

# **Seasonal beach profiling along Malvan and Kotharwadi coast, southern Maharashtra central west coast of India**

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*National Inst. Of Oceanography, Dona Paula, Goa, India*

*2006*

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## **ABSTRACT**

Seasonal morphological variations and effect of oceanographic processes such as erosion or accretion along beaches are important to understand the nature of the beach and the cyclic changes occurring during different seasons. These studies are more significant in the areas where rich beach placer deposits are occurring. This will help in understanding replenishment of these heavy minerals in the area of interest. This report describes results of similar studies (beach profiling) carried out at Malvan and Kotharwadi coast, which is in southern part of Maharashtra along central west coast of India. Malvan is one of the most important prospective area for the heavy mineral placers of Ilmenite and Magnetite. Several techniques are available for collecting these data using different instruments. The required data was collected by using DGPS (Differential Global Positioning System) and Automatic level (Carl Zeiss make). following standard surveying techniques. Beach profiles at ten sites along Malvan and Kotharwadi beaches have clearly shown the specific zones of sand erosion and sand accumulation at various periods. Maximum sand accumulation is found at BP: 3 near Tondavali village during Dec. 2005, resulting to deposition of sand/mineral of volume upto 61.92 cu.meters, which is 57.56% more than the first season observation, which was in Oct. 2004. Another significant observance is the highest erosion found at BP: 4 near Tondavali village during Aug. 2005, resulting in loss of volume of sand/mineral upto 314.05 cu.meters, which is 139.5% less than the first season observation, which was in Oct. 2004. Such variations are due to oceanographic processes, operating in the area. This report analyses the field data collected at different seasons and presents the results with final processed beach profile graphs. The report also highlights the method involved and the instruments used in collection of the field data and processing.

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## **1.0 Introduction**

Shoreline changes and beach profile studies give information on cyclic/seasonal morphological changes, in the area. These studies are essential to understand the erosional and depositional features, which in turn helps in understanding changes in oceanographic processes in the coastal areas. In the areas where high concentrations of detrital minerals is present in form of placer sands, which is likely to be exploited in the near future. Such studies became more important to understand the replenishment of surficial mineral layers. Several techniques are available for collecting such data using different instruments. The present report analyses the results of the beach profiles carried out at different seasons along Malvan and Kotharwadi coast along south Maharashtra, as a part of CSIR network project, 'Capacity Building for Beach Placer mining'.

### **1.1 Physical setting**

The area under study stretches for a distance of 12 Kms. between Pirvadi in the north to Talashil in the south in Malvan taluka. The coastline here is a straight to semi arcuate and open. The beach bordered by protecting promontory on the southern side. The area has two river sources, one in the north (Achara river) and the other in the south (Gad river). The other area is Kotharwadi, which is about 40 kms. north of Pirvadi. The beach at Kotharwadi is semi arcuate in nature. In both the areas, the foreshore gradient is variable and the backshore is characterized by dune ridges of different heights and extent. The beach has a maximum width of 250 meters including backshore dunes. The tide range in the area varies from 0.1 to 2.0 meters and the area receives precipitation in the order of 2500 to 3000 mm, which is confined to the season of southwest monsoon during June to September. This season is also the period of maximum turbulence in the sea. ( Siddique et al., 1979 ). The predominant direction of the waves is from the southwest, west south, west and northwest directions with a period ranging from 5 to 14 seconds. For the waves of southwest, the tendency of sediment transport is mostly northerly and for waves from west-southwest and west, the sediment transport is not likely to be in one direction. For the waves from west-northwest, the sediment transport tendency is generally towards south ( Reddy 1976 ).

The long-shore transport rates are variable from north to south. It is greater towards south than in the north ( Chandramohan et al., 1989 ). The length of littoral transport zone, under uniform wave condition is largely governed by coastal configuration. The sea bed topography in the near shore is characterized by patchy uneven topography with rocky patches in the northern, central and the southern portion, generally upto water depth of 9 – 10 meters beyond which , it is even topography. The overall gradient is generally gentle to moderate.

## **2.0 Description and scope of study**

Under the CSIR network project on “Beach placer mining capacity building”, the institute has undertaken exploration program along south Maharashtra (south of 16° 30' N Latitude). In order to understand the seasonal variations in the beach morphology, which would give the idea about accretion and erosional trends in the study area, the beach profiling was taken up in the areas, where placer mineral concentration was appreciable. These areas are i) at Kotharwadi from Lat. 16° 28' 36.24 N & Lon. 73° 20' 28.11 E to Lat. 16° 28' 27.41 N & Lon. 73°20'34.09 E of Deogad Taluka and ii) at Malvan in a stretch from Lat.16° 05' 48.18 N & Lon. 73° 27' 38.68 E of Talashil to Lat. 16° 11' 42.37 N & Lon. 73° 26' 14.46 E of Pirwadi. The profiling was undertaken in four seasons: October 2004, April 2005, August 2005 and December 2005. The study includes establishing bench marks at ten places for carrying out beach profiles along Malvan and Kotharvadi coasts and beach profile studies with collection of field data. The report also highlights the method of survey and the technical aspects involved including final processed data output.

## **3.0 Methodology**

**i) Horizontal control:** The horizontal location (geographical co-ordinates) permanent benchmarks at eight places along Malvan coast and at two places along Kotharwadi coast, were fixed using Ceeducer DGPS (Differential Global Positioning System).

**ii) Vertical control:** The vertical control is essential to provide the height information for contours and spot heights in topographical mapping and for beach profiling. At all the selected places of study, bench mark pillars were established by carrying out leveling

from the tide level (at the time of observation) along the shore up to the benchmark. The tide level at the time of observation was later processed to get the vertical height of that point from the mean sea level. The vertical height (above or below mean sea level) thus obtained at the tide level point is then transferred to the benchmark (which was selected perpendicular to the coast) using level instrument. The benchmarks, thus fixed formed the base for comparing the beach profiles studied at various seasons. For beach profiling, an automatic level (Carl Zeiss make) with graduated staff and leveling shoes with Marker line, a rope (with clear marks at every 5 meter interval) were used. The tidal data was taken from Maharashtra's Minor Port Tide tables (2005), published by Hydrographer, Maharashtra Maritime Board, Mumbai.

As a regular practice, the calibration of all the survey instruments were carried out before commencing the actual survey, to eliminate all types of errors, while collecting the field data. The geographical co-ordinates for the permanent benchmarks (at selected ten places) were very precisely obtained using Ceeducer DGPS (Differential Global Positioning System), from where beach profile surveys were commenced. The beach profiling was then carried out at all ten locations (See Annexure: I ) using automatic level and a graduated staff, at every 5 meter intervals. Apart from this, extreme care was taken to take field measurements at such points, where sudden rise and fall was existing, on the path of profile. The profiling was started from east to west (i.e from shore to seaward). The last reading was taken in the surf zone and at that observation, the exact time was noted to read the corresponding tide. The collected field data was taken to laboratory for processing. The final beach profile graphs were prepared and were used for computation of sand quantity (either eroded or accumulated).

### **3.1 Equipment used**

#### **i) Ceeducer DGPS (Differential Global Positioning System)**

A Ceeducer make DGPS with RTCM corrections, was used for obtaining the geographical co-ordinates (Horizontal control) of the permanent benchmarks, to extreme precision.. Ceeducer is a small, single unit, versatile survey instrument that provides GPS position as well as digital echo sounder (Dual frequency) depth. This instrument has the facility of about 7.2 hours of full data logging of position and echo-sounding data.

It has an integrated GPS receiver, an electronic processor and data logger. The instrument was used as a Differential GPS position fixing system, as it has integrated differential receiver, which can receive differential base station corrections from the nearest Marine Beacon receivers. The GPS positional accuracy of this system is 2 to 3 meters using 8 channel and less than 1 meter using 12 channel with DGPS. The accuracy of the echo-sounding depth varies from 20 cms. to 2 cms. (L1 channel) and 2 cms.(L2 channel). The data logging is normally every 2 seconds with full position and all echo-sounder depths. The system has a download utility, to transfer the logged data from CEEDUCER RAM to a file on a Personal Computer.

## ii) Automatic Level (Carl Zeiss make)

An automatic level instrument (Carl Zeiss make) and a graduated leveling staff were used for carrying out beach profiling surveys at all selected ten places. This instrument can perform with high degree of accuracy. The accuracy of the instrument is  $\pm 1$  mm. for distances of 1 Km. length. The least count of the leveling staff used is 5 mm.

### 3.2 Establishing reference bench mark pillars

Reference bench mark pillars are essential for the following two reasons:

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- a) To fix the geographical location of every profile, and
  - b) to fix the vertical heights of all the reference pillars, to get vertical heights of every data (along the profile) above M.S.L.
- 

Based on the heavy mineral placer concentrations, ten sites were selected along study area and reference benchmark pillars were established. The values of geographical co-ordinates were obtained first in WGS-1984 datum and later was converted to Indian datum (Indian-Everest 1975). The geographical co-ordinates thus obtained are given in **Annexure : I**. The vertical heights of all the reference benchmark pillars were established using automatic level and a graduated staff. The vertical heights thus obtained are given in **Annexure : II**.

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## 4.0 Results and Discussions

Variations in beach levels obtained represent the periodical changes occurred during pre monsoon and post monsoon periods. The beaches were found to be accreting at many places during the survey period. Accumulation of sand or other beach material due to the natural action of waves, currents and wind formation of prominent berm part at northern part of Malvan bay was observed. The beach width at different stations varied from 60 to 125 meters. Volume of sand either deposited or removed (or washed away) per meter width of the beach at BP:1 is accurately computed using a software (P. Ganesan, 2006.), The details of sand/mineral deposit and loss at all the ten study areas (BP:1 to BP:8 and KP:1 to KP:2)) of Malvan and Kotharwadi coast during pre monsoon and post monsoon observations are given in **Table:1**. The volume of sand/mineral was computed for one meter length of the beach. These variations in the accretion and erosion can be attributed to the oceanographic processes, operating in the area in different seasons. A software by the first author (P.Ganesan) was used for processing the field data for obtaining vertical heights of all the profiles with respect to mean sea level (M.S.L.). The final vertical heights of all the points surveyed along the profiles are given in Table : 2 Interpretation of all these data helped us in investigating the complete stretch of southern Maharashtra coast for morphological changes, in turn for sand/mineral erosion and accumulation, within accuracy limit of the method and system.

## 5. Conclusions

With the results obtained from the field along the southern Maharashtra coast and laboratory studies, the following conclusions are arrived at:

- Overall, Malvan and Kotharwadi coast are found to be accreting during March 2005, while maximum erosion has occurred during August 2005. Both accretion and erosion are observed during Dec. 2005. Formation of prominent berm part at certain areas is also observed.
- Overall, the beach width varied from 60 to 120 meters.



- Net changes in the beach volumes for profiles BP:1 to BP:8 of Malvan coast and KP:1 to KP:2 of Kotharvadi coast during various seasons of study are given in the table (**See Table:1**).
- The maximum sand accumulation was found at BP: 3 during Dec. 2005, resulting to deposition of sand/mineral of volume upto 61.92 cu.meters, which is 57.56% more than the first season observation, which was in Oct. 2004.
- The lowest sand accumulation was found at BP: 2 during Dec. 2005, resulting to deposition of sand/mineral of volume upto 0.622 cu.meters, which is 0.415% more than the first season observation, which was in Oct. 2004.
- Another significant observance is the highest erosion found at BP: 4 during Aug. 2005, resulting to loss of volume of sand/mineral upto 314.05 cu.meters, which is 139.5% less than the first season observation, which was in Oct. 2004.
- The least erosion was found at BP: 1 during March 2005, resulting to the loss of volume of sand upto 7.485 cu.meters, which is 0.03% less than the first season observation, which was in Oct. 2004.

## **Acknowledgement**

The authors are thankful to the Director, Dr. Shetye, of National Inst. of Oceanography, Goa for his kind permission to publish this technical report. This task was funded by CSIR under the CSIR network project and is duly acknowledged here. The authors also thank Dr. Gujar, Shri. P.G. Mislankar and Shri. N.V. Ambre for their kind co-operation in collection of field data. The authors are thankful to Dr. Gujar for reviewing the manuscript and making valuable suggestions.

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Siddique,H.N.;Rajamanickam,G.V. and Almeida,F. (1979). Offshore Ilmenite placers of Ratnagiri, Konkan coast Maharashtra, India. Marine Mining Vol.2 (1-2) pp.91-118.

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## Annexure : I

The geographical co-ordinates (Horizontal control) of benchmarks :

Bench mark Pillar No	Position in WGS-1984		Position in Indian –1975		Name of the local place
	Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)	
	(All values are in degrees, minutes and seconds)				
BP - 1	16 05 52.810	73 27 39.700	16 05 48.178	73°27'38.676	Talashil
BP – 2	16 06 09.930	73 27 32.320	16°06'05.300	73°27'31.295	Talashil
BP - 3	16 06 49.890	73 26 30.670	16°06'45.263	73°26'29.637	Tondavali
BP - 4	16 07 40.800	73 27 19.760	16°07'36.178	73°27'18.734	Tondavali
BP – 5	16 08 56.070	73 27 03.200	16°08'51.455	73°27'02.171	Tondavali
BP - 6	16 09 33.790	73 26 53.180	16°09'29.178	73°26'52.150	Bagwadi
BP - 7	16 10 47.110	73 26 31.160	16°10'42.505	73°26'30.127	Hirlewadi
BP – 8	16 11 46.970	73 26 15.500	16°11'42.371	73°26'14.464	Pirvadi
KP - 1	16 28 40.750	73 20 29.200	16°28'36.243	73°20'28.115	Kotharwadi
KP - 2	16 28 31.920	73 20 35.180	16°28'27.412	73°20'34.096	Kotharwadi

## **Annexure : II**

### **Vertical control of benchmarks :**

Ten permanent benchmark pillars were established along the shores of the study area. All values are reduced to M.S.L. (Mean sea level) and are shown below:

<b>BP : 1</b>	<b>+5.665 meters above M.S.L.</b>
<b>BP : 2</b>	<b>+4.627 meters above M.S.L.</b>
<b>BP : 3</b>	<b>+4.790 meters above M.S.L.</b>
<b>BP : 4</b>	<b>+3.865 meters above M.S.L.</b>
<b>BP : 5</b>	<b>+4.632 meters above M.S.L.</b>
<b>BP : 6</b>	<b>+3.644 meters above M.S.L.</b>
<b>BP : 7</b>	<b>+3.375 meters above M.S.L.</b>
<b>BP : 8</b>	<b>+3.964 meters above M.S.L.</b>
<b>KP : 1</b>	<b>+04.957 meters above M.S.L.</b>
<b>KP : 2</b>	<b>+09.307 meters above M.S.L.</b>

The chart datum is **+ 1.17 meters below M.S.L.** at Malvan, which has been used for reducing vertical heights of all points surveyed on the profiles .with respect to Chart datum.

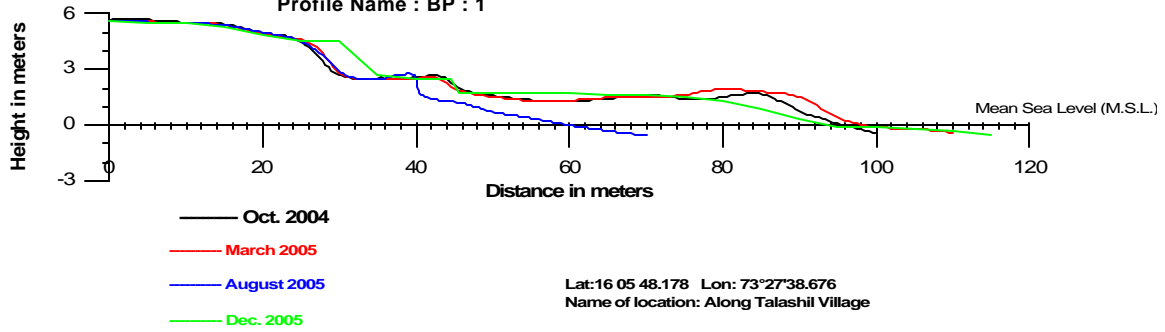
**LIST OF FIGURES**

**PLATE : 1**

**BEACH PROFILING AT MALVAN**

Period of survey : Oct. 2004 to Dec. 2005

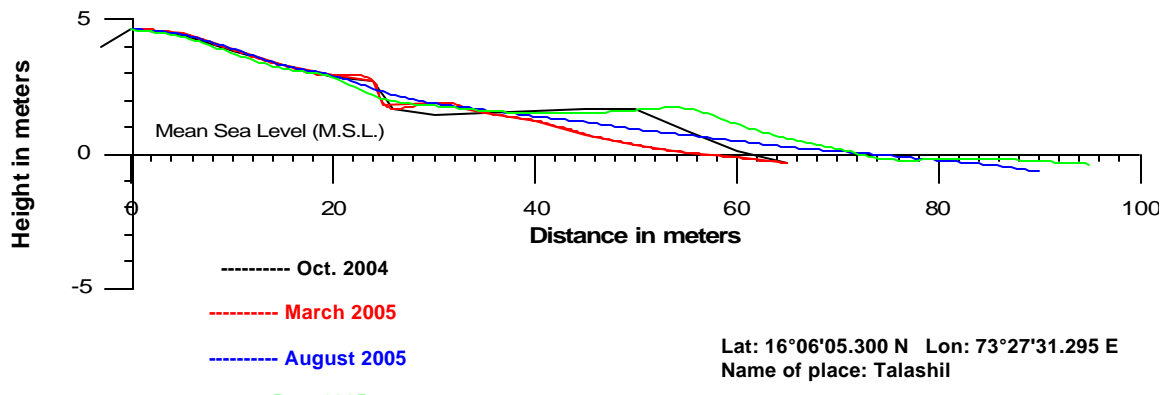
Profile Name : BP : 1



**BEACH PROFILING AT MALVAN**

Period of survey : Oct. 2004 to Dec. 2005

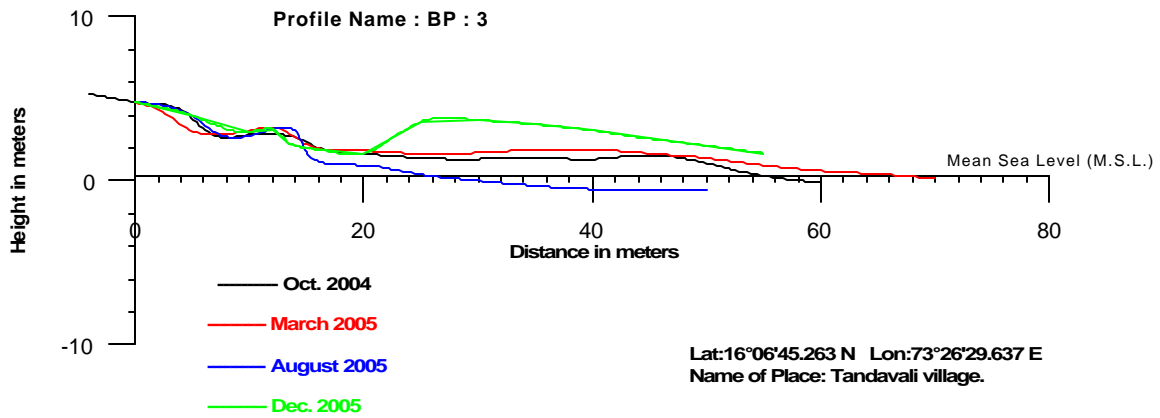
Profile Name : BP : 2



**BEACH PROFILING AT MALVAN**

Period of survey : Oct. 2004 to Dec. 2005

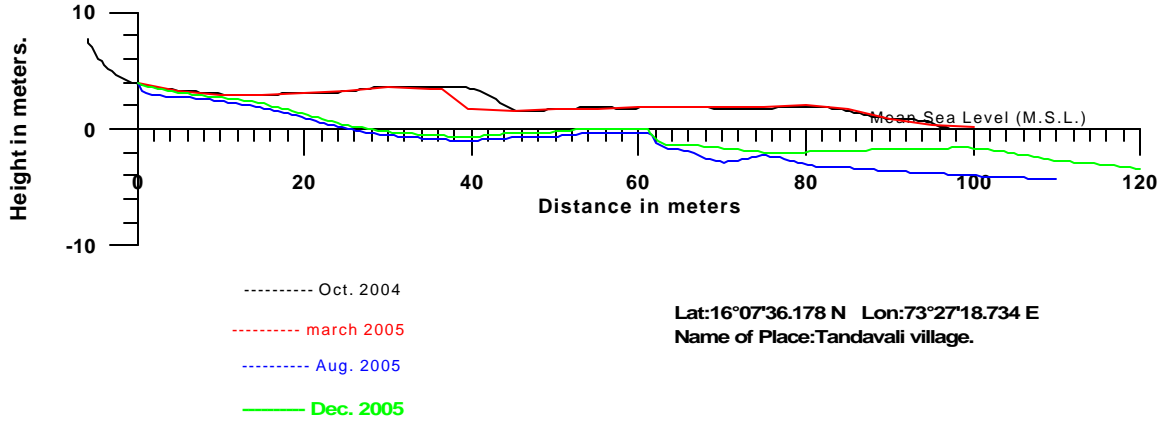
Profile Name : BP : 3



**BEACH PROFILING AT MALVAN**

Period of survey : Oct. 2004 to Dec. 2005

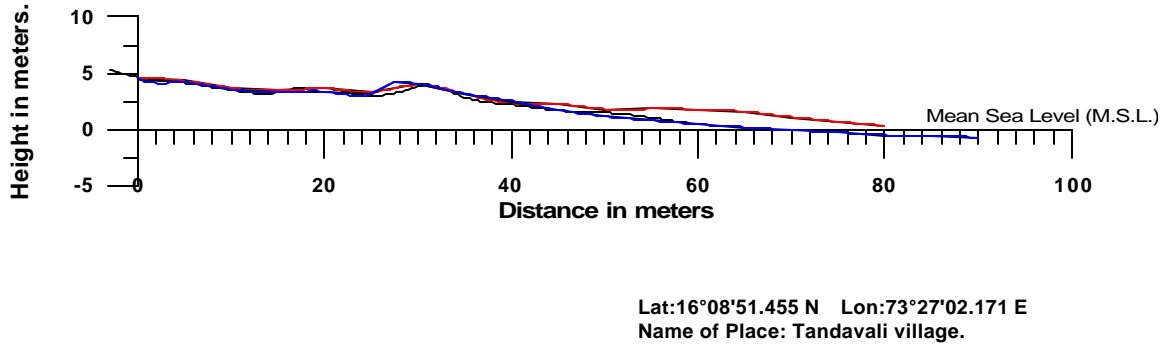
Profile Name : BP : 4



**BEACH PROFILING AT MALVAN**

Period of survey : Oct. 2004 to Dec. 2005

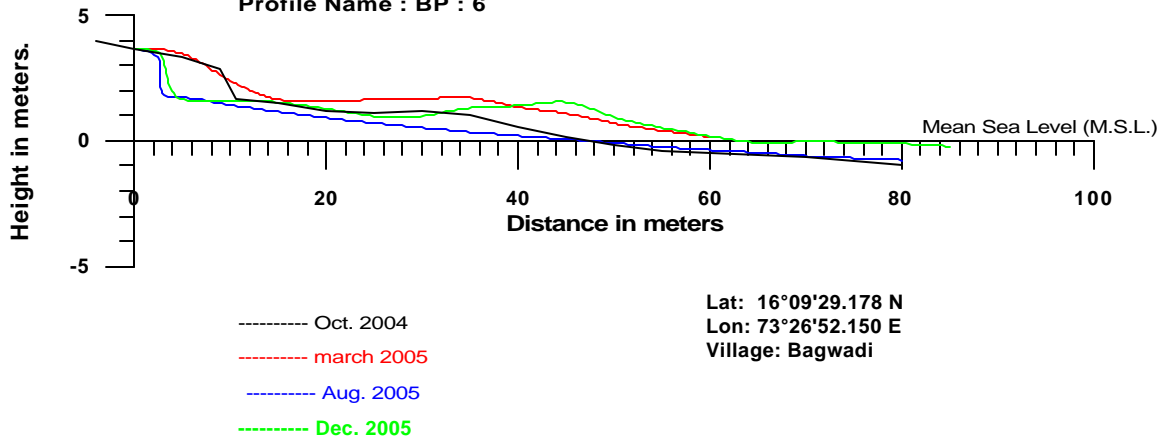
Profile Name : BP : 5



**BEACH PROFILING AT MALVAN**

Period of survey : Oct. 2004 to Dec. 2005

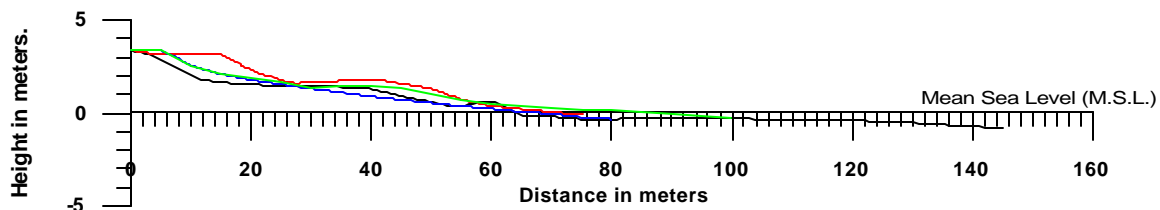
Profile Name : BP : 6



### BEACH PROFILING AT MALVAN

Period of survey : Oct. 2004 to Dec. 2005

Profile Name : BP : 7



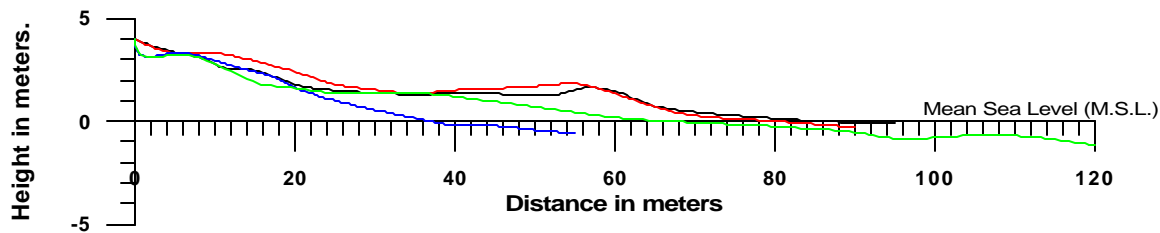
----- Oct. 2004  
----- march 2005  
----- Aug. 2005  
----- Dec. 2005

Lat: 16°10'42.505 N  
Lon: 73°26'30.127 E  
Village: Hirlewadi

### BEACH PROFILING AT MALVAN

Period of survey : Oct. 2004 to Dec. 2005

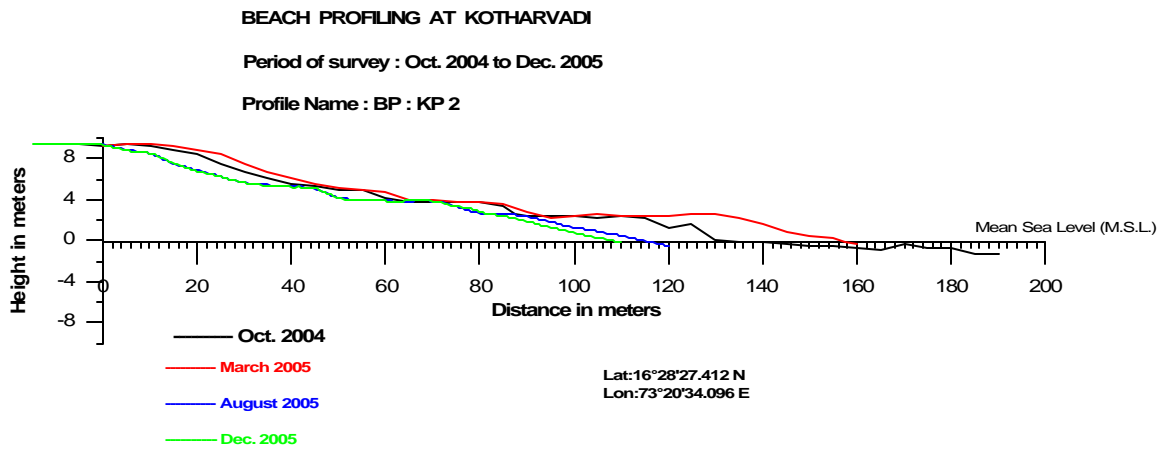
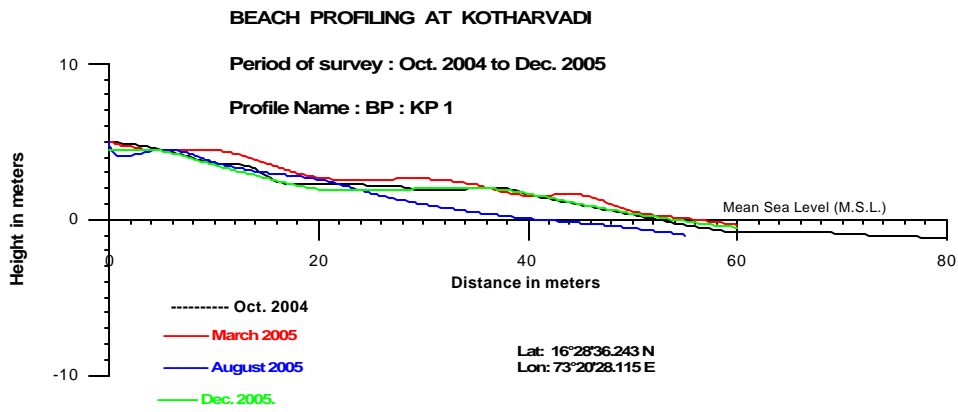
Profile Name : BP : 8



----- Oct. 2004  
----- march 2005  
----- Aug. 2005  
----- Dec. 2005

Lat: 16°11'42.371 N  
Lon: 73°26'14.464 E  
Village: Pirvadi

## Beach Profiling at all two locations along Kotharwadi coast in different seasons.

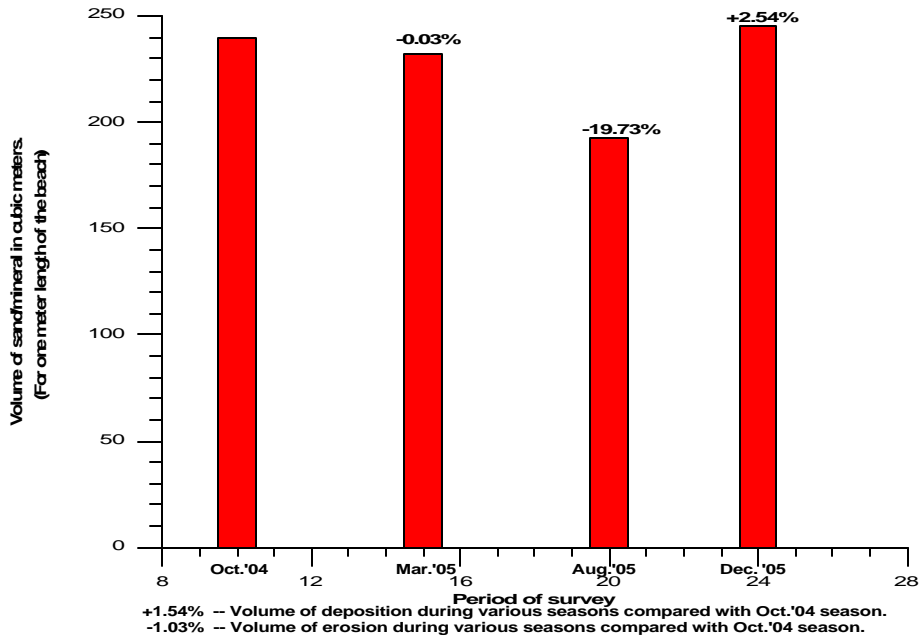




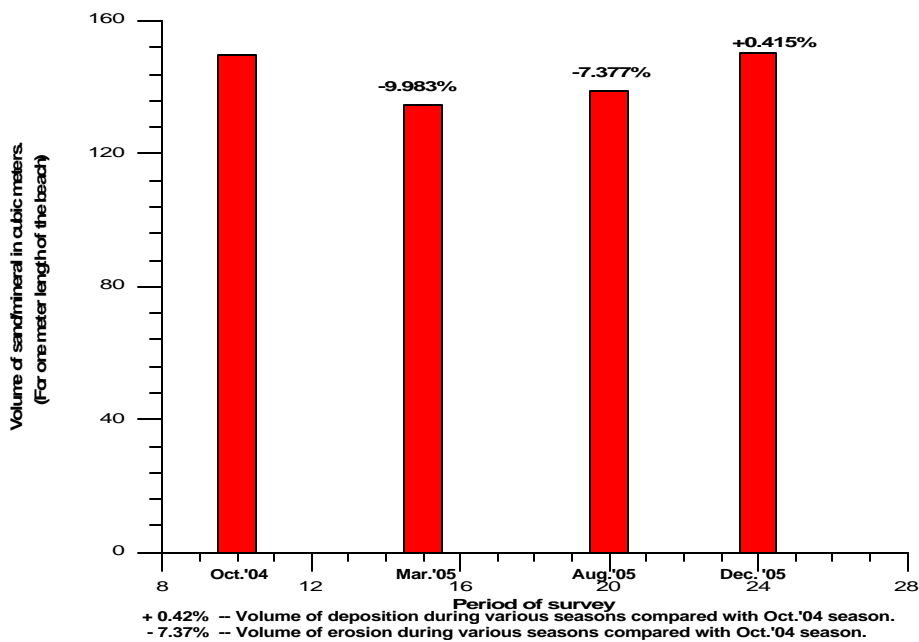
**PLATE : 2**

**Bar charts of all 10 profiles showing volume of sand/mineral erosion**

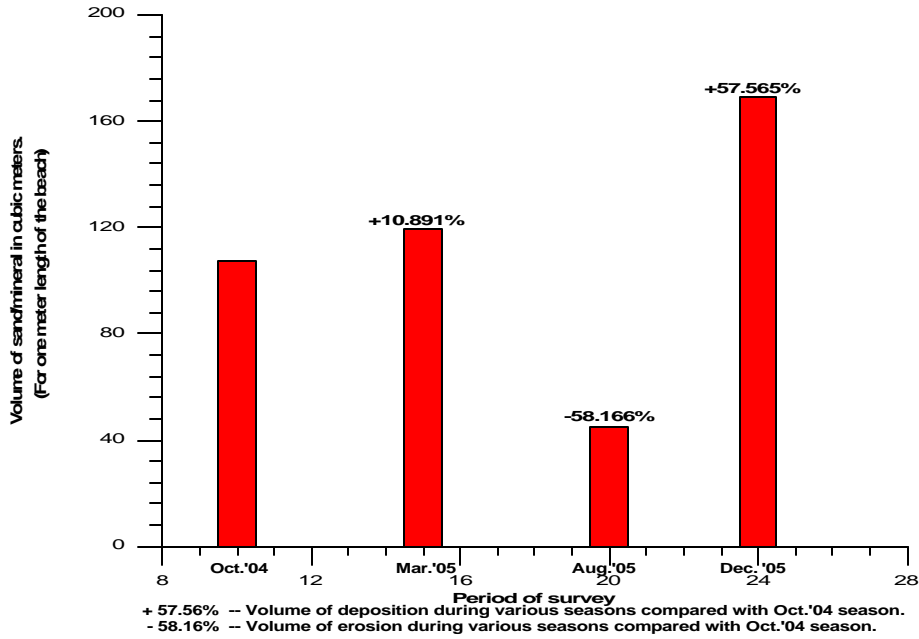
**MALVAN COAST**  
**Volume of sand/mineral along BP : 1 during various seasons.**  
**Total width considered : 75 meters.**



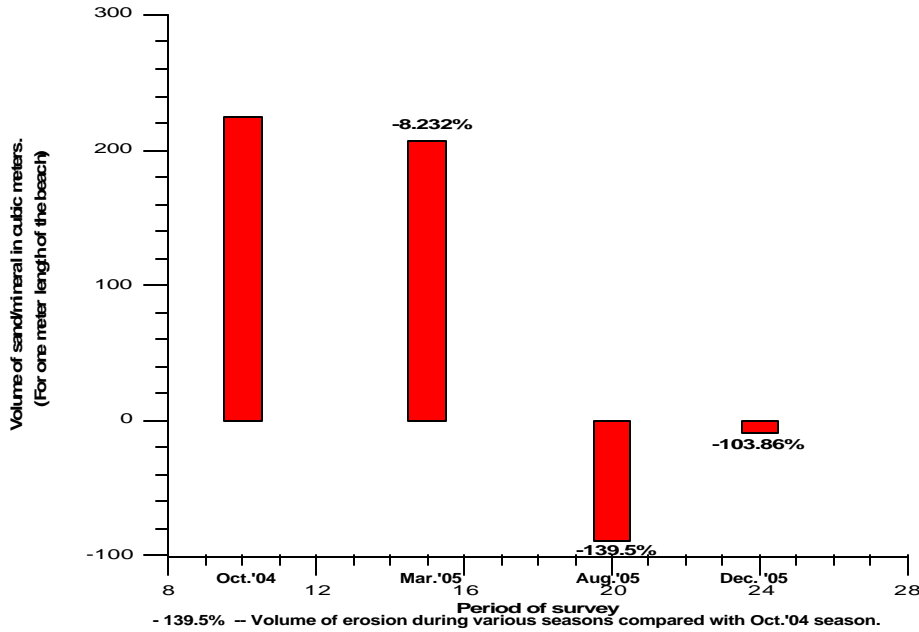
**MALVAN COAST**  
**Volume of sand/mineral along BP : 2 during various seasons.**  
**Total width considered : 70 meters.**



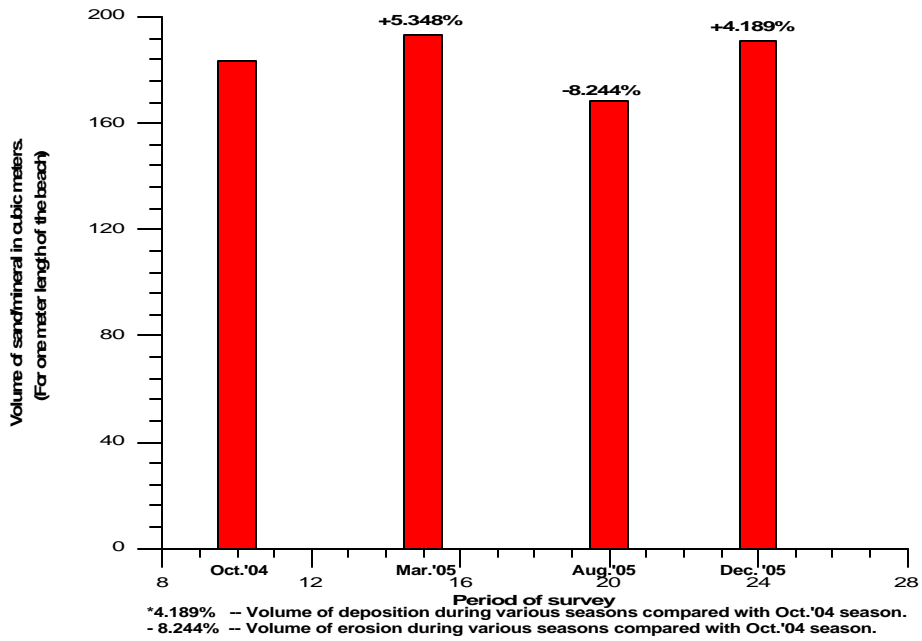
**MALVAN COAST**  
**Volume of sand/mineral along BP : 3 during various seasons.**  
**Total width considered : 60 meters.**



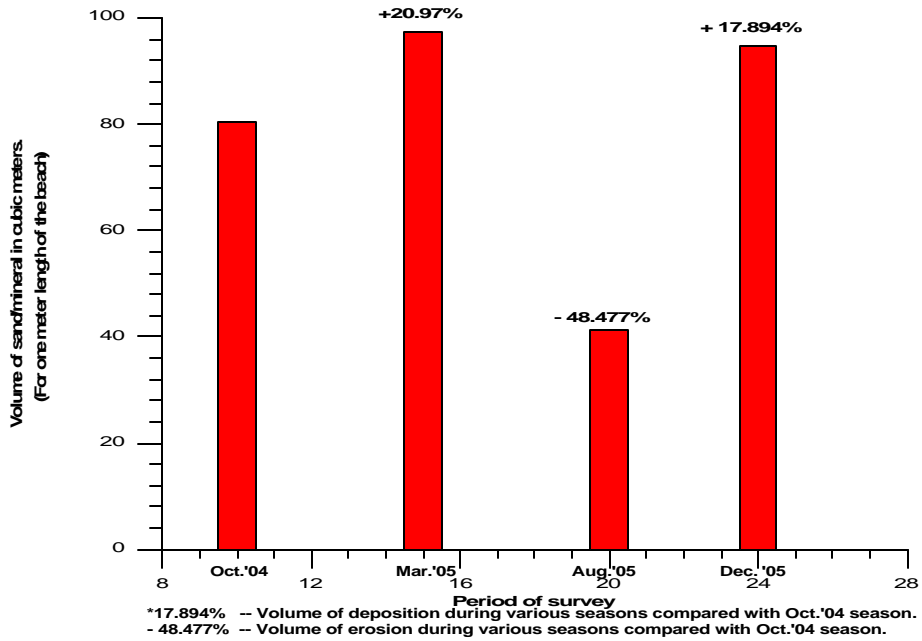
**MALVAN COAST**  
**Volume of sand/mineral along BP : 4 during various seasons.**  
**Total width considered : 100 meters.**



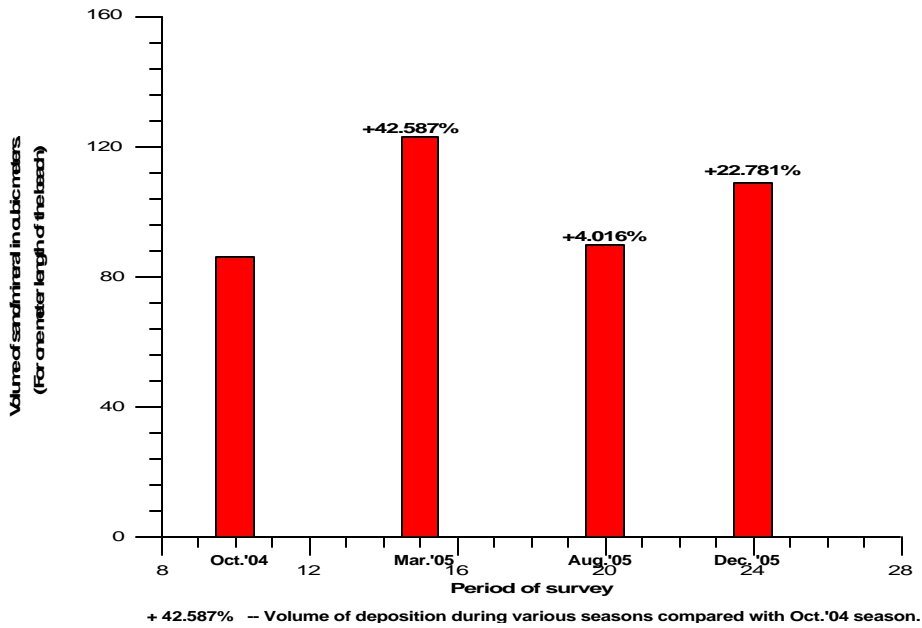
**MALVAN COAST**  
**Volume of sand/mineral along BP : 5 during various seasons.**  
**Total width considered : 65 meters.**



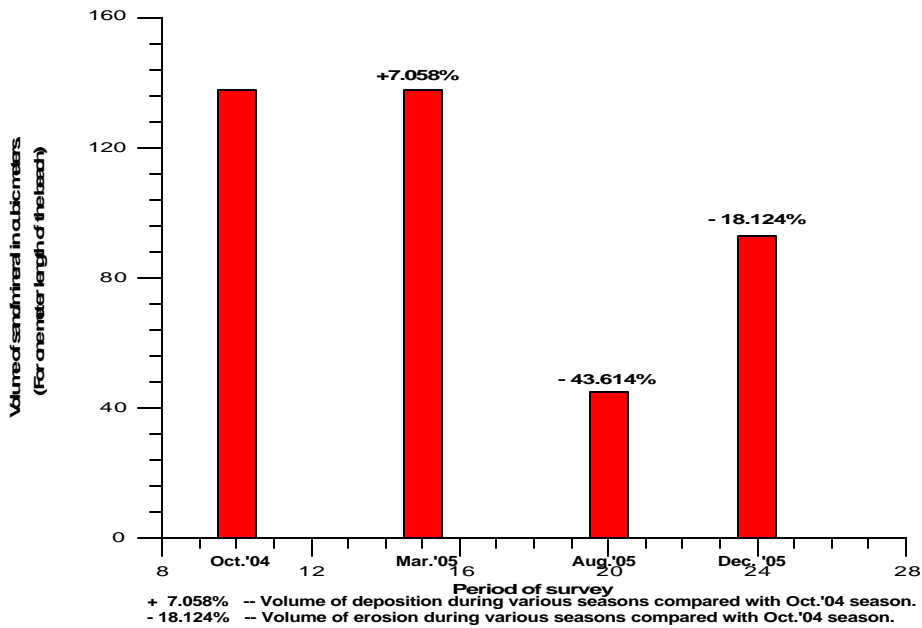
**MALVAN COAST**  
**Volume of sand/mineral along BP : 6 during various seasons.**  
**Total width considered : 60 meters.**



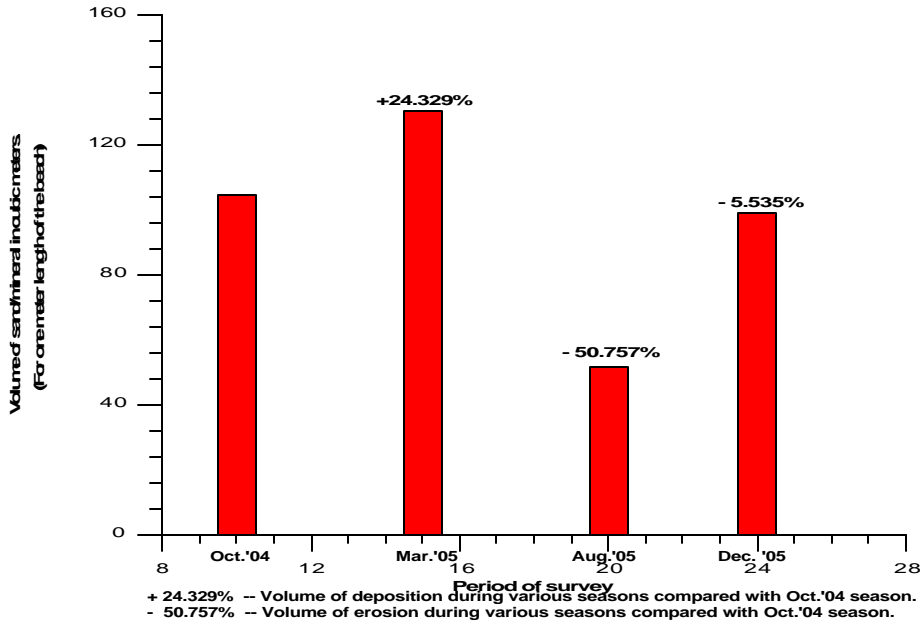
**MALVAN COAST**  
**Volume of sand/mineral along BP : 7 during various seasons.**  
**Total width considered : 75 meters.**



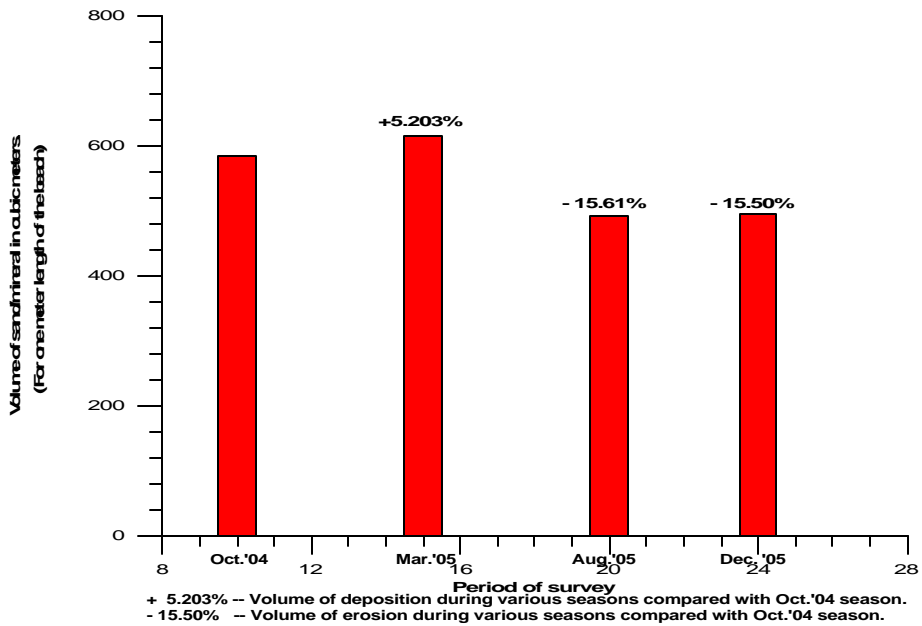
**MALVAN COAST**  
**Volume of sand/mineral along BP : 8 during various seasons.**  
**Total width considered : 80 meters.**



**SOUTHERN MAHARASHTRA COAST (KOTHARVADI)**  
**Volume of sand/mineral along KP : 1 during various seasons.**  
**Total width considered : 75 meters.**



**SOUTHERN MAHARASHTRA COAST (KOTHARVADI)**  
**Volume of sand/mineral along KP : 2 during various seasons.**  
**Total width considered : 115 meters.**



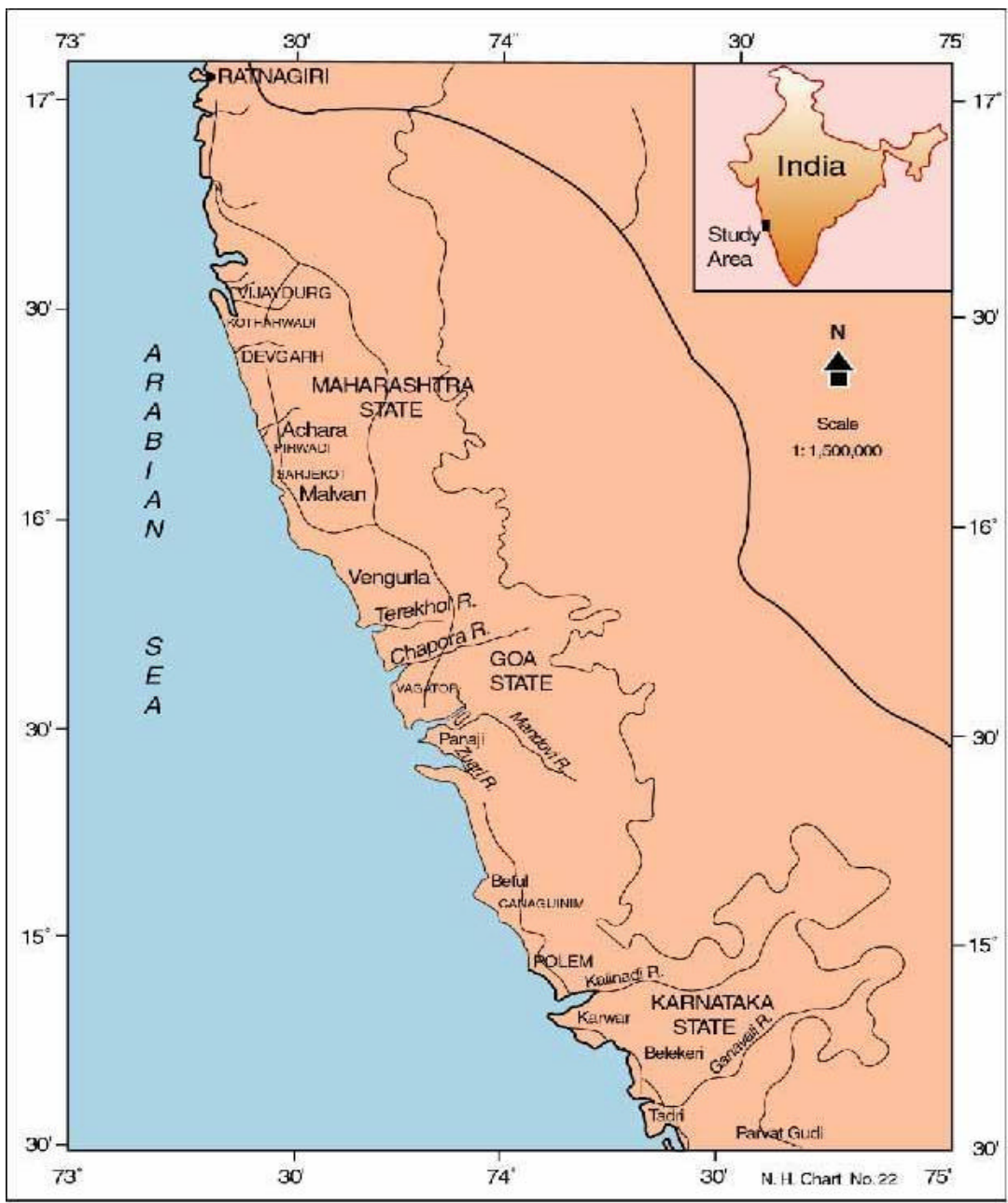


Fig :1 Study area Map.



**Fig: 2 Beach profiling in progress at Kotharwadi coast.**



**Fig: 3 Beach profiling in progress at Pirwadi.**



MAP SHOWING BEACH PROFILING LOCATIONS AT MALWAN

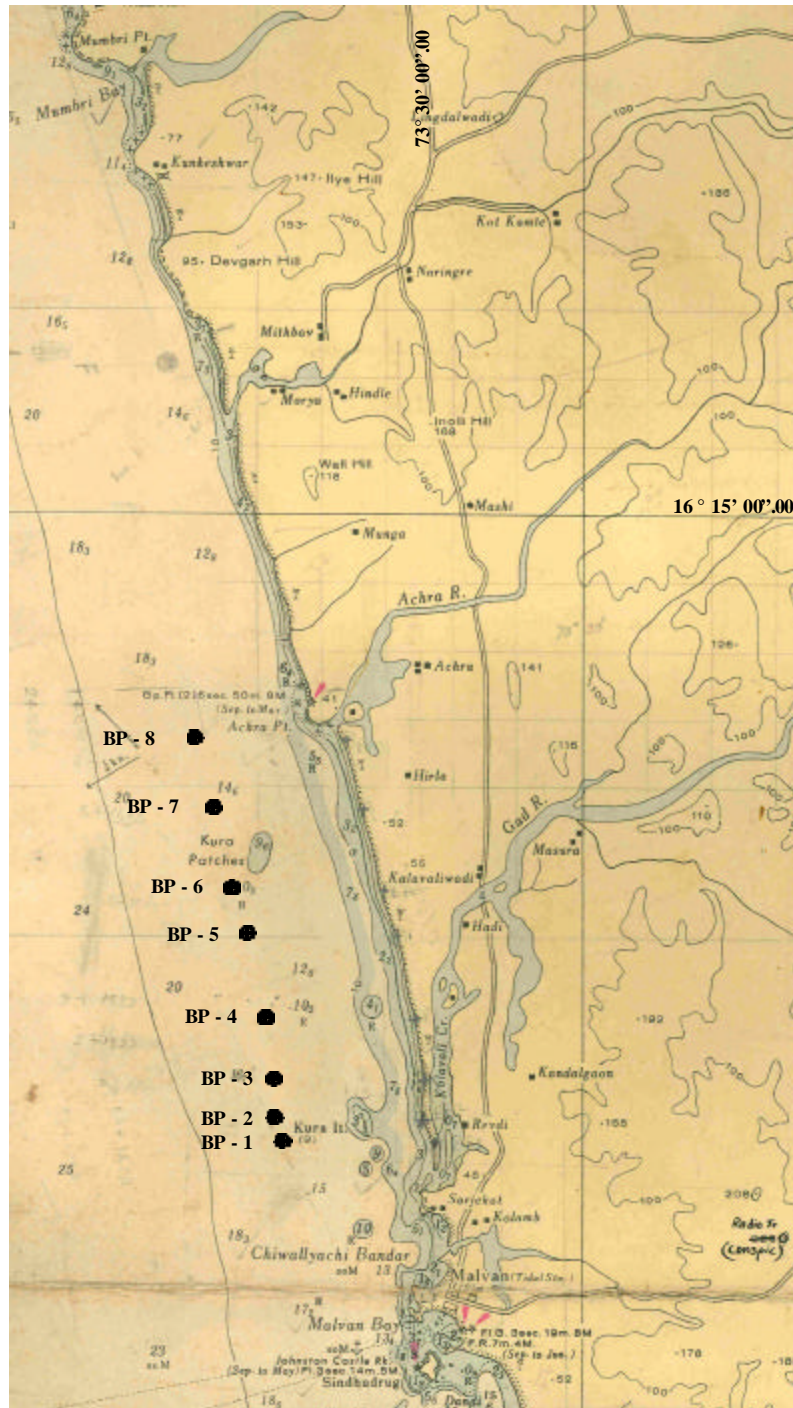


Fig :4 Location of bench mark pillars along Malvan coast.



MAP SHOWING BEACH PROFILING LOCATIONS AT KOTHARWADI

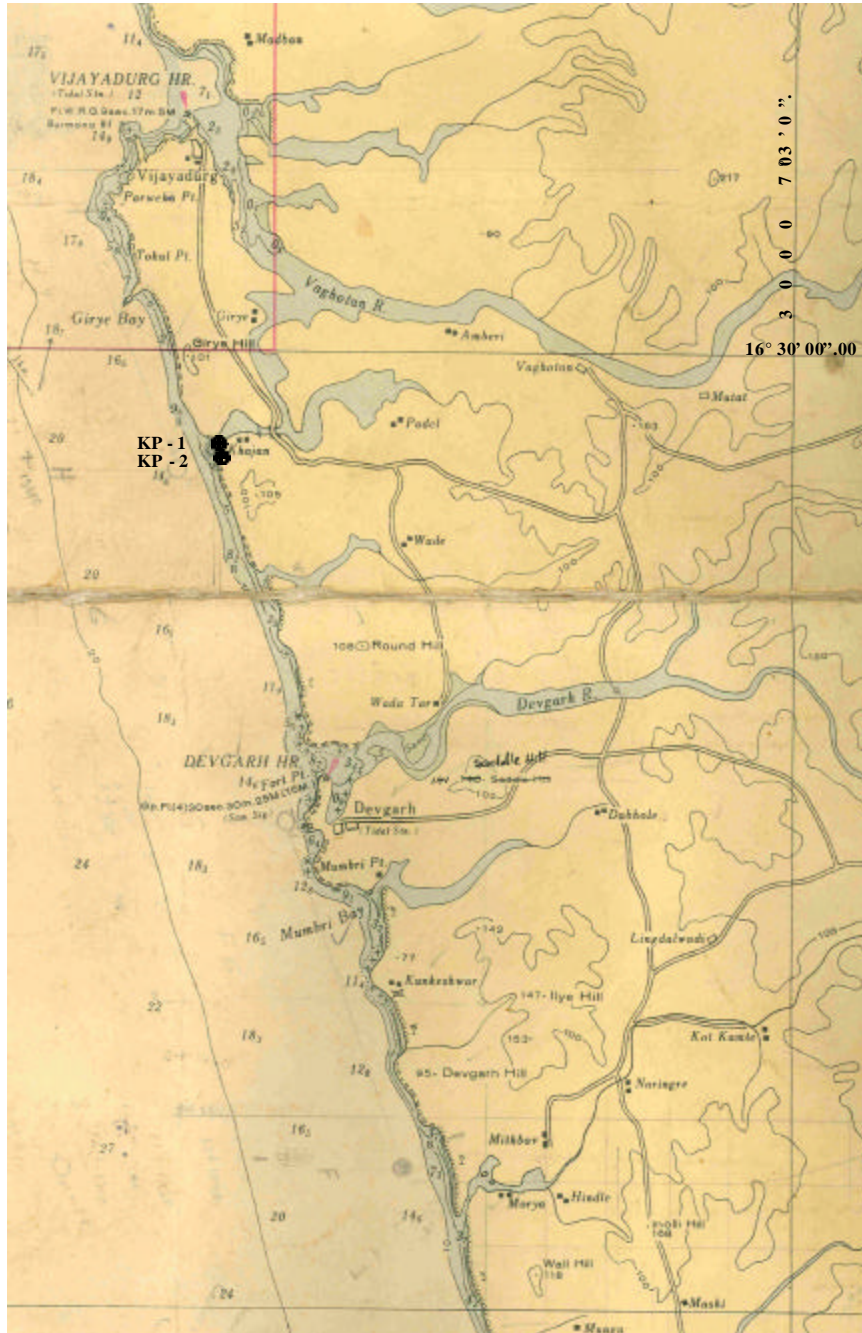


Fig :5 Location of bench mark pillars along Kotharwadi coast.

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## LIST OF TABLES

**TABLE :1**

### Accumulation and erosion in different seasons along study area

“---“ Value indicate volume of sand eroded.

“ + “ Value indicate volume of sand accumulated.

**( Oct. 2004 values are taken as the base over which, other season values are compared).**

Location	Profil Name	Oct. 2004 (Base Profile) (Volume	March 2005 in cubic	August 2005 meters )	Dec. 2005	Width of beach (meters)	Pre - Monsoon (From Oct.2004 To Mar2005	Monsoon (From Oct.2004 To Aug2005	Post - Monsoon (From Oct.2004 To Dec2005
Talashil	BP:1	239.428	231.943	192.186	245.503	75	-- 0.03 %	--19.73%	+2.54%
Talashil	BP:2	149.720	134.774	138.675	150.342	70	--9.98%	--7.38%	+0.41%
Tandavali	BP:3	107.563	119.278	44.998	169.482	60	+10.89%	--58.17%	+57.56%
Tandavali	BP:4	225.124	206.592	-88.929	-08.689	100	--8.23%	--139.5%	-103.8%
Tandavali	BP:5	183.316	193.120	168.203	190.994	65	+5.35%	--8.24%	+4.19%
Bagwadi	BP:6	80.456	97.328	41.453	94.853	60	+20.97%	--48.48%	+17.89%
Hirlewadi	BP:7	86.308	123.064	89.774	109.089	75	+42.59%	+4.02%	+22.78%
Pirwadi	BP:8	138.069	138.023	45.044	93.259	80	+7.06%	--43.61%	--18.12%
Kotharwadi	KP:1	104.646	130.106	51.531	98.854	75	+24.33%	--50.76%	--5.53%
Kotharwadi	KP:2	585.467	615.928	494.078	494.706	115	+5.20%	--15.61%	--15.50%

**TABLE :2**

Final processed vertical heights of all the points surveyed along the ten profiles is given below. (All vertical heights are with respect to Mean sea level)

<b>Dist. from Vertical B.M. Pillar heights ( in meters)</b>	<b>Dist. from Vertical B.M. Pillar heights (in meters)</b>	<b>Dist. from Vertical B.M. Pillar heights ( in meters)</b>
Mal BP: 1 OCT2004 I Phase	Mal BP: 2 OCT2004 I Phase	Mal BP: 3 OCT2004 I Phase
0 5.665	-3 3.995	-4 5.292
5 5.666	0 4.627	0 4.79
10 5.535	5 4.449	4 4.306
15 5.427	10 3.861	7 2.717
20 4.973	15 3.286	10 2.8
25 4.506	20 2.893	13 2.8
30 2.683	24 2.692	14 2.638
35 2.528	26 1.666	16 1.99
40 2.558	30 1.47	20 1.624
43.5 2.595	35 1.527	25 1.37
45 2.15	40 1.621	30 1.324
50 1.592	45 1.701	35 1.413
55 1.337	50 1.652	40 1.307
60 1.297	55 0.845	45 1.557
65 1.417	60 0.115	50 1.067
70 1.577	65 -0.295	54 0.407
72.5 1.55		60 -0.095
75 1.387		
80 1.492		
85 1.672		
90 0.757		
95 0.092		
100 -0.438		

<b>Dist. from Vertical B.M. Pillar heights ( in meters)</b>		<b>Dist. from Vertical B.M. Pillar heights (in meters)</b>		<b>Dist. from Vertical B.M. Pillar heights ( in meters)</b>	
Mal BP: 4 OCT2004   Phase		Mal BP: 5 OCT2004   Phase		Mal BP: 6 OCT2004   Phase	
-6	7.723	-3	5.293	-4	4.006
-3	4.865	0	4.632	0	3.644
0	3.865	5	4.125	5	3.341
5	3.267	10	3.497	9	2.819
10	2.978	15	3.297	10.5	1.683
14	2.84	16	3.502	15	1.493
20	3.126	20	3.702	20	1.204
25	3.178	25	2.972	25	1.106
30	3.625	30	3.802	30	1.221
35	3.56	30.5	3.932	35	1.005
40	3.459	35	2.827	40	0.586
43.5	2.173	40	2.205	45	0.161
45	1.626	45	1.677	50	-0.164
50	1.679	50	1.507	55	-0.372
55	1.777	55	1.035	60	-0.499
60	1.774	60	0.398	65	-0.584
65	1.864			70	-0.669
70	1.719			75	-0.784
75	1.739			80	-0.934
80	1.885				
81.5	1.888				
85	1.498				
90	0.88				
95	0.502				
96	0.231				
100	-0.036				

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

Mal BP: 7 OCT2004 I Phase

0	3.375
5	2.88
10	1.955
15	1.655
20	1.525
25	1.475
30	1.462
35	1.393
40	1.29
45	0.903
50	0.578
55	0.378
60	0.587
65	-0.131
70	-0.208
75	-0.337
80	-0.356
85	-0.236
90	-0.232
95	-0.257
100	-0.302
105	-0.342
110	-0.402
115	-0.336
120	-0.4
125	-0.466
130	-0.536
135	-0.636
140	-0.731
145	-0.826

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

Mal BP: 8 OCT2004

0	3.964
5	3.322
9	2.944
10	2.717
15	2.458
20	1.794
25	1.492
30	1.367
35	1.294
40	1.347
45	1.324
50	1.287
54.5	1.452
55	1.537
60	1.439
65	0.736
70	0.436
75	0.274
80	0.134
85	0.009
90	-0.066
95	-0.111

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

BP:KP1	OCT2004	I Phase
0	4.957	
5	4.493	
10	3.645	
14	3.235	
15.5	2.567	
20	2.257	
25	2.197	
27.5	2.12	
30	1.86	
35	1.99	
37.5	2.035	
40	1.62	
45	0.94	
50	0.3	
55	-0.36	
60	-0.83	
65	-0.785	
70	-0.898	
75	-1.09	
80	-1.155	

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

BP:KP2	OCT2004	I Phase
-5	9.437	
0	9.307	
5	9.424	
10	9.202	
15	8.752	
20	8.452	
25	7.492	
30	6.727	
35	6.147	
40	5.607	
45	5.252	
50	4.977	
55	4.972	
60	4.107	
65	3.847	
70	3.842	
75	3.809	
80	3.747	
85	3.312	
87.5	2.592	
90	2.327	
95	2.312	
100	2.457	
105	2.292	
110	2.322	
115	2.122	
120	1.297	
125	1.657	
130	-0.003	
135	-0.233	
140	-0.183	
145	-0.328	
150	-0.498	
155	-0.583	
160	-0.693	
165	-0.828	
170	-0.408	
175	-0.678	
180	-0.763	
185	-1.243	
190	-1.383	

Dist. from Vertical B.M. Pillar heights ( in meters)		Dist. from Vertical B.M. Pillar heights (in meters)		Dist. from Vertical B.M. Pillar heights ( in meters)	
0	5.665 BP: 1	0	4.627 BP: 2	0	4.79 BP: 3
5	5.57 28/3/05	5	4.476 28/3/05	2.5	4.147 28/3/05
10	5.49 2nd Phase	10	3.875 2nd Phase	5	3 2nd Phase
15	5.4	15	3.295	10	3.05
20	4.93	20	2.91	12.5	3.175
25	4.565	24	2.71	15	2.195
27.5	4.03	25	1.835	20	1.815
30	2.792	30	1.93	25	1.635
35	2.473	35	1.54	30	1.703
40	2.476	40	1.235	35	1.878
42.5	2.561	45	0.745	40	1.905
45	1.961	50	0.335	45	1.663
50	1.534	55	0.055	50	1.378
55	1.286	60	-0.13	55	0.933
60	1.301	65	-0.34	60	0.61
65	1.471			65	0.403
70	1.496			70	0.143
75	1.621				
80	1.931				
85	1.801				
90	1.506				
95	0.393				
100	-0.114				
105	-0.204				
110	-0.427				

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	3.865 BP: 4
5	3.257 28/3/05
10	2.97 2nd Phase
15	2.84
20	3.099
25	3.185
30	3.603
35	3.472
36.5	3.44
39.5	1.722
40	1.646
45	1.597
50	1.627
55	1.707
60	1.787
65	1.827
70	1.83
75	1.927
80	2.012
85	1.722
90	0.892
95	0.332
100	0.107

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

0	4.632 BP: 5
5	4.312 28/3/05
10	3.679 2nd Phase
15	3.417
20	3.637
25	3.332
30	3.95
35	3.139
40	2.347
45	2.293
50	1.808
55	1.817
60	1.784
65	1.585
70	1.095
75	0.683
80	0.338

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	3.644 BP: 6
5	3.449 28/3/05
10	2.389 2nd Phase
15	1.644
20	1.564
25	1.639
30	1.664
35	1.704
40	1.336
45	1.084
50	0.697
55	0.394
60	0.158



**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	3.375 BP: 7
5	3.16 28/3/05
10	3.19 2nd Phase
15	3.123
20	2.283
25	1.772
26.5	1.623
30	1.668
35	1.73
40	1.808
45	1.568
50	1.278
55	0.723
60	0.393
65	0.203
70	0.053
75	-0.092

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

0	3.964 BP: 8
5	3.317 28/3/05
10	3.296 2nd Phase
15	2.914
20	2.399
25	1.797
30	1.519
35	1.367
40	1.506
45	1.592
50	1.694
55	1.806
60	1.347
65	0.688
70	0.264
75	0.119
80	-0.006
85	-0.146
90	-0.316

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	4.957 KP: 1
5	4.416 29/3/05
10	4.468 2nd Phase
15	3.584
20	2.681
25	2.542
30	2.618
35	2.218
40	1.518
45	1.58
50	0.498
55	0.076
60	-0.374
65	-0.68
70	-0.993
75	-1.219

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

0	9.307 KP: 2
5	9.407 29/3/05
10	9.362 2nd Phase
15	9.222
20	8.758
25	8.452
30	7.467
35	6.692
40	6.097
45	5.557
50	5.207
55	4.947
60	4.77
65	4.022
70	3.882
75	3.842
80	3.759
85	3.502
90	2.69
95	2.28
100	2.42
105	2.645
110	2.401
115	2.301
120	2.39
125	2.495
130	2.57
135	2.27
140	1.585
145	0.925
150	0.505
155	0.225
157.5	-0.06
160	-0.345

Dist. from Vertical B.M. Pillar heights ( in meters)		Dist. from Vertical B.M. Pillar heights (in meters)		Dist. from Vertical B.M. Pillar heights ( in meters)	
MalvanBP1	180805BP : 1	MalvanBP2	180805BP : 2	MalvanBP3	180805BP : 3
0	5.665 III Phase	0	4.627 III Phase	0	4.79 III Phase
5	5.555	5	4.441	5	3.921
10	5.485	10	3.912	7.5	2.766
15	5.38	15	3.307	10	2.749
20	4.975	20	2.912	14	3.043
25	4.505	25	2.297	15	1.653
27.5	3.827	30	1.878	20	0.933
30	2.875	35	1.642	25	0.368
35	2.455	40	1.405	30	-0.002
40	2.54	45	1.197	35	-0.322
40.25	1.89	50	0.927	40	-0.512
45	1.25	55	0.708	45	-0.562
50	0.715	60	0.48	50	-0.612
55	0.37	65	0.265	55	-0.658
60	0	70	0.1	60	-0.703
65	-0.32	75	-0.055	65	-0.746
70	-0.575	80	-0.235	70	-0.802
		85	-0.403		
		90	-0.65		

Dist. from Vertical B.M. Pillar heights ( in meters)		Dist. from Vertical B.M. Pillar heights (in meters)		Dist. from Vertical B.M. Pillar heights ( in meters)	
MalvanBP4	180805BP : 4	MalvanBP5	180805BP : 5	MalvanBP6	180805BP : 6
0	3.865 III Phase	0	4.632 III Phase	0	3.644 III Phase
0.3	3.505	0.3	4.477	2.5	3.297
5	2.725	5	4.147	3	1.859
10	2.33	10	3.532	5	1.709
15	1.81	15	3.279	10	1.419
20	0.915	20	3.364	15	1.154
25	-0.005	25	3.109	20	0.909
30	-0.555	27.5	4.152	25	0.699
35	-0.885	30	4.04	30	0.519
40	-1.01	35	3.182	35	0.344
45	-0.765	40	2.522	40	0.194
50	-0.68	45	1.697	45	0.054
55	-0.303	50	1.152	50	-0.096
60	-0.365	55	0.762	55	-0.251
61.5	-0.44	60	0.447	60	-0.371
62	-1.075	65	0.182	65	-0.481
65	-1.817	70	-0.068	70	-0.606
70	-2.875	75	-0.268	75	-0.696
75	-2.323	80	-0.498	80	-0.771
80	-3.081	85	-0.598		
85	-3.373	90	-0.703		
90	-3.628				
95	-3.823				
100	-4.02				
105	-4.183				
110	-4.338				

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

MalvanBP7	170805BP : 7
0	3.375 III Phase
5	3.335
10	2.55
15	2.095
20	1.772
25	1.53
30	1.305
35	1.09
40	0.885
45	0.7
50	0.528
55	0.37
60	0.225
65	0.055
70	-0.05
75	-0.245
80	-0.33

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

MalvanBP8	170805BP : 8
0	3.964 III Phase
0.3	3.322
5	3.311
10	2.929
15	2.394
17.5	2.109
20	1.639
25	0.999
30	0.534
35	0.149
40	-0.196
45	-0.231
50	-0.431
55	-0.576
60	-0.631
65	-0.706
70	-0.789
75	-0.883
80	-0.97

Dist. from Vertical B.M. Pillar heights ( in meters)		Dist. from Vertical B.M. Pillar heights (in meters)	
MalvanKP1	200805 KP : 1	MalvanKP2	200805 KP : 2
0	4.957 III Phase	-10	9.412 III Phase
0.2	4.432	-5	9.332
5	4.492	0	9.307
10	3.672	5	8.852
15	3.002	10	8.482
20	2.562	15	7.499
25	1.672	20	6.872
30	0.974	25	6.237
35	0.462	30	5.637
40	0.057	35	5.41
45	-0.223	40	5.289
50	-0.563	45	5.007
55	-1.003	50	4.202
60	-1.481	55	3.899
65	-1.979	60	3.857
70	-2.375	65	3.837
75	-2.883	70	3.829
		75	3.337
		80	2.642
		85	2.537
		90	2.35
		95	1.806
		100	1.276
		105	0.88
		110	0.451
		115	-0.054
		120	-0.549

Dist. from Vertical B.M. Pillar heights ( in meters)		Dist. from Vertical B.M. Pillar heights (in meters)		Dist. from Vertical B.M. Pillar heights ( in meters)	
0	5.665BP1 DEC	0	4.627BP2 DEC	0	4.79BP3 DEC
5	5.54 PHASE 4	5	4.357 PHASE 4	5	3.97 PHASE 4
10	5.455	10	3.737	10	2.965
15	5.34	15	3.192	12	3.14
20	4.9	20	2.847	13.5	2.26
25	4.57	25	2.042	15	2.005
30	4.49	30	1.797	20	1.665
35	2.685	35	1.602	25	3.6
40	2.455	40	1.537	30	3.7
44.5	2.475	45	1.532	35	3.435
45.5	1.74	50	1.627	40	3.065
50	1.685	55	1.697	45	2.56
55	1.68	60	1.117	50	2.13
60	1.755	65	0.577	55	1.665
65	1.59	70	0.187	60	1.482
70	1.63	75	-0.203	65	1.01
75	1.505	80	-0.198	70	0.863
80	1.305	85	-0.178	75	0.459
85	0.895	90	-0.263	80	0.021
90	0.365	95	-0.373		
95	-0.075				
100	-0.145				
105	-0.21				
110	-0.35				
115	-0.51				

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	3.865 BP4 DEC
5	3.075 PHASE 4
10	2.67
15	2.135
20	1.21
25	0.31
30	-0.245
35	-0.545
40	-0.67
45	-0.39
50	-0.285
55	0.025
60	-0.045
61	-0.095
62	-0.94
65	-1.395
70	-1.675
75	-2.015
80	-2.005
85	-1.9
90	-1.78
95	-1.715
100	-1.66
105	-2.135
110	-2.72
115	-3.055
120	-3.435

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

0	4.632 BP5 DEC
0.3	4.477 PHASE 4
5	4.087
10	3.547
15	3.282
20	3.427
25	3.162
30	4.157
31	3.762
34	1.842
35	1.827
40	1.882
45	1.967
50	2.027
55	1.827
60	1.312
65	0.817
70	0.242
75	-0.395
80	-0.982

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	3.644 BP6 DEC
2.5	3.484 PHASE 4
4	1.904
10	1.594
15	1.519
20	1.269
25	0.974
30	0.974
35	1.314
40	1.394
45	1.524
50	0.944
55	0.509
60	0.184
65	-0.076
70	-0.046
75	-0.071
80	-0.126
85	-0.226



**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	3.375 BP7 DEC
5	3.345 PHASE 4
10	2.53
15	2.13
20	1.86
25	1.705
30	1.37
35	1.425
40	1.475
45	1.38
50	1.03
55	0.705
60	0.485
65	0.345
70	0.255
75	0.18
80	0.105
85	0.02
90	-0.06
95	-0.18
100	-0.3

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

0	3.964 BP8 DEC
0.3	3.335 PHASE 4
5	3.227
10	2.797
15	1.882
20	1.592
25	1.357
30	1.337
35	1.352
40	1.192
45	0.942
50	0.7
55	0.427
60	0.182
65	0.03
70	-0.058
75	-0.163
80	-0.253
85	-0.388
90	-0.533
95	-0.848
100	-0.818
105	-0.683
110	-0.713
115	-0.893
120	-1.193

**Dist. from Vertical  
B.M. Pillar heights  
( in meters)**

0	4.432 KP1 DEC
5	4.387 PHASE 4
10	3.497
15	2.647
20	1.932
25	1.857
30	1.982
35	2.052
40	1.642
45	0.977
50	0.377
55	-0.118
60	-0.528
65	-0.961
70	-1.299
75	-1.78

**Dist. from Vertical  
B.M. Pillar heights  
(in meters)**

-15	9.392 KP2 DEC MALVAN
-10	9.437 PHASE 4 LAST TRIP
-5	9.332
0	9.307
5	8.787
10	8.497
15	7.522
20	6.772
25	6.227
30	5.627
35	5.342
40	5.212
45	5.077
50	4.127
55	3.927
60	3.847
65	3.852
70	3.827
75	3.327
78	3.107
80	2.807
85	2.372
90	1.842
95	1.287
100	0.732
105	0.262
110	-0.183