Distribution of total suspended sediment concentrations in shallow coastal water off the Muda Estuary, Malaysia

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Abstract

Field measurements have been conducted in order to obtain distribution of total suspended sediment (TSS) concentrations in the coastal water off the Muda estuary, northwest of peninsular Malaysia. In addition, five AVHRR satellite images covering the study area of about 10-15 km^2, were analyzed to produce maps of TSS concentrations. The relatively shallow (i.e. 2-5 m water depth) coastal water, with very fine sediments overlying the seabed, receives a continuous discharge of brackish water from the Muda estuary throughout most of the year but the discharge may abruptly change to primarily freshwater during wet seasons. Results showed that TSS concentrations were consistently higher in coastal water vis-à-vis the estuary, indicating the influence of resuspension of seabed sediments by wave activities in the shallow coastal region that enhance the average TSS value originated from the Muda estuary. On spring tides the maximum TSS values were 440 mgl^{-1}, and this value decreased to about 290 mgl^{-1} on neap tides. The higher TSS values during spring tides in comparison with the neap tides conform to the fact that the back and forth sloshing effect of the tide was relatively more intense during the former.

The abovementioned findings were found to be more or less in harmony with AVHRR satellite images of the region. TSS concentration maps showed that high TSS values occurred in the similar coastal water region that was being directly influenced by the Muda estuary discharge.

Keywords: *river discharge, total suspended sediment, tide, coastal water, satellite image*

I. INTRODUCTION

Earlier work by Bakar *et al.* (2002) have recognized that the discharge of the Muda River into the adjacent coastal water forms a layer of brackish water overlying more saline seawater. The observations reveal a highly variable system in which the influence of the freshwater input from the Muda extends northwards from the source and out to 3- 4 km from the coast. They also found that the discharge plume dynamics was the result of inertia, mixing by tides and winds. This paper describes temporal and spatial variations of TSS concentrations associated with such a region of fresh water influence. The objective is to determine how major physical forcings i.e. river discharge and tides influence the accumulation and dispersal of the TSS over the coastal region. Furthermore, suspended sediments within this region can also act as natural tracers detectable by Landsat TM bands (see for example Dinnel *et al.*, 1990).

II. STUDY AREA

The Muda River is located in the northwest of peninsular Malaysia (within latitudes 5^{0}34' N to 5^{0}36' N and longitudes 100^0 19' E to 100^{0}21' E) as shown in Figure 1. The catchments area of the Muda is estimated as 4300 km^2. Tide in coastal area is semidiurnal with observation maximum tidal height varies between 2.8 and 4.1 m (Figure 2). Figure 3 shows a plot of river discharge which was taken at Ladang Victoria station situated about 20 km upstream. River discharge data is believed to be more reliable to use in the analysis compare to rainfall data since the former may be localized in nature. Water depth was less than 5 meters within the study area where clay and mud will be exposed during low tide particularly in the north of the estuary mouth. Coarser grain sediments i.e. sand, however, is predominantly covering areas just outside the estuary mouth as well as in the south. The regional climate is dominated by the northeasterly monsoon from November to March and the southwesterly monsoon from May to September. There are two peaks in the mean annual rainfall, a larger one in September-October and a smaller one in April, correspondingly to the inter-monsoonal periods.

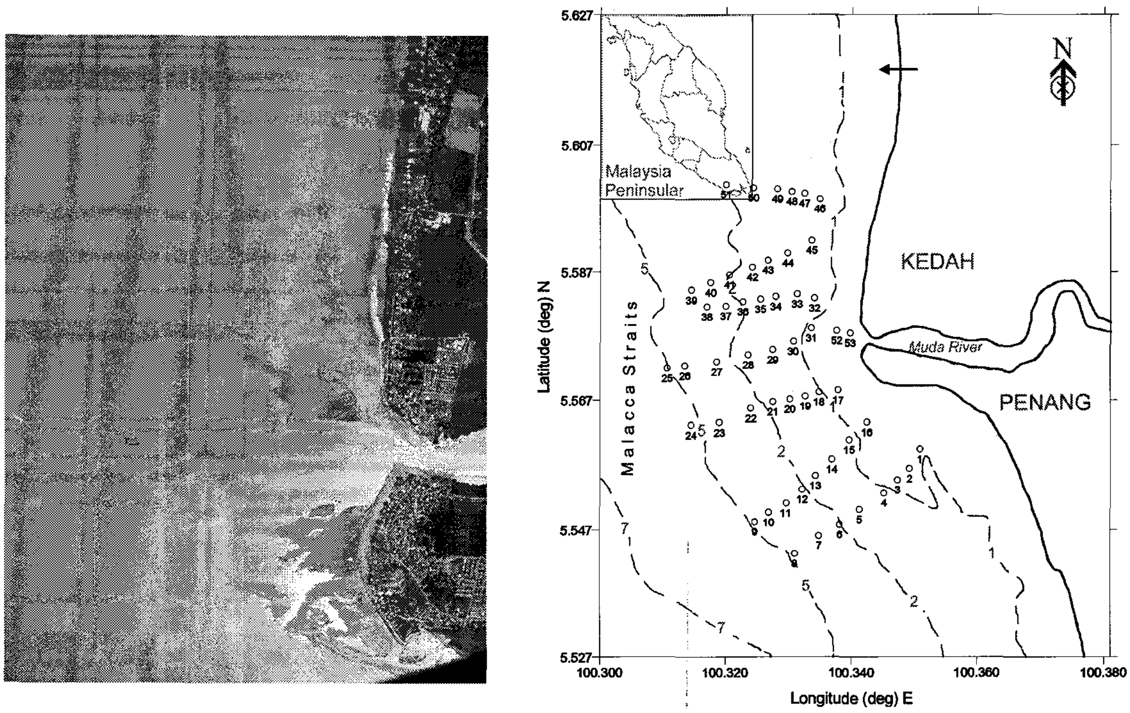

Figure 1. Map of the coastal area under investigation. Left panel is aerial digital image taken on 20 January 2002 during ebb phase of neap tide. Right panel shows bathymetry map in meters where the numbers and circle signs indicate the location of stations for field survey on 7 April 2002.

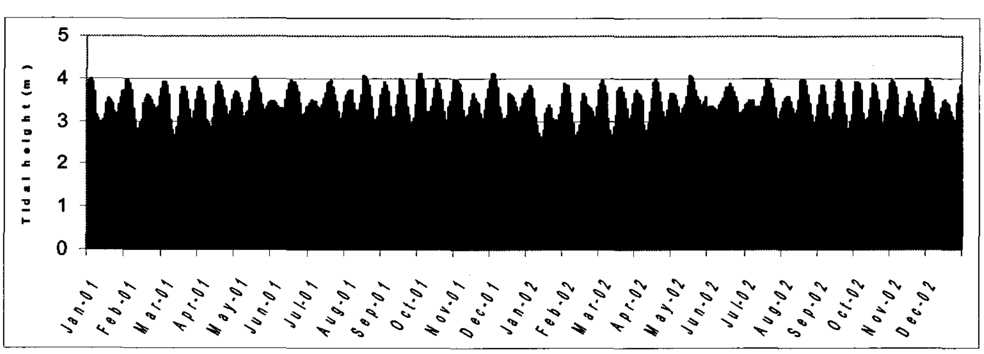

Figure 2. Observation of maximum tidal heights (m) at Swettenham Pier for the year 2001-2002.

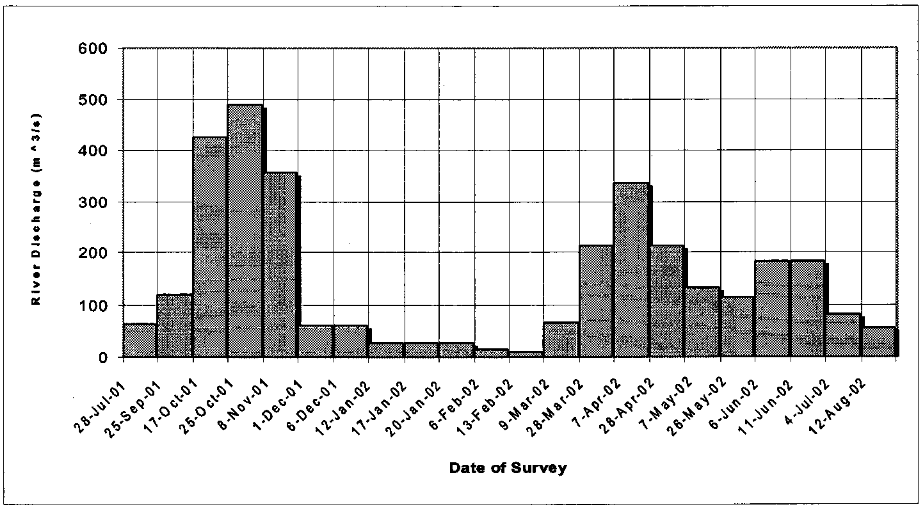

Figure 3. Discharge of the Muda river for year 2001 and 2002 taken at Ladang Victoria sampling station. (Data from Drainage and Irrigation Department, Malaysia).

III. METHODOLOGY

Field measurements were conducted during spring and neap tide in the year 2001-2002 (Table 1). A local fishing boat was used for data collection. The locations of the stations were fixed with hand held global positioning system (GPS), manufactured by Garmin.

Temperature and salinity measurements were carried out using an instrument YSI 30 SCT meter. Water samples were taken from the surface water and were analyzed for TSS in the laboratory. Filtration procedure followed standard methods for examination of water and wastewater (Greenberg *et al.*, 1992). Glasfaser Rundfilter (GF 52) glass fiber filters (ø 47mm) were dried at 105 ^{0}C in Contherm Digital Series oven for 24 hours as dry preparation. Dry weight was recorded and place in the aluminum dish. Each sample (100 mL) was filtered through a filter driven by vacuum pump (model GAST-P). After filtration, the filter was dried in an oven at 105^{0}C for 24 hours, cooled in a desiccator and then reweighed with analytical balance (Denver Instrument AA 200) accurate to 0.0001 grams, to determine the total suspended solids. The calculation of TSS as follows:

$$TSS, mg/l = \frac{(A-B)\,\text{x}1.000}{C}$$

Where:
A = weigh of filter + residue in mg
B = weigh of filter in mg
C = volume of water sample filtered in mL.

IV. RESULT AND DISSCUSSIONS

Spring tide

All surveys of TSS concentrations carried out on spring tide (Figure 4) consistently showed high TSS values (> 250 mgl^{-1}) in front of the estuary mouth. However during high river discharge cases, the corresponding TSS values were surprisingly low for few cases and situated in the south of the estuary mouth. This outcome was unexpected and indicates that river discharge is not the primary source of TSS. This could be due to the nonstop erosion that is taking place at several spot of river banks have been largely reduced, after several days of constant rains, owing to weaker/loose layer of surface sediments have been removed.

Table 1. Summary of field survey dates, tides and the measured maximum TSS concentration.

No.	Date dd/mm/yy	Tides	Max TSS (mgl^{-1})	No.	Date dd/mm/yy	Tides	Max TSS (mgl^{-1})
1.	28/07/01	Neap	230	12.	13/02/02	Spring	440
2.	25/09/01	Neap	280	13.	09/03/02	Neap	260
3.	17/10/01	Spring	260	14.	28/03/02	Spring	305
4.	25/10/01	Neap	180	15.	07/04/02	Neap	220
5.	08/11/01	Neap	180	16.	28/04/02	Spring	300
6.	01/12/01	Spring	No data	17.	07/05/02	Neap	200
7.	06/12/01	Neap	210	18.	26/05/02	Spring	310
8.	12/01/02	Spring	360	19.	05/06/02	Neap	220
9.	17/01/02	Spring	280	20.	11/06/02	Spring	340
10.	20/01/02	Neap	290	21.	04/07/02	Neap	220
11.	06/02/02	Neap	No data	22.	12/08/02	Spring	340

Neap tide

Neap tidal currents are typically much weaker in magnitude than spring tidal currents. Consequently, TSS values were found to be lower (<250 mgl^{-1}) for all surveys during neaps (Figure 5) except in two cases where the values were higher than 250 mgl^{-1}. Unusually increased in wind (and wave activity) may be responsible for the higher TSS in the former cases.

Satellite image

Figure 6 shows a typical map of TSS distribution of the study area for the five Landsat images following the method discussed by Faisal (2004). High concentration (100 – 200 mg/l) of TSS on the generated maps is not reliable and anomalous to normal seawater conditions. It was found that these high values are resulted by hazy cloud covering the area. It is very difficult to remove the hazy clouds from the image. However, the concentration of TSS (> 200 mg/l) located in the front of the river mouth and along the coastline is valid due to high turbidity of the shallow coastal waters, which result in higher reflectance. Generally, high values of TSS were observed: (i) inside the estuary (ii) in the immediate vicinity of the estuary mouth and (iii) along the shoreline to the north and to the south of the estuary mouth. These values can be seen to decrease when moving offshore where the water depth increases to more than 5 m. Here the water column was less turbulence. As a result, the rate of the settling of sediment in the water column was enhanced causing the observed sudden reduction of the TSS value.

V. CONCLUSSION

Weak correlation exists between river discharge and surface TSS value, though there is evidence that increase in discharges produces higher TSS. Stronger spring tidal currents forced bed sediments into suspension, hence increase the TSS values whilst weaker neap tidal currents reduce TSS. Results show that tidal stirring controls mixing in the shallow study area thus surface distribution of TSS in the water column regime.

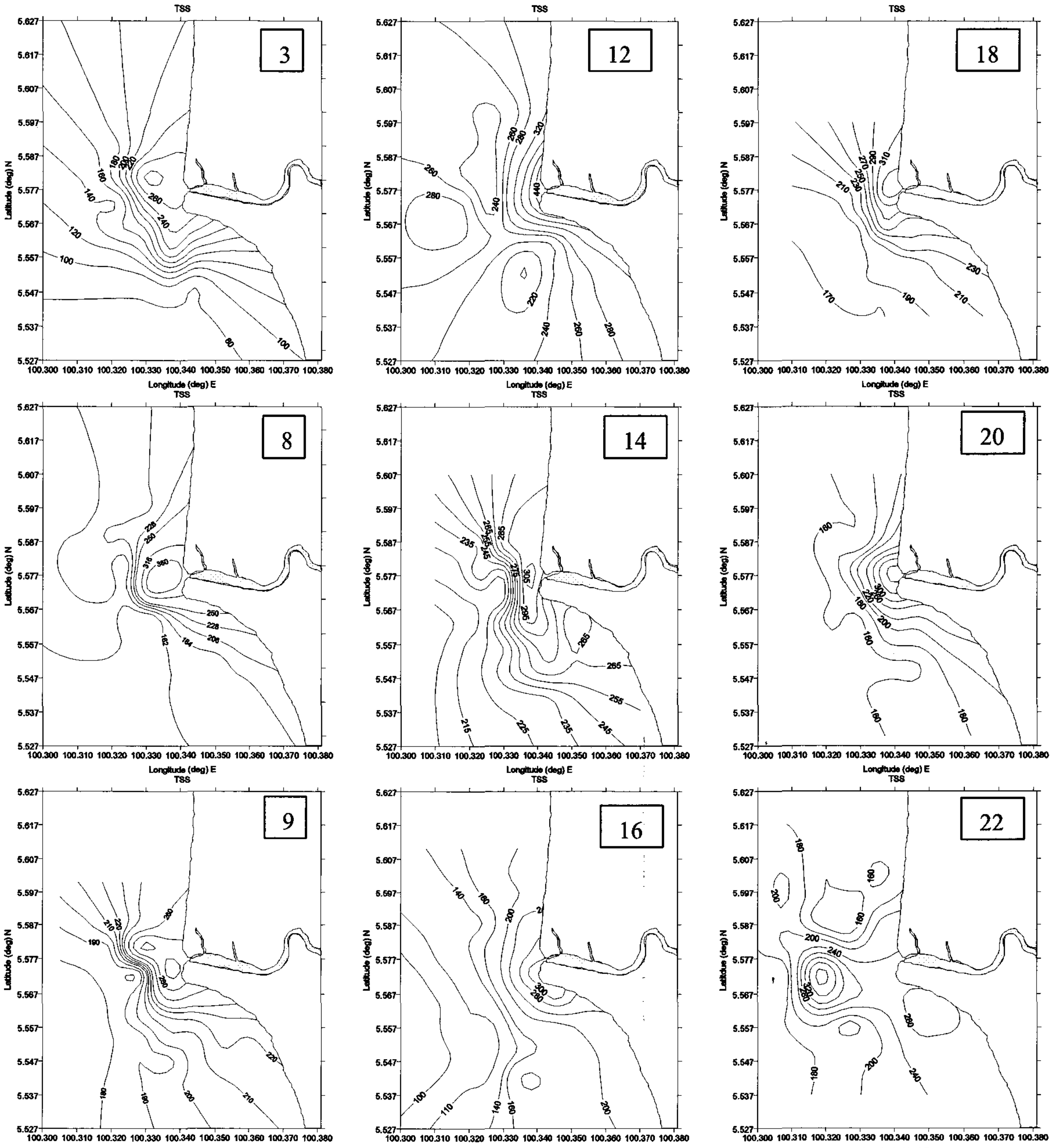

Figure 4. Distribution of all the TSS concentrations during spring tide period.
The number in the box indicated the date of survey as shown in Table 1.

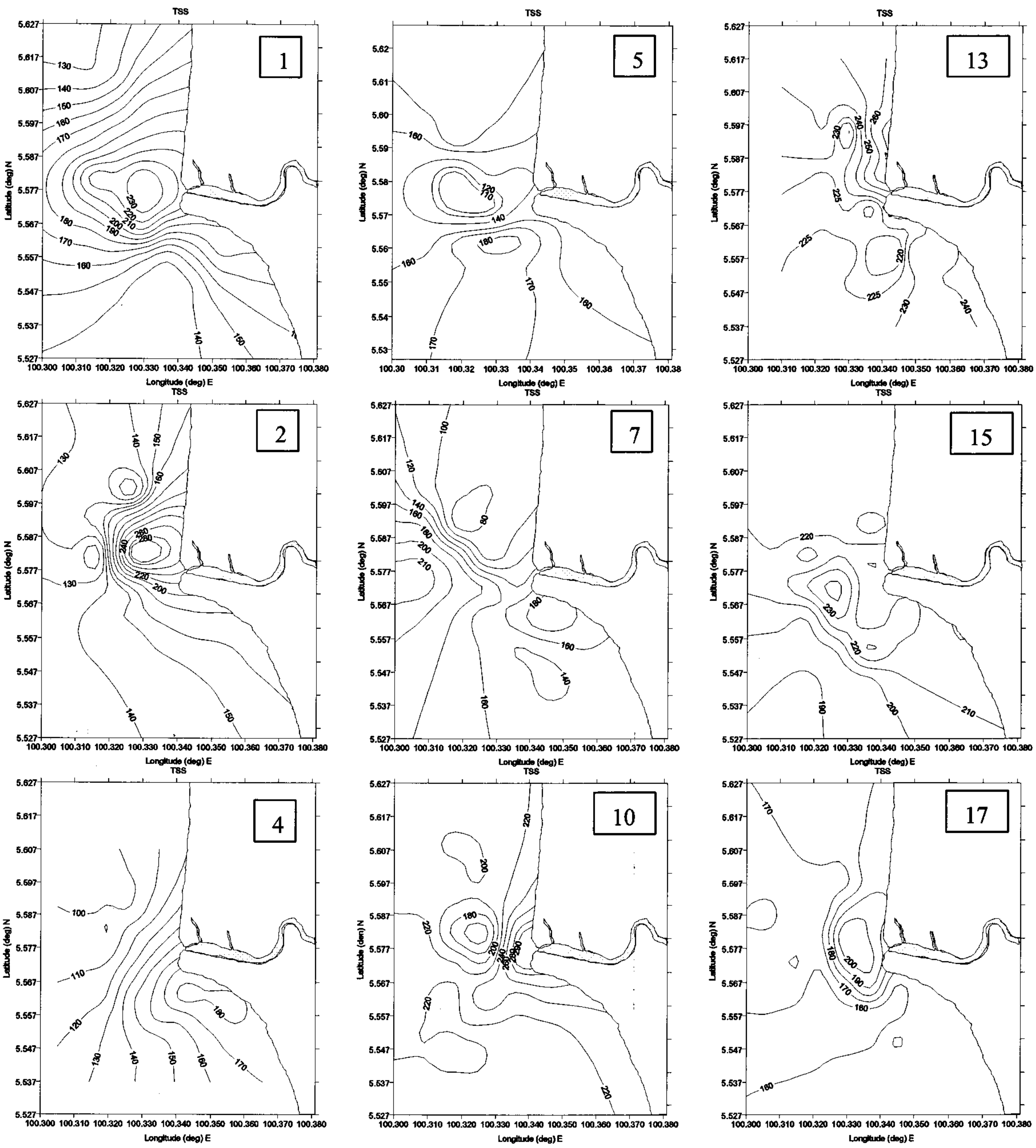

Figure 5. Distribution of all the TSS concentrations during neap tide period.
The number in the box indicated the date of survey as shown in Table 1.

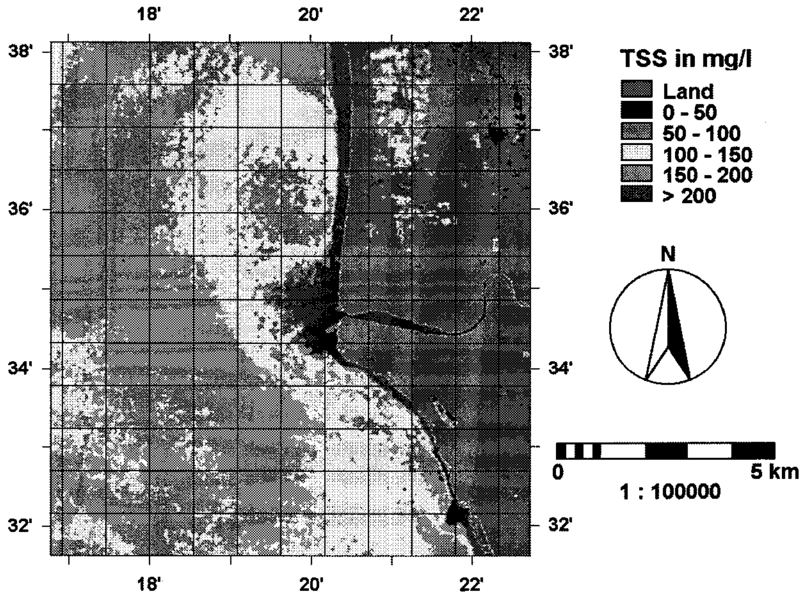

Figure 6. Satellite image showing a region of freshwater influence off the Muda estuary mouth. TSS value was relatively high (red colour) adjacent to the estuary mouth and to the north and south along the coastline.

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VI. REFERENCES

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