Literature Review on Practices of Deep Cement Mixing (DCM) Overseas

1. DCM operation in Japan and turbidity/suspended solids monitoring results

From literature review, DCM operation is being practiced for marine works in Japan since 1970s. The cases below are some DCM operations with turbidity or suspended solids monitoring.

A. DCM operation at Yawatahama harbor

DCM works were operated in 1978 – 1979. One DCM rig with six shafts was used. Location of DCM operation is presented in **Figure 1(a)**.

Turbidity monitoring results before DCM operation were 2.7 ppm at upper level and 2.2 ppm at lower level. During DCM operation, the turbidity results at upper and lower water levels are presented as follow:

- At 20 m from DCM rig: 30 ppm at upper level and 15 ppm at lower level;
- At 50 m from DCM rig: 15 ppm at upper level and 7 ppm at lower level;
- At 100 m from DCM rig: 6 ppm at upper level and 5 ppm at lower level; and
- At 200 m from DCM rig: 5 ppm at upper level and 3 ppm at lower level.

The original figure showing the turbidity results is presented in **Figure 1(b)**.

B. DCM operation at Port of Tokyo

DCM works were operated in 1981 – 1982. One DCM rig with 6 shafts was used. Locations of DCM operation and water quality monitoring are presented in **Figure 2(a)** and **Figure 2(b)** respectively.

Monitoring of turbidity was carried out at different stages including baseline, pre-operation, impact (operation), post-operation and post-work monitoring. Turbidity at 50 m to 200 m from the DCM rig ranged 4 – 8 ppm at upper water level, 2 – 5 ppm at middle water level and 1 – 3 ppm at lower water level. The original figure showing the turbidity results is presented in **Figure 2(c)**.

C. DCM operation at Inner Tokyo Bay

DCM works were operated in 2005. One DCM rig with three shafts was used. There were six major water quality impact monitoring stations locating 450 – 700m from DCM works. Their locations are shown in Plate 3(a). Levels of suspended solids (SS) was monitored once per week.

Monitoring result of SS is shown in Plate 3(b). SS levels throughout the DCM works were below the criterion of 50 mg/L. Average SS level was 3.1 mg/L, while SS ranged 0.3 mg/L to 6.4 mg/L. Differences between downstream impact and upstream control SS levels ranged from -79 % to +30 % and mostly well-below +30 %.

D. DCM operation at Haneda Airport D-runway

DCM works were implemented for construction of part of the runway from late-September 2007 to mid-February 2008, as presented in **Figure 4(a)**. A maximum of four DCM rigs were used: three rigs with eight shafts for each rig; and one rig with four shafts.

Six water quality monitoring stations were located at 1 km to 2 km away from the DCM works site. Location of these monitoring stations is presented in **Figure 4(b)**. Three water levels (upper, middle and lower) were monitored for level of suspended solids.

At the upper water level, average SS level was 4.1 mg/L (ranging from 0.6 to 30.5 mg/L); At the middle water level, average SS level was 2.8 mg/L (ranging from 0.0 to 18.6 mg/L); At the lower water level, average SS level was 8.6 mg/L (ranging from 1.3 to 28.3 mg/L). Graphs of the SS monitoring results are shown in **Figure 4(c)**.

E. DCM operation at seawall of New Marine Disposal Site in the Port of Tokyo

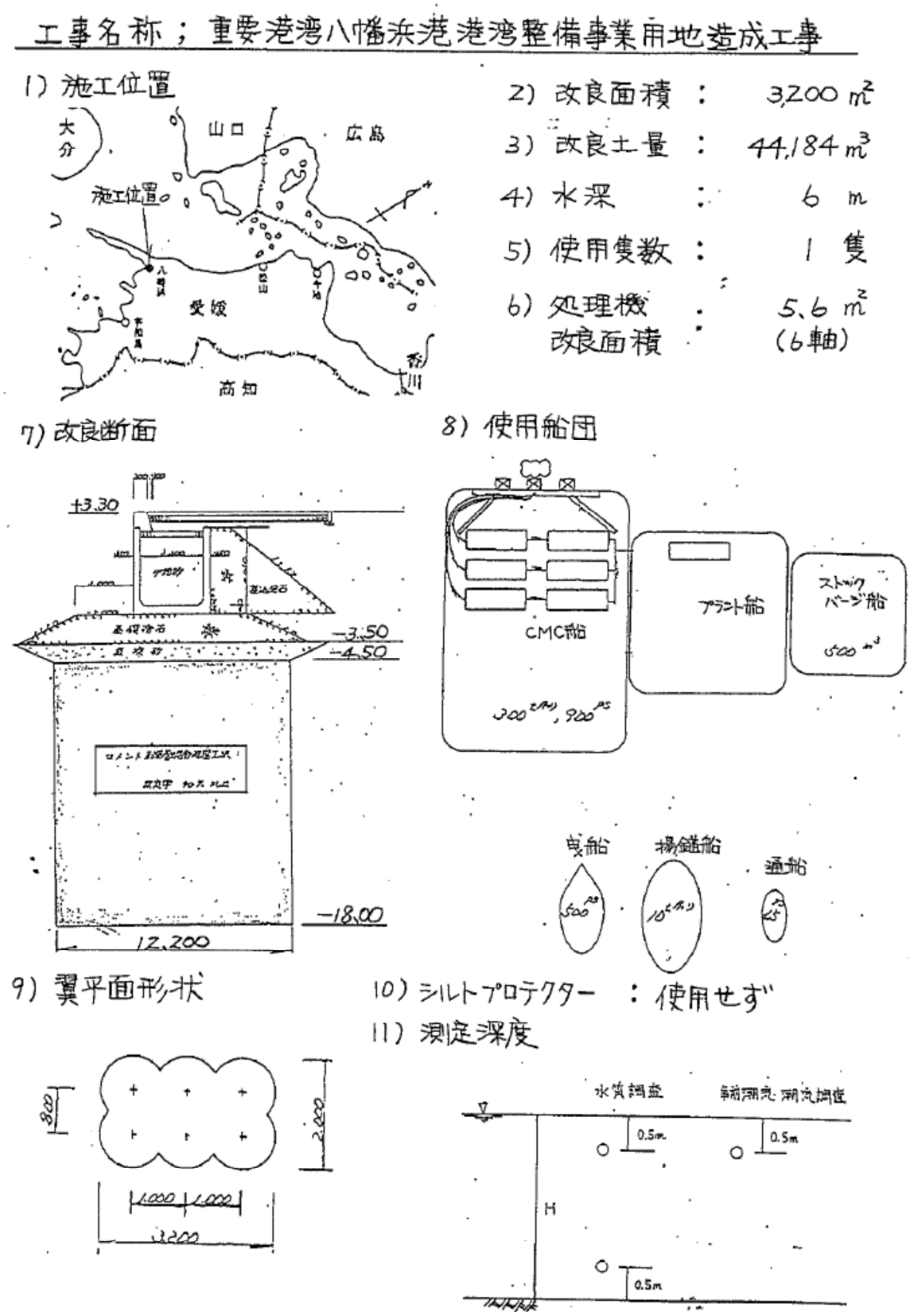
DCM works were operated in 2012. Two DCM rigs with four shafts for each rig were used. Location of DCM works is presented in **Figure 5**.

Two water quality monitoring stations were located at 340 m and 580 m away from the DCM works site, as shown in **Figure 5**. Three water levels (upper, middle and lower) were monitored for level of suspended solids.

Information on SS monitoring result is presented in **Figure 5**. At the upper water level, SS level ranged 1 – 4 mg/L; At the middle water level, SS level also ranged 1 – 4 mg/L; At the lower water level, SS level ranged 1 – 8 mg/L.

Figure 1: Information sheet on DCM operation at Yawatahama harbor (in Japanese)

(a) Part 1 – details of DCM operation



(b) Part 2 – details of water quality monitoring

Jul 1978 ~ Mar 1979

工期 ; S 53.7 ~ 54.3

6 軸

12) 調査項目および測定方法

調査項目		調査位置
事前潮流調査		② (固定点)
水質調査	pH, 濁度, 透明度	① ~ ⑩
	SS, Ca^{2+}, 水温, 塩分濃度 COD, DO	①, ②, ⑤, ⑧
潮流調査		② あるいは ①~⑩

水質調査は、右調査位置において、採水し、試料を室内に持ち帰り、各々の方法により分析。

- pH … ガラス電極法によりpH計で測定
- 濁度 … ポイッフ積分球式濁度計により測定

13) 測定結果 (pHおよび濁度) ~ サンドマットなし

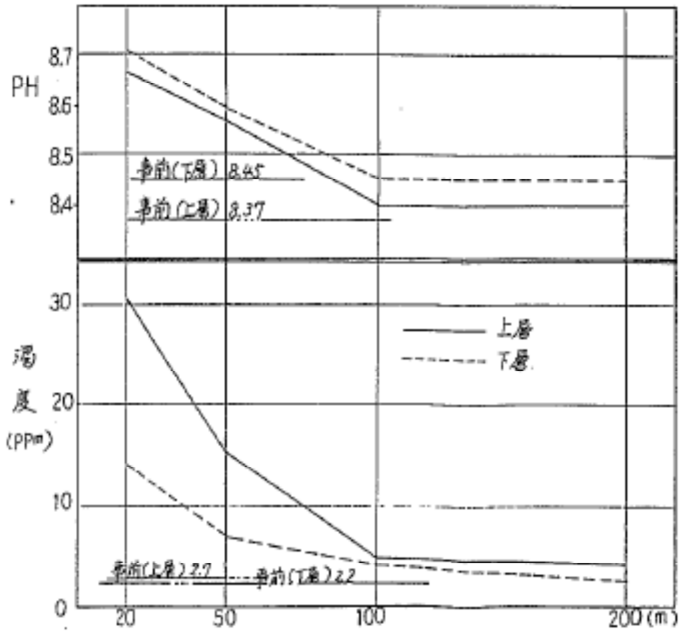
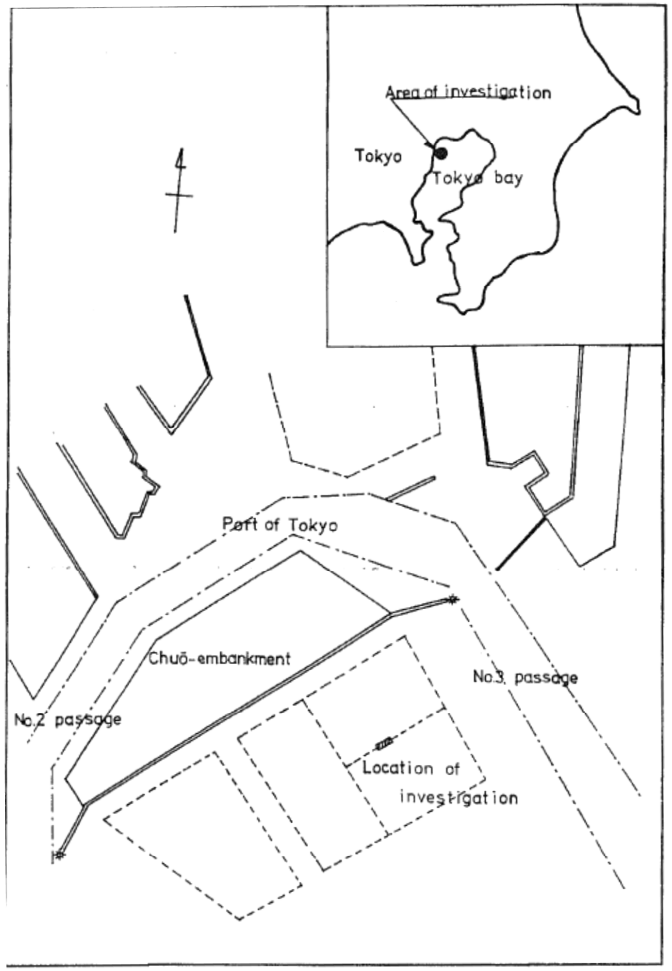


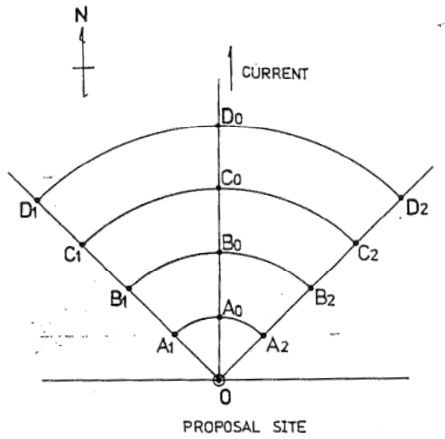
Figure 2:Information sheet on DCM operation at Port of Tokyo

(a) Location of DCM operation



図－17　調 査 海 域

(b) Water Quality Monitoring Locations



図－18　調 査 地 点

○ 透視度

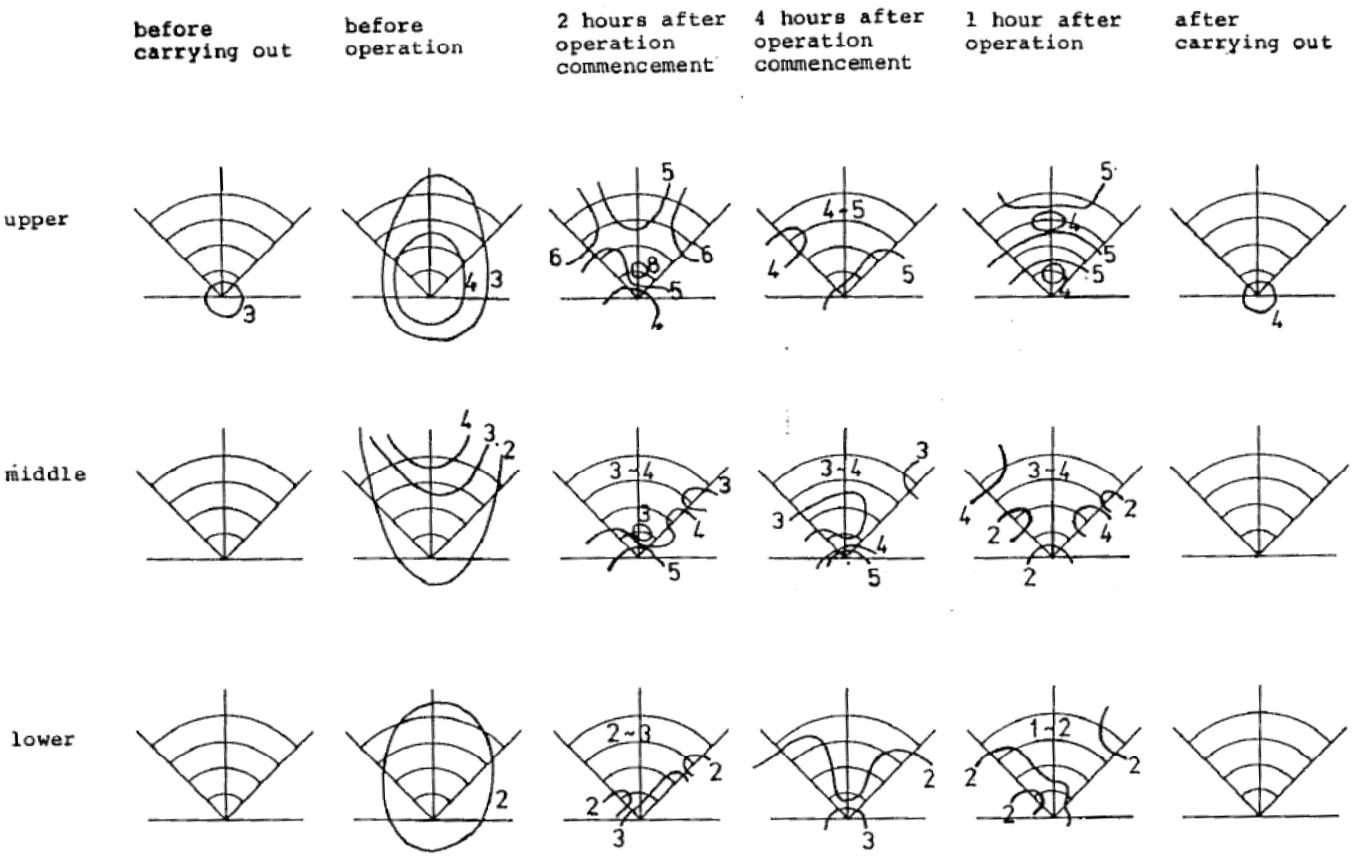
いずれの場合とも，各調査地点における透視度は，３０cm以上の値を示した。

○ 濁　度

各調査時における濁度の測定結果については，図－１９に示すとおりである。

これをみると，作業開始前には平均で上層部4.1 ppm，中層3.0 ppm，下層2.5 ppm程度の値となっていた。そして，工事中の濁度の分布状態を，施工地点からの距離の程度，各層ごとにそれぞれそれらの平均値で比較してみると，当然のことながら，作業開始２，４時間後には，施工地点寄りの地点程高目の値いを示す傾向が認められ，０m（St．0），５０m（St．A_0）地点では4.0 ppm を越える若干高目の値がみられた。また上層部では，4.1～5.5 ppm 程度の若干高目の値が認められたが，中層では3.0～3.5 ppm，下層では2.0～2.6 ppm と作業開始前と余り変化なく，下層部程低い値となっていた。このように，

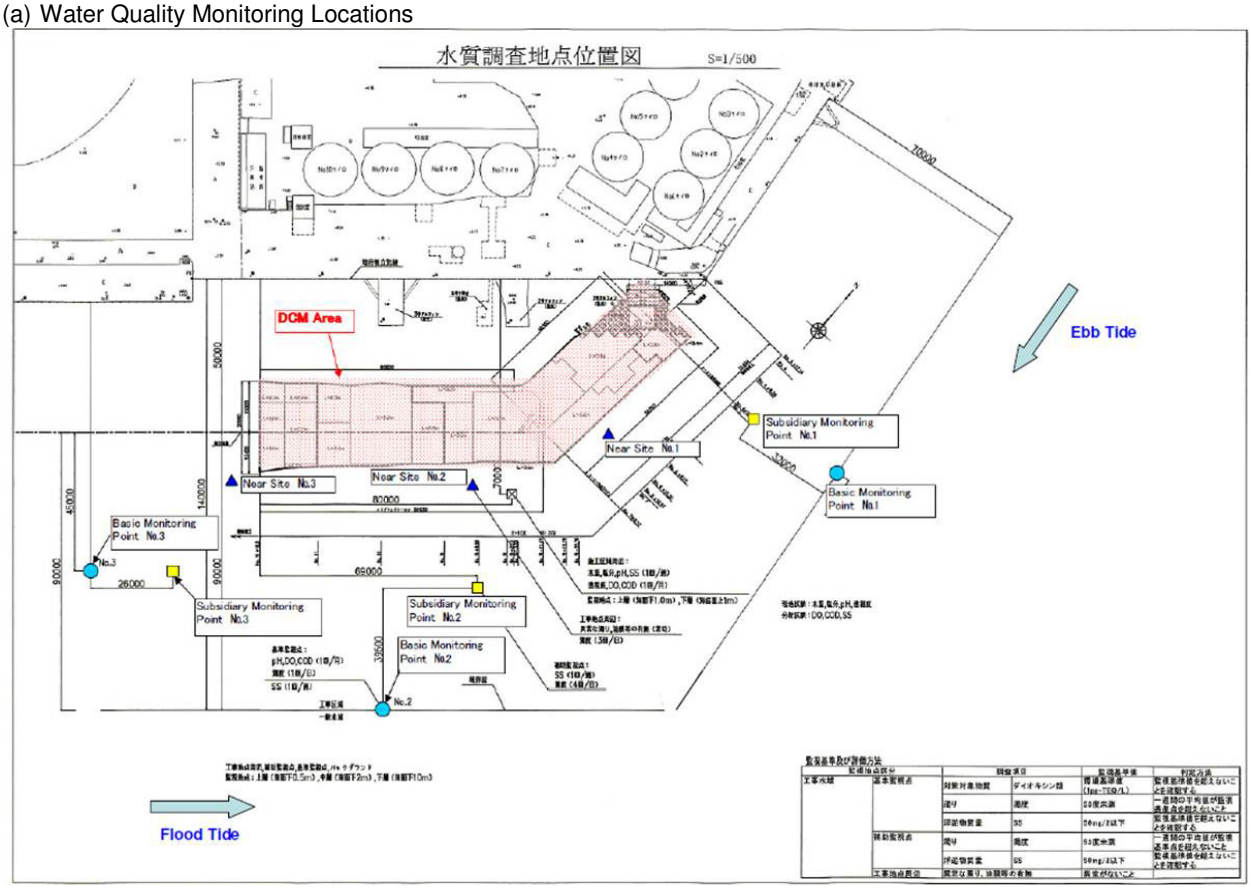
(c) Water Quality Monitoring Results



図－19　濁度の分布（ppm）

Figure 3:Information sheet on DCM operation at Inner Tokyo Bay

(a) Water Quality Monitoring Locations



(b) Suspended Solids Monitoring Result

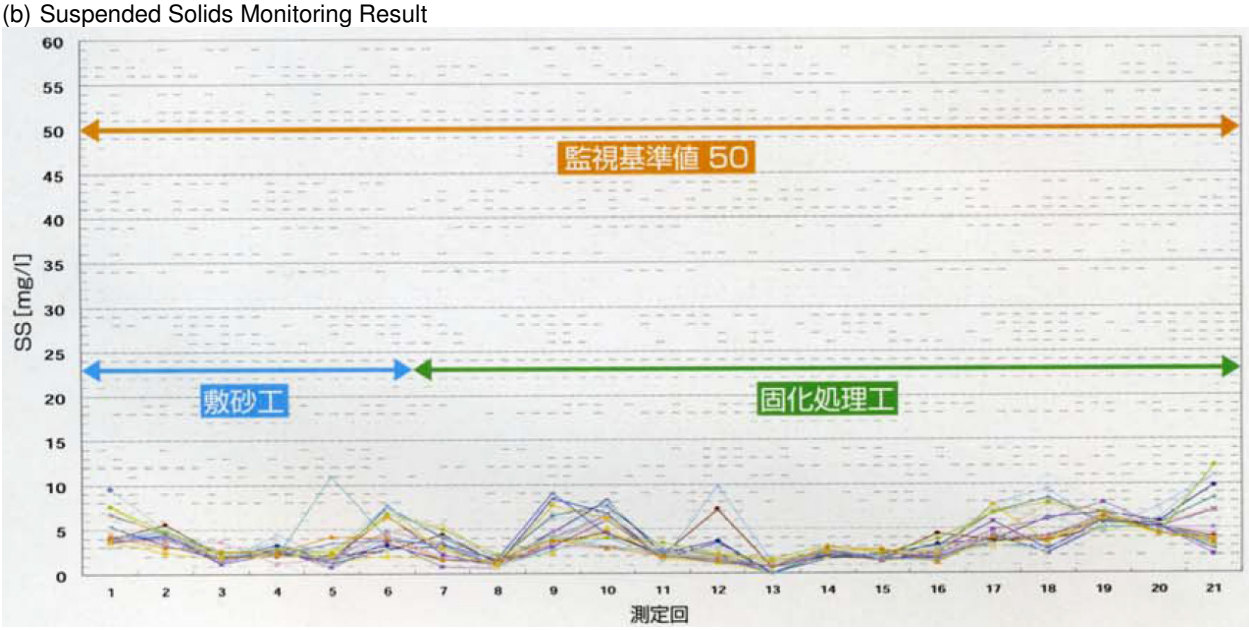
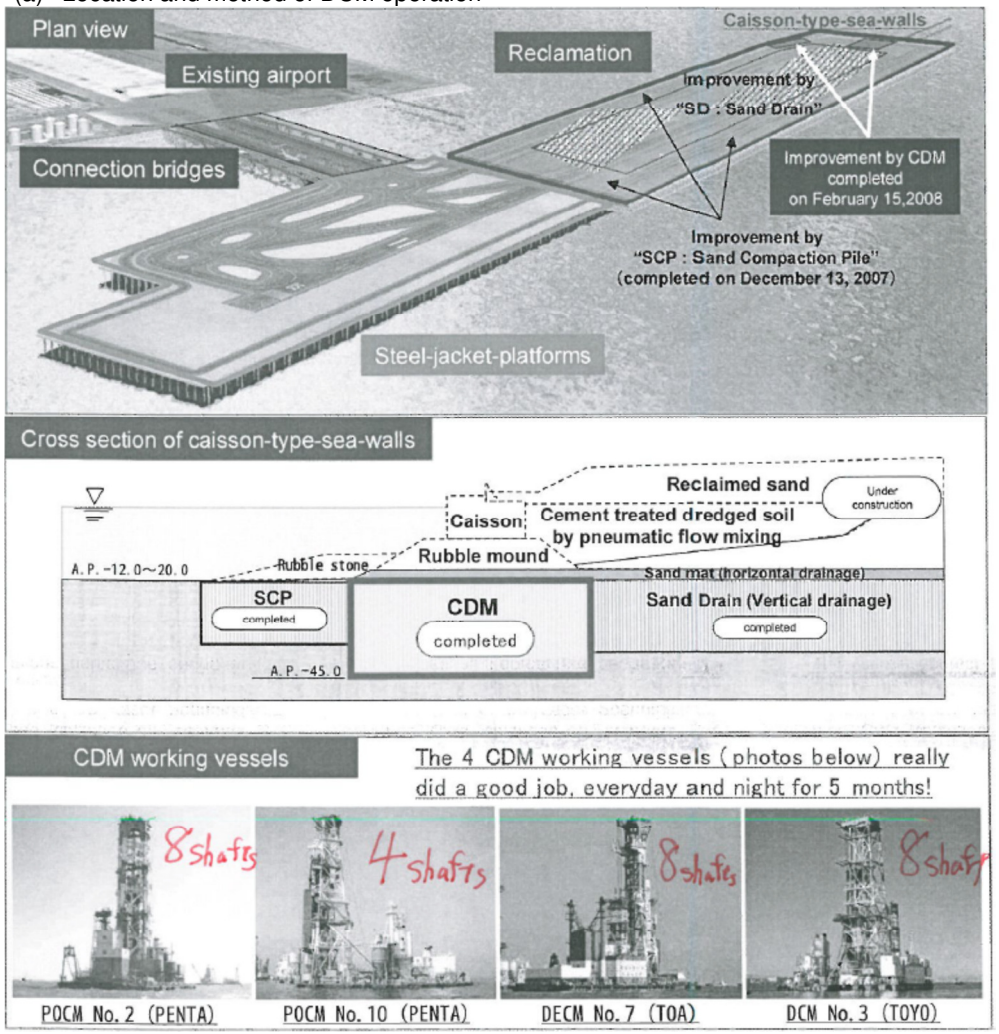
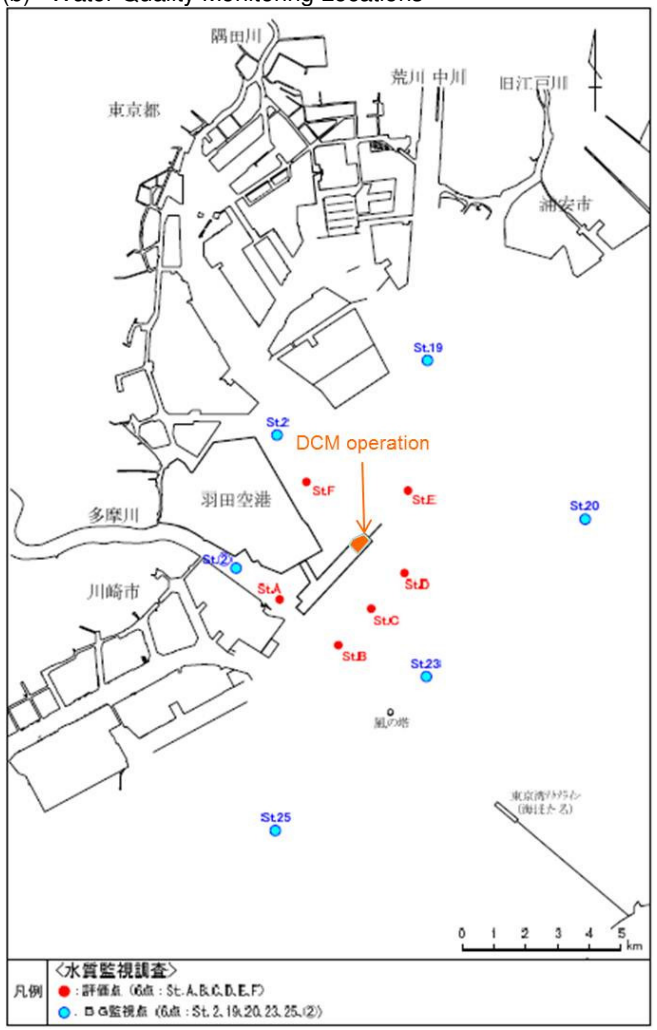


Figure 4:Information sheet on DCM operation at Haneda Airport D-runway

(a) Location and method of DCM operation



(b) Water Quality Monitoring Locations



(a) Suspended Solids Monitoring Results

図1－1 水質監視結果（毎日・機器計測） 平成19年度：H19.3.30～H20.3.31

Figure 5: Information sheet on DCM operation at seawall of New Marine Disposal Site in the Port of Tokyo (in Japanese)

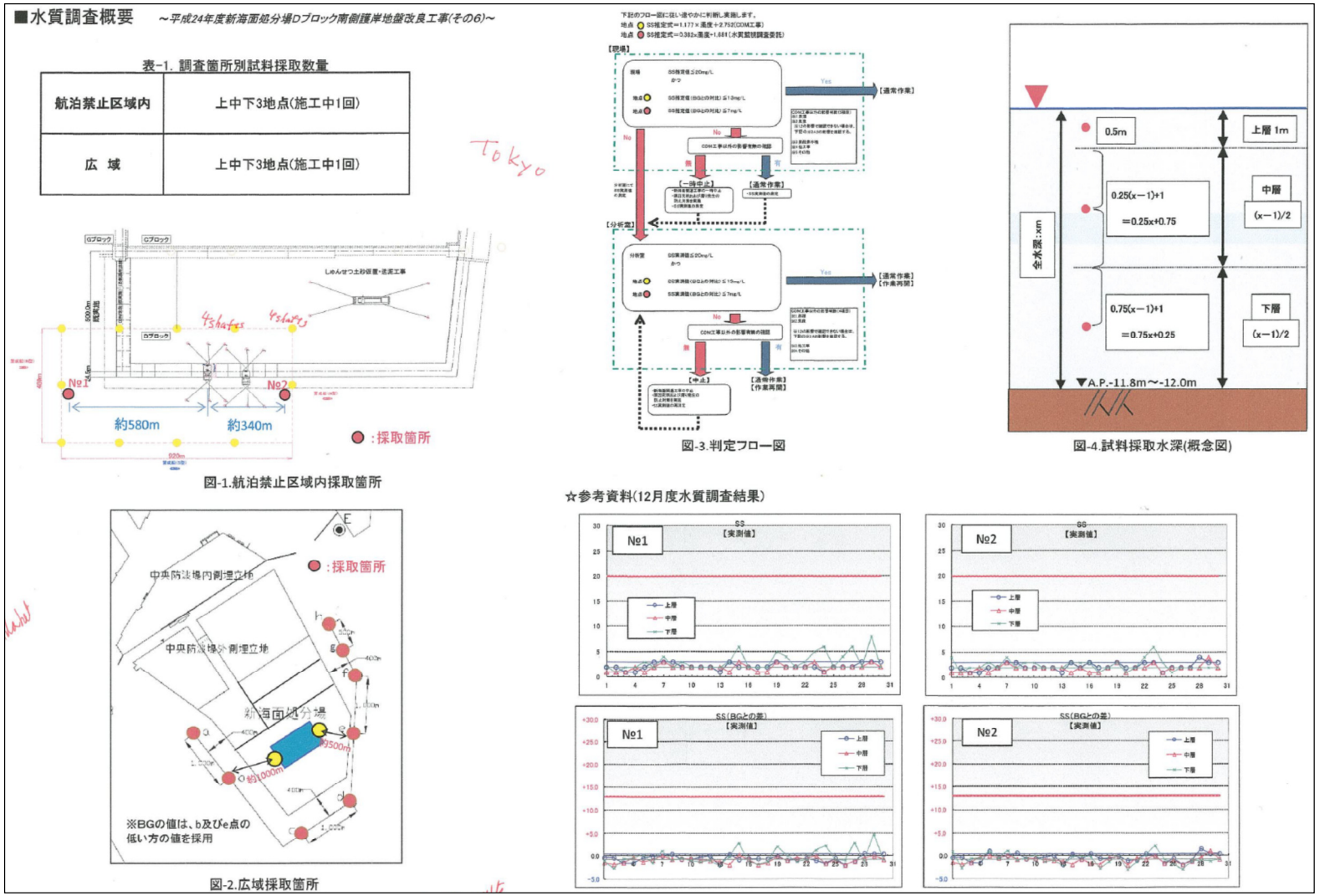


Table 1: Summary of DCM operation in Japan and suspended solids monitoring results

Case and Location	No. of DCM rig	No. of shafts per DCM rig	Distance of monitoring locations from DCM rigs	Average/Range of SS level (mg/L)
A. Yawatahama harbor	1	6	20 m 50 m 100 m 200 m	(Turbidity in ppm) Upper: 30; Lower: 15 Upper: 15; Lower: 7 Upper: 6; Lower: 5 Upper: 5; Lower: 3
B. Port of Tokyo	1	4	50 – 200 m	(Turbidity in ppm) Upper: 4 – 8 Middle: 2 – 5 Lower: 1 – 3
C. Inner Tokyo Bay	1	3	450 – 700 m	3.1 (0.3 – 6.4)
D. Haneda Airport D-runway	4	8 (for 3 rigs); 4 (for 1 rig)	1 – 2 km	Upper: 4.1 (0.6 – 30.5) Middle: 2.8 (0.0 – 18.6) Lower: 8.6 (1.3 – 28.3)
E. New Marine Disposal Site in the Port of Tokyo	2	4	340 – 580 m	Upper: 1 – 4 Middle: 1 – 4 Lower: 1 – 8

2. DCM operation in New Jersey, USA and suspended solids monitoring results

A demonstration project was conducted in New Jersey (NJ) of the United State of America (USA) to investigate the feasibility of using Cement Deep Soil Mixing (CDSM) in-situ solidification/stabilization technology to treat highly contaminated sediments. The study area was located at the Darling International Site waterfront area in Newark Bay, near the mouth of the Passaic River, as shown in **Figure 6(a)**.

Total Suspended Solids (TSS) was measured prior to, during and after the CDSM was conducted. The TSS survey area is shown in **Figure 6(b)**.

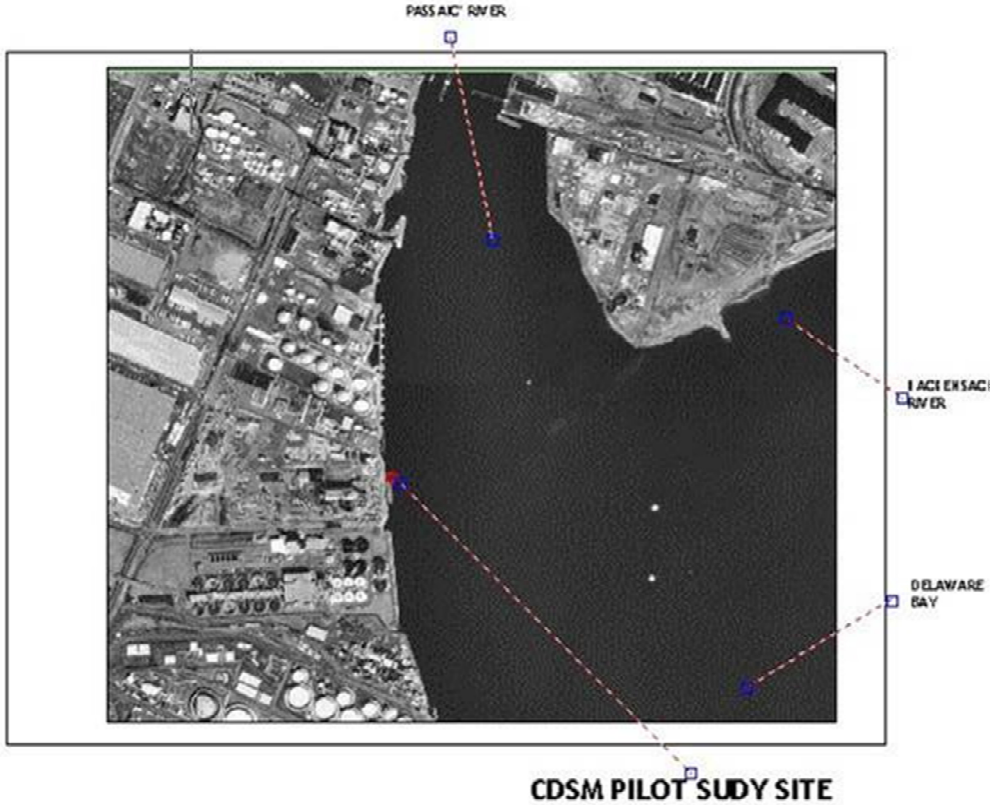
Background TSS results indicated that TSS increases with water depth, in which such increase is typical of low-flow rivers such as the lower Passaic River. During CDSM operation, while TSS concentration reached levels as high as 437 ppm at 27 feet depth, there was no measurable increase in TSS at 9 feet and 18 feet depth. The result of TSS concentrations at various measured depths is presented in **Figure 6(c)**.

Monitoring data were also evaluated with respect to distance from the mixing operations to evaluate the areas of high TSS, and the result is shown in Plate 6(d). While the CDSM equipment was operating, there was a significant correlation between TSS and distance from the mixing area in both horizontal and vertical planes. Specifically, while sample locations at a distance of 0 to 75 feet from mixing operations exhibited TSS as high as 437 ppm, the TSS dropped to background at locations 135 feet from the mixing area. The highest TSS concentrations corresponded to samples collected at 90 % depth, while samples taken at 15 feet or less (33 % depth) were indistinguishable from background even in the 0 to 75 foot radius from CDSM augers. At distances between 75 and 125 feet, samples taken at 25 feet or less (66 % depth) were at background. Once outside of a 125 foot radius, no samples were greater than background, regardless of depth.

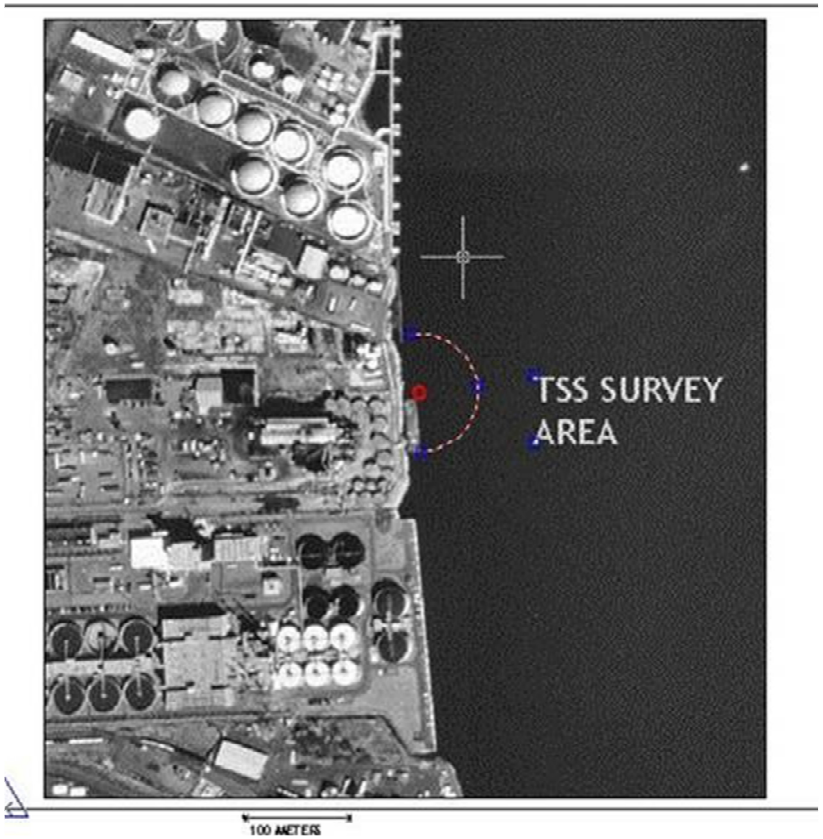
The results indicate that noticeable TSS increases over background in the vicinity of the mixing operations were detected. However, this phenomenon was highly localized, with increased TSS observed only slightly over the background at depths greater than 25 feet and locations at 75 to 125 feet from the mixing activities. TSS concentration levels were no longer distinguishable from background values at 125 feet or more from the mixing activities, irrespective of depth.

Figure 6:Information on Cement Deep Soil Mixing (CDSM) operation in New Jersey

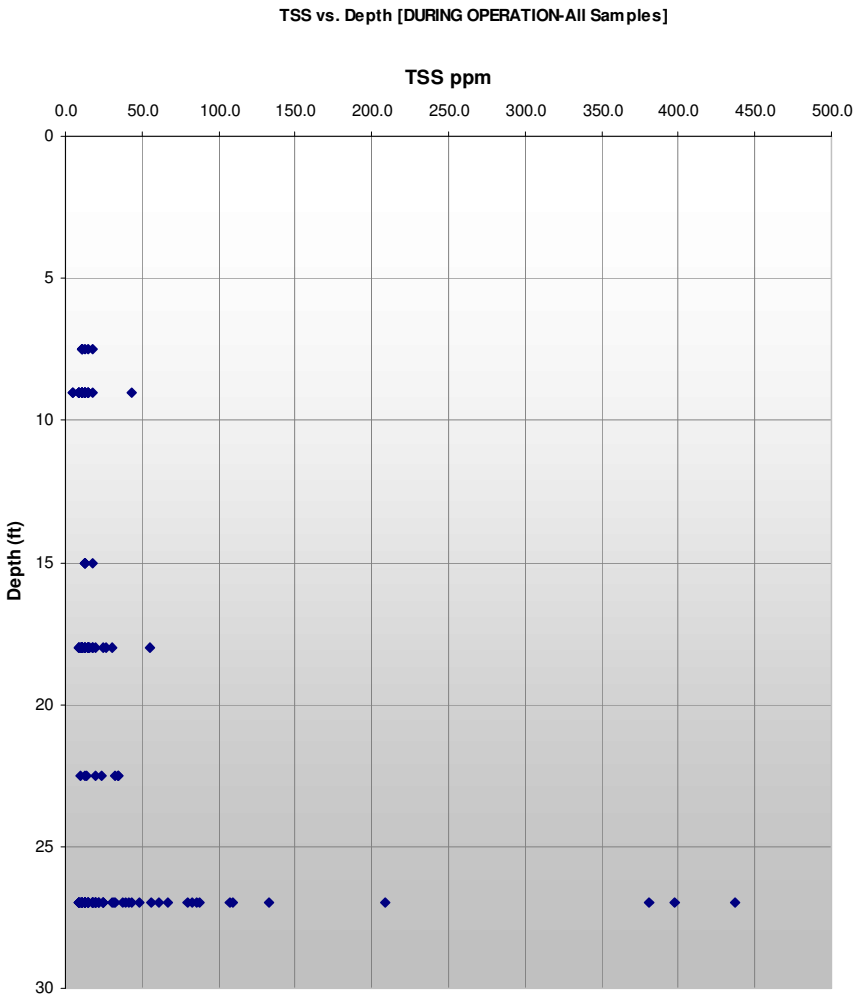
(a) General Study Area

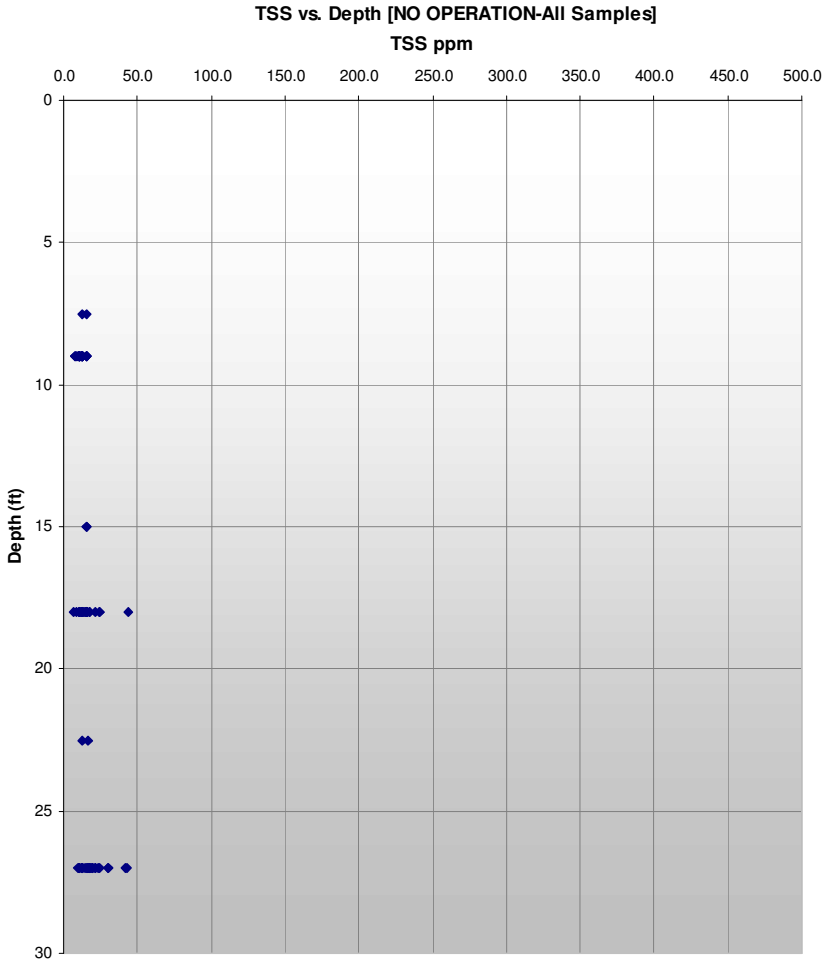


(b) Total Suspended Solids (TSS) Survey Area



(c) TSS vs. Depth without and during CDSM operations





(d) TSS Concentration vs. Distance from CDSM operations