected to be insignificant. However, certain land reclamation activities, such as rock bund and rock revetment construction, will produce noticeable levels of noise caused by the movement of excavators on the rock barge, transferring the rocks from barge to lorry and rock-laying activities. These may become a problem during the construction of the rock bund nearest to the residential area, as shown in F7.88. The issue of noise pollution from rock bund construction is expected to be apparent if the activity is carried out at night. Even though the residential area is separated approximately by 40 to 250 m to the rock bund alignment, noise from rock bund construction may still be perceivable at night time because of the lower background noise, thus becoming a source of nuisance.

7.11 Air Quality

Impacts on air quality related to the proposed development will primarily come from dust generation and exhaust emission from vessels, generator set, machineries and equipment. It should be noted that the impacts on air quality are rather concentrated and short-termed, depending on the direction and velocity of the existing wind along with the magnitude of work. It is projected that only land-based activities will produce a significant amount and meriting proper management in order to alleviate this particular impact.



F7.88 Section of revetment nearby residential areas

7.11.1 Pre-dredging

This activity involves land-clearing works as well as working on exposed topsoil. If unmitigated, the construction activities will churn up significant amounts of dust, especially during dry season, which will cause deterioration in air quality. Although the dust generation may be significant, the impact is expected to be naturally alleviated by the lush vegetation that surrounds the site location. Furthermore, the site location is located away from any sensitive receptor. However, vehicles travelling through the access road may cause dust to scatter to the surrounding area, especially at the entry point connecting the access road and the existing main road. If left unmitigated, residents nearby the entry point and along the main road used by the lorries will be affected.

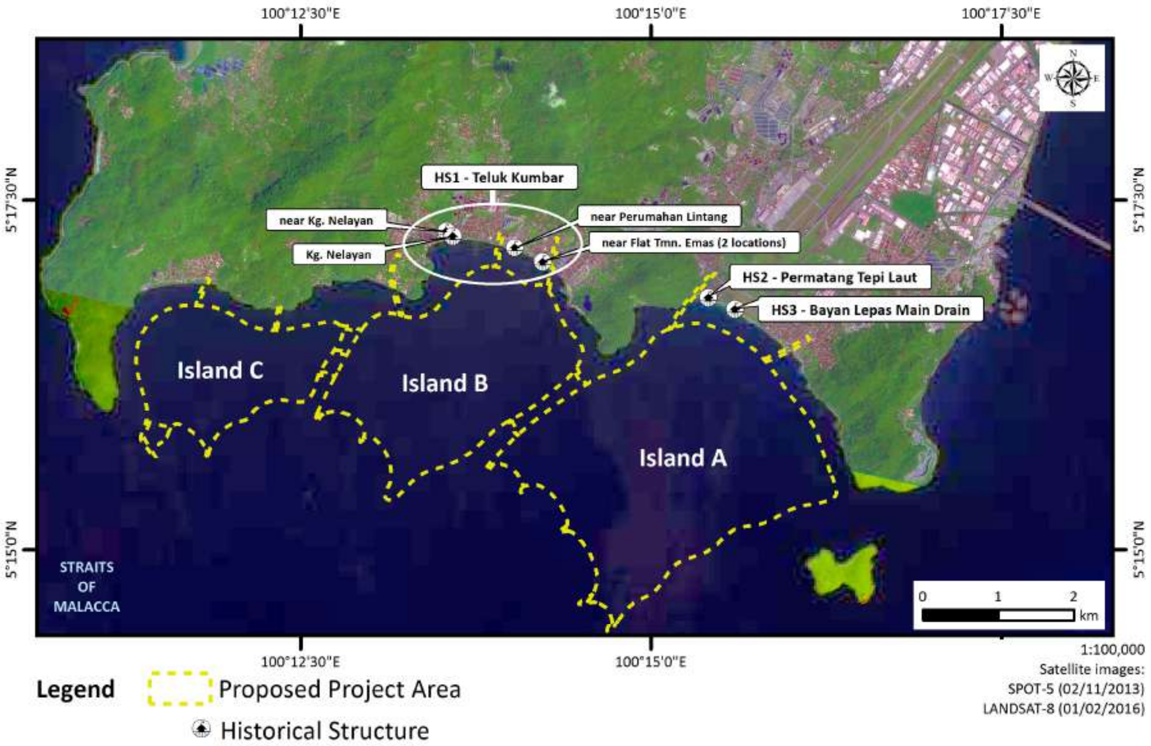
7.11.2 Land Reclamation and Dredging

The nature of land reclamation and dredging activities does not involve working with material containing dry fine material that can be dispersed by wind. Thus dust generation can be considered as insignificant. While vessels and machineries deployed will produce emission from their exhaust, the location where they operate (at sea, away from residential areas) will significantly reduce the impact on air quality.

7.12 Historical Structures

Several historical structures, namely World War II pillboxes, can be found scattered along Penang's southern coastline, as shown in F7.89. Currently, all pillboxes are neglected and in a state of disrepair. For pillboxes located at Teluk Kumbar, they are found to be located inland from the shore, thus shielding them from the hydraulic impact caused by the proposed Project. As such, it is expected that these pillboxes will be unaffected by the proposed Project.

Meanwhile, the pillboxes located at Permatang Tepi Laut and near Bayan Lepas Main Drain are situated on the shoreline and thus considered vulnerable to the impact. Nevertheless, findings from the hydraulic simulation has shown that the location of these two pillboxes will not receive any significant changes brought about by the proposed Project and thus can be considered as being unaffected.



F7.89 Locations of historical structures (WWII pillbox)

7.13 Tsunami Impact Assessment

Earthquake-generated tsunami waves evolve from generation followed by propagation, run-up and ends with inundation. Tsunami hazards are generally concentrated along exposed coastlines. Tsunami primarily affects low-lying coastal area as the advancing tsunami waves propagate inland. The resultant inundation can cause damage and loss of properties as well as human lives.

7.13.1 Tsunami Incident on 26th December 2004

Penang Island was hit by tsunami waves following the devastating earthquake that occurred off the coast of northern Sumatra on 26th December 2004. The strength of the earthquake was measured to 9.0 on the Richter scale. The area east of Pantai Sungai Batu at Teluk Kumbar did not experience serious inundation. The nearby road was inundated about 50 m inland. Slight movement of rocks occurred along the nearby river training structure (DID, 2005).

7.13.2 Tsunami Simulation

It is noted that the probability of a tsunami coinciding with HAT is extremely low. The return period of HAT is approximately 18.3 years. In comparison, the percentage of time that water levels exceed the MHWS level and MSL are about 4 and 50%, respectively. The percentage exceedance of the actual tidal level at the time of arrival of the historical tsunami at Penang Island is 22% of the time. For the purpose of assessment, the plots of the tsunami event of 2004 simulated at MHWS level are presented in this report. However, the analysis is done for results from simulations for all four tidal levels, which is referred to as Cases 1 to 4 as shown in T7.52. The difference in maximum water levels between existing and post-reclamation condition were derived. The impact also depends on the floodability of the coastal hinterland and in particular, the topographic settings.

T7.52 Tidal characteristics at Kedah Pier tidal station, Penang

Level	Simulation Case	Value (m CD)	Exceedence in Percentage of Time (%)
Mean Sea Level (MSL)	1	1.71	50
Actual water level (1300 hrs, 26th December 2004)	2	2.16	22
Mean High Water Spring (MHWS)	3	2.69	4
Highest Astronomical Tide (HAT)	4	3.09	*

Note: The probability of a Tsunami coinciding with HAT is extremely low, as the return period is about 18.3 years

Although the probability of another tsunami with magnitude high enough to impact the south coast of Penang is judged to be low, the assessment has not quantified the risk associated with tsunami events as it requires detailed knowledge of the following elements:

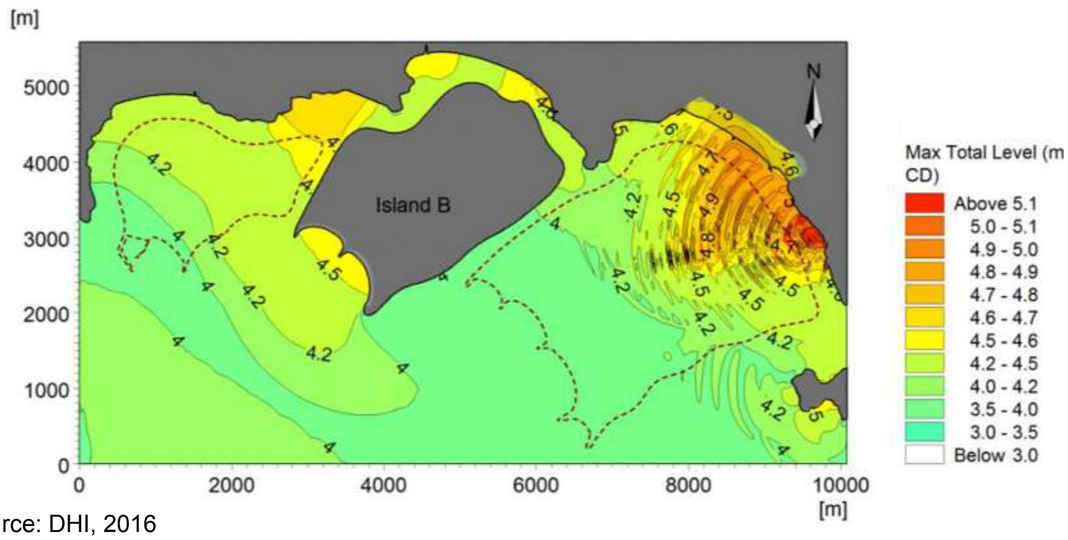
a) Cause to trigger a tsunami in this region particularly the tsunami hazards occurring around Sumatra-Andaman area;
b) Probability of a destructive tsunami, i.e. the probability of an earthquake of a given magnitude occurring along a given fault-line at a given time, which is extremely difficult to quantify; and
c) The associated water level at the time of occurrence of the tsunami as this could occur during mean, low and high water levels. An analysis of water levels shows that it is unlikely that a tsunami will occur during high water levels, particularly during HAT condition as the HAT return period (without storm surge levels) is about 18.3 years.

The potential inundation in inland areas has also been analysed as an uncertainty in the tsunami assessment since topographic data is limited around the nearshore region. The results show that increased inland storage reduced water levels.

7.13.3 Impact Assessment

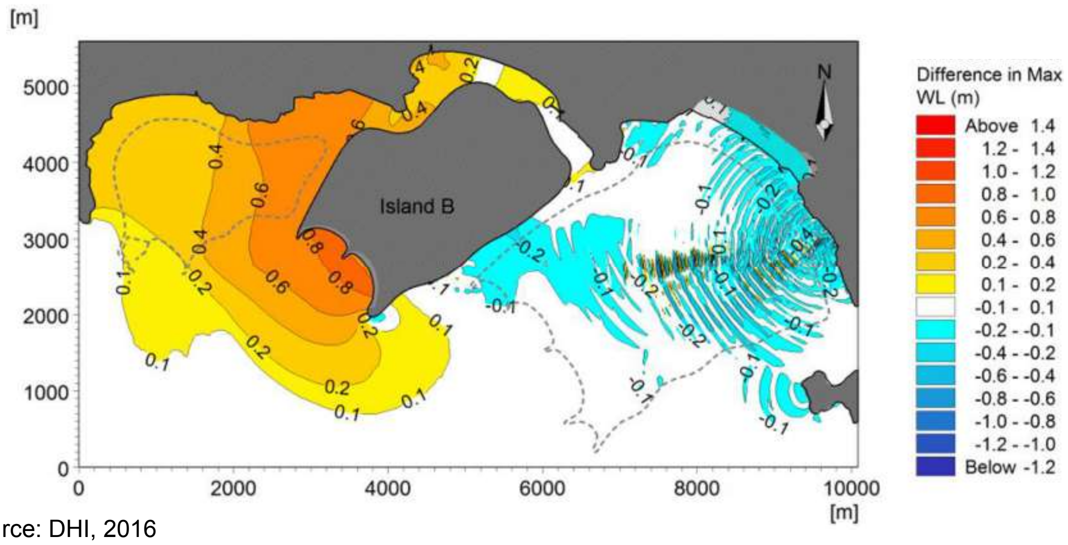
a) Scenario 2

The maximum absolute water level and the difference plots are presented in F7.90 and F7.91 respectively. The results show that the proposed Island B induces an increase in water levels of up to 0.8 m within the waters sandwiched by the reclamation and Tanjung Gertak Sanggul. A reduction in water levels of up to about 0.2 m with respect to the existing condition occurs east of the Island B. A water level increase of about 0.8 m is experienced between the artificial headlands of Island B. The furthest extent of 0.1 m increase in water level is predicted at an offshore area about 4 km from the existing the coastline.



Source: DHI, 2016

F7.90 Maximum water levels during the impact of tsunami waves with a tidal level corresponding to MHWS level for Scenario 2

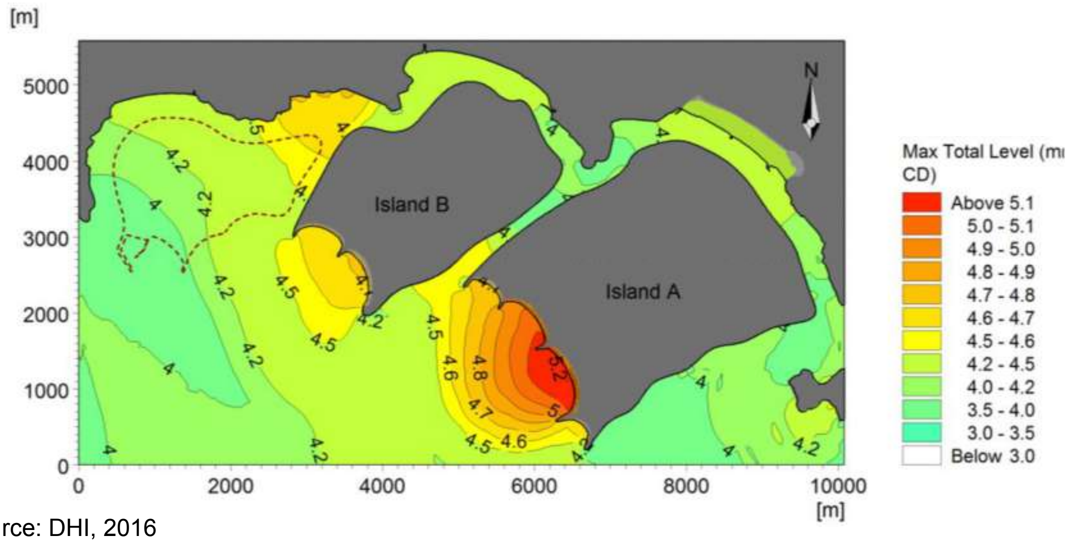


Source: DHI, 2016

F7.91 Difference in maximum water levels during the impact of tsunami waves with a tidal level corresponding to MHWS level for Scenario 2 compared with the existing condition

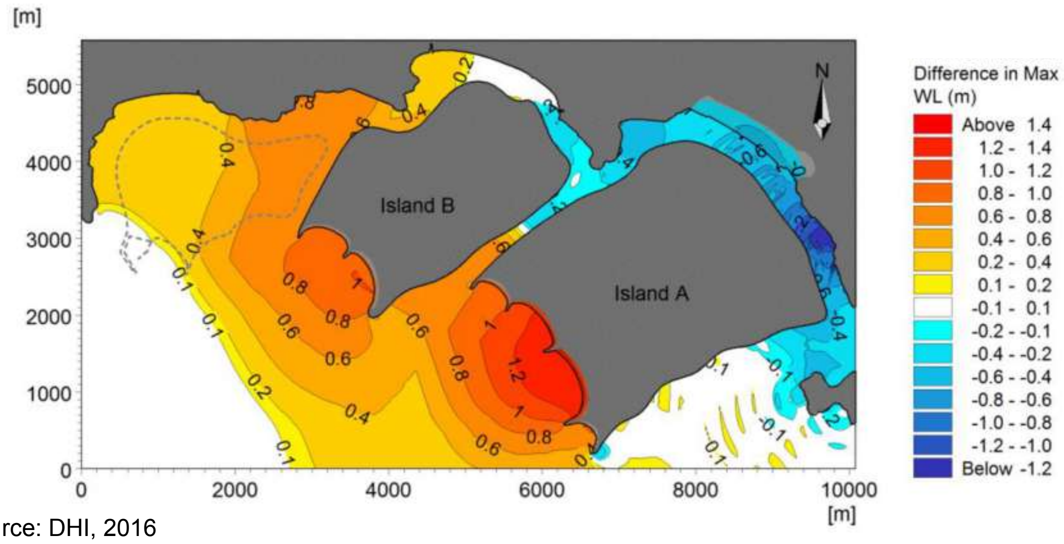
b) Scenario 3

The maximum absolute water level and the difference plots are shown in F7.92 and F7.93 respectively. The water body east of the reclamation and within the channels benefits from the sheltering effect of the islands that results in a maximum water level reduction of up to 0.6 m. The proposed islands will induce an increase in water level within the area extending from the seaward-facing edge of Island A towards Tanjung Gertak Sanggul. The magnitude of the increase is up to 0.6 m at the existing coastline and up to 1.2 m at the seaward-facing edge of Island A. The furthest extent of 0.1 m increase in water level is up to about 5 km eastwards and 8 km southwards from the existing coastline.



Source: DHI, 2016

F7.92 Maximum water levels during the impact of tsunami waves with a tidal level corresponding to MHWS level for Scenario 3

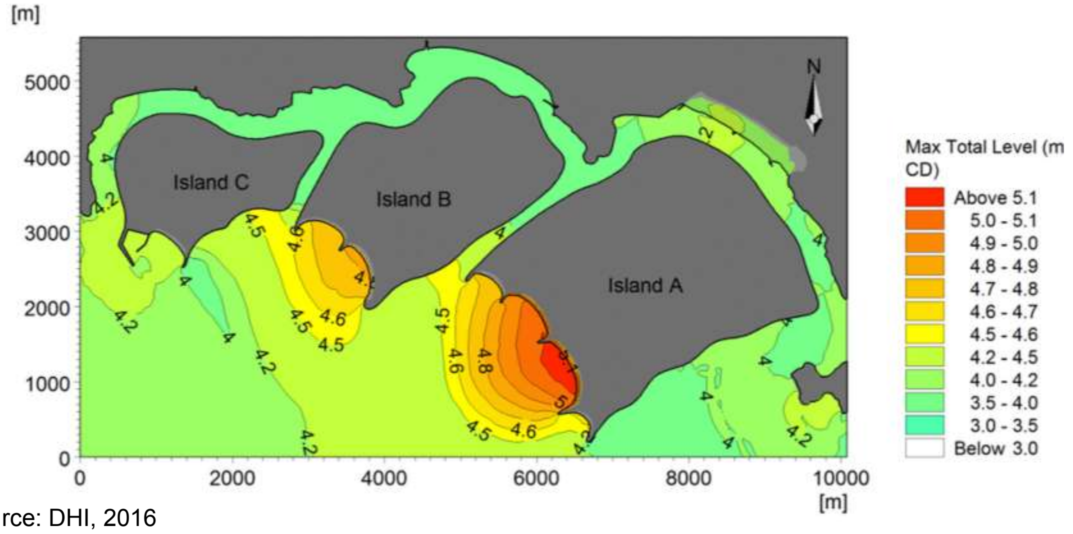


Source: DHI, 2016

F7.93 Difference in maximum water levels during the impact of tsunami waves with a tidal level corresponding to MHWS level for Scenario 3 compared with the existing condition

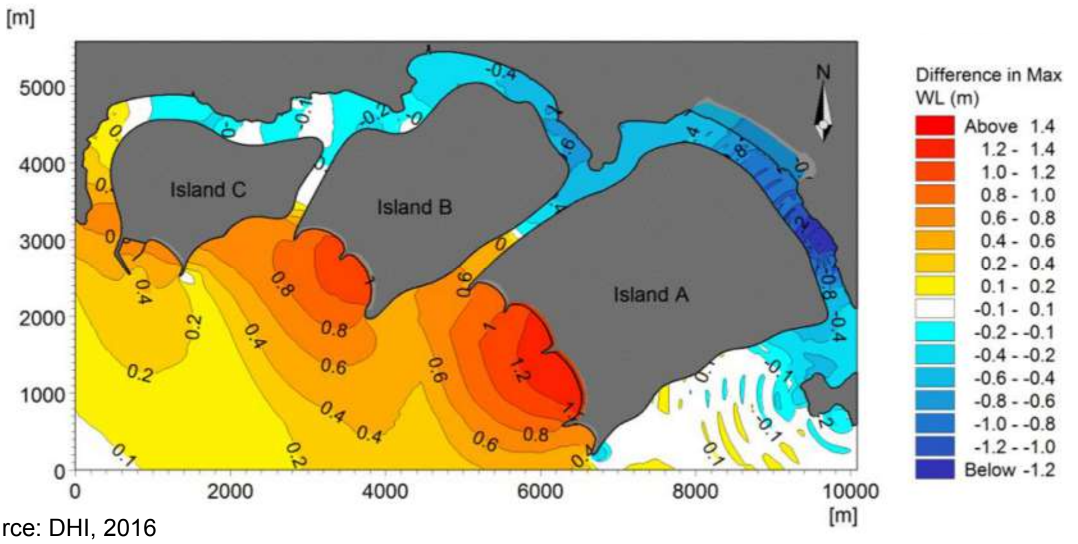
c) Scenario 4

The maximum absolute water level and the difference plots are presented in F7.94 and F7.95 respectively. From the simulation results, it can be observed that the islands will induce a reduction in maximum water levels by up to 1 m between Tanjung Teluk Tempoyak extending within the channels until Island C. This is due to the sheltering afforded by the presence of the islands seawards of the existing coastline. The furthest extent of 0.1 m increase in water level occurs about 8.5 km eastwards and 8.5 km southwards from the existing coastline. Increase in water levels extending from the seaward face of Island A towards Tanjung Gertak Sanggul are up 1.2 m occurring at Island A.



Source: DHI, 2016

F7.94 Maximum water levels during the impact of tsunami waves with a tidal level corresponding to MHWS level for Scenario 4



Source: DHI, 2016

F7.95 Difference in maximum water levels during the impact of tsunami waves with a tidal level corresponding to MHWS level for Scenario 4 compared with the existing condition

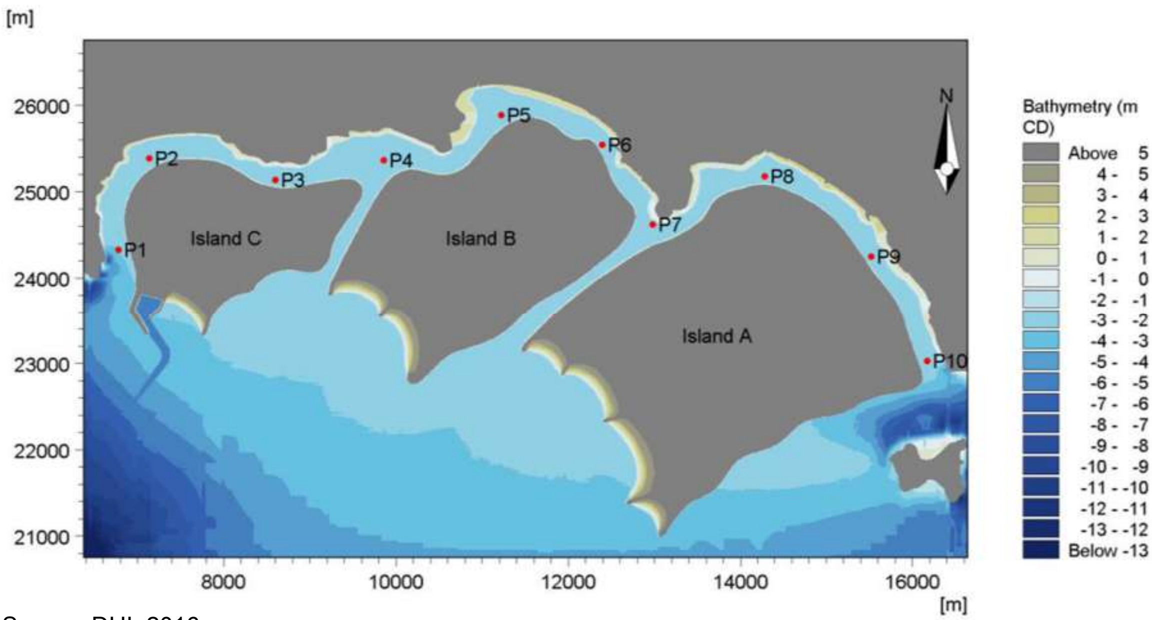
7.12.4 Overall Findings for Tsunami

The differences in maximum water levels in the vicinity of the existing coastline are presented at 10 locations as shown in F7.96 and summarised in T7.53. It can be inferred from the modelling results that the predicted differences of maximum water levels between “with Project” and the existing conditions are significantly influenced by the sheltering effects provided by the reclaimed islands. It is predicted that the impact of the tsunami on the existing shoreline will mainly reduce after the development is fully completed. However, impacts are different for the different phases of the Project as follows:

a) *Scenario 2* – A decrease in maximum water levels is observed along the frontage of Permatang Damar Laut. The reduction is found to be about 0.1 m at P9. The proposed reclamation will induce an increase in water levels along the west/southwest frontage of Island B and along the frontage of Gertak Sanggul. The increase in maximum water levels is predicted at P4 which would experience an increase of 0.8 m;

b) *Scenario 3* – Island A and B will provide protection to the coastal waters behind the development resulting in a water level reduction of up to 0.7 m (P9) compared with the existing conditions. Water levels are found to increase by up to 0.8 m at P4, which is relatively similar to Scenario 2 along the western and southwestern frontage of Island B as well as the existing Penang southern coastline; and

c) *Scenario 4* – The existing coastline behind the proposed reclamations becomes well-protected due to the sheltering offered by the reclaimed islands. A reduction in water levels of up to 0.9 m is predicted particularly along the inner channel that separates the proposed reclamation islands from the existing coastline. Increase in water levels extending from the seaward face of Island A towards Tanjung Gertak Sanggul are up 1.2 m occurring at Island A.



Source: DHI, 2016

F7.96 Location of predicted differences of maximum water level extraction in the vicinity of the existing southern Penang coastline

T7.53

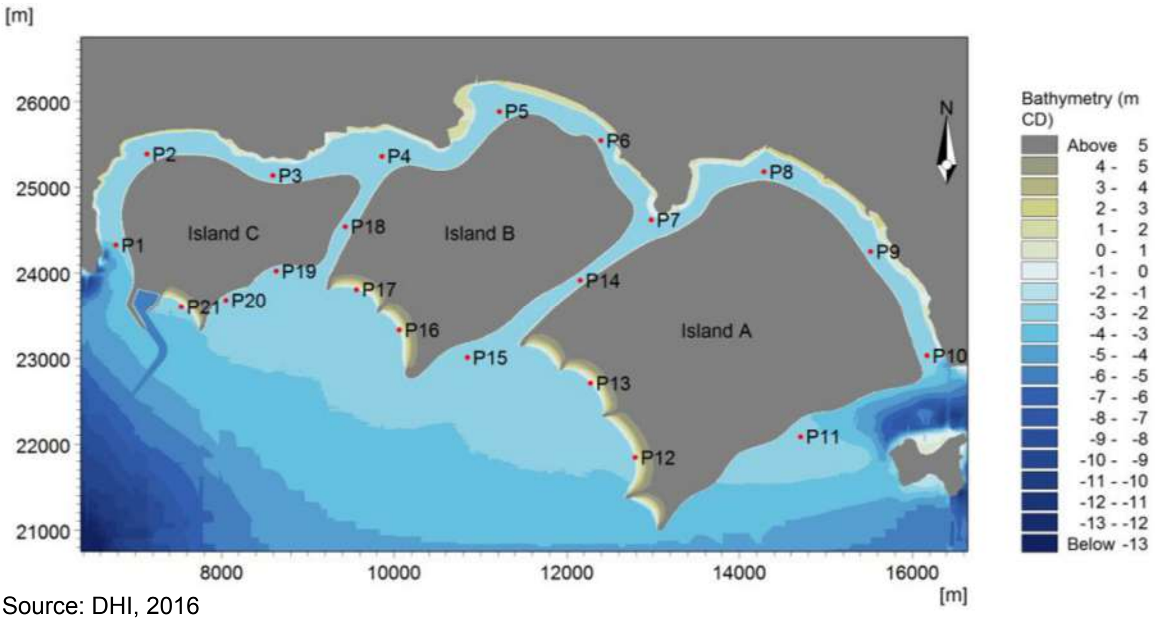
Summary of predicted difference in maximum total water levels in the vicinity of the existing southern Penang coastline during the impact of tsunami waves for Case 1 (MSL), Case 2 (actual tidal level), Case 3 (MHWS) and Case 4 (HAT) for all development phasing

Phase	Points	Difference in Maximum Water Level (m)			
		Case 1	Case 2	Case 3	Case 4
Scenario 2 (Island B)	P1	+0.1	+0.2	+0.3	+0.3
	P2	+0.4	+0.4	+0.4	+0.3
	P3	+0.5	+0.5	+0.6	+0.6
	P4	+0.7	+0.8	+0.7	+0.7
	P5	*	+0.2	+0.3	+0.4
	P6	*	*	+0.1	+0.2
	P7	*	+0.1	+0.1	+0.1
	P8	-0.1	-0.1	*	*
	P9	-0.3	-0.1	-0.2	-0.1
	P10	*	*	-0.1	-0.1
Scenario 3 (Islands A and B)	P1	+0.1	+0.1	+0.3	+0.3
	P2	+0.3	+0.3	+0.3	+0.3
	P3	+0.5	+0.6	+0.6	+0.7
	P4	+0.7	+0.8	+0.7	+0.7
	P5	*	+0.2	+0.3	+0.3
	P6	-0.2	-0.2	-0.1	*
	P7	-0.2	-0.2	-0.2	-0.1
	P8	-0.2	-0.2	-0.3	-0.2
	P9	-0.7	-0.7	-0.7	-0.5
	P10	-0.3	-0.4	-0.5	-0.6
Scenario 4 (All Islands)	P1	+0.6	+0.6	+0.6	+0.5
	P2	+0.1	+0.1	+0.1	+0.1
	P3	-0.2	-0.1	-0.1	*
	P4	-0.2	-0.1	-0.1	-0.1
	P5	-0.6	-0.4	-0.3	-0.3
	P6	-0.7	-0.7	-0.6	-0.5
	P7	-0.5	-0.6	-0.5	-0.5
	P8	-0.5	-0.4	-0.5	-0.4
	P9	-0.8	-0.9	-1.0	-0.8
	P10	-0.3	-0.4	-0.5	-0.6

Note: * - changes are between -0.1 to +0.1 m
Source: DHI (2016)

The southern coast of Penang Island has limited exposure to tsunami effects from the Indian Ocean compared to the western and northern coasts. The simulation results have demonstrated that the proposed reclaimed islands could provide sheltering to the coastline behind it for the simulated 2004 tsunami event.

The predicted maximum tsunami-induced water levels for each modelling scenario and phasing have also been extracted at 21 locations as shown in F7.97 and summarised in T7.54. This was done to assess the maximum water levels that can occur within the direct vicinity of the project site as a result of the tsunami event.



Source: DHI, 2016

F7.97 Location of predicted differences of maximum water level extraction for tsunami waves' propagation around the proposed Project site

T7.54 Summary of predicted maximum tsunami-induced water levels during the impact of tsunami waves for Case 1 (MSL), Case 2 (actual tidal level), Case 3 (MHWS) and Case 4 (HAT) for all development phasing

Phase	Points	Maximum Water Level (m CD)			
		Case 1	Case 2	Case 3	Case 4
Scenario 2 (Island B)	P1	2.77	3.28	3.87	4.29
	P2	3.27	3.76	4.30	4.70
	P3	3.36	3.81	4.38	4.79
	P4	3.60	4.08	4.63	5.05
	P5	3.23	3.84	4.48	4.94
	P6	3.36	3.87	4.52	5.00
	P7	2.98	3.57	4.22	4.68
	P8	3.44	3.91	4.63	4.93
	P9	3.57	4.21	4.82	5.21
	P10	3.26	3.81	4.42	4.89
	P11	2.91	3.37	4.00	4.44
	P12	2.85	3.29	3.81	4.21
	P13	2.76	3.21	3.73	4.16
	P14	2.68	3.12	3.80	4.27
	P15	2.93	3.36	3.86	4.26
	P16	3.56	4.00	4.54	4.92
	P17	3.56	4.04	4.55	4.93
	P18	3.52	3.98	4.51	4.91
	P19	3.35	3.84	4.36	4.75
	P20	3.06	3.56	4.11	4.52
	P21	2.88	3.33	3.86	4.26

T7.54

Summary of predicted maximum tsunami-induced water levels during the impact of tsunami waves for Case 1 (MSL), Case 2 (actual tidal level), Case 3 (MHWS) and Case 4 (HAT) for all development phasing (cont'd)

Phase	Points	Maximum Water Level (m CD)			
		Case 1	Case 2	Case 3	Case 4
Scenario 3 (Islands A and B)	P1	2.72	3.23	3.82	4.25
	P2	3.22	3.70	4.25	4.65
	P3	3.35	3.83	4.43	4.85
	P4	3.59	4.09	4.65	5.09
	P5	3.17	3.76	4.40	4.87
	P6	3.07	3.64	4.30	4.80
	P7	2.74	3.31	3.99	4.49
	P8	3.29	3.75	4.31	4.74
	P9	3.13	3.67	4.35	4.85
	P10	2.91	3.41	3.98	4.33
	P11	3.13	3.55	4.03	4.42
	P12	4.32	4.73	5.18	5.52
	P13	4.12	4.53	5.02	5.39
	P14	2.91	3.43	4.00	4.44
	P15	3.48	3.94	4.48	4.87
	P16	3.64	4.13	4.70	5.09
	P17	3.60	4.11	4.67	5.07
	P18	3.50	3.97	4.53	4.94
	P19	3.35	3.86	4.41	4.82
	P20	3.06	3.58	4.16	4.59
	P21	2.85	3.29	3.82	4.26
Scenario 4 (All Islands)	P1	3.21	3.64	4.15	4.53
	P2	3.03	3.48	4.01	4.41
	P3	2.64	3.14	3.72	4.13
	P4	2.70	3.22	3.82	4.28
	P5	2.62	3.16	3.81	4.28
	P6	2.64	3.19	3.86	4.34
	P7	2.46	2.92	3.61	4.10
	P8	3.06	3.57	4.15	4.59
	P9	2.99	3.49	4.04	4.53
	P10	2.94	3.43	4.00	4.35
	P11	3.09	3.48	4.06	4.43
	P12	4.32	4.71	5.13	5.45
	P13	4.15	4.55	5.03	5.38
	P14	2.86	3.28	3.83	4.29
	P15	3.45	3.90	4.42	4.82
	P16	3.74	4.23	4.80	5.20
	P17	3.65	4.14	4.72	5.14
	P18	2.77	3.28	3.87	4.31
	P19	3.40	3.90	4.50	4.93
	P20	3.13	3.66	4.28	4.72
	P21	3.38	3.82	4.34	4.71

It can be concluded from the results presented in T7.54 that:

a) The predicted maximum total water levels generally increase with an increase in tidal datum. The tsunami-induced excess water levels do not alter significantly for HAT, MHWS and MSL levels. The tsunami-induced water level does not increase with an increase in tidal datum;

b) Upon development, the highest increase in water levels around Island A predicted off the seaward-facing island's edge, i.e. proposed beach area are represented by the following points:

  i) P12 (5.5 m CD for HAT, 5.2 m CD for MHWS, 4.3 m CD for MSL); and
  ii) P13 (5.4 m CD for HAT, 5.0 m CD for MHWS, 4.2 m CD for MSL).

c) The highest total water levels around Island B predicted off the proposed beach area are represented by the following points:

  i) P16 (5.2 m CD for HAT, 4.8 m CD for MHWS, 3.7 m CD for MSL); and
  ii) P17 (5.1 m CD for HAT, 4.7 m CD for MHWS, 3.7 m CD for MSL).

d) The highest total water levels around Island C predicted off the proposed beach area are represented by the following points:

  i) P19 (4.9 m CD for HAT, 4.5 m CD for MHWS, 3.4 m CD for MSL);
  ii) P20 (4.7 m CD for HAT, 4.3 m CD for MHWS, 3.1 m CD for MSL); and
  iii) P21 (4.7 m CD for HAT, 4.3 m CD for MHWS, 3.4 m CD for MSL).

e) The seaward-facing edge of the reclaimed islands experience relatively high water levels during the tsunami event. The water levels as high as about 1.2, 1.0 and 0.6 m could occur along the beach fronts of Island A, B and C respectively; and

f) It is considered reasonable to base the design of the reclamations' platform levels on the prediction for the final phasing and disregard the other interim phases as the construction of the interim phases are of relatively short duration compared with the full project phasing. However, if there is a large uncertainty in the duration of the construction of the different project phasing then a conservative estimate (i.e. the largest value for the different phases) should be considered to avoid potential risks.

7.14 Human Environment and Socio-economy

Social impacts are the outcome of the reactions between the activities of a project and the components of the host social environment. As a host society, the communities surrounding the Project area would be affected from the changes introduced to the area, either directly or indirectly and either positively or negatively (if any). Socio-economically, such changes could be seen outright. But more often than not, these are less discernible, especially when they involve perceived notions, feelings and sentiment. The latter could only be seen and felt when they become manifested into other forms.

For this component, the impacts will be discussed according to the Project implementation activities listed as follows:

a) Pre-dredging;
b) Land reclamation and dredging; and
c) Post-reclamation and operation.

The activities during the reclamation or construction phase and that of the operational phase would normally trigger different changes and reactions from their implementation. The socio-economic components that are predicted to be impacted during construction are labour, livelihood, health and safety, tranquility and aesthetics as well as psychological well-being. Those that may be impacted during post reclamation shall pertain to employment, income and revenue, wider multiplier impacts, impacts on demography, socio-cultural impacts and aesthetics.

7.14.1 Pre-dredging

Construction workers are normally housed in base or workers' camps. Some of the workers will also be living in work vessels (e.g. TSHD). This is often a potential source of health and safety hazards and are also not without their socio-cultural implications.

Approximately 500 workers would have to be accommodated during the construction period. Assuming that local workers who would be living within commuting distance of the Project site do not stay in, and those of the managerial level and the engineers would be housed in accommodations available in nearby residential areas, the majority of the workers would have to be accommodated on the landward side of the Project site. Thus, the construction of the workers' camps would have to be undertaken first before construction work commences.

During occupation of the accommodation provided, crowding may occur not only on a per room basis but also in the overall arrangement of the lodging blocks which may tend to be close to one another. Such a situation may become a potential source of health, safety and fire hazards as mentioned earlier, especially when unhygienic and unsystematic living conditions are allowed to occur.

Another significant potential impact pertains to the socio-cultural makeup of the workers' racial mix. Malaysia is known to rely heavily on foreign workers in many of its economic sectors. It is not surprising if most of the employment opportunities created by the Project would rely on and be taken up by foreign workers. Again, the locals would have to be more alert and be ready to compete and fill up the opportunities created. Otherwise, they would become bystanders in the midst of the development of their area.

Accommodating and putting foreign workers or workers from other states of Malaysia together under the same roof or within the same workers' camp complex may have their repercussions. The presence of foreign workers, probably numbering up to several hundreds and co-existing alongside the locals, could disrupt the cultural and racial balance of the area, thus transforming the social makeup of the area into a more cosmopolitan entity. Physical conflict could easily develop as a result of the differences in culture and subculture, values, attitude and tolerance level among the different ethnics and races.

This is understandable as the different cultures, values, attitude and tolerance level of the locals and aliens coexisting alongside each other, could and have been proven volatile, to erupt even with slight friction.

Other associated problems are those of social and health problems. Such view is normally based on the alleged increase in crimes and diseases unknown to the country or the reappearance of those which had long since been eradicated such as malaria and tuberculosis. Hence, care should be taken that their occurrence be avoided. Changes in the local crime rate are often associated with an influx of young male itinerant employees into the zone of impact during construction.

The influx of young male workers would not change the population age and sex structures of the study area but would accentuate them. The current young age structure may be even younger when the presence of the young in-migrant workers would cause a slight decrease in the percentage of the mature-matured and old age groups.

With the current sex ratio of the study area being already imbalanced with 111 M per 100 F, the presence of excessive young male workers would put the sex ratio of the area in the near future to being highly skewed with an excess of males. Such an imbalanced sex structure may cause social repercussions and abnormal sexual behaviour.

7.14.2 Land Reclamation and Dredging

7.14.2.1 Labour

Reclamation would require a large number of workers as the nature of work requires both in-shore and overland construction activities. As the reclamation is to be carried out in phases, the manpower requirements for reclamation in the first phase will be in the range of 500 workers during the peak of the reclamation works, although not as many during dredging activities.

The workforce will comprise engineers, skilled, semi-skilled and unskilled workers. The requirement of several hundred workers will boost the local labour market or employment opportunities. This will lead to a boost in the local economy, thus improving the economic standing of the locals. Although employment of foreign workers is expected during the reclamation phase, the total engagement of only foreigners would result in disadvantage and opportunity to the locals being forfeited. To be locally relevant, local labour should be given priority. This would be especially so when increased employment opportunities for the local population is perceived by some of the locals as being one of the advantages of the Project, and which is also one of the reasons for supporting the Project.

The impact of the Project on the labour force will be significant - again if at least 30% of the jobs generated are filled by the locals from within as well as from the surrounding study area. However, these job opportunities are temporary in nature and only for a limited duration of the construction period.

The hiring of foreign workers would bring with it different kinds of impact, of both positive and negative. The main advantage would be in the fulfillment of the labour demand for the construction works. On the other hand, the negative point would be the potential social and cultural implications that may arise. Although these impacts could be significant, they are also short-term in nature.

The activities would also require the deployment of contractors and the mobilization of vehicles and equipment. This would again boost local participation and the economy should these activities be made to involve the locals. The impact on contracting works is also significantly high for the duration of the construction period. Again, should the contracting works come with providing the contractors' own workers, it should be stipulated that a fraction of those workers would have to be locals.

7.14.2.2 Livelihood

The main socio-economic issue in the development of the proposed Project pertains to the economic pursuits of the locals, particularly the fishing communities numbering approximately 866 fishermen from Kampung Permatang Damar Laut, Kampung Permatang Tepi Laut, Kampung Sungai Batu, Kampung Teluk Kumbar and Kampung Gertak Sanggul. Although the setting up of the project would entail the creation of numerous economic opportunities, be they in new economic ventures or employment opportunities, it would also pose inconveniences to the local fishermen. This is especially so to the inshore fishermen toiling in the Zone A area, in disrupting their activities, affecting local marine life (although temporarily) and most importantly covering their current fishing ground. As such, the fishermen were of the opinion that they should be compensated for the inconveniences that they would likely be facing when the Project is under construction or what they would face when the particular fishing ground would be lost forever and become a trade-off to the Project.

The deployment of 500 workers would slightly push up the current population size of the study area. Increased population size would bring about increased demand in basic goods and services. Those that would be in high demand include accommodation, prepared food services, convenient goods, etc. The local business ventures in the nearby small townships such as at Kampung Sungai Batu, Teluk Kumbar and Gertak Sanggul should grab this opportunity in improving their livelihood and income earned from such spin-off effect, thus making the development of the area surrounding them more relevant by indirectly taking part in its implementation.

By realizing and undertaking this source of potential spin-off benefits, the locals would stand to gain and would again be made to feel relevant in the development that is taking place around them. This is especially so for the enterprising operators in the surrounding area.

7.14.2.3 Tranquility and Aesthetics

Reclamation activities shall create a scene of bustling activities and constant humming of machineries. To those staying near and regulars who ply the area would often find the area disturbing and no longer tranquil.

The natural panorama of the sea view fronting the stretch from Tanjung Teluk Tempoyak in the east and Tanjung Gemuruh in the west would be lost forever. But in its stead, three islands would be put in place together with the transport, industrial, housing and mixed development in the near future. These new structures may have their own charms and the aesthetic value of the sea front would be in the eyes of the beholders. Their presence may actually help to attract different types of visitors or tourists who have a preference for coastal structures. However, it must also be acknowledged that the creation of the three islands would change the configuration of the map of the southern coast of Pulau Pinang altogether.

7.14.2.4 Psychological Well-being

Since knowing the sea fronting their settlements is to be reclaimed, the fishermen of the fishing settlements who would be directly affected, especially the inshore fishermen, have been worrying over their fate. They fear the reclamation that would totally eliminate the fishing ground, which is said to be rich in prawns and fish. This would shrink and limit their fishing area, resulting in reduced catch and landing and consequently their livelihood and income.

Going further out to open sea does not only mean going for longer distances but also at higher cost due to higher petrol consumption. Furthermore, prawns are not available in deeper waters. Also, the fishermen of Kampung Permatang Tepi Laut had been worrying over the status of their settlement and that they would be dislocated. Constant worry of an uncertain future may lead to stress and consequently affecting the psychological well-being of the fishermen.

7.15.3 Post-reclamation and Operational Phases

7.15.3.1 Employment

An industrial development, housing and mixed development ventures would undoubtedly generate direct employment opportunities for the different levels of skills required i.e. from skilled, semi-skilled to unskilled job opportunities in the various sectors of the development, be they in industrial, commercial or services sectors. At the peak of the development of the newly-reclaimed land, a labour force of 1,100 is expected to be employed. By year 2050, during the operational phase, an estimated 300,000 new employment opportunities will be created primarily in the manufacturing and services sector.

The impact on employment could be significant, depending on the ratio of labour recruited from the local area or from an external area, with benefits accrued to the former if some are employed from within. The latter would be most beneficial if recruited from among the trained but unemployed or those looking for a job for the first time. The impact would be long-term in nature.

The impact of the external labour would be different depending on the number moving or not moving into the locality and those who move with or without family. Either trend would have implications on changing population size, earnings spent in the locality and its contribution to additional local income.

7.15.3.2 Income and Revenue

Direct employment render direct income earned from the salary paid. This is a definite positive remuneration and contribution to additional local earnings and from those spent locally which would contribute to additional local income. However, the additional contribution would very much depend on the amount or proportion of earnings spent locally by the outside workers who may or may not move into the local area; either bringing in or not bringing in their family as mentioned above.

Workers who commute from the surrounding urban areas such as Bayan Lepas, Jelutong, Georgetown or even Seberang Perai would make little economic contribution to the local economy. So too would those moving in without their family. If the trend persists, i.e. not many moving into the locality, benefits to the local economy would not be significant. However, should the trend reverse, i.e. more moving into the local area and with their family which would be most probable when accommodation and other facilities, amenities and services are available and provided, the local area would tend to benefit from it most significantly. The latter is expected as low-cost and affordable housing are to be built in the newly created land area providing dormitory function to the accommodation needs of the labour force.

Notwithstanding that, the capital investment in the proposed Project will be significant to other related agencies. If the percentage of total expenditure on goods and services (excluding labour) that would be spent in the local area in purchasing local goods and services is significant, then the local economy would thrive.

There are also rates such as assessment rates, quit rent, fees and royalties to be paid, and these would create net change in local authority receipts pointing to surpluses or higher returns. Other utilities and services providers for water supply and electricity would also tend to benefit from rates collections. Such revenues would stay for the duration of the proposed Project operation.

In addition to the direct local and/or regional employment effects, a mega project such as the proposed Project has a range of secondary or indirect impacts. The workforce, which may be substantial (and well paid), can generate considerable retail expenditure in the locality, on a whole range of goods and services. This may be a considerable boost for the local retail economy.

The proposed Project itself requires supplies ranging from components to be supplied by local engineering firms, to provisions for the canteen and homes. These can also boost the local economy. Such demands create employment, additional to that directly created by the proposed Project. The additional workforce may demand other services locally such as health, education, and housing which may generate additional construction. These demands will create additional employment.

Also, the existing coastal area may undergo further development, upgrading or renewal as being feared by the affected fishing communities of Kampung Permatang Tepi Laut as the majority of them are lodgers on the land where their houses were built. Overall, the net effect may be considerably larger than the original direct injection of jobs and income into the locality or southern Penang Island. Such wider economic impacts are considered as beneficial and long-term in nature.

7.15.3.3 Demography, Housing and Other Services

The workforce involved in the operation of the proposed Project is likely to be drawn partly from local sources (within daily commuting distance of the Project site) and partly from farther afield or from an external source. Those employees recruited from beyond daily commuting distance can be expected to move into the development area permanently during operation. Some of these employees will bring their families into the area. In-migrant workers and their families will have several effects on the locality, namely:

a) They will result in an increase in the population of the area and possibly changing the age and sex structure of the nearby local population;
b) They will require accommodation in the area or housing within reasonable commuting distance of the proposed Project site;
c) They will place additional demands on a range of local services, including schools, health and recreational facilities, police and emergency services; and
d) They will have financial implications for the local authorities in the area, with additional costs of service provision set against an increase in revenues.

7.15.3.4 Socio-cultural

In-migrant workforce or house buyers and their families will have other social impacts which can be wide-ranging and may include:

a) Changes in the occupational and socio-economic mix of the area's population and the potential ensuing impacts of conflict – ethnic, social or cultural;
b) Problems of integration among the incoming house buyers and workforce and families in the Project area and probably into the local community and community activities; and
c) There may be a clash of lifestyle and expectations between incomers and the local community of Southern Penang Island insofar where culture is concerned.

With a new population size living in the area, the magnitude of the social impacts could be enormous. Those (including foreigners) who may be of multiple social, economic and cultural background would be staying and living alongside each other as well as the host society. Social and cultural conflicts and frictions may evolve if measures for cordial and harmonious living are not promoted.

Likewise, non-participation of the host communities would tend to make them feel marginalized and alienated.

7.15.3.5 Aesthetics

The natural panorama of the sea view fronting the traditional fishing settlements of South Pulau Pinang from Kampung Permatang Damar Laut to Kampung Gertak Sanggul would be lost forever. But in its stead, a massive land area with industrial, commercial and housing structures would be put in place in the near future. These may have their own charms although they may also be offensive to nature lovers. The aesthetic value of the sea front would stand to be relative depending on the onlookers. As mentioned earlier, these structures may in fact attract different type of visitors or tourists too.

Overland, the traditional fishing villages too have their own uniqueness and charm. This too would have to be considered. The fishing communities' plea for relocation in one place only saw the manifestation of their awareness to preserve their way of life and heritage. However, in the era of infrastructure development and high urbanization, their preservation only calls for rebuilding them with a provision of better infrastructure and facilities whilst preserving their cultural life intact.

7.16 Viewshed Analysis

The viewshed analysis function determines visibility on a surface from one point to another along a line of sight or across the entire surface by assigning code 1 for areas which are in view and code 0 for areas which are not (Bratt, 2004, Longley *et al.*, 2005, O'Sullivan *et al.*, 2003). Viewshed is useful in assessing how visible certain objects might be.

7.16.1 Methodology

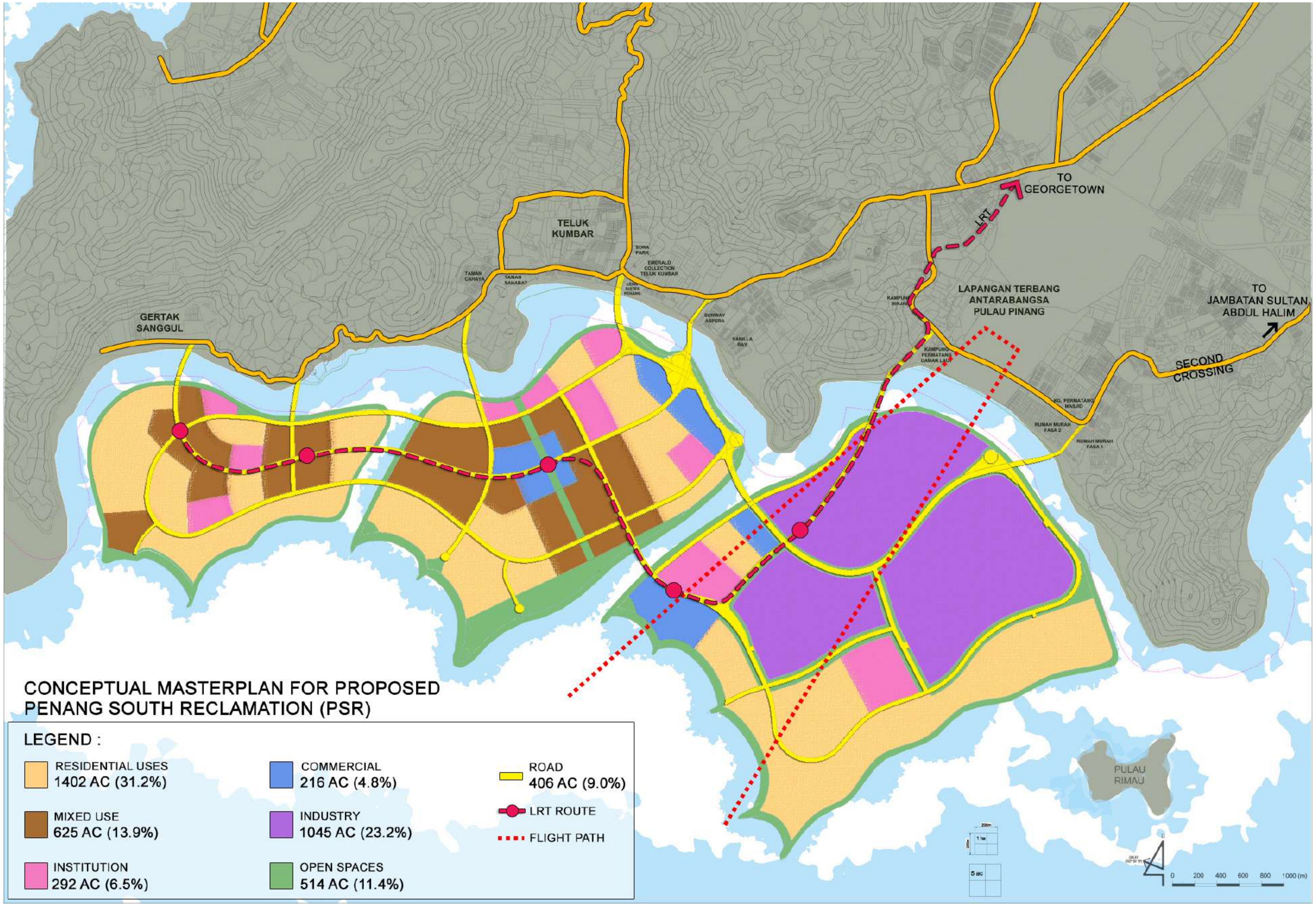
For this assessment, the viewshed from an observation tower is identified. The elevation raster displays the height of the land (darker locations represent lower elevations), and the observation tower is marked as a green triangle. Cells in green are visible from the observation tower, and cells in pink are not.

Factors involved in the viewshed analysis are as view location, topography and features that prevent building from being seen. High rise and impacted location in the surroundings of the study area are shown in T7.55.

T7.55 High rise and impacted location (within 5-km circumference)

Location	Height of Sight from Mean Sea Level (m)	Distance from Proposed Site (m)	Type
Gertak Sanggul	5	400	Beach
Lexis Suites Hotel	5 (ground floor) & 100 (top floor)	500	Hotel
Permatang Damar Laut	5	550	Beach

F7.98 shows the proposed layout of the proposed development. The proposed tallest building for residential is 20 levels (66 m) and for commercial are 15 levels (55 m). The locations where the analysis is conducted can be identified as Lexis Suites Hotel at Teluk Kumbar (F7.99), Gertak Sanggul (F7.100) and Permatang Damar Laut (F7.101).



F7.98 Proposed topside development at PSR

F7.99 Lexis Suites Hotel at Teluk Kumbar

F7.100 View from Gertak Sanggul

F7.101 Permatang Damar Laut

7.16.2 Findings for Viewshed Analysis

7.16.2.1 Gertak Sanggul

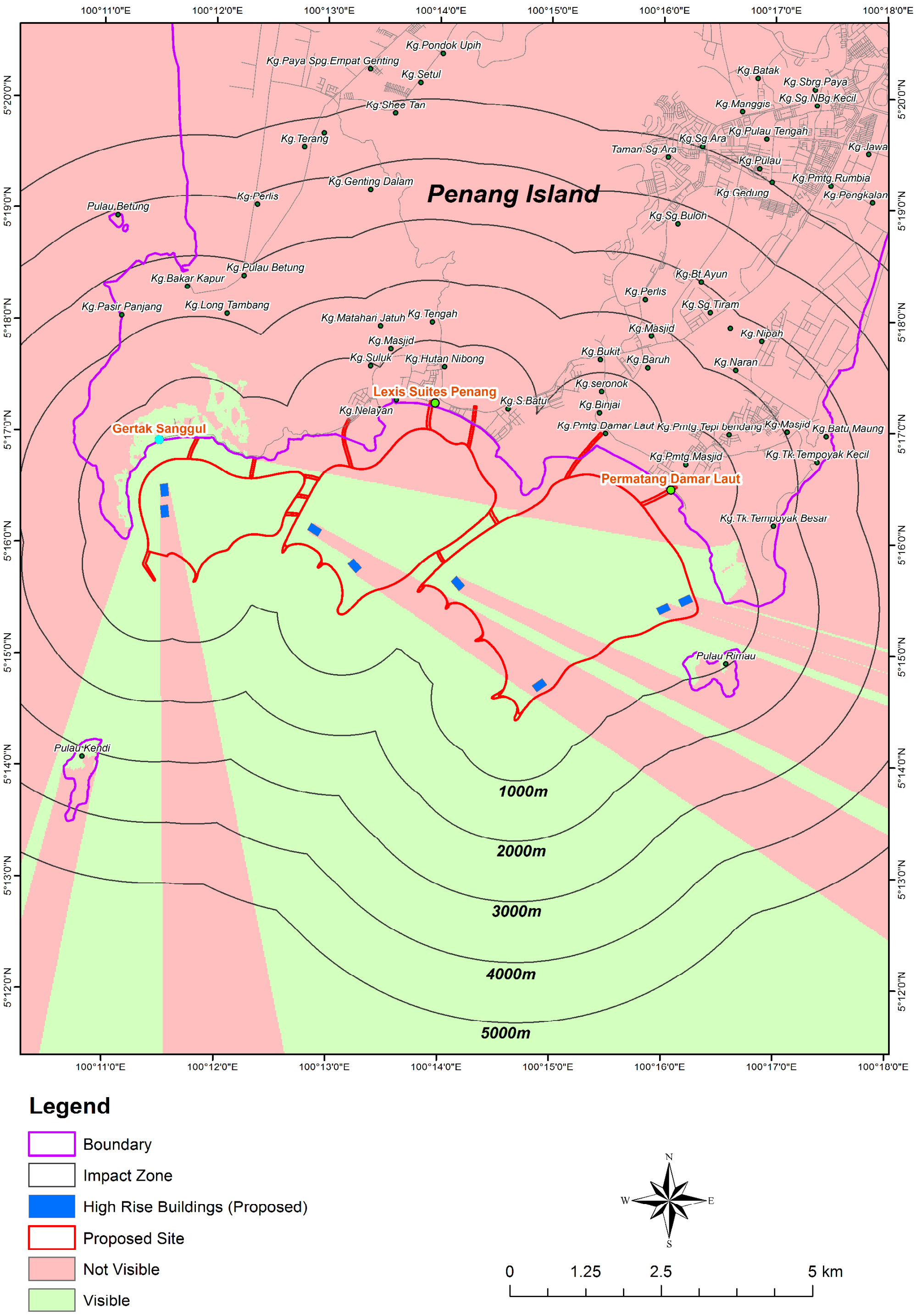
The distance from Gertak Sanggul's view point on the beach to the proposed development is approximately 400 m. F7.102 shows a map view from Gertak Sanggul.

7.16.2.2 Lexis Suites Hotel

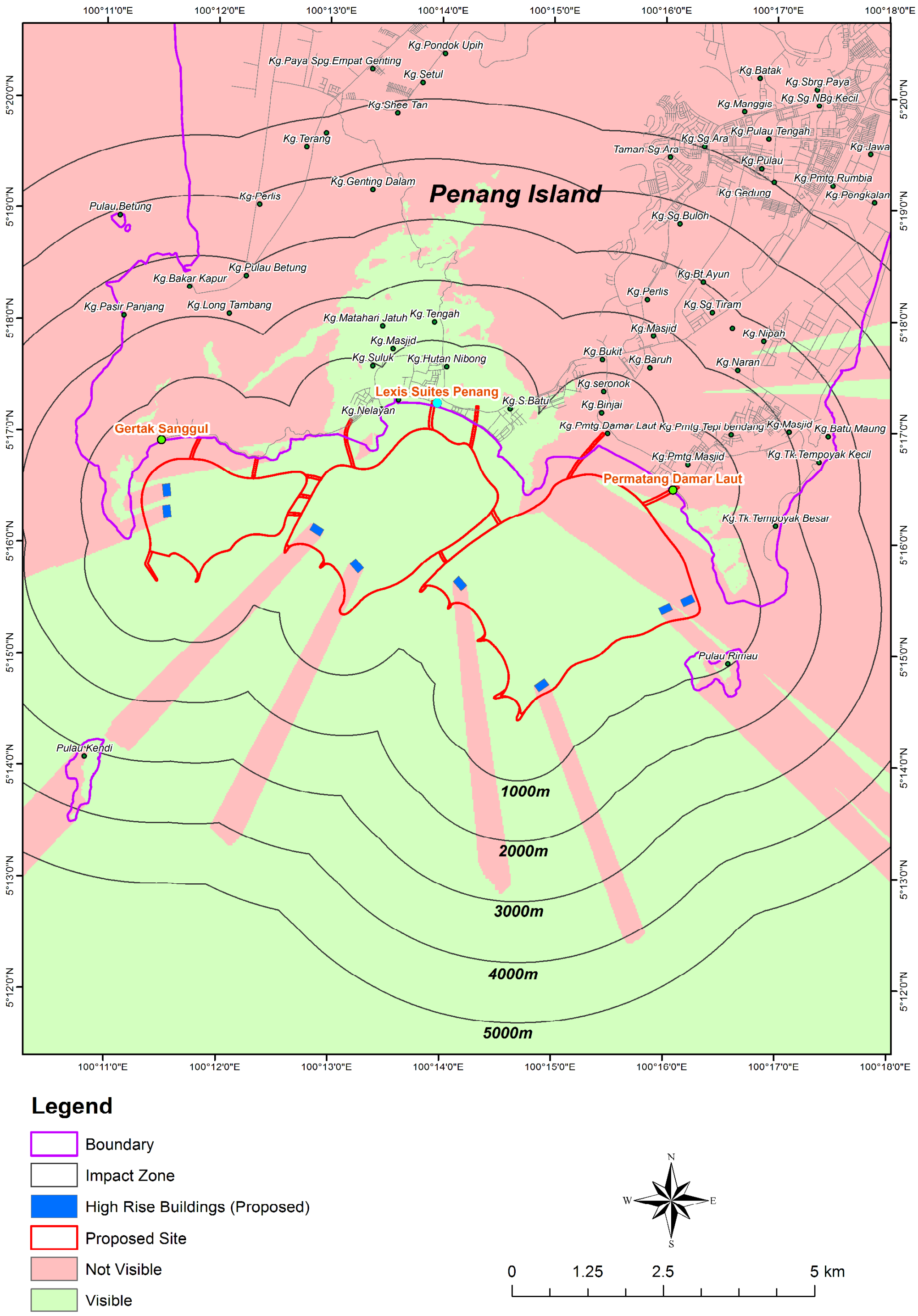
Lexis Suites Hotel is situated at the southern part of Penang Island. With accommodations of 222 rooms and 26 floors, the Lexis Suites Hotel is among the tallest high rise building in Teluk Kumbar. The analysis consists of two parts which are from the top floor and ground level (beach). The top floor and ground floor map view from Lexis Suites Hotel are shown in F7.103 and F7.104 respectively.

7.16.2.3 Permatang Damar Laut

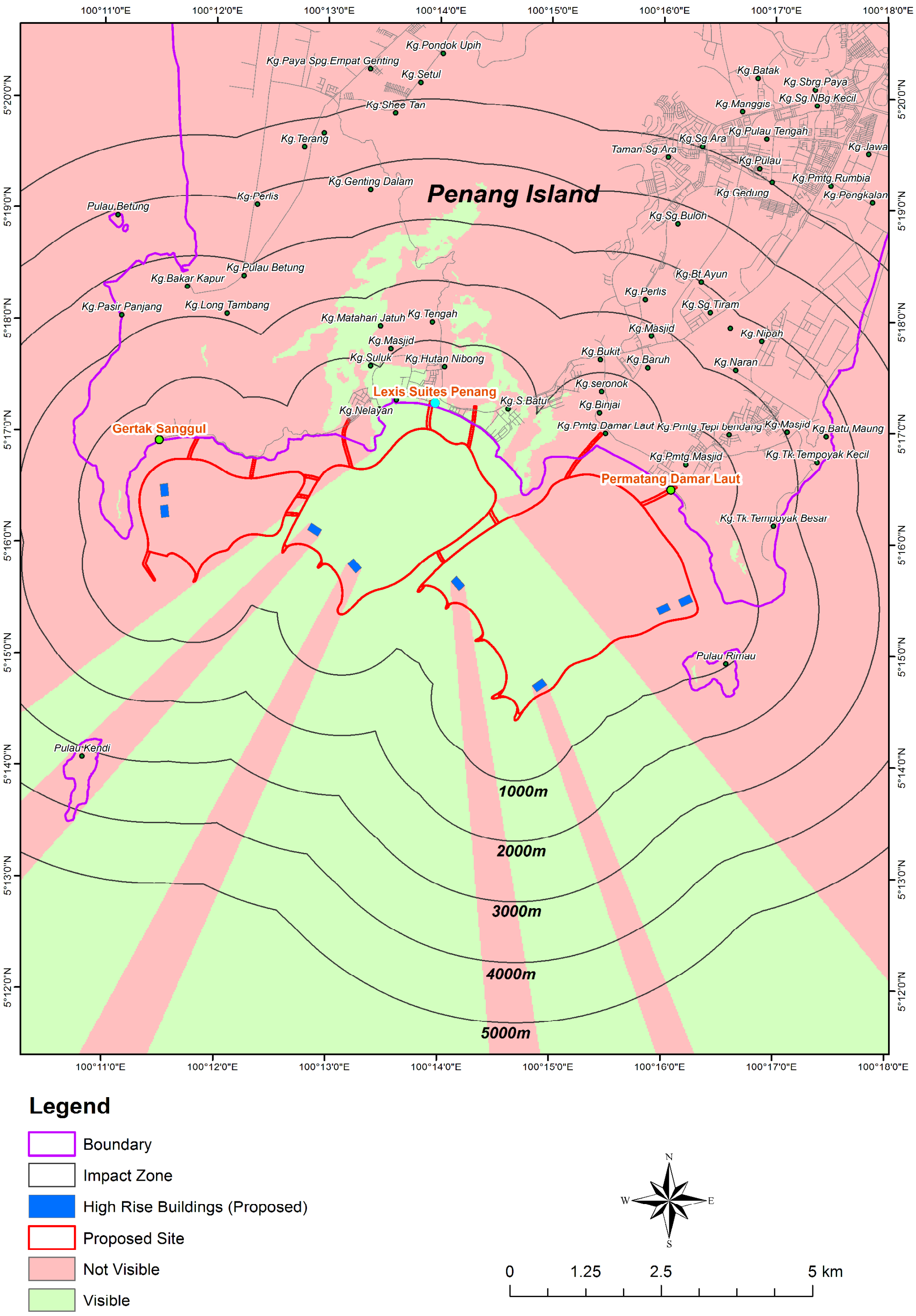
The distance from Permatang Damar Laut's view point on the beach to the proposed development is approximately 550 m. F7.105 shows the map view from Permatang Damar Laut.



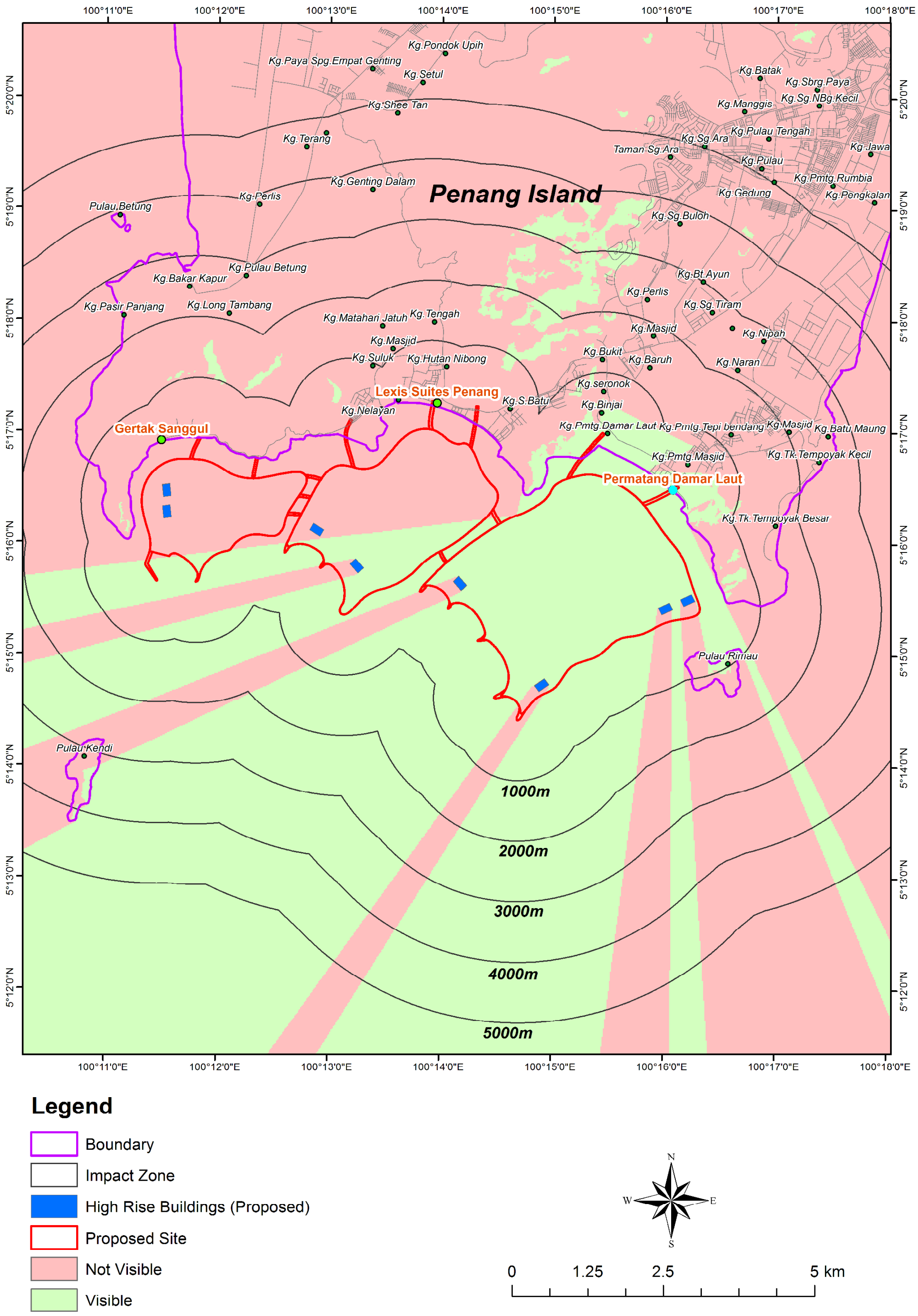
F7.102 Viewshed from Gertak Sanggul



F7.103 Viewshed from Lexis Suites Hotel (top floor)



F7.104 Viewshed from Lexis Suites Hotel (ground floor)



F7.105 Viewshed from Permatang Damar Laut

7.17 Economic Valuation of Environmental Impact

Due to the substantial capital investment and subsequent operation, the proposed Project is expected to provide a boost to the local economy. However, the land reclamation and dredging activities as well as the operation of the proposed Project are also likely to cause some negative environmental impacts that must be mitigated.

Contained in this section are commitments of the Project Proponent to mitigate many of the expected environmental impacts, as detailed in *Chapter 8: Pollution Prevention and Mitigation Measures*. As is common for any proposed development of this nature, some of the negative impacts cannot be completely mitigated, thus justifying the need to quantify, and to the extent possible in monetary terms, the degradation in services obtainable from the disturbed natural environment. Such valuation serves to demonstrate the significance of the environmental values of the services and thus providing some measure of trade-off that will be incurred if the Project were to be implemented. The flows of environmental services that will be foregone following Project implementation are real economic loss to different stakeholders and hence, must be quantified so that informed decisions can be made. The valuation process is facilitated by recent progress in the methods and protocol of environmental resources evaluation that allows for the computation of reliable monetary estimates of the value of losses in environmental services.

This section outlines the methodology and presents the results of the economic valuation of the environmental impacts of the proposed Project. The aim is to quantify the gains and losses in environmental services that can be attributed to the proposed Project.

7.17.1 Objective

The objective of the economic valuation is to quantify and monetize the impacts of the proposed Project on the flow of environmental services. This requires valuation in monetary terms the changes (both negative and positive if any) in environmental services arising from Project implementation over an assessment period of 50 years.

7.17.2 Methodology

A critical step in the valuation process revolves around the need to ensure valid attribution of impacts on environmental services to the proposed Project. In order to satisfy this requirement, physical environmental impacts that can reasonably be attributable to the proposed Project must first be demonstrated. In other words, the approach requires the establishment of a clear link between Project impacts on the physical functions of the environment and the alteration of the quality and quantity of streams of environmental goods and services. The Guidelines on the Economic Valuation of the Environmental Impacts for EIA projects published by DOE is very clear in this regards where it specifies that:

"… a key issue is to identify and quantify the changes in the flow of goods and services produced by the environment which are impacted by a development project, and then to monetize these changes into costs or benefits".
The valuation process can be divided into nine steps, as follows:

a) *Step 1: Identify the project stakeholders.*

The stakeholders are determined by establishing clear links between the degradation in environmental services to the impacted parties.

b) *Step 2: Define the "with project" and "without project" scenarios.*

A contrast is considered under the "with" and "without" project scenarios, as opposed to "before" and "after" scenarios. It involves the conceptualization of the "with" and "without" project scenarios. For the current project under evaluation, the "with project" scenario is defined as the situation where the project is implemented that entails reclamation works, and the construction and operation of the proposed mixed development. "Without project" scenario is depicted as the situation in which the proposed project is not implemented i.e. maintenance of the status quo.

c) *Step 3: Describe the physical impacts.*

A listing of potential physical impacts of the project that can be reliably attributed to the project is prepared and described by focusing on the physical extent of the impact and the link between the project and its impact on the flow of environmental services.

d) *Step 4: Quantify the impacts on the environment over the duration of the project.*

The physical impacts of the project on the environment are explained and quantified via scientific assessments of the study team that include among others marine biologists, air and water quality specialists, and hydraulic specialist.

e) *Step 5: Monetize the impacts.*

The quantified impacts produced in Step 4 are monetized using market and non-market valuation techniques. Value parameters of similar environmental services obtained in other studies are used as reference points for evaluation.

f) *Step 6: Discounting.*

Costs and benefits over time (50 years) are discounted to present values using several discount rates (4, 6 and 8%). Fifty years is typically used as the standard period of evaluation since the present value of future benefits/costs beyond 50 years tend to become quantitatively insignificant.

g) *Step 7: Determine the Net Present Value.*

The net present value is computed in this step by adding up the discounted values of the losses and gains in environmental services.

h) *Step 8: Perform sensitivity analysis.*

Sensitivity test is conducted for different discount rates to demonstrate the impact of variation in discount rates on the net present value of the environmental costs and benefits.

i) *Step 9: Make a recommendation.*

An overall assessment is made based on the magnitude of Net Present Values at different levels of discount rates

7.17.3 Identification of Changes in Environmental Services

As indicated earlier, only marginal impacts on environmental services (losses or gains) are considered in the analysis. This is to ensure that only changes in environmental services as a result of selecting the “with Project” option, and not the “without Project” option is made part of the evaluation.

Based on discussions with other (consultants) team members responsible to assess the impacts of the Project on all environmental components as well as reports prepared by them, T7.56 shows the environmental services that may change as a result of Project implementation. The table describes the kind and spatial extent of the impacts as well as their respective locations. From among these potential impacts, mitigation measures are considered, and only those that remain to be significant are evaluated in this study.

7.17.4 Valuation of Significant Change in Environmental Services

Eight environmental services (T7.56) can potentially change as a result of Project implementation. These are: loss of mudflat due to reclamation, loss of mudflat due to capital and maintenance dredging, potential impact on mangrove area, potential impact on coral area, loss of fishing ground and access to sea (higher cost of fishing effort), reduction in water quality due to increase in suspended sediment, erosion and accretion, and change in area’s aesthetic. Of the eight potential changes in environmental services, four are considered to be significant enough for evaluation. These are:

a) Loss of mudflat or muddy seabed due to reclamation,
b) Loss of mudflat or muddy seabed due to capital and maintenance dredging,
c) Reduction in coral area productivity, and
d) Loss of fishing ground access to sea (higher cost of fishing effort).

The other impacts are considered insignificant following the implementation of mitigation measures. The nature of losses in environmental services for each of the impact is described and evaluated below.

7.17.4.1 Loss of Mudflat or Muddy Seabed Due to Reclamation

Reclamation will result in permanent loss of the mudflat or muddy seabed. The loss of mudflat or muddy seabed will result in some reduction in the amount of resources important to support marine lives. The total area that will be affected is 1,800 hectares (4,500 acres).

Mudflat provides habitat for some fishery resources like cockles, bivalves and gastropods/ snails and shrimps. In addition, sediment communities play a critical role in the food chain for both marine organisms as well as shorebird populations (Chong *et al.*, 1990). Sediment communities are crucially important food source for marine fish and shorebirds (Erftemeyer *et al.*, 1989; Sasekumar, 1984; Sasekumar *et al*., 1984).

Past valuation studies have tended to use nationwide average productivity as a basis for valuing the loss of environmental services produced by mudflats. The use of this approach is understandable because local studies are typically non-existent. This study *initially* uses such an approach, but subsequently makes some adjustments to the values to better reflect local condition.

T7.56 Valuation of Significant Change in Environmental Services

Environmental Service	Location and Impacted Individuals/ Communities	Spatial Extent	Remarks
Coastal Morphology - **Erosion** and **accretion** due to the introduction of reclaimed land to the existing coastal area.	Hydraulic modelling results show that erosion and sedimentation impact occur after the reclamation is completed. It is projected that sedimentation will occur at Tanjung Gertak Sanggul and within the dredged channel. Meanwhile, erosion is expected to occur offshore of Island C, Tanjung Teluk Tempoyak and Pulau Rimau.	The bed level changes induced by the various development scenarios are expected to result in erosion rates of up to +- 0.2 m/year at Tanjung Teluk Tempoyak and Pulau Rimau	Pulau Rimau is uninhabited while Tanjung Teluk Tempoyak consists of rocky headlands as well as being uninhabited. No economic loss of significance is expected so no valuation is therefore necessary.
Marine Biology - Loss of **mudflat and muddy seabed** due to **reclamation**. Permanent loss is expected for the entire mudflat and muddy seabed making up the footprint of the reclamation site. This area serves as crustacean feeding ground and macrobenthos habitat. This activity will result in some loss in the amount of resources important to support marine life since such area serves as habitat for benthos and feeding ground for fishes.	The exact location of the reclamation site is given in the *Project Description* chapter of this EIA report. Fishermen and local communities deriving benefits from the marine resources.	A total of 1,800 hectares (4,500 acres) will be reclaimed. (See also Item 2 for loss of mudflat/ muddy seabed due to dredging)	Total loss of mudflat or muddy seabed. The productivity loss method is used to evaluate the loss in environmental services and functions. Reclamation is expected to begin in 2018 for Island B (560 hectares), then in 2020 for Island A (920 hectares), and in 2024 for Island C (320 hectares).
Marine Biology - Loss of **mudflat or muddy seabed** due to **capital and periodic dredging**. Temporary loss is expected for the entire would-be-dredged area. This mudflat serves as crustacean feeding ground and macrobenthos habitat. This activity will result in some loss in the amount of resources important to support marine life since such area serves as habitat for benthos and feeding ground for fishes.	The exact location of the reclamation site is given in the *Project Description* chapter of this EIA report. Generally, it is located in the navigation and access channels and marina basin. Fishermen and local communities deriving benefits from the marine resources.	A total of 345.5 hectares (863.75 acres) will be dredged mostly for the navigation and access channels between the reclaimed islands, and between the reclaimed islands and Penang Island	Initial loss of mudflat habitat during dredging work. Dredging will be conducted in four phases: Phase 1 (115 hectares) in 2017, Phase 2 (110 hectares) in 2021, Phase 3 (80 hectares) in 2025 and Phase 4 (40 hectares) in 2028. The frequency of maintenance dredging required is about once every 5 years. Further, a 5-year full-recovery period for marine organisms is assumed, suggesting an average productivity of about one-fifth for the year following dredging work. Marine organisms are expected to just about fully recover during the intervening period in between dredging works. The productivity loss method is used to evaluate the loss in environmental services and functions.

T7.56 Valuation of Significant Change in Environmental Services (cont'd)

Environmental Service	Location and Impacted Individuals/Communities	Spatial Extent	Remarks
Marine Biology – Potential reduction in environmental services obtainable from **coral** area due to increase in total suspended sediment, sedimentation and erosion, thus resulting in some loss in the amount of resources important to support marine life. Coral areas provide a range of valuable ecosystem services including sheltering habitat essential to a variety of marine species. In addition, the biodiversity of coral reefs provides scientific, pharmaceutical (discovered or yet-to-be discovered), and educational value. Moreover, many coral areas also attract tourists, and protect coastal developments from shoreline erosion. The productivity of corals in delivering these services will be impacted by water quality degradation and sedimentation.	Pulau Rimau (0.5 km from Project location) and Pulau Kendi (5 km from Project location). Fishermen and local communities deriving benefits from marine resources.	The size of the Pulau Rimau coral area on the western side of the island is approximately 0.918 hectare	Sediment spill dispersion modelling results indicate that the suspended sediment concentrations due to dredging works for the access channels as well as the reclamation works would not be significant for the coral area of Pulau Rimau (no impact is expected at Pulau Kendi). However, to be conservative, this study assumes that environmental services obtainable from the coral area will be reduced by 50% during the construction period and thereafter for the Pulau Rimau coral.
Terrestrial Biology – Potential reduction in environmental services obtainable from **mangrove** area due to sedimentation and erosion, thus resulting in some loss in the amount of resources important to support marine life. Mangrove areas are known to provide environmental services including (a) Production of charcoal and poles, (b) Provision of feeding and breeding grounds for shrimp, fish, crab and mollusc, (c) Provision of traditional goods (d) Carbon sequestration function, (e) Shoreline protection, and (f) Option, existence and biodiversity value.	Mangroves of Teluk Tempoyak Kecil, Teluk Tempoyak Besar, Permatang Tepi Laut, Kampung Binjai, Bayan Lepas Main Drain, Sungai Batu, Teluk Kumbar and Gertak Sanggul. Fishermen and local communities deriving benefits from the marine resources as well as the general population that benefit from carbon sequestration function.	Results of hydraulic modelling show that the impact due to sedimentation and erosion is negligible	Since no impact is expected, no valuation is necessary.
Aesthetic - Change in the form of **intrusion** of man-made structures into the **view scape** following Project completion.	Areas surrounding the reclaimed land. Coastal villagers and visitors to where the newly reclaimed land is visible.	The shore area where the reclaimed land plus built structures are visible	The direction of impact of the Project on aesthetic is uncertain since it is hard to argue with certainty that the Project will give rise to negative impact on the general aesthetics of the area. Furthermore, even if the Project is perceived (by the current residents and visitors) to cause some negative impacts on aesthetics, it may well be argued that this will be compensated by the gain in sea view scape of future residents and visitors of the reclaimed islands.

T7.56 Valuation of Significant Change in Environmental Services (cont'd)

Environmental Service	Location and Impacted Individuals/ Communities	Spatial Extent	Remarks
Socio-economy – Loss of **fishing ground** and hindrance of access to the sea. Reduction in the size of fishing ground because part of the sea will be reclaimed. The reclamation will force the fishermen to find alternative fishing ground/s, potentially increasing their operational cost. The reclaimed land mass and terminal will also hinder direct movements of costal fishing vessels. Thus, some fishermen will incur additional cost of going to and back from the fishing ground.	The reclaimed area as given in the Project Description section of this DEIA report. The directly affected stakeholders are the coastal (Zone A) fishermen operating from four landing sites identified in the study area namely, Kampung Permatang Damar Laut (85 vessels), Kampung Sungai Batu (105 vessels), Kampung Teluk Kumbar (131 vessels), and Kampung Gertak Sanggul (77 vessels).	All of the reclaimed area	Fishermen who routinely fish in the affected area will have to find other locations. The additional cost of fishing involves the increase in cost of travelling to and back from the alternative fishing ground. They may have to travel farther because conflict may arise as they encroach into traditional fishing grounds of existing fishermen.
Water Quality – Increase in suspended TSS during reclamation and dredging work that reduces the quality and therefore productivity of marine habitat. Furthermore, any degradation of water quality at the water abstraction points of the hatcheries near Kampung Permatang Damar Laut, Kampung Teluk Kumbar, Pulau Betung, and Kampung Gertak Sanggul will adversely affect their operations and output.	Coastal waters around reclaimed land and the dredging work area. Of significance are the aquaculture sites near Pulau Betung and Kampung Teluk Tempoyak Kecil; and hatcheries near Kampung Permatang Damar Laut, Kampung Teluk Kumbar, Pulau Betung, and Kampung Gertak Sanggul.	With the installation of perimeter bund and silt curtain during reclamation and dredging, the extent of impact is predicted by the hydraulic modelling to be much reduced, especially at the environmental sensitive areas. In the case of the aquaculture sites, the predicted concentration is well below the tolerable limits of 80 mg/L [Water Quality Standards for Aquaculture in Malaysia (Liong, P.C., 1984)]. However, the hydraulic modelling results indicate that the water abstraction points of the hatcheries near Kampung Permatang Damar Laut and Kampung Teluk Kumbar will be temporarily impacted during reclamation. This impact will be mitigated by an upgrade to the filtration systems of the hatcheries as well as relocation of pipes for water abstraction as proposed in the EIA.	Mitigating measures through the installation of perimeter bund and silt curtain during reclamation and dredging work will render the impact insignificant. No valuation is necessary. However, also see the impact on dredging work and reclamation on marine biology.

Sasekumar *et al.* (1998) produced an estimate of the value of cockle production for mudflats of Peninsular Malaysia in a study conducted in 1995. The said study estimated the total gross value of production at US$26.4 million. The same study also estimated the values of production for bivalves, gastropods/snails, shrimps, and fish at US$17.6 million, US$0.3 million, US$2.9 million and US$2.2 million respectively. The values were obtained by multiplying the estimated quantity of production by the unit prices of US$2,600/ton (bivalves), US$600/ton (gastropods/snails), and US$200/ton (shrimp and fish). To arrive at the net value of production, the researchers then applied the net revenue factor of 60% for cockle and bivalves, 30% for gastropods/snails and shrimps, and 25% for fish.

Total size of mudflats in Peninsular Malaysia is estimated at 35,064 hectares. Dividing the estimates on the annual value of the production of cockles, bivalves, gastropods/snails, shrimps and fish by the total size of mudflats, the estimated environmental service of mudflats in the form of direct use value (adjusted for price increase at the rate of 4% per year) is provided in T7.57. The direct use value for mudflat is therefore estimated at RM6,981.24/hectare/year.

Confirmatory site visit indicates that not all components of valuation presented in T7.57 are relevant to the site. In particular, gastropods/snails are minimal at the proposed site. Hence, the relevant components of valuation are cockles, bivalves, shrimps and fish. The adjusted loss in environmental services from mudflat is therefore RM6,955.38/hectare/year.

The annual value of environmental services forgone from the loss of mudflat is obtained by multiplying the size of the affected area by the estimated value of environmental services loss per hectare of reclaimed area (i.e. RM6,955.38/hectare/year). The loss is expected to build up as reclamation will begin in 2018 for Island B (560 hectares), then in 2021 for Island A (920 hectares), and in 2025 for Island C (320 hectares).

T7.57

Estimated average loss in environmental services (per hectare per year) from mudflat by service type

	Environmental Services (Production)	Unit Value (RM per hectare per year)
Direct Use Value	Cockles	3,954.90
	Bi valves	2,645.54
	Gastropods/snails	25.86
	Shrimps	217.46
	Fish	137.48
Total		**6,981.24**

7.17.4.2 Loss of Mudflat or Muddy Seabed Due to Capital and Maintenance Dredging

Loss of mudflat due to dredging works (capital and maintenance dredging) will take place at the navigation and access channels between the reclaimed islands, and between the reclaimed islands and Penang Island. The estimated size of mudflat or muddy seabed affected is 345.5 hectares (863.75 acres). Periodic maintenance dredging is expected to be conducted on average about once every 5 years.

The benthic communities are known to recover after dredging work. A 5-year impact period on the benthic communities is typically assumed for each dredging exercise, which is the time required for the seabed life to recover. Hence, one possible way of computing the loss is by assuming that the benthic communities recover at a constant rate throughout each dredging cycle. A 5-year full-recovery period implies an average productivity of about one-fifth for the year following dredging work.

The frequency of maintenance dredging required is about once every 5 years, so a 5-year frequency is used as the basis of computation. Further, a 5-year full-recovery period for marine organisms is assumed, suggesting an average productivity of about one fifth for the year following dredging work. Marine organisms are expected to just about fully recover during the intervening period in between dredging works.

The projected loss in environmental services is computed by multiplying the size of the affected area by the estimated value of environmental services loss per hectare of reclaimed area (i.e. RM6,955.38/hectare/year). The size of impacted area will increase over time in tandem with the four dredging phases. The size and timing of area to be dredged are as follows: Phase 1 (115 hectares) in 2017, Phase 2 (110 hectares) in 2021, Phase 3 (80 hectares) in 2025 and Phase 4 (40 hectares) in 2028.

The estimation of the environmental services lost due to dredging work follows the method used in determining the loss of mudflat or muddy seabed due to reclamation. After adjusting for general increase in price level the value of cockle, bivalves, shrimp and fish production of mudflats is estimated at RM6,955.38/hectare/year. Since some recovery can be expected within dredging cycles, total loss is expected following any dredging work and will gradually fall up to the fifth year. Thereafter, the cycle is repeated when the area is re-dredged. This method implies that the loss of RM6,955.38/hectare in the first year of dredging and gradually falls up to the fifth year in a linear fashion.

7.17.4.3 Loss of Coral Area Productivity

Corals are found in the oceans all over the world, from the coast of Alaska to the warm tropical waters of Southeast Asia and the Caribbean. The bigger coral reefs that grow quickly are found in the shallow ocean waters of the tropics. Within 5 km of the Project site, there are two coral areas of significance, namely at Pulau Rimau and Pulau Kendi. Based on locational proximity of the coral area of Pulau Rimau (about 0.5 km away from Project site), it may be affected by reclamation activities. However, results of the hydraulic modelling show that with strict mitigation measures (e.g. installation of perimeter bund and silt curtain), the impact of sediment plume at Pulau Rimau coral is not expected to be significant. (No impact is expected for Pulau Kendi). However, to be conservative, this study assumes that environmental services obtainable from the coral area will be reduced by 50% during the construction period and thereafter. The size of the Pulau Rimau coral is approximately 0.918 hectare.

Reclamation and dredging work may cause sediment plume to reach the coral area thus reducing its productivity and health. However, as mentioned earlier, this is not expected to be significant if mitigation measures are put in place before reclamation work begins. Coral areas provide a range of valuable ecosystem services. First, they provide sheltering habitat essential to a variety of marine species. In the Philippines, for example, coral areas supply between 11 and 29% of the total fisheries production (Burke *et. al.*, 2002). In addition, the biodiversity of coral reefs provides scientific, pharmaceutical (discovered or yet-to-be discovered), and educational value. Moreover, many coral areas also attract tourist, and protect coastal developments from shoreline erosion. Corals are also thought to facilitate the growth of mangroves and seagrasses. The productivity of corals in delivering these services will be impacted by water quality degradation and sedimentation.

No valuation study has been conducted for the value of environmental services provided by coral areas of Malaysia. Internationally, although not as abundant as valuation studies on mangrove, several published studies on the value of environmental services provided by coral areas are available. Unit values from these studies were converted to the current 2016 price to determine the respective values of environmental services.

■ Economic Value of Coral Area

The Millennium Ecosystem Assessment (MEA) provides a framework to define and assess the global status of the ecosystem goods and services. The framework identifies four categories of services provided by ecosystems: provisioning services, regulating services, cultural services and supporting services (T7.58). It is within this framework that the services provided by the coral area found at Pulau Rimau and Pulau Kendi.

T7.58

Ecosystem services provided by coral area

Provisioning Services *Products obtained from ecosystems*	■ Food (fish and shellfish) ■ Genetic resources ■ Natural medicines and pharmaceuticals ■ Ornamental resources ■ Building materials
Regulating Services *Benefits obtained from regulation of ecosystem processes*	■ Erosion control ■ Storm protection ■ Climate regulation
Cultural Services *Non-material benefits obtained from ecosystem*	■ Spiritual and religious values ■ Knowledge systems/educational values ■ Inspiration ■ Aesthetic values ■ Social traditions ■ Sense of place ■ Recreation and ecotourism
Supporting Services *Natural processes that maintain the other services*	■ Sand formation ■ Primary production

Source: Adapted from Millennium Ecosystem Assessment (MEA), 2003, "Ecosystems and Human Well-being: A Framework for Assessment." Washington DC: Island Press.

Past valuation studies have tended to report average ecosystem service productivity as a basis for valuing the loss of environmental services produced by coral sites. This study

adopts these average values but updates them to the present to take care of general price inflation. As most of the values are reported in USD, this study also adjusts the values to reflect the current exchange rate.

In a seminal paper published in the prestigious Journal of Nature, Constanza *et. al.* (1997) classifies ecosystem services produced by coral areas into eight categories namely:

a) Disturbance regulation - Capacitance, damping and integrity of ecosystem response to environmental fluctuations;
b) Waste treatment - Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds;
c) Biological control - Trophic-dynamic regulations of populations;
d) Habitat/refugia - Habitat for resident and transient populations;
e) Food production - That portion of gross primary production extractable as food;
f) Raw materials - That portion of gross primary production extractable as raw materials;
g) Recreation - Providing opportunities for recreational activities; and
h) Cultural - Providing opportunities for non-commercial uses.

The values are reproduced in T7.59. They ranged from a low of USD1 for cultural service per hectare per year to a high of USD3,008 for recreation. The total value of ecosystem services is USD6,075/hectare/year. These values are converted to 2016 by assuming a 3% inflation rate and an exchange rate of USD1 = RM4.20.

T7.59 Estimated environmental services value (per hectare per year) of Pulau Rimau corals by service type

Services	Constanza *et. al.* (1997) USD/ha/year	Hoisington and Eadie (2012) AUD/ha/year	Burke *et. al* (2002) USD/ha/year (Mid Value/ Range)	Average Values (2016) (RM)
Provisioning Services *Products obtained from ecosystems*				
■ Food (fish and shellfish) ■ Genetic resources ■ Natural medicines and pharmaceuticals ■ Ornamental resources ■ Building materials	247	140	277.50/ 145-410	1,367.33
Regulating Services *Benefits obtained from regulation of ecosystem processes*				
■ Erosion control ■ Storm protection ■ Climate regulation	2,813	79	577.50/ 55-1,100	8,226.39
Cultural Services *Non-material benefits obtained from ecosystem*				
■ Spiritual and religious values ■ Knowledge systems/ educational values ■ Inspiration ■ Aesthetic values ■ Social traditions ■ Sense of place ■ Recreation and ecotourism	3,009	9	553.50/ 7-1,100	8,570.07
Supporting Services *Natural processes that maintain the other services*				
■ Sand formation ■ Primary production	7	134	52/ 24-80	293.20
Total	**6,076**	**362**	**1,460.50**	**18,456.99**

In another study, Hoisington and Eadie (2012) set out to estimate the economic value of ecosystem services for the proposed Commonwealth Marine Reserves Network in Australia. The study identifies five ecosystem services produced by coral areas. The researchers explicitly state that they have been conservative in their estimation and have not included existence and non-use values. The five (5) services are:

a) Food production;
b) Raw materials;
c) Climate regulation;
d) Habitat services – Lifecycle maintenance; and
e) Recreation and tourism.

Consistent with their conservative approach, the estimated values start from a low of AUD1 for raw materials per hectare per year to a high of AUD134 for lifecycle maintenance. These values are converted to 2016 by assuming a 3% inflation rate and an exchange rate of AUD1 = RM3.30. The values are reproduced in T7.59.

Closer to home, Burke et. al (2002) produces a range of estimates for ecosystem services produced by coral areas in South East Asia. The study listed five broad categories of services namely:

a) Sustainable fisheries (local consumption);
b) Sustainable fisheries (live fish export);
c) Coastal protection (erosion prevention);
d) Tourism and recreation; and
e) Aesthetic/Biodiversity value.

Instead of providing point estimates, the study provides a range of values for each category. This is mainly because the proposed values are sourced from several other studies (i.e. White *et. al.* (2000), White and Cruz-Trinidad (1998), and Cesar (1996)). The values (also reproduced in T7.59) are within expected bound for some but tend to have a wide range for others. For example, sustainable fisheries for local consumption is valued at the USD120-USD360 range, while those for tourism and recreation at the USD7-USD1,110 range.

The last column of T7.59 provides the average value of ecosystem service by type as well as the total economic value. The average values in RM are established by first updating all figures to 2016 prices assuming an inflation rate of 3%, and subsequently converting them into RM using current exchange rates. The three estimates of value of each service type are them summed and divided by three to produce the average values in RM for 2016. The total economic value of ecosystem services produced by corals amounts to RM18,456.99/ hectare/year.

Because of the mitigation measures that will be implemented (e.g. perimeter bund and silt curtain), the impact of sediment plume is not expected to be very significant. However, in order to be conservative in approach, this study assumes that services obtainable from the coral area of Pulau Rimau will be reduced by 50% during the construction period and thereafter. The reduction in ecosystem services produced by the coral area of Pulau Rimau is therefore estimated at RM8,472 per year.

7.17.4.4 Loss in Fishing Ground and Increase in Fuel Cost for Fishermen

The directly-affected fishermen are the coastal (Zone A) fishermen operating from four landing sites identified in the study area namely, Kampung Permatang Damar Laut, Kampung Sungai Batu, Kampung Teluk Kumbar, and Kampung Gertak Sanggul. The area to be reclaimed is part of the fishing ground as well as used as direct routes to fishing ground by local fishermen.

A total of 398 fishing boats operate regularly within the area to be reclaimed, based on data provided by local leaders of the fishermen communities. By landing sites, the number of vessels are as follows:

a) Kampung Permatang Damar Laut (85 vessels);
b) Kampung Sungai Batu (105 vessels);
c) Kampung Teluk Kumbar (131 vessels); and
d) Kampung Gertak Sanggul (77 vessels).

Fishing takes place by day and by night, and at various stages of the tide. The fishermen will be directly impacted because the would-be reclaimed area is their regular fishing ground or used as direct routes to fishing ground, and they will have to travel longer distances to alternative fishing grounds. They can only do so at a higher cost since they will have to travel further to these areas, with added difficulty of encroaching into traditional fishing grounds of existing fishermen.

This study notes that in estimating the impact of reclamation, double counting the loss in catch due to a reduction in fish feeding ground must be avoided since it is already captured in the computation of the loss of seabed habitat.

By consulting several representatives of the fishermen community, it is determined that the fishermen generally use outboard engines ranging from 30 to 115 horsepower. The most popular engines are the 30, 60 and 115 horsepower while a significantly smaller proportion of fishermen use bigger horsepower engines. The corresponding estimated fuel usage per day are 30 to 115 litres per trip depending on engine horsepower. A litre of subsidized petrol costs the fishermen RM1.00. However, for economic valuation, the true resource cost as reflected by unsubsidized market price should be used. For this study a market price of RM2.00 per litre is applied to determine fuel cost.

In order to assess the likely increase in the cost of fuel as a result of the reclamation, the following assumptions are employed:

a) The average number of fishing days is 20 trips in a month. This figure is derived from the survey conducted on the fishermen;
b) The proportion of boats belonging to the 30, 60 and 115 horsepower categories is approximately 32.5, 59.9 and 7.6% respectively. This is based on information gathered from the fishermen; and
c) The additional fuel cost for trips to alternative fishing grounds is assumed 25% higher than the current cost.

The additional fuel cost per month can then be computed for each engine size as:

Fuel in litres/trip x RM2.00/litre x 20 trips x 25%

The additional cost for each type of engine is then aggregated over all engine sizes to arrive at the total increase in fuel cost. Note that a 25% increase is assumed since the fishermen may have to increase their fishing effort substantially because of the fact that encroaching on the traditional fishing grounds of other fishermen can give rise to conflict. This situation may necessitate the affected fishermen to travel further afar.

7.17.5 Overall Findings for Economic Valuation of Environmental Impact

T7.60 to T7.62 show the streams of discounted loss of environmental services over a period of 50 years that can be attributed to the proposed Project. The 8% rate is chosen to reflect the market rate of interest conventionally use for Project evaluation while 6 and 4% are more appropriate rates for social evaluation.

When discounted at the rate of 8%, the total present value of the stream of annual loss amounts to RM193.2 million over a period of 50 years. The corresponding values for 6 and 4% discounts rates are RM251.0 million and RM344.7 million respectively. This study notes that the sum should not be construed as indicating Project feasibility. Rather, they provide some indication of the magnitude, in monetary terms, of the reduction in the flow of environmental services as a result of the implementation of the Project over the evaluation period.

T7.60 Estimates of the discounted environmental loss (discount rate = 8%)

Year	Loss of Mudflat (Reclamation)	Loss of Mudflat (Dredging)	Reduction in Coral Productivity	Loss of Fishing Ground - Additional Fuel Cost	Discounted Loss
0	3,895,013	799,869	8,472	2,592,000	7,295,353
1	3,606,493	592,495	7,844	2,400,000	6,606,833
2	8,825,413	411,455	7,263	2,222,222	11,466,354
3	8,171,679	253,985	6,725	2,057,613	10,490,002
4	7,566,369	1,150,293	6,227	1,905,197	10,628,086
5	7,005,898	852,069	5,766	1,764,072	9,627,804
6	7,889,524	591,714	5,339	1,633,400	10,119,977
7	7,305,115	365,256	4,943	1,512,407	9,187,721
8	6,763,995	1,146,121	4,577	1,400,377	9,315,071
9	6,262,959	848,979	4,238	1,296,645	8,412,821
10	5,799,036	589,569	3,924	1,200,598	7,593,126
11	5,369,478	483,253	3,633	1,111,664	6,968,028
12	4,971,739	930,820	3,364	1,029,319	6,935,242
13	4,603,462	685,404	3,115	953,073	6,245,054
14	4,262,465	471,239	2,884	882,475	5,619,063
15	3,946,726	355,205	2,671	817,106	5,121,709
16	3,654,376	684,180	2,473	756,580	5,097,610
17	3,383,682	503,793	2,290	700,537	4,590,301
18	3,133,039	346,375	2,120	648,645	4,130,179
19	2,900,962	261,087	1,963	600,598	3,764,609
20	2,686,076	502,893	1,818	556,109	3,746,895
21	2,487,107	370,303	1,683	514,916	3,374,008
22	2,302,877	254,596	1,558	476,774	3,035,805
23	2,132,293	191,906	1,443	441,457	2,767,100
24	1,974,346	369,641	1,336	408,757	2,754,080
25	1,828,098	272,183	1,237	378,478	2,479,997
26	1,692,683	187,136	1,145	350,443	2,231,407
27	1,567,299	141,057	1,061	324,484	2,033,901
28	1,451,203	271,697	982	300,448	2,024,331
29	1,343,707	200,063	909	278,193	1,822,872
30	1,244,173	137,550	842	257,586	1,640,151
31	1,152,012	103,681	780	238,506	1,494,978
32	1,066,678	199,706	722	220,839	1,487,944
33	987,664	147,052	668	204,480	1,339,865
34	914,504	101,104	619	189,333	1,205,560
35	846,763	76,209	573	175,309	1,098,853
36	784,040	146,790	531	162,323	1,093,683
37	725,963	108,088	491	150,299	984,841
38	672,188	74,314	455	139,166	886,123
39	622,396	56,016	421	128,857	807,690
40	576,293	107,895	390	119,312	803,890
41	533,604	79,448	361	110,474	723,887
42	494,078	54,623	334	102,291	651,326
43	457,480	41,173	310	94,714	593,676
44	423,592	79,306	287	87,698	590,883
45	392,215	58,396	265	81,202	532,079
46	363,162	40,150	246	75,187	478,744
47	336,261	30,264	228	69,618	436,370
48	311,353	58,292	211	64,461	434,317
49	288,290	42,923	195	59,686	391,094
Total	**141,975,821**	**16,827,614**	**111,930**	**34,245,928**	**193,161,293**

T7.61 Estimates of the discounted environmental loss (discount rate = 6%)

Year	Loss of Mudflat (Reclamation)	Loss of Mudflat (Dredging)	Reduction in Coral Productivity	Loss of Fishing Ground - Additional Fuel Cost	Discounted Loss
0	3,895,013	799,869	8,472	2,592,000	7,295,353
1	3,674,540	603,674	7,992	2,445,283	6,731,490
2	9,161,590	427,128	7,540	2,306,871	11,903,128
3	8,643,009	268,634	7,113	2,176,293	11,095,049
4	8,153,782	1,239,595	6,710	2,053,107	11,453,195
5	7,692,247	935,544	6,331	1,936,893	10,571,015
6	8,825,883	661,941	5,972	1,827,258	11,321,054
7	8,326,305	416,315	5,634	1,723,828	10,472,082
8	7,855,004	1,330,987	5,315	1,626,253	10,817,559
9	7,410,381	1,004,518	5,014	1,534,201	9,954,115
10	6,990,926	710,744	4,731	1,447,359	9,153,760
11	6,595,213	593,569	4,463	1,365,433	8,558,678
12	6,221,899	1,164,878	4,210	1,288,145	8,679,132
13	5,869,716	873,936	3,972	1,215,231	7,962,854
14	5,537,468	612,198	3,747	1,146,444	7,299,857
15	5,224,027	470,162	3,535	1,081,551	6,779,275
16	4,928,327	922,692	3,335	1,020,331	6,874,685
17	4,649,365	692,239	3,146	962,577	6,307,326
18	4,386,193	484,918	2,968	908,091	5,782,171
19	4,137,918	372,413	2,800	856,690	5,369,821
20	3,903,697	730,859	2,642	808,198	5,445,395
21	3,682,733	548,318	2,492	762,451	4,995,993
22	3,474,276	384,101	2,351	719,293	4,580,021
23	3,277,619	294,986	2,218	678,579	4,253,401
24	3,092,093	578,909	2,092	640,168	4,313,263
25	2,917,069	434,319	1,974	603,932	3,957,295
26	2,751,952	304,244	1,862	569,748	3,627,805
27	2,596,181	233,656	1,757	537,498	3,369,092
28	2,449,227	458,550	1,657	507,073	3,416,508
29	2,310,592	344,021	1,564	478,371	3,134,548
30	2,179,804	240,989	1,475	451,293	2,873,562
31	2,056,419	185,078	1,392	425,749	2,668,636
32	1,940,018	363,214	1,313	401,650	2,706,194
33	1,830,205	272,497	1,238	378,915	2,482,856
34	1,726,609	190,886	1,168	357,467	2,276,130
35	1,628,876	146,599	1,102	337,233	2,113,810
36	1,536,676	287,700	1,040	318,144	2,143,559
37	1,449,694	215,843	981	300,136	1,966,654
38	1,367,636	151,200	925	283,147	1,802,908
39	1,290,222	116,120	873	267,120	1,674,335
40	1,217,191	227,885	824	252,000	1,697,900
41	1,148,293	170,968	777	237,736	1,557,774
42	1,083,296	119,764	733	224,279	1,428,072
43	1,021,977	91,978	692	211,584	1,326,231
44	964,129	180,506	652	199,608	1,344,896
45	909,556	135,423	615	188,309	1,233,903
46	858,072	94,865	581	177,650	1,131,167
47	809,502	72,855	548	167,594	1,050,499
48	763,681	142,978	517	158,108	1,065,283
49	720,453	107,268	488	149,158	977,367
Total	**185,136,554**	**22,412,533**	**141,543**	**43,306,027**	**250,996,657**

T7.62 Estimates of the discounted environmental loss (discount rate = 4%)

Year	Loss of Mudflat (Reclamation)	Loss of Mudflat (Dredging)	Reduction in Coral Productivity	Loss of Fishing Ground - Additional Fuel Cost	Discounted Loss
0	3,895,013	799,869	8,472	2,592,000	7,295,353
1	3,745,204	615,284	8,146	2,492,308	6,860,942
2	9,517,347	443,714	7,833	2,396,450	12,365,343
3	9,151,295	284,432	7,531	2,304,279	11,747,537
4	8,799,322	1,337,735	7,242	2,215,652	12,359,951
5	8,460,886	1,029,027	6,963	2,130,435	11,627,311
6	9,894,488	742,087	6,695	2,048,495	12,691,765
7	9,513,931	475,697	6,438	1,969,707	11,965,772
8	9,148,010	1,550,080	6,190	1,893,949	12,598,229
9	8,796,164	1,192,369	5,952	1,821,105	11,815,589
10	8,457,850	859,881	5,723	1,751,062	11,074,517
11	8,132,548	731,929	5,503	1,683,714	10,553,694
12	7,819,757	1,464,032	5,291	1,618,956	10,908,037
13	7,518,998	1,119,495	5,088	1,556,688	10,200,269
14	7,229,805	799,295	4,892	1,496,815	9,530,808
15	6,951,736	625,656	4,704	1,439,246	9,021,342
16	6,684,361	1,251,461	4,523	1,383,890	9,324,236
17	6,427,271	956,949	4,349	1,330,663	8,719,232
18	6,180,068	683,241	4,182	1,279,484	8,146,975
19	5,942,373	534,814	4,021	1,230,273	7,711,481
20	5,713,820	1,069,754	3,866	1,182,955	7,970,396
21	5,494,058	818,004	3,718	1,137,457	7,453,236
22	5,282,748	584,037	3,575	1,093,708	6,964,068
23	5,079,565	457,161	3,437	1,051,643	6,591,806
24	4,884,197	914,430	3,305	1,011,195	6,813,128
25	4,696,344	699,233	3,178	972,303	6,371,058
26	4,515,715	499,237	3,056	934,906	5,952,915
27	4,342,034	390,783	2,938	898,949	5,634,703
28	4,175,032	781,659	2,825	864,374	5,823,890
29	4,014,454	597,708	2,716	831,128	5,446,007
30	3,860,052	426,750	2,612	799,162	5,088,576
31	3,711,589	334,043	2,512	768,425	4,816,568
32	3,568,835	668,165	2,415	738,870	4,978,286
33	3,431,572	510,923	2,322	710,452	4,655,269
34	3,299,589	364,788	2,233	683,127	4,349,736
35	3,172,682	285,541	2,147	656,853	4,117,223
36	3,050,655	571,150	2,064	631,589	4,255,459
37	2,933,322	436,739	1,985	607,297	3,979,344
38	2,820,502	311,822	1,909	583,940	3,718,173
39	2,712,021	244,082	1,835	561,481	3,519,419
40	2,607,713	488,222	1,765	539,885	3,637,585
41	2,507,416	373,326	1,697	519,120	3,401,560
42	2,410,977	266,547	1,631	499,154	3,178,310
43	2,318,247	208,642	1,569	479,956	3,008,414
44	2,229,084	417,334	1,508	461,496	3,109,422
45	2,143,350	319,121	1,450	443,746	2,907,668
46	2,060,913	227,845	1,395	426,679	2,716,833
47	1,981,648	178,348	1,341	410,268	2,571,605
48	1,905,430	356,739	1,289	394,489	2,657,947
49	1,832,145	272,786	1,240	379,316	2,485,486
Total	**255,022,137**	**31,571,968**	**189,272**	**57,909,095**	**344,692,472**

In view of the expected loss in the value of environmental services it is recommended that the Project Proponent initiate offsetting programmes to enhance some environmental services such as construction of artificial reef, replanting of mangroves and fish stocking.

While the economic gain from the Project outweighs this loss of environmental services, the parties affected by this loss, especially the fishermen community, must be supported so that their livelihood is not adversely affected by the Project. The support can be in the form of *ex-gratia*/compensation, training and employment scheme, improved facilities and others measures as discussion in *Chapter 8: Mitigation Measures*.