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(भारत सरकार का उपक्रम)
(मिनिरत्न कंपनी)
महाप्रबंधक (पर्यावरण) का कार्यालय

Western Coalfields Ltd.
(A Govt. Of India Enterprise)
(A Miniratna Company)
Office of the General Manager (Environment)

Website: westerncoal.nic.in CIN: U10100MH1975GOI018626 E-mail: gmenvironment@westerncoal.gov.in

पंजीकृत कार्यालय: कोल एस्टेट, सिविल लाइन्स, नागपुर - ४४० ००१
Regd. Office.: Coal Estate, Civil Lines, Nagpur - 440 001.

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Ref. No: WCL/ENV/HQ/8-K & 20 -C/ 506 Date: 20.10.2016

To,
Shri. Dr. S.K.Srivastava,
'Scientist-F', IA - II
Coal Mining Division,
Ministry of Environment, Forests & Climate Change,
Govt. of India,
Indira Paryavaran Bhawan, Vayu Wing,
Jor Bagh Road,
New Delhi – 110 003.

Sub:- Expansion of Naheriya Underground Coal mine Project from 0.36 MTPA to 0.54 MTPA of Western Coalfields Limited within existing ML area of 300 Ha located in Tehsil Parasia, District Chhindwara (Madhya Pradesh) under Clause 7(ii) of the EIA Notification, 2006.

Ref:- Meeting Minutes of 53rd & 62nd EAC Meeting.

Dear Sir,

This has reference to the 53rd & 62nd EAC meeting held on 17-03-2016 & 23-08-2016 for the Expansion of Naheriya Underground Coal mine Project from 0.36 MTPA to 0.54 MTPA of Western Coalfields Limited within existing ML area of 300 Ha located in Tehsil Parasia, District Chhindwara (Madhya Pradesh) under Clause 7(ii) of the EIA Notification, 2006.

As directed by EAC, Additional Information / Reply on issues raised (listed below) has been prepared and enclosed along with this letter.

1. Mine Water Discharge vis-à-vis treatment of Acid Mine Discharge.
2. Ambient Air Quality Scenario of Naheriya Village
3. Subsidence Management

Therefore, you are most earnestly requested to kindly consider our above submission for grant of EC to Expansion of Naheriya Underground Coal mine Project from 0.36 MTPA to 0.54 MTPA of Western Coalfields Limited within existing ML area of 300 Ha located in Tehsil Parasia, District Chhindwara (Madhya Pradesh) under Clause 7(ii) of the EIA Notification, 2006.

Encl. As above
1. Additional Information.

Yours faithfully

20/10/16

GM(Env)/HoD

Copy to:-
1. RD, CMPDIL, RI – IV, Jaripatka, Nagpur
2. AGM, Pench Area, WCL

Compliance Report

on

Issues Discussed
&
Additional Information Sought
in 53rd & 62nd EAC
For

Naheriya UG Expansion,
Pench Area,
Chhindwara (M.P.)

October 2016

Western Coalfields Limited

Nagpur

Naheriya UG Expansion

1.0 Background & Issues Raised

Sub:- EC for Expansion of Naheriya Underground Coal mine Project from 0.36 MTPA to 0.54 MTPA of Western Coalfields Limited within existing ML area of 300 Ha located in Tehsil Parasia, District Chhindwara (Madhya Pradesh) under Clause 7(ii) of the EIA Notification, 2006.

The issues discussed and additional information sought in 53rd & 62nd EAC meeting held on 17-03-2016 & 23-08-2016 are:-

1. Mine Water Discharge vis-à-vis treatment of Acid Mine Discharge
2. Ambient Air Quality Scenario of Naheriya Village
3. Subsidence Management

The Action taken & Additional information on the aforesaid issues are placed in subsequent pages.

2.0 Mine Water Discharge Vis-à-Vis Treatment of Acid Mine Discharge

2.1 About the Project

Effluents generated from mining operations are essentially collected strata water & have to be handled for secure & safe mining operations. WCL makes all-out effort for control and treatment of effluent.

Mine is operating since year 2000 and acidity in effluent was first detected in 2014 and intermittent in nature and periodicity. Lime dosing in mine sump was started which continues till date. New additional measures to improve confidence levels on effluent quality has been implemented.

Treatment of acid mine drainage using mixed approach, which is better suited for the project has been implemented to improve treatability of acid mine drainage with the objective to provide effective mode of treatment.

EAC desired detailed information on Treatment of Acid Mine Drainage at Naheriya UG which is placed below in subsequent paragraphs.

2.2 Current Acid Mine Drainage Treatment Methodologies

2.2.1 Acid Mine Drainage / Acid Rock Drainage: The term acid mine drainage, or AMD, was introduced in the 1980s and 90s to indicate that acidic drainage can originate from mines. The term Acid Mine Drainage (AMD) is a misnomer as it implies drainage from an acid generating source, whereas the acid generating source may not be connected with drainage.

2.2.2 Methodologies to treat AMD

Methodologies related to lime dosage: Use of quicklime in place of caustic soda or ammonia for treating AMD, has demonstrated efficient and cost effective treatment. (Skousen & Jenkins, 2000).

The treatment of the AMD included pre-treatment / pH adjustment with CaO until pH 7-8 is achieved.

Neutralization of strong or weak acidic solutions using limestone or powder calcium carbonate is an cost-effective way for removal of metals such as iron(II), iron(III) and aluminum. Metals such as zinc and manganese are not removed during limestone neutralization. Partial sulphate removal through gypsum crystallization to the saturation level of gypsum.

Methodologies related to limestone bed: Limestone (LS)-based systems for treating AMD are available with little or no maintenance. Problem is that the hydroxides tend to settle into and plug the pore spaces in LS beds forcing water to move around rather than through the LS. While both are caused by the precipitation of metal hydroxides, armouring and plugging are two different problems. Plugging of LS pores can be avoided by maintaining a high flushing rate through the LS bed. (Ziemkiewicz et al.)

The water treatment performances of anoxic limestone drains (ALDs) are intended to add bicarbonate alkalinity to flow through acid mine drainage. Concentrations of K, Mg, Mn, and $SO4^{2-}$ all decreased by an average 17%, an effect attributed to dilution with uncontaminated water. Iron, which decreased by 30%, was partially retained within the ALD. The ALDs have theoretical effective lifetimes in excess of 20 yr. By significantly increasing alkalinity concentrations in the mine waters, both ALDs increased metal removal in downstream constructed wetlands.

There is no shortage of selection when it comes to choosing an active treatment method for mine water effluents. Where sludge disposal volume is an important concern, then the High Density Sludge Process or Geco Process should be selected. For improved lime efficiency, the Geco or Staged-Neutralization process should be considered. If capital investment is a concern and a large surface area is available, then ALD pond treatment would be an effective treatment option.

Treating of AMD with limestone results in a surface coating of metal hydroxides, a process known as limestone armouring. Once armoured, limestone is assumed to cease dissolution and acid neutralization. The open limestone channels in the field neutralize more acidity than the model predicted (Ziemkiewicz, 1997) with the increasing pressure to treat mine and industrial wastes, many of which are acidic, the use of lime as an alkaline material for acid neutralization is increasing and its physical and chemical characteristics are being more fully utilized.
(Lewis, 1995)

Methodologies related to Constructed Wetland:

Acid mine drainage (AMD) released from coal mining industry usually has a low pH and contains heavy metals, which can affect the water quality and ecosystems. Constructed wetlands have been considered effective, low cost and a practical approach for the cleanup of different wastewaters including AMD.

The treatment options that may be suitable for use in acidic saline drains include lime-sand beds, subsoil carbonate beds, in-drain composting beds and diversion wells. Lime-sand basins, composting wetlands, lime-sand reactors and hydrated lime dosing units are suited for treatment at drain ends. These options range in effectiveness from full treatment of a range of acidic waters to partial neutralization.

One method to treat acid mine drainage is to divert water through wetlands. Constructed wetlands increase pH and alkalinity influences heavy metal concentrations, while microbial and plant activity mineralizes containments to form precipitates.

Biological treatment of mine waste water is typically conducted in a series of small excavated ponds that resemble, in a superficial way, a small marsh area.

Seasonality of the locale in which the wetland is to be constructed is an important factor in wetland design, in particular areas where climate fluctuations are great. The bacteria catalyzing AMD creation is as active during cold seasons as in warmer seasons. The dormant season and its effect on the vegetation's ability to remediate AMD is therefore important to consider. *Typha spp.* are subject to a efficiency decline at locales with colder temperatures regime, whereas *Sphagnum* spp. does not face these same restrictions. (Smith, 1997).

Option	Application	Best performance outcomes	Limits and risks
Lime-sand beds*	In-drain with limited sedimentation rates	Continuous low-level neutralisation of baseflows with low pH and low iron concen-trations throughout a drainage system; no excavation costs	Iron coating of sand greatly reduces effectiveness (increases with water containing high soluble iron concentrations) Burial by sedimentation Flushing of sludges from drain
Subsoil carbonate beds*	In-drain when available during construction	Continuous low-level neutralisation of baseflows with low pH and low iron concentrations throughout a drainage system; no excavat on costs	Not available at all sites Iron coating of carbonates greatly reduces effectiveness (increases with water containing high soluble iron concentrations) Burial by sedimentation Flushing of sludges from drain Marginally increases cost of drain construction
Subsoil carbonate lining	On berms when available during construction	Provides additional loading of alkalinity to runoff into drains, potentially reducing acidity flushing in high flows	Not available at all sites May contribute to sedimentation in drain

Contd..

Option	Application	Best performance outcomes	Limits and risks
Composting beds	In-drain, but sections not subject to high flows	Continuous treatment (acidity and a broad-spectrum of dissolved metals) of baseflows particularly with high iron and/or aluminium concentrations throughout a drainage system; limited construction costs Minimises flushing of acidity in higher flows	Sizing limited by area available in drain base Greater risk of failure in drains with high acidity loads in baseflows Loss of drain depth (but may be comparatively cheaper than alternatively large end of drain wetland) Potential flushing of sludges in drains with high flows Treatment rates decline with time
Lime-sand reactors	In-drain where power available or solar power possible	Continuous mid–high level point neutralisation of baseflows	Power supply needed or solar feed, continuous supply of lime-sand required High iron concentrations may reduce efficiency of lime-sand use Not effective for all dissolved metals

(Reference: Proposed guidelines for treating acidic drain water in the Avon catchment, Western Australia: adapting acid mine drainage treatment systems for saline acidic drains)

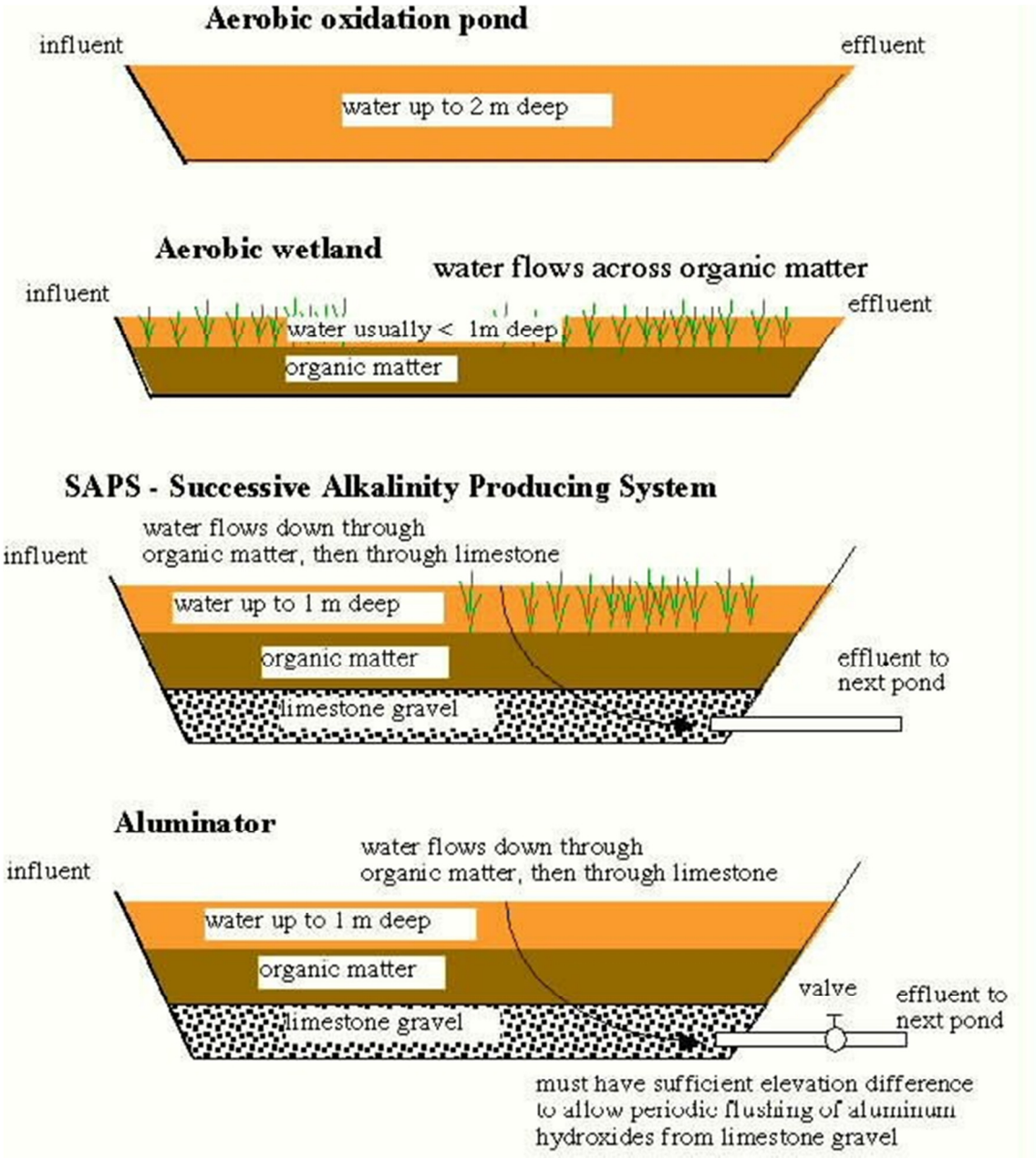
Acid tolerant aquatic species:

- *Typha sp. (cattails)*
- *Sphagnum dominates:* Found to accumulate iron
- Green algae*: Chlamydomonas aplanata* (pH<3)
- Blue-green algae : *Spirulina nordstedtii* (pH 4.9)
- Diatoms *: Navicula nivalis* (pH 3.0)

At pH above 4, acid production proceeds slowly and is controlled by the rate of oxygen diffusion into the spoil. Below pH 4, an alternative oxidation pathway exists involving the *bacterium Thiobacillus ferrooxidans* therefore chances of *Typha sp.* are not best in low pH. (Shiel). It is thus essential to pre-treat highly acidic discharges to ensure treatment by Typha Species.

The attractiveness of a constructed wetlands solution lies in its relative low cost. They are limited by the metal loads they can deal with (either from high flows or metal concentrations), though current practitioners have succeeded in developing constructed wetlands that treat high volumes and highly acidic water (with adequate pre-treatment). Typically, the effluent from constructed wetland receiving near-neutral water will be well-buffered at between 6.5 - 7.0 and can readily be discharged.

Fig.1 : Schematic cross-sectional diagrams of four different pond treatment components



Schematic cross-sections of an oxidation pond, aerobic wetland, SAPS, and "Aluminator"
Different pond types are called for depending on the mine drainage chemistry.

2.3 Technology & Design

Site Visit, Data Collection and On-Site Testing of Effluent: Mine management corresponded to Environment Department, RI-IV, CMPDI, for appropriate solution for the problem. A site visit was conducted on 03-03-2016. It was observed that, an on- site treatment was possible as it was underground mine and it was decided that the space near the existing settling tanks (439 KL) will be used, as shown in Figure 1

Photograph-1: Existing Settling Tanks

Data Collected from First Site Visit: Plan & Section of existing Sedimentation tank along with dimension of tank was given by Mine Management.

1. Average pumping rate from Mine sump is: 298 KLD (Table-1)
2. Life of mine as on date is 15 years @ 0.54 MTPA

Based on the previous studies (Lab Scale Pilot studies) carried out by CMPDI regarding remediation / reduction in acidity from Mine water Discharge, Acid Mine Discharge Treatment plant was designed.

It was decided that vacant land near the existing settling tanks & clear water tank will be utilized for construction of preliminary, secondary treatment tanks and constructed Wetlands for the project.

2.4 Design & Working

Mine discharge is of pH value 3.5, after treatment in stages, this value reaches to around 7.00. The treatment methodology given in following steps:

Stage-1: Preliminary Treatment - Tank-1

Initially, Lime dosing is done at underground mine sump (0.04 g/l), then the water is pumped to surface settling tanks (Capacity – 439 KL) with a detention time of 4 hours and from there water is pumped to Tank-1 (18 x 6 x 3 m) for preliminary treatment.

Dosage: Optimum dose of lime (CaO) is added to water to improve the pH value. As suggested by CMPDIL, a dose of 0.04gm of lime per litre of water is added. This improves the pH from initial 3.0 - 3.5 to 4.0 - 4.2.

The average pumping of water per day at Naheriya UG mine is around 300 KL. So, the quantity of lime required per day comes to: $\frac{300*1000*0.04 \text{ Kg}}{1000} = 12$ Kg/day.

Detention Time: 4 hrs in settling tanks & 30 minutes in Tank -1 at surface.

Capacity: Capacity of Settling Tanks is 439 KL & Lime Dosing Tank -1 is 324 KL are sufficient to hold 298 KLD of mine water. This capacity will be sufficient to hold surplus water for one day.

As the acidity of the mine is intermittent and detention time at preliminary tank is 4 & ½ hours, mixing by manual means has been arranged by deputing plant operator instead of installation of clarifier. Also lime dozing is done at mine sump, mine water pumping augments mixing process.

Stage-2: Primary Treatment (Limestone Bed Filter)- Tank-2

After preliminary treatment (Stage-1), water is taken to 2nd tank where Limestone chips (Commercial name – marble dana – 1" size) is used as bed of the tank. The capacity of the tanks is 160 KLD (80 + 80). Dimension of the

Composite tank 2 is length 16 m, width 5 m and depth 2.0 m. As suggested by CMPDIL, a layer of 0.5 m marble dana is stacked at the bed of this tank. On calculation the weight of marble dana comes to 52 tonne for giving 0.5 m of layer.

Limestone bed works as acid neutralizing agent and acidity of water decreases when water is allowed to detain in this tank. Detention period is very important, CMPDIL has suggested a detention period of 6 hrs. On giving this detention period, pH value improves to 4.5 to 5.5.

Detention Time: 6 hours of detention time is provided at Tank-2 (Lime bed filter)

Sludge Generation: Acid generation due to pyrite

$FeS_2 + 7/2\ O_2 + H_2O = Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+$ ……Equation 1.1
$Fe^{2+} + 1/4\ O_2 + H^+ = Fe^{3+} + ½\ H_2O$ ……Equation 1.2
$Fe^{3+} + 3\ H_2O = Fe\ (OH)_3 + 3\ H^+$ ……....Equation 1.3
$FeS_2 + 14\ Fe^{3+} + 8\ H_2O = 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$ …….Equation 1.4

Taking equation 1.1 as fe2+ oxidises as pH ~9-10 making equation 1.2, 1.3 and 1.4 not applicable at pH ~5.0

Reaction at Limestone filter bed
$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$

$CaSO_4$ deposits as sludge

$CaCO_3$	Molecular weight	-	40+12+48= 100
$CaSO_4$	Molecular weight	-	40+32+64= 136

1 mol of $CaCO_3$ will generate 1 mol of $CaSO_4$
100 gm of $CaCO_3$ will generate 136 gm of $CaSO_4$
11.92 Kg of $CaCO_3$ will generate (136/100) X11.92 Kg of $CaSO_4$ = 16.2 Kg / Day

Total sludge generation including Tank 1 & Tank 2 will be 16.2 Kg per day and it would mainly consist of $CaSO_4$.

Capacity: 2 Tanks of 80 KL each are provided. Cleaning of Filter bed will be done once in a 6 months. During cleaning or descaling one tank will be in operation.

Stage-3: Secondary Treatment (Constructed Wetland) – Tank-3

In this stage, a plant species Typha latifolia has been used as a means for treating acidity of water. It is a perennial plant which grows in temperate, subtropical and tropical area throughout the Northern Hemisphere. It grows in marshy area and flowers in mid to late summer. It is 1.5 to 3.0 m high and it has 2-4 cm broad leaves. It generally grows in 0.75 to 1.5 m deep water. It has unique potential to remove acidity.

Typha latifolia plant is planted at close spacing of 10 cm. Long detention period of water with this plant is very important, only then the plant will show its efficacy. CMPDIL has suggested a detention period of 24 hrs. For providing such a long detention period, the size of the tank must be commensurate with the quantity of water pumped out daily. The dimension of the tank is 30m*15m*1m i.e. 450 m^3 or 450 KL.

In actual operation of the plant, this detention period is provided. The result has been found satisfactory. The pH improves to 6.0 - 7.0.

Utilization of Treated Water

1. Treated mine water will be utilized within mine premises for Dust suppression, Fire Fighting, plantation etc.
2. Treated water is not discharge outside Mine premises.

Fig.2: Flow Diagram Showing Water Utilization in Mine premises

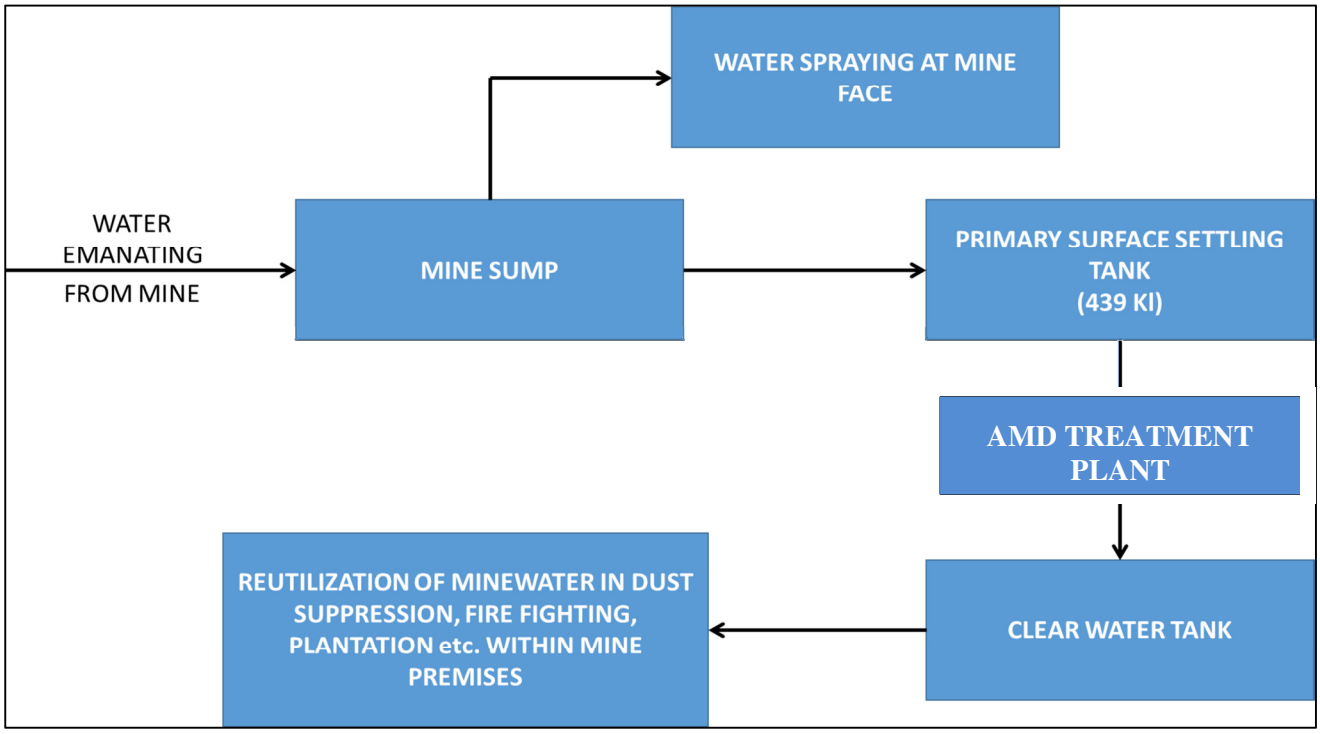
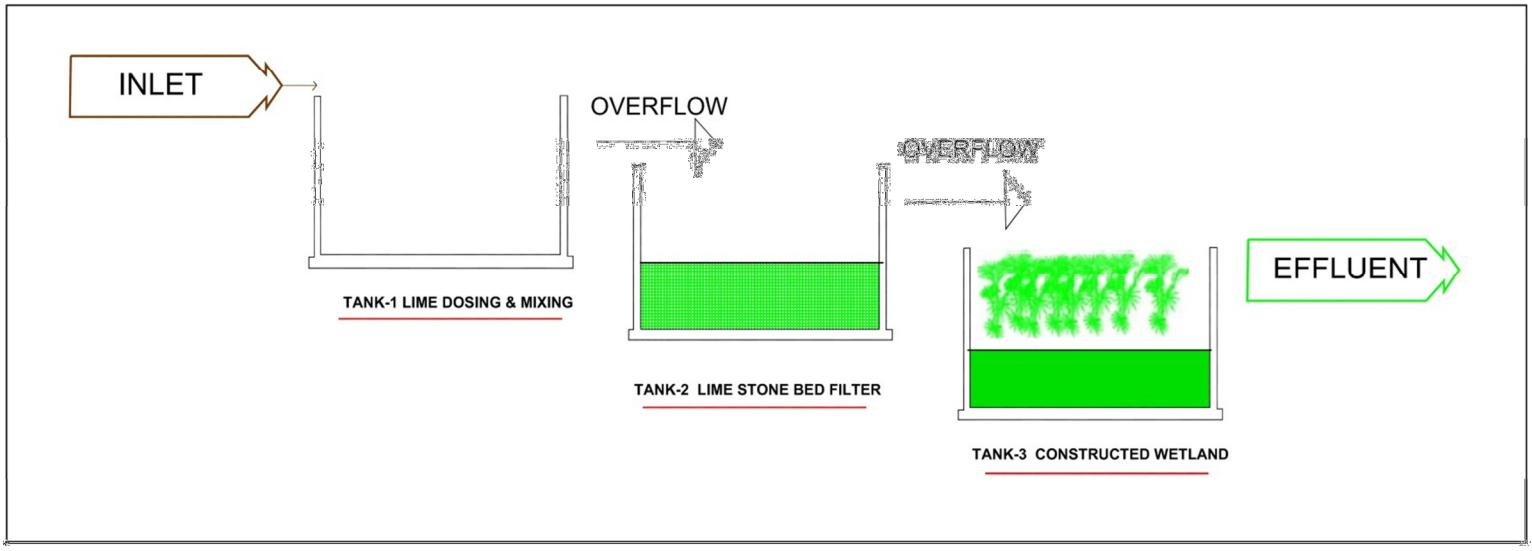


Fig.3: Schematic Diagram of AMD Treatment Plant at Naheriya UG



Photographs-2: of AMD Treatment Plant in Operation at Naheriya UG Mine

Tank 1
Lime Dosing Tank
Dimensions of 18 m x 6 m x 3 m

Tank 2
Lime Filter Bed Tank
Dimensions of 16 m x 5 m x 2 m

Tank 3
Aquatic Wetland
Dimensions of 30 m x 15 m x 1 m

Tank 4
Clear Water Tank

Photographs-3: of Mine water utilization in Naheriya UG Mine

Filling of tanker from Clear water tank via Pump for dust suppression & Plantation

Sprinkling of Water through Portable Water Sprinklers (An in-house innovation of WCL) in Coal Stock yard

Sprinkling of Water through Portable Water Sprinklers on Coal transportation Road & Coal Stock yard

Reply to the Issues Raised by EAC

S.No	Issues Raised	Reply
1	Volume of water treated	Average of 298 KLD water (Table-1) is being treated in the Acid Mine Drainage Treatment system
2	Dosage of lime	0.04 grams/liter of lime is being used.
3	Disposal of Waste Residue	As mentioned above 16.2 kg per day of Sludge will be generated. On regular basis Sludge will be removed. Characteristics of Sludge (Enclosed as Table-3) are not hazardous and will be utilized as fertilizer for plants or disposed along with other domestic waste.
4	Use of Treated water	The treated water is completely utilized within the premises for Dust suppression, Firefighting & for plantation (Photographs-3 shown above)
5	Enhancement of pH from 6.9 to Neutral (±7.2)	pH achieved after present treatment is neutral (6.0 – 7.0) (Table-2, 2.1 & 2.2 showing parameters before & after treatment)
6	Characteristics of Water before & After treatment	Water quality analysis is given in Tables – 2, 2.1 & 2.2
7	Water of Mine needs to be drained out / pumped out rather than intake before start of mine working	It is a UG mine and due to unique regional geological formation, less quantity of water seeps from the strata (Avg. 298 KLD). Treated mine water is being utilized for Dust suppression, firefighting & for plantation.
8	Treatment Technology	Existing Treatment Technology (Lime Treatment + Constructed Wetlands) is Effective, Efficient & Economical.
9	Defining water flows (indicating number of streams)	**1.** As detailed out above in the Stage wise Design, the existing Capacity of the treatment plant is more than sufficient (>30 %). 2 Settling Tanks of 439 KL capacity, Tank 1 of 324 KL capacity, Tank 2 of 80 + 80 = 160 KL capacity and Tank 3 of 450 KL capacity are in operation. **2.** During Maintenance, Existing system can hold additional 2 days water in UG sump & settling Tanks. **3.** In Tank 2, 2 tanks each of 80 KL capacity are in operation and while maintenance, 1 tank will be in operation.

Table-1

Daily Water Discharge Details

Date	Water Meter Reading (*10 KL)	Discharge Details (*10 KL)
01-07-16	00433	26
	00459	
02-07-16	00488	29
04-07-16	00518	30
05-07-16	00544	26
06-07-16	00570	26
07-07-16	00596	26
08-07-16	00623	27
09-07-16	00649	26
11-07-16	00675	26
12-07-16	00702	27
13-07-16	00728	26
14-07-16	00755	27
15-07-16	00781	26
16-07-16	00809	28
18-07-16	00840	31
19-07-16	00867	27
20-07-16	00892	25
21-07-16	00919	27
22-07-16	00944	25
23-07-16	00972	28
25-07-16	01003	31
26-07-16	01029	26
27-07-16	01055	26
28-07-16	01081	26
29-07-16	01109	28
30-07-16	01139	30
01-08-16	01171	32
02-08-16	01196	25
03-08-16	01222	26
04-08-16	01248	26
05-08-16	01276	28
06-08-16	01306	30
08-08-16	01338	32
09-08-16	01367	29
10-08-16	01394	27
11-08-16	01421	27
12-08-16	01449	28
13-08-16	01475	26
16-08-16	01507	32
17-08-16	01535	28
18-08-16	01562	27
19-08-16	01587	25

Table-1

Daily Water Discharge Details

Date	Water Meter Reading (*10 KL)	Discharge Details (*10 KL)
20-08-16	01613	26
22-08-16	01644	31
23-08-16	01672	28
24-08-16	01697	25
25-08-16	01722	25
26-08-16	01748	26
27.08.16	01773	25
29.08.16	01802	29
30.08.16	01827	25
01.09.16	08156	29
02.09.16	01886	30
03.09.16	01910	24
05.09.16	01939	29
06.09.16	01965	26
07.09.16	01990	25
08.09.16	02018	28
09.09.16	02043	25
10.09.16	02067	24
12.09.16	02095	28
13.09.16	02118	23
14.09.16	02144	26
15.09.16	02166	22
16.09.16	02190	24
17.09.16	02215	25
19.09.16	02244	29
20.09.16	02268	24
21.09.16	02294	26
23.09.16	02345	26
24.09.16	02370	25
26.09.16	02400	30
27.09.16	02424	24
28.09.16	02447	23
29.09.16	02471	24
30.09.16	02496	25

Table-2

Effluent Water Quality Report (CMPDI)

Month	Parameters	Standard for Discharge Part A, Schedule VI	Analysis Result	
			Mine Water Discharge	Outlet of AMD Plant
Sep	pH Value	5.5 – 9.0	3.67	6.50
	TSS (Mg/l)	100	54	20
	TDS (Mg/l)	---	560	650
Aug	pH Value	5.5 – 9.0	3.16	6.95
	Acidity CaCO3 (Mg/l)	--	124	10

Table-2.1

Effluent Water Quality Report- August (PHED)

S.N	Characteristics	Units	As Per BIS 10500, 2012		Standard for discharge Part A, Schedule VI	Samples Result	
			Requirement (Desirable limit)	Permissible limit in absence of Alternate Source		Inlet	Outlet
Physical Tests							
1	Temperature	^{O}C	---	---	Te < Ts + $5^{O}C$	26.2	26.2
2	Turbidity	NTU	1	5	----		
3	Odour	----	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
Routine Chemical Tests							
4	pH	pH	6.5 – 8.5	No relaxation	5.5 – 9.0	3.58	7.63
5	Conductivity $25^{O}C$	Mg/l	---	---	---	---	---
6	Total Alkalinity as $CaCO_3$	Mg/l	200	600	---	---	125.0

Contd..

S.N	Characteristics	Units	As Per BIS 10500, 2012		Standard for discharge Part A, Schedule VI	Samples Result	
			Requirement (Desirable limit)	Permissible limit in absence of Alternate Source		Inlet	Outlet
7	Chloride as Cl	Mg/l	250	1000	---	45.6	30.4
8	Nitrate as NO_3	Mg/l	45	45	---	0.8	2.6
9	Total Hardness as $CaCO_3$	Mg/l	200	600	---	348.0	612.5
10	Calcium as Ca^{++}	Mg/l	75	200	---	20.9	29.2
11	Magnesium as Mg^{++}	Mg/l	30	100	---	15.0	21.0
12	Total Dissolved Solids	Mg/l	500	2000	---	515	307
13	Iron	Mg/l	0.3	0.3	3.0	3.79	3.55
14	Manganese as Mn	Mg/l	0.1	0.3	2.0	---	---
15	Sulphate as SO_4	Mg/l	200	400	---	1473	427
16	Flouride	Mg/l	1.0	1.5	2.0	1.20	1.18
17	Residual Chlorine as Cl_2	Mg/l	0.2	1.0	1.0	---	---
Bacteriological Test							
18	MPN of Coliform	Per 100ml	Nil	Nil	---	---	---
19	Faecal Coliform	Per 100ml	Nil	Nil	---	---	---

Table-2.2

Effluent Water Quality Report (Unit Level)

Date of Sample collection	pH Results			
	Mine Water	Tank 1 (Lime Mixing Tank)	Tank 2 (Lime Stone Filter bed)	Tank 3 (Constructed wetland (Typha))
Detection Limit	**0.2**			
01.09.16	3.40	4.48	4.97	6.41
02.09.16	3.48	4.52	5.01	6.48
03.09.16	3.51	4.53	5.0	6.47
05.09.16	3.58	4.61	5.10	6.40
07.09.16	3.57	4.62	5.08	6.48
08.09.16	3.57	4.60	5.01	6.42
09.09.16	3.60	4.62	5.07	6.48
10.09.16	3.61	4.67	5.03	6.51
12.09.16	3.62	4.60	5.02	6.57
13.09.16	3.51	4.52	4.97	6.47
14.09.16	3.54	4.52	4.95	6.49
15.09.16	3.60	4.63	4.95	6.51
16.09.16	3.61	4.62	5.01	6.57
19.09.16	3.57	4.58	4.98	6.52
20.09.16	3.52	4.51	4.91	6.48
21.09.16	3.51	4.60	4.89	6.50
23.09.16	3.48	4.57	5.02	6.58
24.09.16	3.50	4.52	5.07	6.53
26.09.16	3.57	4.62	4.98	6.51
27.09.16	3.52	4.63	4.91	6.49
28.09.16	3.58	4.57	4.93	6.51
30.09.16	3.51	4.56	5.01	6.52
01.08.16	3.30	4.12	4.80	6.17
02.08.16	3.34	4.18	4.87	6.21
03.08.16	3.31	4.22	4.89	6.27
04.08.16	3.32	4.17	4.92	6.31
05.08.16	3.37	4.13	4.98	6.33
06.08.16	3.31	4.13	4.97	6.32
08.08.16	3.38	4.12	4.89	6.27
09.08.16	3.32	4.16	4.86	6.25
10.08.16	3.31	4.17	4.89	6.29
11.08.16	3.37	4.16	4.84	6.23
12.08.16	3.31	4.15	4.82	6.24
13.08.16	3.45	4.32	4.95	6.10
16.08.16	3.42	4.28	4.81	6.20
17.08.16	3.52	4.51	4.89	6.28
18.08.16	3.48	4.48	4.97	6.31
19.08.16	3.37	4.42	4.92	6.40
20.08.16	3.41	4.35	4.87	6.42
22.08.16	3.40	4.38	4.91	6.38
23.08.16	3.43	4.40	4.89	6.39

Table-2.2

Effluent Water Quality Report (Unit Level)

Date of Sample collection	pH Results			
	Mine Water	Tank 1 (Lime Mixing Tank)	Tank 2 (Lime Stone Filter bed)	Tank 3 (Constructed wetland (Typha))
Detection Limit	**0.2**			
24.08.16	3.38	4.37	4.90	6.40
25.08.16	3.41	4.39	4.91	6.42
26.08.16	3.37	4.38	4.92	6.48
27.08.16	3.36	4.41	4.93	6.47
29.08.16	3.39	4.40	4.97	6.51
30.08.16	3.40	4.41	4.96	6.57
31.08.16	3.39	4.32	4.82	6.37
01.07.16	3.78	4.51	4.81	6.08
02.07.16	3.62	4.17	4.89	6.13
04.07.16	3.73	4.23	4.90	6.31
05.07.16	3.81	4.20	4.94	6.41
06.07.16	3.84	4.08	5.01	6.47
07.07.16	3.85	4.12	5.07	6.44
08.07.16	3.81	4.03	5.12	6.40
09.07.16	3.89	4.19	5.14	6.32
11.07.16	3.32	4.09	5.17	6.17
12.07.16	3.33	4.13	5.15	6.19
13.07.16	3.41	4.23	5.02	6.07
14.07.16	3.43	4.24	5.09	6.03
15.07.16	3.19	4.27	5.02	6.01
16.07.16	3.31	4.11	4.87	6.03
18.07.16	3.32	4.14	4.91	6.13
19.07.16	3.35	4.18	4.82	6.07
20.07.16	3.37	4.23	4.89	6.13
21.07.16	3.38	4.16	4.90	6.12
22.07.16	3.39	4.18	4.97	6.19
23.07.16	3.31	4.21	4.92	6.13
25.07.16	3.30	4.24	4.89	6.23
26.07.16	3.32	4.17	4.93	6.32
27.07.16	3.27	4.16	4.84	6.08
28.07.16	3.21	4.18	4.89	6.09
29.07.16	3.19	4.13	4.81	6.04
30.07.16	3.13	4.09	4.78	6.01

Table-3

Characteristics of Sludge from AMD Treatment Plant

S.No	Parameters	MoEF Schedule VI (Inland Surface Water) Standards	Sample result
1	pH	5.5 – 9.0	8.06
2	Total Hardness as $CaCO_3$ – Mg/l	---	108

3.0 Ambient Air Quality Scenario of Naheriya Village

Above Permissible Air Quality (PM_{10}) Values in Naheriya Village: EAC pointed that the air quality in Naheriya village is above permissible standards (Ambient Air Quality Standards).

Submission:

1. In Naheriya UG, Monitoring of Ambient Air quality parameters in respect of SPM, PM_{10}, SO_x & NO_x is being carried out on fortnightly basis.
2. Seasonal Meteorological Pattern of the Naheriya UG Mine showing predominant wind direction is given below in windrose plot Fig.4
3. Naheriya village is located about 650 m on the West-South-West direction with respect to Naheriya UG (Fig 5) and Coal transportation road lies about 100m on south direction with respect to Naheriya Village.
4. It can be observed from wind rose diagram that predominant wind direction during most of the time is from North-West i.e. most of the time wind flows from North-West direction to south east direction.
5. From the above it can be inferred that above permissible Air quality standards at Naheriya Village is not due to mine operations & allied activities but could be due to local phenomenon (unpaved roads, use of wood/coal for cooking, storm dust etc.)
6. After simulation by Air quality impact prediction modeling packages it was predicted that there is no significant additional pollution load due to enhancement of production. Air quality will remain within permissible limits (Fig - 6).
7. Existing air pollution control measures are sufficient enough and additional measures will be installed / operated on need basis.

Fig-4 : Seasonal Wind rose Plot Diagram

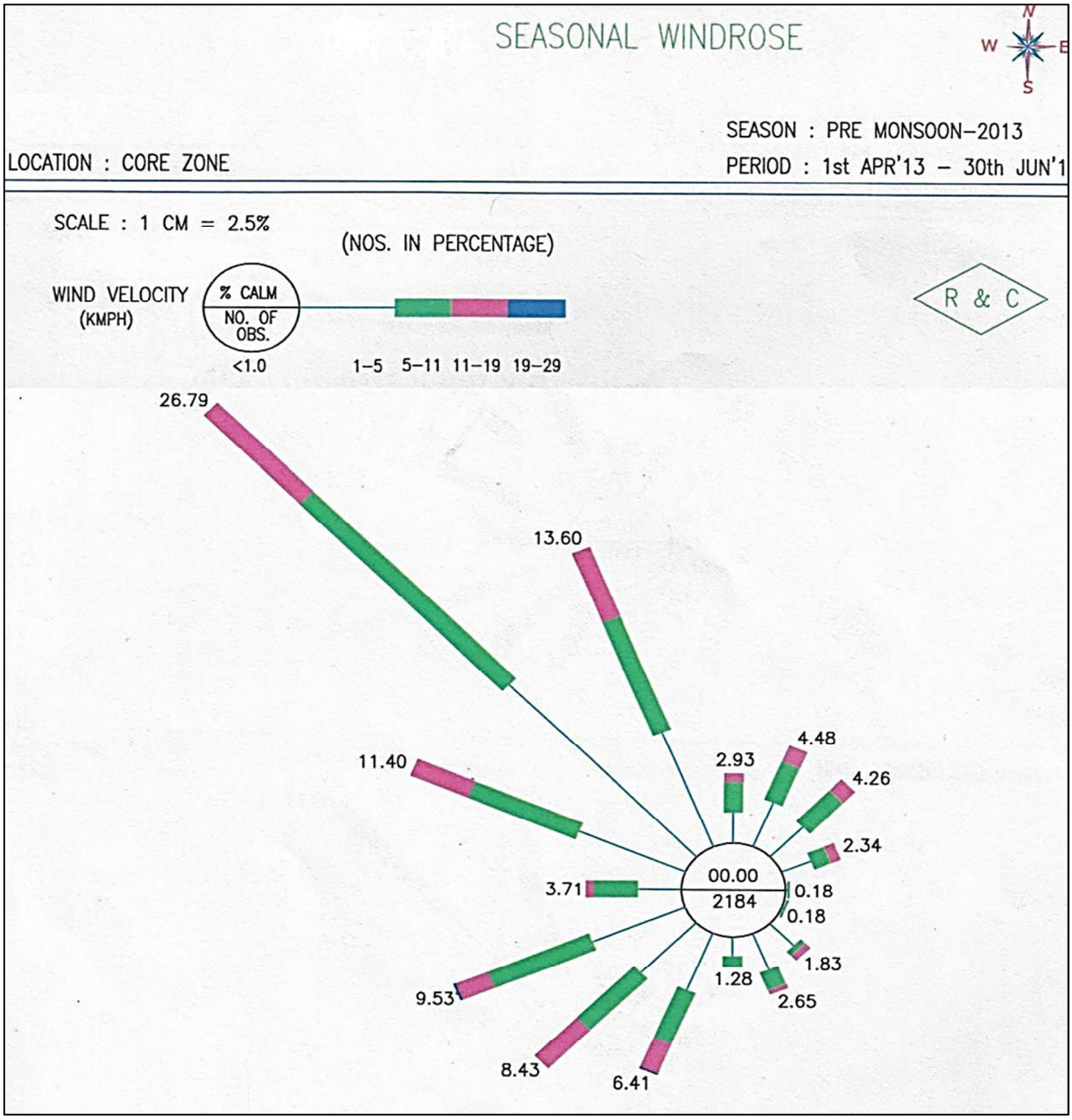
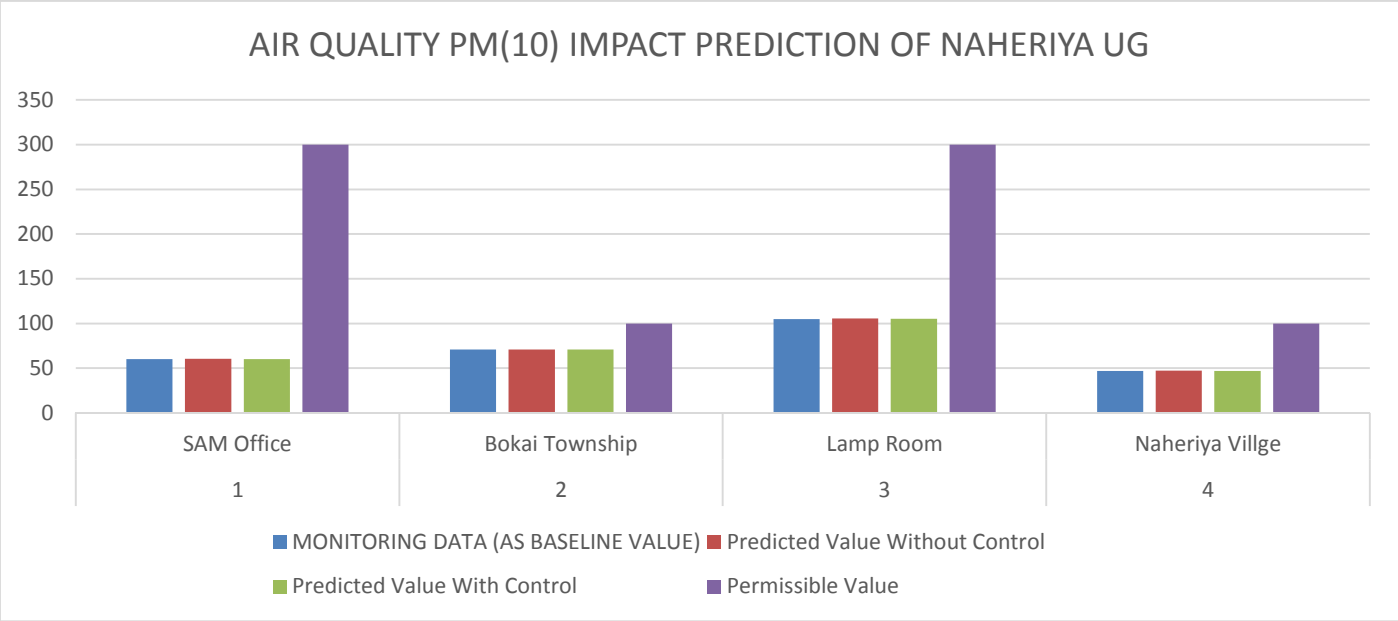


Fig-5. Location of Naheriya Village vis-à-vis Naheriya UG

Fig-6. Air Quality Impact Prediction for the proposed Naheriya UG Expansion



- From the above it can be seen that the increase in pollution due to enhancement in capacity of this UG mine is insignificant. Hence the values will remain within permissible limits.

Reply to the Issues Raised by EAC

Issue: Above permissible (Ambient Air Quality Standards) Air quality values in Naheriya Village

Reply: Air pollution arising from Mining activities is well controlled by operation pollution control measure eg. Dust suppression by Sprinklers, Mobile water tankers etc at dust generating sources. Because of this air quality within the core zone is within the standards. Air quality monitoring report is enclosed as (Table-4).

Regarding above permissible air quality values at Naheriya Village it is submitted that based on wind pattern, it can be interpreted that the air borne pollution at Naheriya village is not due to mining & its allied activities but could be local phenomenon like unpaved roads, use of wood / coal for cooking, burning of waste in open land, dust storms etc.

Table-4

Air Quality Monitoring Report of Naheriya UG Mine

Month	Location	Parameters							
		TPM		PM_{10}		NO_X		SO_X	
		Min	Max	Min	Max	Min	Max	Min	Max
April	Naheriya Village	72	88	39	63	14	15	19	19
May		42	85	22	47	15	20	11	14
June		40	40	35	35	15	15	12	12
Permissible Standards		200		100		80		80	

4.0 Subsidence Management

Reply to the Issues Raised by EAC

Issue : Additional information on Study of Subsidence using Prediction models

Reply: Detailed Study report is enclosed with this report.

Recommendations made in the report and recommendations made by DGMS from time to time will be implemented as and when required.

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REPORT ON

SUBSIDENCE PREDICTION AND MANAGEMENT FOR NAHERIYA UNDERGROUND MINES

WESTERN COALFIELDS LIMITED

SEPTEMBER 2016

REPORT ON

SUBSIDENCE PREDICTION AND MANAGEMENT

FOR

NAHERIYA UNDERGROUND MINES

WESTERN COALFIELDS LIMITED

SEPTEMBER 2016

MINING LABORATORY (UMD)
CENTRAL MINE PLANNING & DESIGN INSTITUTE LTD.
GONDWANA PLACE, KANKE ROAD
RANCHI – 834 008

Report on subsidence prediction and management for Naheriya Underground Mine, WCL.

Job No. **: 030416116**

Customer: WCL, Through Regional Director, RI-IV, CMPDI

Reference: Letter no. NGP/WCL/GM(P &P)/359 dated 16.06.2016.

Submission of report **:** September 2016

CONTENTS

LIST OF TABLES

ANNEXURE

LIST OF PLATES

1.0 INTRODUCTION :

A project report for Naheriya Underground Mine, Pench Area, WCL was prepared by CMPDI, Regional Institute-IV, for a targeted production of 0.36MTY. As per project report, in the proposed mining area four coal seams, viz. Seam II, Seam III, Seam IV and Seam V, were proposed to be extracted by bord and pillar method with caving. A ‘ Feasibility Study to Ascertain Safe Extraction of all the Four Contiguous Seams of Naheriya Underground Mine’ was conducted in 2008 by CIMFR, Dhanbad and it was suggested to develop and depillar Seam II separately and taking coal of Seam IC by heightening during depillaring of Seam II wherever possible. It is also recommended not to depillar Seam III. Further in the above report of CIMFR, it is proposed to depillar Seam IV and Seam V simultaneously with caving, using LHDs as mechanisation. Considering the revised production target of 0.54 MTY as proposed in CIMFR report, the total balance life of the mine has been assessed as 15 years. The mining area is covered by Forest land, Govt. Revenue land, Tenancy land, villages and roads. Considering these aspects subsidence prediction has been done for this mine.

As required by General Manager (P&P), WCL vide letter no. NGP/WCL/GM (P&P)/359 dated 16.06.2016. Mining Laboratory (UMD) of CMPDI (HQ) has carried out subsidence prediction study accordingly including likely impact of subsidence on surface topography, surface features and forest. The subsidence prediction study is intended to constitute a part of EMP report. The results of the study and subsidence management are presented in the following sections.

2.0 DETAILS OF THE MINE:

2.1	Mine	:	Naheriya Underground Mine
2.2	Area	:	Pench Area
2.3	Company	:	Western Coalfields Limited
2.4	Mining area	:	3.0 sq.km
2.5	Balance Extractable reserves	:	8.1 MT

2.6 Details of the coal seams to be worked (in descending order):

	Seam	Thickness	Depth	Extraction thickness
a)	Seam IC&II Comb.	0.71m to 6.53m	62.89m to 172.61 m	2.10 m to 4.50m
	Parting	4.07 m to 19.0 m		
b)	Seam IV	0.65m to 5.04m	78.70m to 184m	1.5m to 4.5m
	Parting	0.77 m to 8.85 m		
c)	Seam V	1.19m to 3.80m	82.14m to 194m	1.5m to full seam thickness

2.7 Proposed method of: extraction — Bord and pillar method with caving using LHDs.

2.8 Anticipated percentage: of extraction. — 80%

2.9 Overlying rock mass: — Medium to coarse grained sandstone, shale and flows of basalt.

2.10 Size of the panels: — sub- critical to super-critical.

2.11 Balance life of the mine: — 15 years

2.12 Topography: — The general elevation varies from 700m to 784m above MSL.

2.13 Surface properties and their protection: — Forest land, Govt. revenue land, Private(Tenancy) land, road, Gunor River and seasonal nallas exist over the mining area.

3.0 TOPOGRAPHY, DRAINAGE AND LAND USE:

The entire mining area is covered with flows of basalt which on differential erosion has been formed rugged terrain comprising of hills and

valleys. The elevation within the proposed area of the working is found to be ranging from 700m to 784m. i.e. a difference of elevation of 84m.

The drainage in the area is mainly controlled by perennial Gunor River which is almost encircles and forms the south-western, north-western and northern boundary of the proposed mining block. A number of seasonal nallas flow in this block in different directions guided by local topography and ultimately meet in the Gunor river. The HFL of the Gunor river and Dhankasa nalla is 720m.

Out of total area of 4.2 sq. km. of geological block the forest cover is 3.0 sq. km. while 1.2 sq. km. area is used for cultivation. Naheriya underground mine comprises of 3.0 sq. km. out of which 2.37 sq. km. is forest land and 0.63 sq. km. is agriculture land.

4.0 GEOLOGY:

The borehole drilled in the mining area indicate that the coal bearing strata consists of medium to coarse grained sandstone, shale, shaly coal and coal seams and basalt. There are five coal seams occurring in the mining area, out of which three coal seams, viz. Seam II & IC, Seam IV and Seam V seam are considered for depillaring. The uppermost workable seam is Seam IC&II which occurs at a depth range of 62.89m to 172.61m. The thickness of this seam varies from 0.71m to 6.53m. The workable thickness is considered from 1.5m to full 4.5m. The middle workable seam is Seam IV which occurs at a depth range of 78.70m to 184m. Thickness of the seam varies from 0.65m to 5.04m. The workable thickness is considered from 1.5m to 4.5m. The lower most workable seam is Seam V which occurs at a depth range of 82.14 to 194m. Its thickness varies from 1.19m to 3.8m. The workable thickness is considered to be 1.5m to full seam thickness. Gradient of the coal seams is 1 in 11 to 1 in 18.

5.0 METHOD OF MINING:

Naheriya UG mine is has been developed on Bord and Pillar method. The extraction of pillars (depillaring) is proposed to be done by caving

method. LHD is to be used for mechanisation. The minimum and maximum thickness of extraction have been considered 1.5m to 4.5m.

Proposed layouts of all the three seams considered for depillaring (i.e. Seam IC & II, Seam IV and Seam V) are shown in different colours in Plate 1. Layouts of the panels in Seam IC & II, Seam IV and Seam V are shown in Plates 2, 3 and 4 respectively. The layout of the panels proposed for depillaring have been taken from mine projection plan of each seam as provided by mines.

6.0 SUBSIDENCE PREDICTION:

The subsidence prediction numerical model based on Influence Function method, developed in CMPDI, has been used for estimation of likely subsidence over the mining area. Subsidence prediction has been done for the panels proposed to be extracted by caving method in the mine plans of Seam IC&II, Seam IV and Seam V. As per project report, the minimum and maximum thickness of extraction have been considered to be 1.5m to 4.5m. Input data used for subsidence prediction, such as mining parameters, geology, panels' dimension, sequence of extraction of the panels and surface features have been collected from project reports and mine plans sent by the mine.

Details of mine layout, surface contours, surface features, forest and other relevant features have been digitised from mine projection plan of the respective seams, surface plan and land use plan. The digitised data have been used as input parameters for subsidence prediction model.

For subsidence prediction, subsidence parameters such as values of subsidence factor and angle of draw for single and multiple seam extraction have been taken considering the rock mass factor, geo-mining conditions and subsidence data observed in Sukri and Chandametta mines. At Sukri mine, the subsidence factor and angle of draw observed are 0.33 and 33° respectively. The parameters taken for subsidence prediction are as follows :

i)	Subsidence factor:	0.33 for single seam extraction and 0.51 for multiple seam extraction.
ii)	Angle of draw:	33^0 for single seam extraction and 35^0 for multiple seam extraction.
iii)	Anticipated percentage: of extraction in panels	80% within the panel
iv)	Depth:	Average depth for each panel.
v)	Thickness of extraction:	Average thickness of the seam for each panel.

Before subsidence prediction, the prediction model has been calibrated according to the above mentioned subsidence parameters. For subsidence calculation, underground extraction area has been divided into 20m x 20m grid blocks as individual elements. The numerical procedure followed for prediction involves estimation of subsidence at the grid points of each element and subsequent integration to arrive at resultant values and the final area influenced by ground movement. Subsidence has been calculated over 20,690 points.

Subsidence prediction has been done for the Seam IC&II, Seam IV and Seam V individually & cumulatively i.e. at the end of mine life. Panels proposed for depillaring in Seam IC&II, Seam IV and Seam V are shown in different colours in plates 2, 3 and 4 respectively.

7.0 SUBSIDENCE PREDICTION RESULTS:

7.1 Maximum Subsidence, Subsidence contours and Subsidence profiles:

The anticipated maximum possible subsidence likely to occur over the mining area due to extraction of Seam IC&II, Seam IV and Seam V individually are 1.49m over panel SW5A, 1.60m over panel SW7 and 1.36m over panel NE2 respectively. The estimated maximum possible subsidence likely to occur at the end of mine life is 3.68m, which is likely to take place over the panels SW5A of Seam IC&II, Seam IV and Seam V. In the forest

area, the maximum possible subsidence likely to occur is 3.66m, which is likely to take place over SW1 panels of the seams. From the estimated subsidence at each grid point, subsidence contours are drawn due to extraction of Seam IC&II, Seam IV and Seam V individually and cumulatively i.e. after 15 years (i.e. at the end of mine life) of mining and shown in plates 6, 8, 10 and 12 respectively. In the plates, subsidence contours are shown alternately in violet and orange colours at 0.3m intervals in Plates 6, 8 & 10 and at 0.6m intervals in Plate 12. Final subsidence profiles along line AA' and BB' have also been drawn and shown in plates 17 and 18 respectively. Both the lines are intersecting at the maximum subsidence point over the mining area. Subsidence will be delayed due to presence of basalt.

7.2 Effect of subsidence on surface topography and surface features along with mitigative measures :

Topography before mining, due to extraction of Seam IC&II, Seam IV and Seam V individually and at the end of mine life are shown in Plates 7, 9, 11 and 13 respectively. Change in topography due to subsidence can be seen by comparing the above mentioned plates. For a comparative assessment of ground condition before and after mining, 3D views of surface before and after mining, (i.e. after extraction of Seam IC&II, Seam IV and Seam V) are shown in Plates 14 and 15 respectively. By comparing the above two views, it is observed that there is negligible change in surface topography. Surface profiles before mining and after final subsidence (i.e. after extraction of all the three seams proposed to be depillared) have also been drawn along lines AA' and BB' and shown in Plates 17 and 18 respectively.

The topography of the mining area is hilly and rugged with thick forest cover in the eastern part and the northern and north western part regions are comparatively flat. The general elevation varies from 700m to 784m above MSL. i.e. a difference of elevation of 84m. For such terrain, the maximum anticipated subsidence of 3.68m is unlikely to affect the drainage pattern in the area. However, subsidence may result in the formation of depressions over the centre of the panels and cracks at the zones of high tensile strain

such as along the boundary and barriers. Pools of water are likely to be formed in these depressions during rains, which may be retained wherever possible for the benefit of vegetation in the forest land or filled up/drained out by cutting drains depending on safety of underground workings. The surface cracks, developed due to subsidence, need to be filled up properly and regularly with clay and stone chips to achieve the original drainage pattern of the area and to prevent ingress of air and water into the goaf. This will minimise the chances of underground inundation and spontaneous heating.

For estimating the effects of subsidence on surface features, panel wise anticipated maximum possible subsidence, slope and tensile strain have been calculated due to extraction of Seam IC&II, Seam IV and Seam V individually and cumulatively, which are shown in Tables 1, 2 3 and 4 respectively. Strain developed due to subsidence is the prime cause of damage to the surface features. Thus, values of strain likely to occur near important surface features have been estimated to envisage the extent of damages to the surface features. The impacts of subsidence on different surface features are outlined below.

Impact of subsidence on roads:

Road passing parallel to Gunor river near southern boundary is not likely to be affected by subsidence as it is out of subsidence influence area. Road passing through the mining area is likely to be affected by a maximum amount of 3.66m subsidence and 71.76 mm/m slope. Such amount of subsidence and slope will cause severe damage to the road and major repairs will be required. However, to keep the road out of the subsidence influence area solid coal barrier may be left un-extracted vertically below and within 35^0 angle of draw from such roads.

Impact of subsidence on Gunor River and nalas:

Gunor river is likely to be affected by a maximum amount of 0.31m subsidence and 5.93 mm/m strain near then panel SW7. This amount of strain is above the permissible limit of 4mm/m strain considered in pench

area. Therefore, it is suggested to leave solid coal unextracted vertically below and within 35^0 angle of draw from Gunor river.

Dhankasa nala is likely to be affected by a maximum amount of 0.07m subsidence near the panel NE Part which does not have any damaging effect due to such small magnitude.

Impact of subsidence on Tenancy Land:

Tenancy Land over the mining area are likely to be affected by a maximum amount of 3.68m subsidence, 73.60mm/m slope and 38.64mm/m tensile strain over panel SW5A. Such amount of subsidence and tensile strain will result in reduction in yield and water retention capacity of sub-soil and the surface will get distorted. Therefore crop compensation has to be paid to the owners in the year when depillaring commences below such land.

Impact of subsidence on Govt. Revenue Land:

Govt. revenue Land over the mining area are likely to be affected by a maximum amount of 3.48m subsidence, 47.03mm/m slope and 24.69mm/m strain over the panels SW5B. Such amount of subsidence and tensile strain will result in very severe distortion in the surface.

Impact of subsidence on Villages

Villages over the mining area are likely to be affected by a maximum amount of 2.64m subsidence, 41.25mm/m slope and 21.65mm/m strain over the panels SW3. Such amount of subsidence is likely to have severe damaging effect on villages. Therefore, it is suggested to leave solid coal unextracted vertically below and within 35^0 angle of draw from the villages and built up areas.

Impact of subsidence on HT Lines

HT Lines over the mining area are likely to be affected by a maximum amount of 3.66m subsidence, 71.76mm/m slope and 37.68mm/m strain. Such high amount of subsidence will cause severe damage to the trestles of

HT Lines. Therefore, it is suggested to leave solid coal unextracted vertically below and within 35^0 angle of draw from the HT Lines.

7.3 Effect of subsidence on forest with mitigative measures :

All the panels partly or fully are below the forest land. For estimating the effect of subsidence on forest, panel wise anticipated maximum possible subsidence, slope and tensile strain have been calculated due to extraction of Seam IC&II, Seam IV and Seam V individually and cumulatively, which are shown in Tables 1, 2, 3 and 4 respectively. Table 4 shows the estimated maximum possible subsidence, slope and tensile strain due to extraction of all the seams proposed to be depillared.

It is evident from the data in the above tables that due to extraction of all the four seams proposed to be depillared, the values of tensile strain likely to occur over the forest area exceed the limit as prescribed by MOEF for the purpose of Net Present Value, i.e. values of strain in the forest area are more than 20 mm/m. Due to extraction of Seam IC&II only, the maximum value of subsidence and tensile strain likely to occur in the forest area are 1.12m over panel SW5N and 9.05 mm/m over the same panel respectively. Due to extraction of Seam IV only, the maximum value of subsidence and tensile strain likely to occur in the forest area are 2.29m and 18.93 mm/m respectively over the panel NE1. Due to extraction of Seam V only, the maximum value of subsidence and tensile strain likely to occur in the forest area are 1.36m and 10.20mm/m respectively over the panel NE2. Due to extraction of all the four seams proposed to be depillared, the cumulative maximum subsidence and tensile strain likely to occur over the forest area are 3.66m and 37.68 mm/mover the panels SW1 respectively.

Thus, the area experiences a maximum strain of 37.68mm/m. Such amount of tensile strain is likely to develop surface cracks more than 300mm wide. The anticipated maximum possible slope likely to occur in the forest area is 71.76mm/m, i.e. a tilt of 4.10^0, which is unlikely to cause falling of trees in the forest area.

Thus, it is anticipated that the forest may not be considerably affected by subsidence. Only a limited number of trees falling on the edges of

subsidence trough and surface cracks may get tilted or dislodged. However, provision has to be made for compensatory afforestation and strengthening of forest cover to take care of losses, if any. Surface cracks likely to develop in the forest area should be filled up with clay and stone chips and thereafter with about 0.3m high clay heap over the cracks.

As per recommendation of MOEF, the area in the forest having more than 20 mm/m strain would be considered as subsidence affected area due to underground mining and accordingly NPV is to be paid. Thus considering the above, the area likely to be affected by 20 mm/m or more strain due to extraction of all the three seams that are proposed to be depillared i.e. at the end of mine life is shown in Plate 16.

8.0 SUBSIDENCE MANAGEMENT:

Considering the impact of subsidence on surface topography, forest and surface features, as explained in earlier chapters, the following subsidence management aspects are required to be undertaken to overcome or to minimise adverse effects.

i) Due to subsidence, surface cracks likely to develop over the mining area need to be filled up properly and regularly by clay and stone chips and thereafter with about 0.3m high clay heap over the cracks. It will help in achieving the original drainage pattern over the mining area, improving the water retention capacity of the soil, minimising the top soil erosion and avoiding chances of underground inundation and spontaneous heating.

ii) It is suggested that a team is formed by the mine management which will be responsible for the proper and regular filling of surface cracks developed due to subsidence. The team will also maintain record of the development and filling of surface cracks. Adequate supply of filling materials should be arranged by mine management at the site.

iii) It is suggested that a time lag of about 5 years should be maintained before extracting the panels of lower seam immediately below the extracted panels of upper seam. This will allow the super incumbent strata

to consolidate and settle before the extraction of lower seam. With this time lag in multiple seam extraction, depressions on the surface will take place in steps and after long intervals of time, and as a result reduced amount of slope and strain will occur on the surface. Hence, it is not expected to have adverse impact on the forest. Only a limited number of trees located on the edges of subsidence trough and surface cracks may get tilted or dislodged. Therefore, it is recommended that the depillaring of the panels is scheduled in such a manner that at least a gap of 5 years is maintained between extractions of successive panels in superimposition.

iv) Provision has to be made for compensatory afforestation and strengthening of forest cover to take care of losses, if any.

v) Subsidence may result in depressions on the surface with accumulation of water during the rains. Such accumulation of water may be beneficial for vegetation in the forest. These water bodies may be retained wherever possible or filled up/drained out by cutting drains depending on safety of the underground workings.

vi) Surface drains should be made outside of the subsidence influence area to prevent the surface water of adjoining area from coming into active subsidence area.

vii) Coal pillars are to be left un-extracted vertically below and within subsidence influence area from the surface features which need to be protected from subsidence damages, if any.

viii) Considering the make of water in small seasonal streamlets existing over the mining area, due care has to be undertaken while extraction is made below these streamlets such as avoiding extraction during monsoon and filling up cracks developed in the bed of the streamlets, when dry. However, if it is required to keep these streamlets totally out of subsidence influence area, coal pillars should be left un-extracted vertically below and within angle of draw from the streamlet, i.e. within 35^0 angle of draw for multiple seam extraction.

The impact of subsidence on different surface features and forest land along with the degree of damage are provided in Annexure I for reference, i.e. the “Subsidence Impact Matrix”. The Subsidence Impact Matrix (SIM) shown therein was developed under a Ministry of Coal funded S&T project.

9.0 CONCLUSION:

i) Due to extraction of Seam IC&II only, the anticipated maximum possible subsidence likely to occur over the mining area is 1.49m, which is likely to take place over the panel SW5A. The estimated maximum possible slope and tensile strain likely to occur are 38.21 mm/m and 20.06 mm/m respectively over the panel SW5A.

ii) Due to extraction of Seam IV only, the anticipated maximum possible subsidence likely to occur over the mining area is 1.60m, which is likely to take place over the panel SW7. The estimated maximum possible slope and tensile strain likely to occur are 27.23 mm/m and 14.30 mm/m respectively over the panel SW5A.

iii) Due to extraction of Seam V only, the anticipated maximum possible subsidence likely to occur over the mining area is 1.36m, which is likely to take place over the panel NE2. The estimated maximum possible slope and tensile strain likely to occur are 20.98 mm/m and 11.01 mm/m respectively over the panel SW1.

iv) After extraction of all the three seams proposed to be depillared, i.e. after extraction of Seam IC&II, Seam IV and Seam V, the anticipated maximum possible subsidence likely to occur over the mining area is 3.68m, which is likely to take place over the panels SW5A of all the seams mentioned above. The estimated maximum possible slope and tensile strain likely to occur are 73.60 mm/m and 38.64 mm/m respectively over the panels SW5A of all the seams mentioned above.

v) All the panels partly or fully, are below the forest land. Due to extraction of all the three seams proposed to be depillared, the cumulative maximum subsidence and tensile strain likely to occur over the forest area are 3.66m and 37.68 mm/mover the panels SW1 respectively. Thus, the area experiences a maximum strain of 37.64mm/m. Such amount of tensile strain is likely to develop surface cracks more than 300mm wide. The anticipated maximum possible slope likely to occur in the forest area is 71.76mm/m, i.e. a tilt of 4.10^0, which is unlikely to cause falling of trees in the forest area. To minimise the slope and strain in the forest area, it is recommended to maintain at least a gap of 5 years between extractions of successive panels in superimposition. This will allow the strata to settle before the extraction of lower seam as well as tilt will take place in steps (after extraction of each seam) and after an interval of 5 year time. . Thus, it is anticipated that the forest may not be considerably affected by subsidence. Only a limited number of trees falling on the edges of subsidence trough and surface cracks may get tilted or dislodged.

vi) Provision has to be made for compensatory afforestation and strengthening of forest cover to take care of losses, if any.

vii) For the purpose of Net Present Value (NPV), Central Government has made a recommendation for subsidence affected area in the forest due to underground mining, which depicts that the area in the forest having more than 20 mm/m strain would be considered as affected area and accordingly NPV is to be paid. Considering the above, the surface over the mining area likely to be affected by 20 mm/m or more strain (due to extraction both the workable seams) is drawn and shown in Plate 16. For the affected area of forest, as shown in Plate 16, NPV has to be paid.

viii) Though the small seasonal streamlets have not been shown on surface plan but if such streamlets exist over the mining area to control the surface drainage are likely to be affected by subsidence. Considering the make of water in these streamlets, due care has to be taken while extraction is made below it, such as avoiding extraction during monsoon

and filling up cracks developed in the bed of streamlets, when dry to avoid inrush of water belowground in the rainy season. However, if it is necessary to bring the streamlets out of subsidence influence area, coal pillars should be left un-extracted vertically below and within subsidence influence area from it.

ix) Road passing over the mining area parallel to Gunor river near southern boundary is not likely to be affected by subsidence as it is out of subsidence influence area. Road passing through the mining area is likely to be affected by a maximum amount of 3.66m subsidence and 71.76 mm/m slope. Such amount of subsidence and slope will cause severe damage to the road and major repairs will be required. However, to keep the road out of the subsidence influence area solid coal barrier may be left un-extracted vertically below and within 35^0 angle of draw from such roads.

x) Gunor river is likely to be affected by a maximum amount of 0.31m subsidence and 5.93 mm/m strain near the panel SW7. This amount of strain is above the permissible limit of 4mm/m strain considered in pench area. Therefore, it is suggested to leave solid coal unextracted vertically below and within 35^0 angle of draw from Gunor river.

Dhankasa nala is likely to be affected by a maximum amount of 0.07m subsidence near the panel NE Part which does not have any damaging effect due to such small magnitude.

xi) Govt. revenue Land over the mining area are likely to be affected by a maximum amount of 3.48m subsidence, 47.03mm/m slope and 24.69mm/m strain over the panels SW5B. Such amount of subsidence and tensile strain will result in very severe distortion in the surface.

xii) Tenancy lands over the mining area are likely to be affected by subsidence. Therefore, crop compensation has to be paid to the owners in the year when depillaring commences below such land.

xiii) Villages over the mining area are likely to be affected by a maximum amount of 2.64m subsidence, 41.25mm/m slope and 21.65mm/m strain over the panels SW3. Such amount of subsidence is likely to have severe damaging effect on villages. Therefore, it is suggested to leave solid coal unextracted vertically below and within 35^0 angle of draw from the villages and built up areas.

xiv) HT Lines over the mining area are likely to be affected by a maximum amount of 3.66m subsidence, 71.76mm/m slope and 37.68mm/m strain. Such high amount of subsidence will cause severe damage to the tresles of HT Lines. Therefore, it is suggested to leave solid coal unextracted vertically below and within 35^0 angle of draw from the HT Lines.

xv) The topography of the mining area is hilly and rugged with thick forest cover in the eastern part and the northern and north western part regions are comparatively flat. The general elevation varies from 700m to 784m above MSL. i.e. a difference of elevation of 84m. For such terrain, the maximum anticipated subsidence of 3.68m is unlikely to affect the drainage pattern in the area. However, subsidence may result in the formation of depressions over the centre of the panels where water may accumulate during rains. The accumulation of water may be beneficial for vegetation in the forest. Thus, the desirable water bodies may be retained after extraction of both the workable seams. In case the safety of underground workings is impinged by it, the depressions should be filled up or water from them should be drained out by cutting drains.

xvi) Surface cracks formed due to subsidence will need to be filled up with clay and stone chips and thereafter with about 0.3m high clay heap over the cracks. It will help in achieving the original drainage pattern in the mining area, improving water retention capacity of the soil, minimising the top soil erosion and avoiding chances of underground inundation and spontaneous heating.

xvii) It is suggested that the mine management forms a team that will be responsible for the proper and regular filling of surface cracks developed due to subsidence. The team will also maintain a record of the development and filling of surface cracks. Adequate supply of filling materials should be arranged by the mine management at the site.

xviii) Surface drains should be made outside of the subsidence influence area to prevent the surface water of adjoining area from coming into active subsidence area.

xix) For the safety of underground workings it will be necessary to prevent the formation of water bodies on the surface while extracting panels in the lower seam. It is also suggested that dewatering of the goaves of upper seam should be continued as long as the lower seam is worked to prevent the formation of large water bodies over the working area.

xx) It is recommended that while carrying out extraction in the Lower Workable seam, close subsidence monitoring required to be done over some initial panels. On the basis of observed data, necessary correction in subsidence estimation may be done, if required.

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Table 1: Anticipated maximum subsidence, slope and strain at surface due to extraction of panels of seam IC&II only.

Panel No.	Av. Width	Av. Depth	Extraction Thickness	Max. Subsidence	Max. Slope	Max. Strain
	(m)	(m)	(m)	(mm)	(mm/m)	(mm/m)
SW7	220	144	3.0	920	12.78	6.71
SW6	140	117	4.5	1190	20.34	10.68
SW5A	200	78	4.5	1490	38.21	20.06
SW5B	200	125	4.5	1420	22.72	11.93
14DA	80	157	1.8	280	3.57	1.87
14DB	140	157	1.8	260	3.31	1.74
NE3B	90	130	3.6	350	5.38	2.83
SW5N	220	130	3.6	1120	17.23	9.05
SW6N	120	134	3.6	230	3.43	1.80
NE PART	200	153	3.6	1050	13.73	7.21
SW4	120	85	3.5	1010	23.76	12.48
SW3	120	90	3.5	970	21.56	11.32
SW2	160	98	3.2	940	19.18	10.07
SW1	240	75	3.2	1060	28.27	14.84
MD1	120	109	2.1	580	10.64	5.59
MD2	120	150	2.1	260	3.47	1.82

Table 2: Anticipated maximum subsidence, slope and strain at surface due to extraction of panels of seam IV only.

Panel No.	Av. Width	Av. Depth	Extraction Thickness	Max. Subsidence	Max. Slope	Max. Tensile Strain
	(m)	(m)	(m)	(mm)	(mm/m)	(mm/m)
SW7	220	159	3.3	1600	20.13	10.57
SW6	160	129	3.2	1420	22.02	11.56
SW5A	180	94	2.5	1280	27.23	14.30
SW5B	200	142	2.5	1210	17.04	8.95
SW4	120	110	2.3	960	17.45	9.16
14D	140	165	3.0	950	11.52	6.05
SW3	120	125	2.7	1190	19.04	10.00
SW2	160	117	3.2	1430	24.44	12.83
SW1	360	97	3.0	1530	31.55	16.56
SW5N	200	139	2.8	1370	19.71	10.35
SW6N	100	144	2.8	680	9.44	4.96
NE PART	200	167	2.0	940	11.26	5.91
NE3	200	156	2.5	1130	14.49	7.61
NE2	280	135	4.0	2040	30.22	15.87
NE1D1	240	130	4.5	1560	24.00	12.60
NE1B2	100	114	4.5	1240	21.75	11.42
NE1C2	120	119	4.5	1600	26.89	14.12
NE1D2	120	124	4.0	1480	23.87	12.53
NE1	120	127	4.5	2290	36.06	18.93
NE1C1	120	129	4.5	1500	23.26	12.21
MD1	208	119	2.2	1110	18.66	9.79
MD2	208	154	2.2	980	12.73	6.68

Table 3: Anticipated maximum subsidence, slope and strain at surface due to extraction of panels of seam V only.

Panel No.	Av. Width	Av. Depth	Extraction Thickness	Max. Subsidence	Max. Slope	Max. Tensile Strain
	(m)	(m)	(m)	(mm)	(mm/m)	(mm/m)
SW7	220	168	2	940	11.19	5.88
SW6	160	137	2.3	960	14.01	7.36
SW5A	180	100	1.8	910	18.20	9.56
SW5B	200	148	1.8	860	11.62	6.10
SW3	120	128	2	730	11.41	5.99
SW2	160	122	2.4	1050	17.21	9.04
SW1	360	102	2.1	1070	20.98	11.01
NE2	180	140	2.7	1360	19.43	10.20
NE3	160	162	2.4	1030	12.72	6.68
NE3 PART	220	173	1.8	830	9.60	5.04
MD1	208	134	2.5	1230	18.36	9.64
MD2	180	160	2.5	1030	12.88	6.76

Table 4: Anticipated maximum possible subsidence, slope and tensile strain at surface after extraction of seam IC&II, seam IV and Seam V.

Panel No.	Max. Subsidence	Max. Slope	Max. Strain	Likely width of cracks
	(mm)	(mm/m)	(mm/m)	(mm)
2SW7	3450	41.07	21.56	>300
2SW6	3510	51.24	26.90	>300
2SW5A	3680	73.60	38.64	>300
2SW5B	3480	47.03	24.69	>300
2,14DA	1480	17.94	9.42	<100
2,14DB	1190	14.42	7.57	<50
2NE3B	1760	21.73	11.41	<100
2SW5N	2490	35.83	18.81	<300
2SW6N	900	12.50	6.56	<50
2NEPART	2690	31.10	16.33	<200
2SW4	1960	35.64	18.71	<300
2SW3	2700	42.19	22.15	>300
2SW2	3410	55.90	29.35	>300
2SW1	3660	71.76	37.68	>300
2MD1	2880	42.99	22.57	>300
2MD2	2110	26.38	13.85	<150
4SW7	3450	41.07	21.56	>300
4SW6	3510	51.24	26.90	>300
4SW5A	3680	73.60	38.64	>300
4SW5B	3480	47.03	24.69	>300
4SW4	1960	35.64	18.71	<300
414D	1190	14.42	7.57	<50
4SW3	2700	42.19	22.15	>300
4SW2	3410	55.90	29.35	>300
4SW1	3660	71.76	37.68	>300
4SW5N	2490	35.83	18.81	<300
4SW6N	900	12.50	6.56	<50
4NEPART	2690	31.10	16.33	<200
4NE3	2160	26.67	14.00	<150
4NE2	3380	48.29	25.35	>300
4NE1D1	1560	24.00	12.60	<100
4NE1B2	1240	21.75	11.42	<100
4NE1C2	1600	26.89	14.12	<100
4NE1D2	1480	23.87	12.53	<100
4NE1	2290	36.06	18.93	<300
4NE1C1	1500	23.26	12.21	<100
4MD1	2880	42.99	22.57	>300
4MD2	2200	27.50	14.44	<150
5SW7	3450	41.07	21.56	>300
5SW6	3510	51.24	26.90	>300
5SW5A	3680	73.60	38.64	>300
5SW5B	3480	47.03	24.69	>300

Panel No.	Max. Subsidence	Max. Slope	Max. Strain	Likely width of cracks
	(mm)	(mm/m)	(mm/m)	(mm)
5SW3	2700	42.19	22.15	>300
5SW2	3410	55.90	29.35	>300
5SW1	3660	71.76	37.68	>300
5NE2	3380	48.29	25.35	>300
5NE3	2160	26.67	14.00	<150
5NEPART	2690	31.10	16.33	<200
5MD1	2880	42.99	22.57	>300
5MD2	2200	27.50	14.44	<150

Note: Panel no. is prefixed by seam no. as 2SW7 means panel SW7 of seam IC&II, 4SW7 means panel SW7 of seam IV and 5SW7 means panel SW7 of seam V and so on.

SUBSIDENCE IMPACTS

The Subsidence Impact Matrix given below shows the degrees of damage for various surface features, including forest land, vis-a-vis subsidence, slope and strain values was developed as part of a Ministry of Coal funded S&T project and is extracted from the S&T Report titled "Subsidence in Mining Areas" by CMRI.

Sl. No.	Impact	Subsidence	Slope	Strain
		mm	mm/m	mm/m
1	2	3	4	5
SURFACE TOPOGRAPHY				
1.	Practically no impact	<500	<3	<3
2.	Some fine cracks or one or two 50mm wide cracks with visible depression	<500 500-1000	3-5 5-10	3-5 3-5
3.	A large number of fine cracks or a few 100mm wide cracks with marked depression	500-2000	10-20	5-10
4.	A large number of 50-100mm wide cracks or a few 200mm wide cracks with stepping. Marked distortion in surface topography	500-2000	>20	10-20
5.	500mm wide cracks with stepping and prominent distortion in surface topography	>1000	>50	20-50
6.	Many 500mm wide cracks some upto 1000mm width, large stepping. Severe distortion in surface topography	>2000	>100	50-100
7.	Very severe distortion in surface topography. Stepped subsidence with very wide cracks.	>2000	>100	>100

1	2	3	4	5
		mm	mm/m	mm/m
SURFACE WATER BODIES (Ponds, Rivers, Nallahs, Jores, HFL)				
1.	Practically no impact. No loss of water	<500	<3	<3
2.	Marginal impact in some cases only. Some loss of water and water logging	<1000	<5	<5
3.	Severe impacts. Major loss of water. Severe water logging	>1000	>5	>5
SUB-SURFACE WATER TABLE				
1.	Marginal depletion in water retaining capacity	<500	<3	<3
2.	Severe depletion in water retaining capacity	-	-	>5
AQUIFERS				
1.	Depletion in water retaining capacity	-	-	>3
WATERLOGGING ON SURFACE				
1.	Very little waterlogging	<500	-	-
2.	Some (300-500mm deep depending on surface topography)	500-1000	-	-
3.	Marked waterlogging	>1000	-	-
ROADS				
1.	Practically no impact	<500	<5	-
2.	Depressions with gentle slope	-	5-10	-
3.	Steeper slopes (speed restriction may be necessary)	-	20-50	-
4.	Marginal repairs necessary	-	20-50	>10
5.	Major repairs necessary	-	>50	>10

1	2	3	4	5
		mm	mm/m	mm/m
RAILWAY LINES - JOINTED CONSTRUCTION				
1.	Practically no impact	-	<10	<3
2.	Minor to severe impacts, repairs necessary due to bending twisting and breaking of rails and steeper gradients	-	>10	>3
RAILWAY LINES - WELDED CONSTRUCTION				
1.	No subsidence permitted. Even very small strain can cause twisting and breaking of rails,			
RAILWAY SIDINGS (Jointed Construction)				
1.	Practically no impacts	-	<10	<3
2.	Minor to severe impacts, repairs necessary	-	>10	>3
SINGLE STORY HUTMENTS (Kuccha)				
1.	Practically no impact. A few fine cracks in plastered walls	-	<5	<3
2.	Minor repairable impacts. Fine cracks. A few 10mm wide cracks.	-	<10	3-5
3.	Major/severe impacts. Wide cracks, stepping, tilting	-	>10	>5
SINGLE STORY BUILDINGS				
1.	Very little impact. A few fine cracks or one/two 5-10mm wide crack in plaster	-	<5	<3
2.	Minor impacts, repairable. 5-10mm wide cracks, doors and windows getting slight jamming, slight tilting.	-	5-10	3-5
3.	Severe impacts, major repairs necessary. Wider cracks, stepping, crushing and marked tilting.	-	>10	>5

1	2	3	4	5
		mm	mm/m	mm/m
DOUBLE STORY BUILDINGS				
1.	Very little impact. A few fine cracks or one/two 5-10mm wide cracks	-	<5	<3
2.	Little repairable impact, 5-10mm wide cracks, slight displacement of walls against roof, doors and windows getting slightly jammed.	-	5-10	3-5
3.	Severe impacts, major repair necessary. Wider cracks, stepping, crushing and tilting. Gaps between walls and roof.	-	>10	>5
MULTI-STORY BUILDINGS				
1.	Little impacts, repairable 5-10mm wide cracks, doors and windows getting slight jamming, displacement of walls against roof.	-	<5	<3
2.	Severe impacts. Winder cracks, crushing, tilting, and stepping.	-	>5	>3
LARGE BUILDINGS, MONUMENTS, HISTORICAL BUILDINGS, ETC.				
1.	Very little impact. A few fine cracks or one/two 5-10mm wide cracks	-	<3	<1.5
2.	Little impact, 5-10mm wide cracks, Damage to decorations; slight displacements; doors and windows getting jammed.	-	3-5	1.5-3
3.	Severe impacts. Wider cracks, tilting, crushing, etc. Major repairs necessary.	-	>5	>3
AERIAL ROPEWAYS				
1.	Practically no impact	-	<5	<3
2.	Little repairable impacts	-	5-10	3-5
3.	Severe impacts. Ropes may leave pullies due to change in alignment. Tilting of pylons. Buckling of structure.	-	>10	>5
HIGH TENSION PYLONS				
1.	Practically no impact	-	<5	<3
2.	Severe impacts. Tilting, buckling and may be collapse of pylons	-	>5	>3

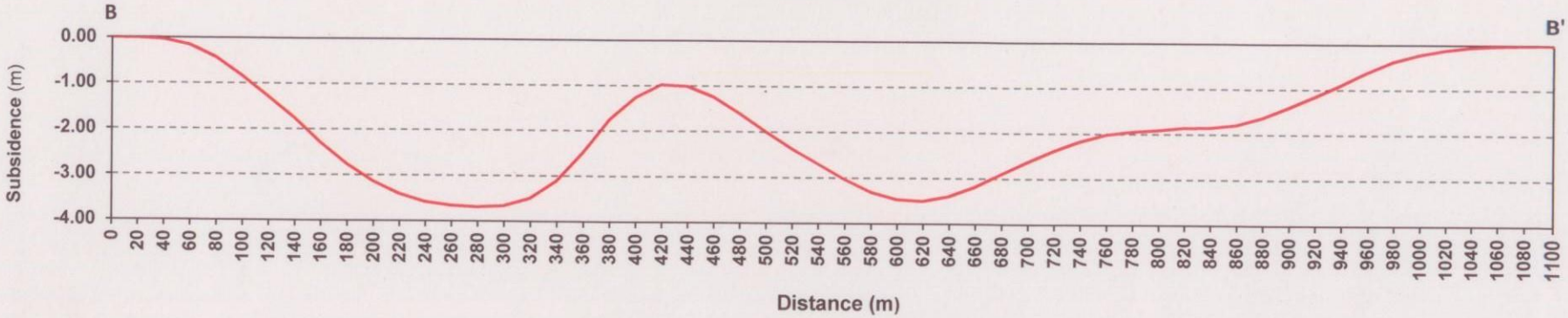
1	2	3	4	5
		mm	mm/m	mm/m
UNDERGROUND CABLES				
1.	Practically no impact	-	-	<3
2.	Severe impacts (cables may break due to tension).	-	-	>3
UNDERGROUND PIPELINES				
1.	Practically no impact	-	-	<1.5
2.	Severe impacts. Breaking of pipes	-	-	>1.5
OVERLYING VIRGIN SEAMS				
1.	Practically no impact. No visible signs of subsidence when the seams are developed.	-	<5	<3
2.	A little impact. A little crushing of coal, roof and floor rock. Fire risk when development is done in upper seam.	-	5-10	3-5
3.	Severe impacts. Crushing of coal, roof and floor rock. Stepping in tensile strain zone. Fire risk. Heaving, supports necessary during development.	-	10-20	5-10
4.	Very severe impacts. Severe crushing, large stepping, entry into subsided area rather difficult. High fire risk. Arching necessary.	-	>20	>10
OVERLYING WORKINGS (Standing on developed pillars)				
1.	Practically no impact on galleries and pillars. Some spalling.	-	<5	<3
2.	Visible floor lifting, side spalling and roof falls. Supports required. Fire risk.	-	-	3-5
3.	Marked floor lifting, side spalling and roof falls. High fire risks. Workings unsafe.	-	-	5-10
4.	Severe floor lifting, large roof falls, wide spread side spalling, stepping, very high fire risk, workings unsafe.	-	-	>10
OVERLYING WORKINGS (Standing on reduced pillars)				
1.	Practically no impact.	-	<3	<1.5

1	2	3	4	5
		mm	mm/m	mm/m
2.	Marginal impact on stability of stooks. The stooks with marginal factor of safety may collapse increasing loading on adjoining stooks.	-	<5	<5
3.	Failure of a few stooks may lead to chain of failures causing partial or total collapse of area. Thus causing additional subsidence on overlying horizons.	-	>5	>3
OVERLYING WORKINGS (Packed or stowed)				
1.	Practically no impact on stowed workings. Some loss of water.	-	-	<5
2.	Complete loss of water from stowed areas and also from adjoining rise side areas.	-	-	>5
WATERLOGGED OVERLYING WORKINGS (Standing on developed pillars)				
1.	Practically no impact on pillars, galleries and water retaining capacity of the workings.	-	-	<3
2.	Marginal loss of water through fine cracks in strata around. Dewatered areas may have risk of fires, roof falls, side spalling, floor lifting.	-	-	<5
3.	Major loss of water. High fire risk in dewatered areas with roof falls, side spalling, floor lifting, etc.	-	-	5-10
4.	Total loss of water. Very high fire risk with severe floor lifting, roof falls and spalling.	-	-	>10
WATERLOGGED OVERLYING WORKINGS (Standing on reduced pillars/stooks)				
1.	Stooks may collapse causing additional subsidence on surface.	-	-	<3
2.	Partial loss of water. Collapse of stooks. Additional surface subsidence. Fire risk.	-	-	3-5
3.	Total loss of water. Collapse of workings. Additional surface subsidence; fire risk.	-	-	>5

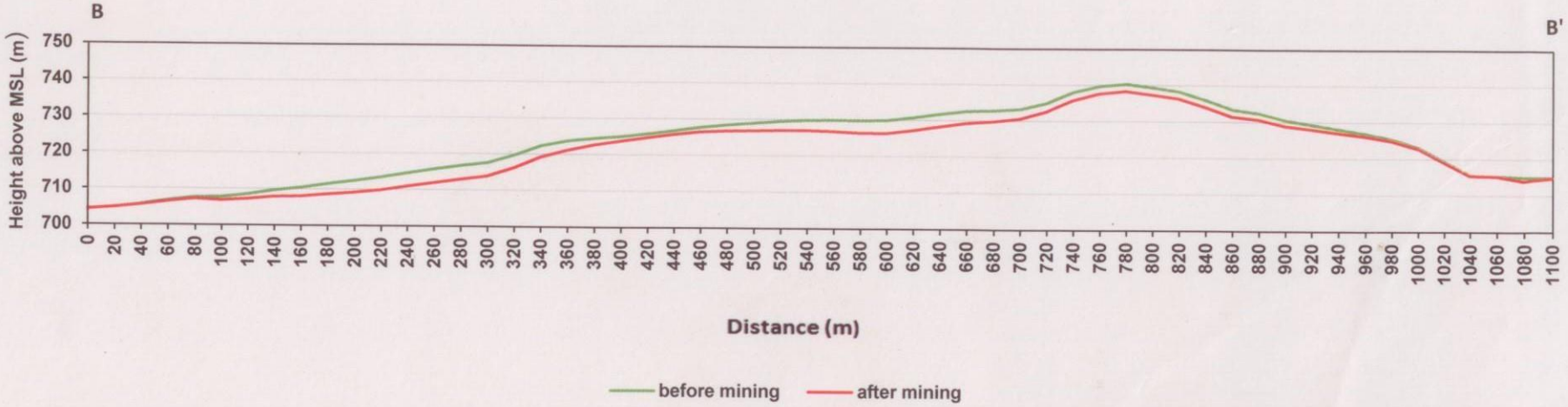
1	2	3	4	5
		mm	mm/m	mm/m
IN CURRENT WORKINGS FROM SUBSIDENCE AT THE LEVEL OF SURFACE				
1.	Practically no impact.	-	-	<5
2.	Leakage of air. Fire in goaves at shallow depth.	-	-	>5
IN CURRENET WORKINGS FROM SUBSIDENCE AT THE LEVEL OF OVERLYING TATER BODIES				
1.	Practically no impact	-	-	<3
2.	Marginal increase in make of water.	-	-	3-5
3.	Appreciable increase in make of water.	-	-	5-10
4.	Heavy increase in make of water, which may lead to inundation.	-	-	>10
SURFACE ATMOSPHERE				
1.	Practically no impact.	-	-	<5
2.	Some air from underground workings at shallow depth may leak to surface.	-	-	5-10
3.	Air leakage from shallow depth workings. If the workings have fire, surface atmosphere is likely to be polluted by gases coming from the fire.	-	-	>10
SUB-SOIL				
1.	Practically no impact.	-	-	<3
2.	Very little impact in the form of reduction of water retaining capacity.	-	-	3-5
3.	Temporary loss in water retaining capacity. Cracks filling may improve water retaining capacity.	-	-	5-10
4.	Long term loss of water retaining capacity. Suitable protective measures necessary.	-	-	>10
AGRICULTURE				
1.	Practically no impact.	-	-	<5
2.	Marginal impact, i.e. reduction in yield due to loss in water retaining capacity of sub-soil.	-	-	5-10
3.	Major impact, i.e. sizeable reduction in yield.	-	-	>10

1	2	3	4	5
		mm	mm/m	mm/m
FOREST AND PLANTATION				
1.	Practically no impact.	-	<10	<5
2.	Temporary loss in water retaining capacity of top-soil may affect undergrowth slightly. Slight tilting of plants/trees.	-	10-20	5-10
3.	Short term impact on trees in zones having cracks. The cracks may get filled in due course. Tilting of trees.	-	20-50	10-20
4.	Wide cracks may severely affect undergrowth but may not have much impact on large trees except those in the tensile strain zone where wide cracks develop; high tilting may cause some trees to fall in the high slope zone.	-	>50	>20

SUBSIDENCE PROFILE ALONG LINE BB'
(At the end of mine life)



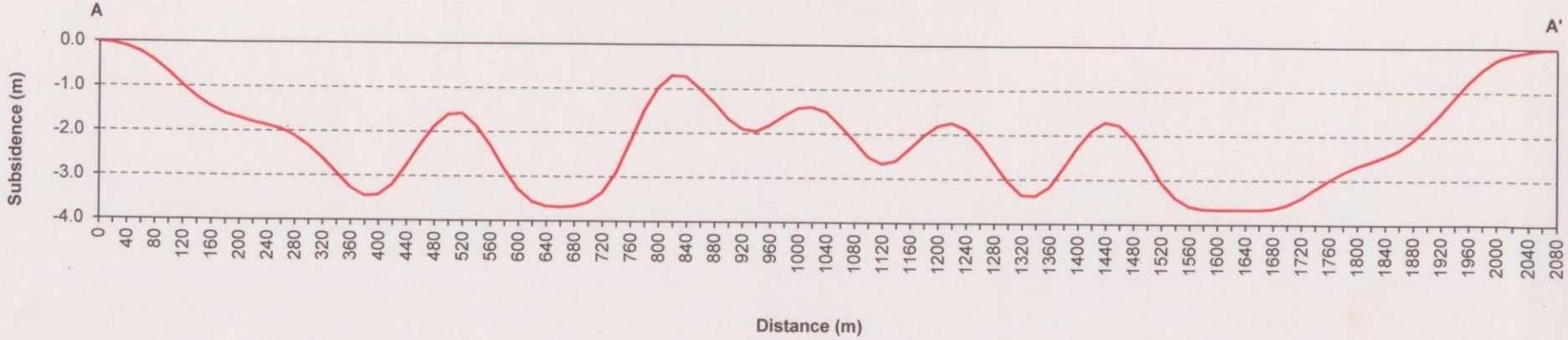
SURFACE PROFILE ALONG LINE BB'
(At the end of mine life)



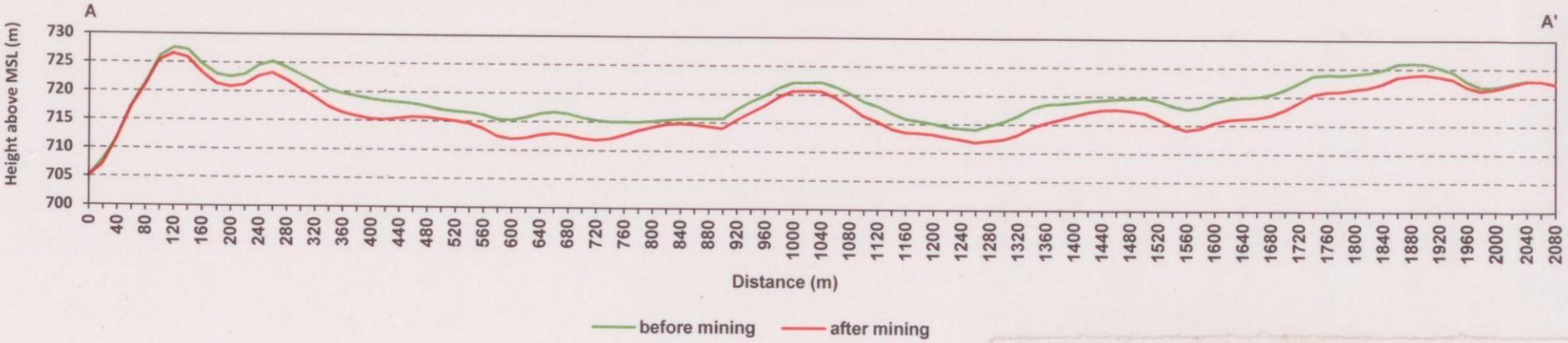
NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030416116	
SUBJECT: Subsidence and surface profiles along line BB'(as shown in plates 5,12 & 13).	ACTIVITY	NAME	DESIG.	SIGN	DATE
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		
	CHECKED	M.SAHAY	CH.MGR.		
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : NTS			SHEET 18 OF 18	
	DRG. NO. PLATE-18			REV. NO. 0	

SUBSIDENCE PROFILE ALONG LINE AA'
(At the end of mine life)

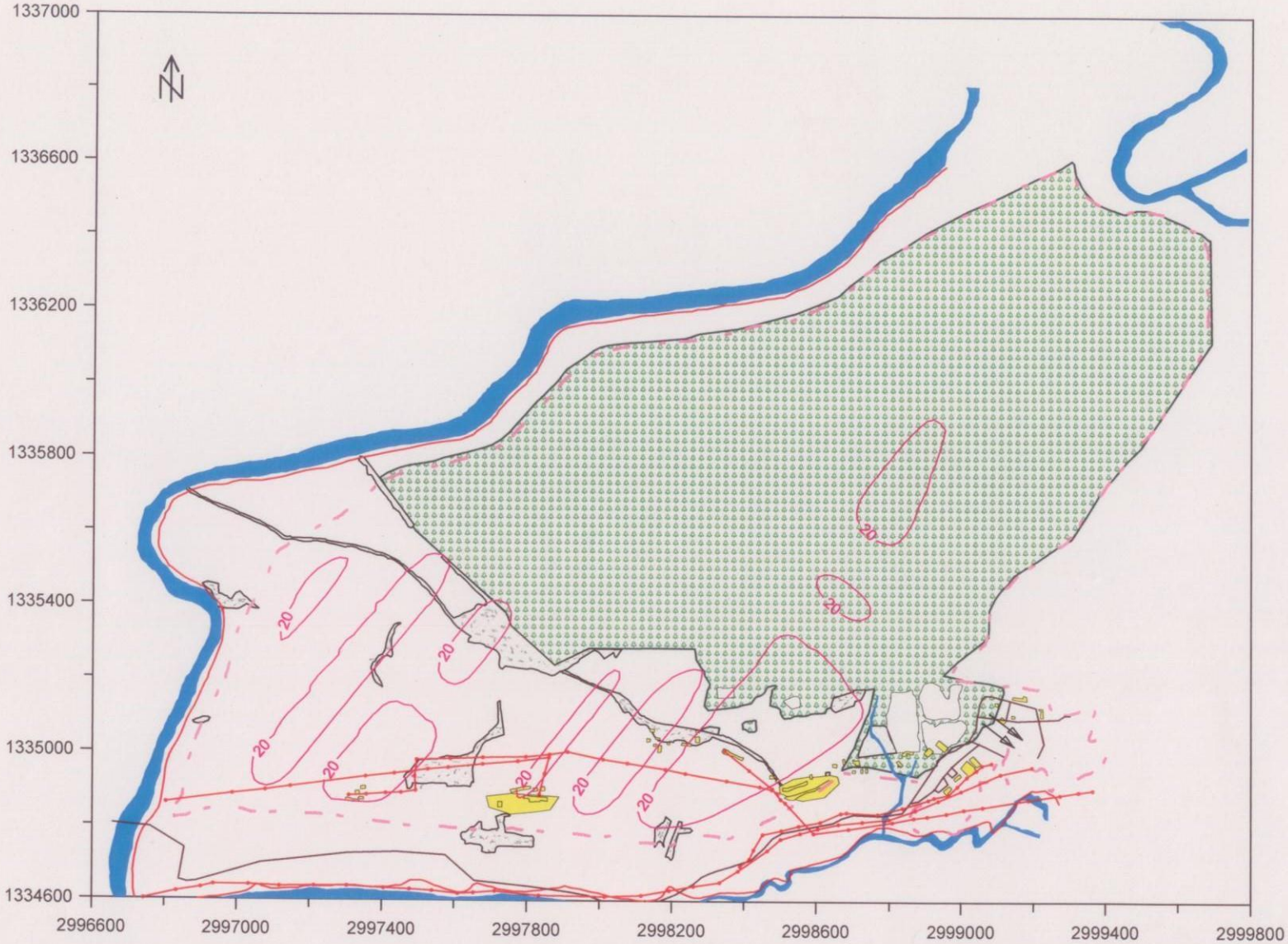


SURFACE PROFILE ALONG LINE AA'
(At the end of mine life)



NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.03041611	
SUBJECT: Subsidence and surface profiles along line AA'(as shown in plates 5, 12 & 13).	ACTIVITY	NAME	DESIG.	SIGN	DA
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		
	CHECKED	M.SAHAY	CH.MGR.		16
	APPROVED	A.K.RANA	GM		16
CMPDI ISO 9001 COMPANY	SCALE : NTS			SHEET 17 OF 18	
	DRG. NO. PLATE-17			REV. NO. 0	



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- AREA AFFECTED BY >20MM/M STRAIN
- RIVER / NALLA
- HFL
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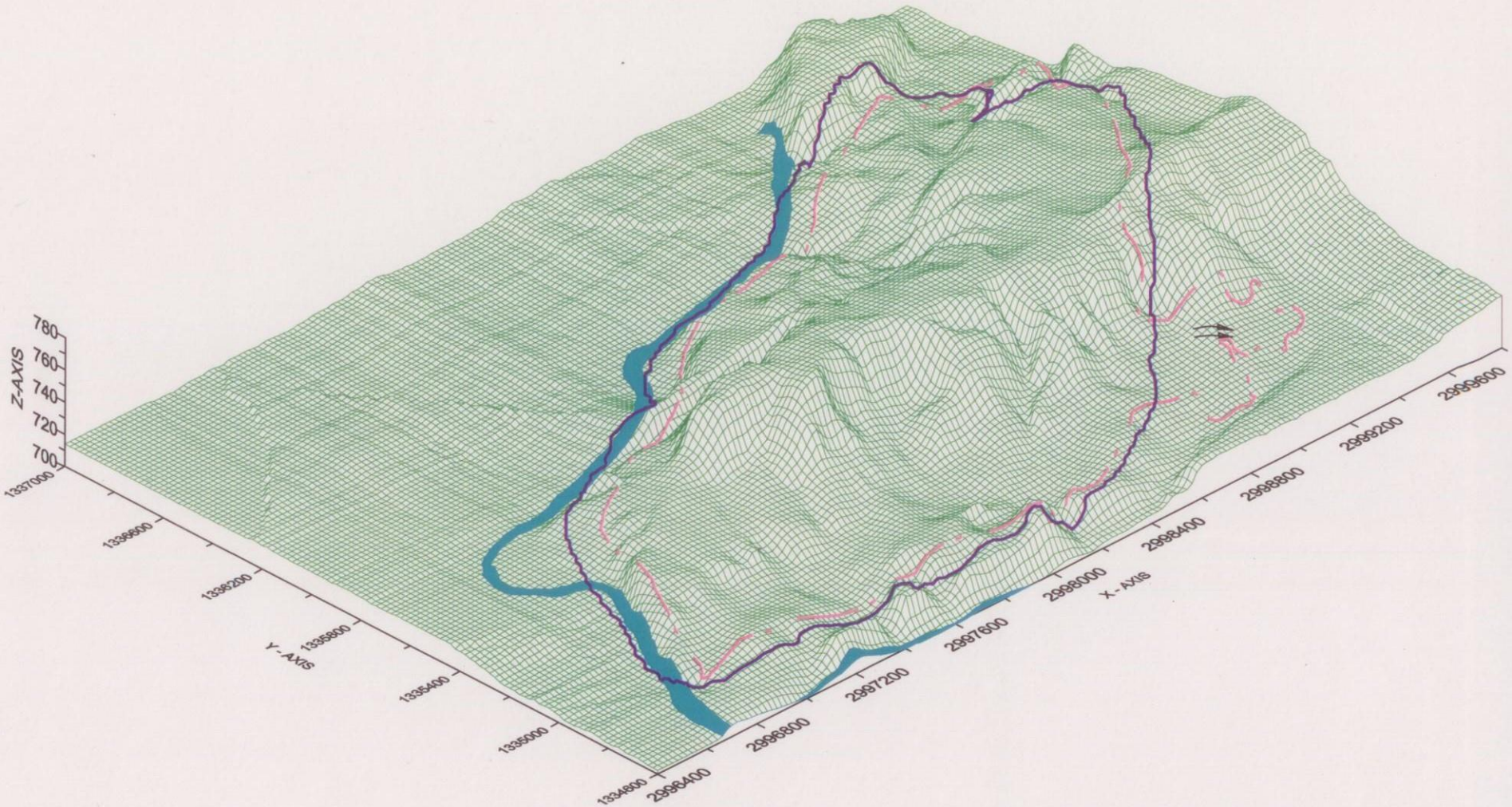
- ROAD
- HT LINE

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED				
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030416
SUBJECT: Mining Area likely to be affected by>20mm/m strain(At the end of mine life).	ACTIVITY	NAME	DESIG.	SIGN
	PREPARED	V.SINGH	SR.MGR.	
	PROCESSED	V.SINGH	SR.MGR.	16
	CHECKED	M.SAHAY	CH.MGR.	
	APPROVED	A.K.RANA	GM	
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 16 OF 18
	DRG. NO. PLATE-16			REV. NO. 0



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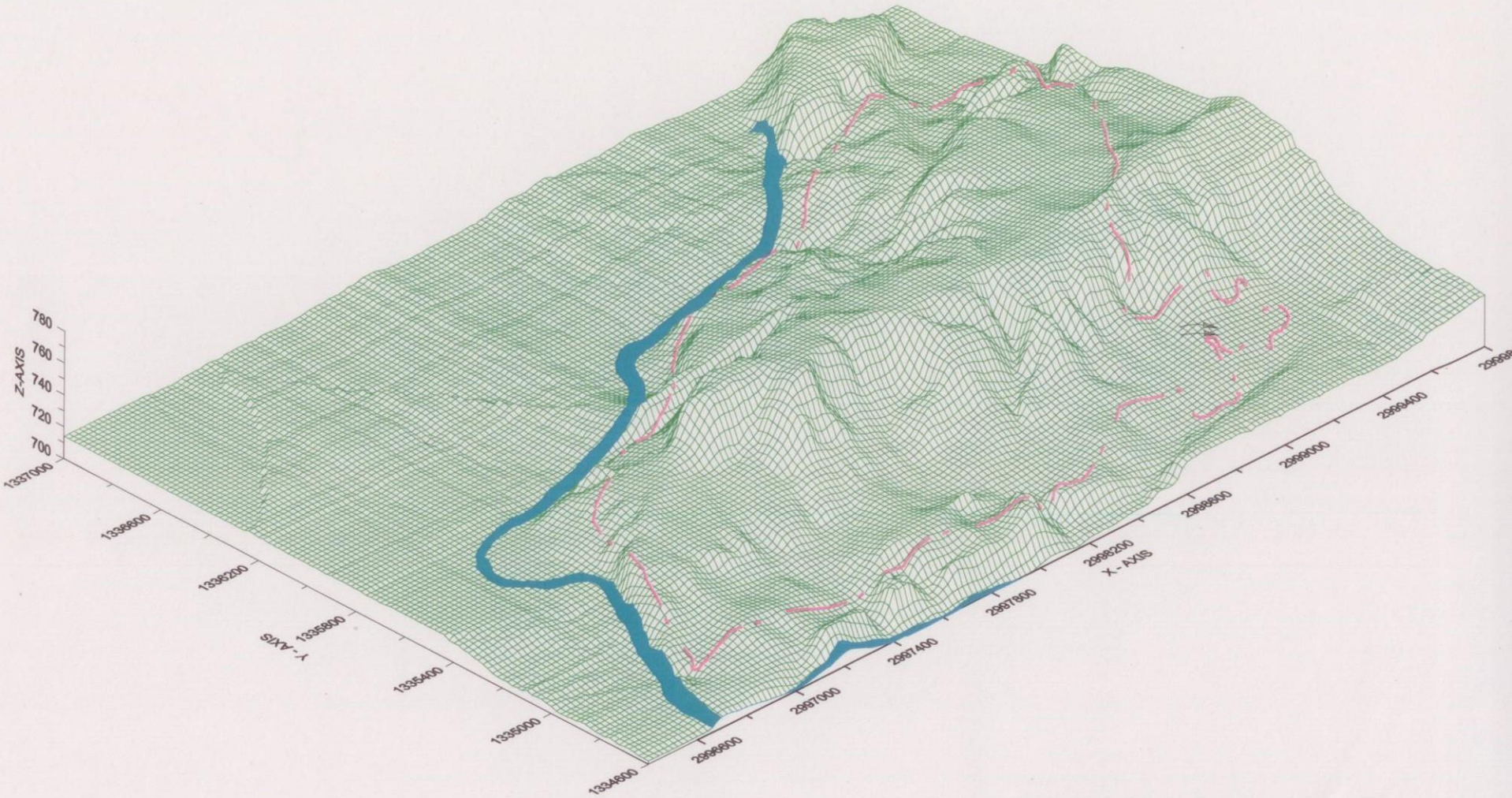
SUBSIDENCE INFLUENCE AREA

MINE BOUNDARY

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.0304	
SUBJECT:3D view of surface after mining.	ACTIVITY	NAME	DESIG.	SIGN	
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		
	CHECKED	M.SAHAY	CH.MGR.		
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 15 OF 18	
	DRG. NO. PLATE-15			REV. NO. 0	



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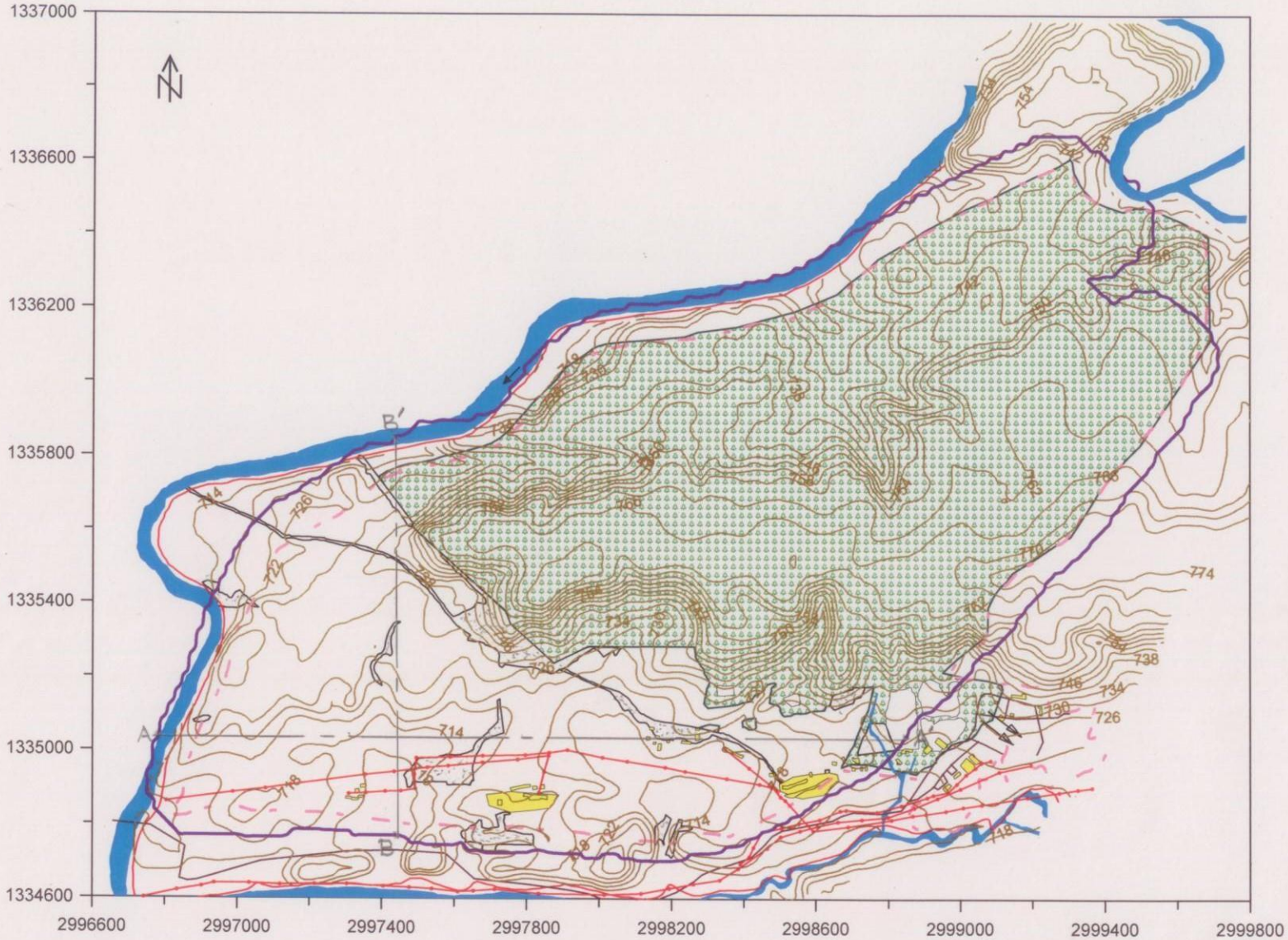
MINE BOUNDARY

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED				
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030416
SUBJECT:3D view of surface before mining.	ACTIVITY	NAME	DESIG.	SIGN
	PREPARED	V.SINGH	SR.MGR.	
	PROCESSED	V.SINGH	SR.MGR.	
	CHECKED	M.SAHAY	CH.MGR.	
	APPROVED	A.K.RANA	GM	
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 14 OF 18
	DRG. NO. PLATE-14			REV. NO. 0



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- HFL
- MINE BOUNDARY
- ROAD
- HT LINE

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : **WESTERN COALFIELDS LIMITED**

JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE

JOB NO.0304161

SUBJECT:Topograpy after 15 years of mining (At the end of mine life).

ACTIVITY	NAME	DESIG.	SIGN	
PREPARED	V.SINGH	SR.MGR.		
PROCESSED	V.SINGH	SR.MGR.		16
CHECKED	M.SAHAY	CH.MGR.		16
APPROVED	A.K.RANA	GM		

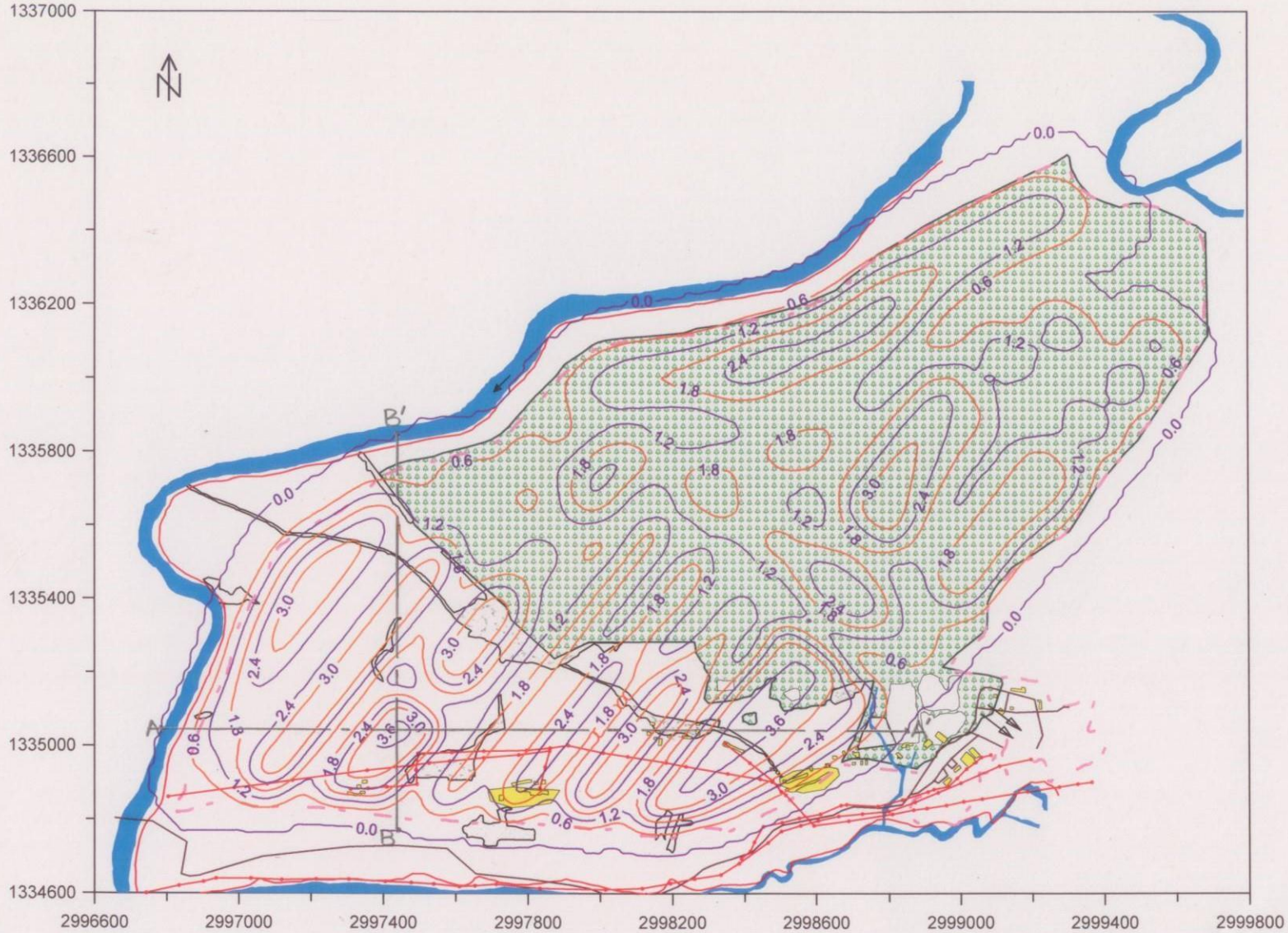
CMPDI ISO 9001 COMPANY

SCALE : 1:17000

SHEET 13 OF 18

DRG. NO. PLATE-13

REV. NO. 0



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- HFL
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- HT LINE

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : **WESTERN COALFIELDS LIMITED**

JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE

JOB NO.0304161

SUBJECT:Subsidence contours after 15 years of mining (At the end of mine life).

ACTIVITY	NAME	DESIG.	SIGN
PREPARED	V.SINGH	SR.MGR.	
PROCESSED	V.SINGH	SR.MGR.	16-
CHECKED	M.SAHAY	CH.MGR.	
APPROVED	A.K.RANA	GM	

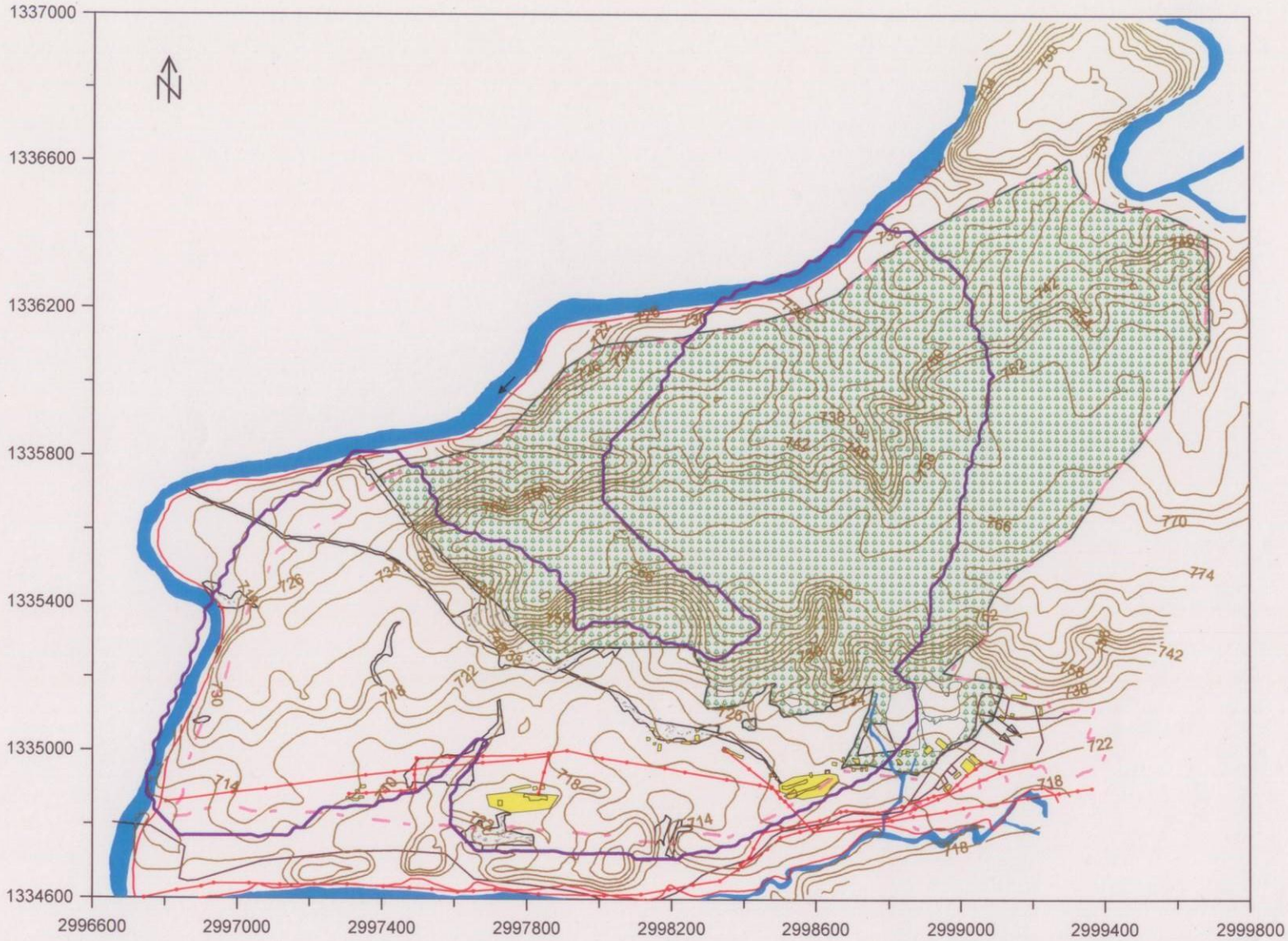
CMPDI
ISO 9001 COMPANY

SCALE : 1:17000

SHEET 12 OF 18

DRG. NO. PLATE-12

REV. NO. 0



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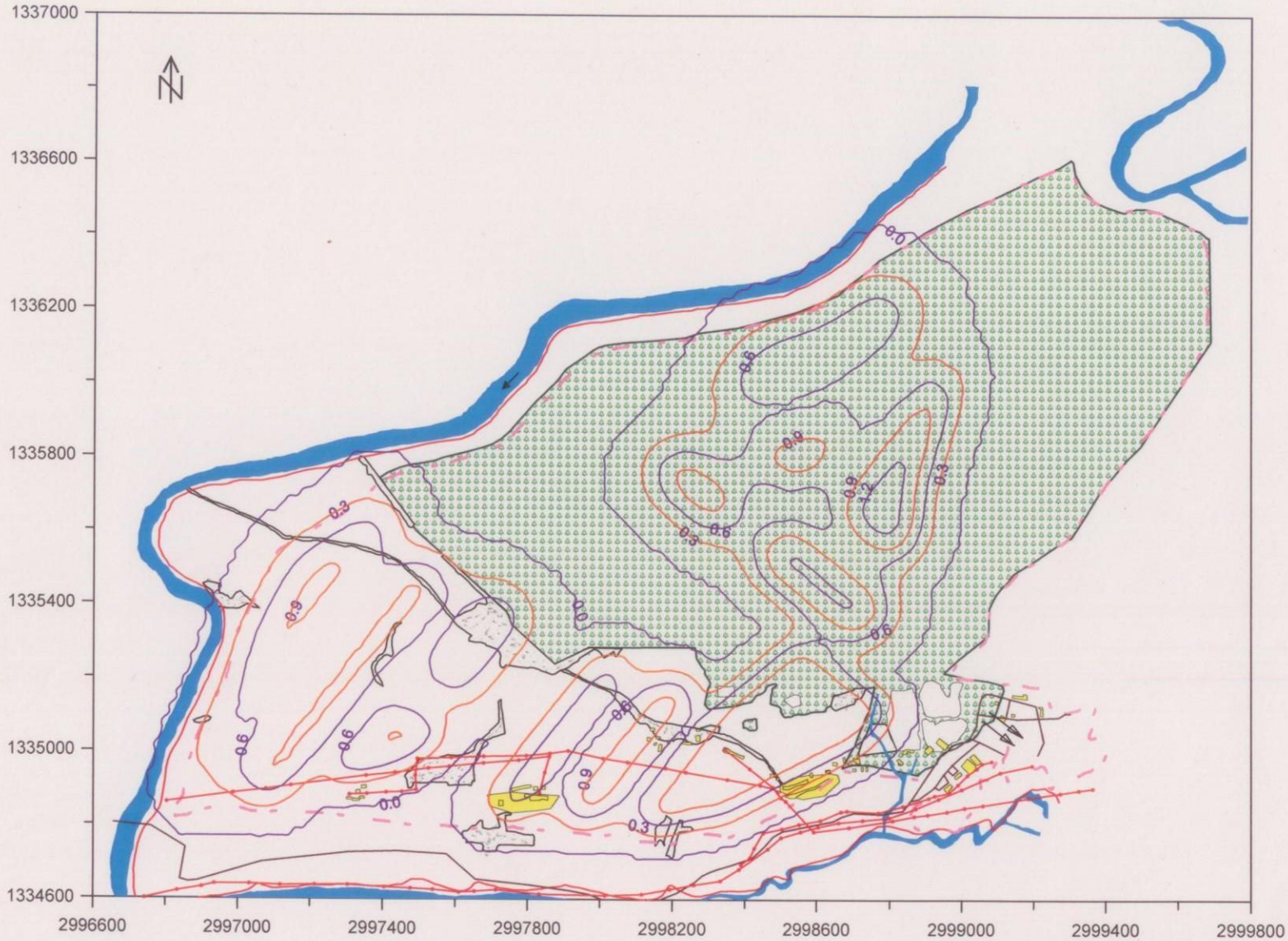
- SUBSIDENCE INFLUENCE AREA
- RIVER / NALLA
- HFL
- MINE BOUNDARY
- ROAD
- HT LINE

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED				
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030416
SUBJECT:Topography due to extraction of seam V only.	ACTIVITY	NAME	DESIG.	SIGN
	PREPARED	V.SINGH	SR.MGR.	
	PROCESSED	V.SINGH	SR.MGR.	16
	CHECKED	M.SAHAY	CH.MGR.	16
	APPROVED	A.K.RANA	GM	
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 11 OF 18
	DRG. NO. PLATE-11			REV. NO. 0



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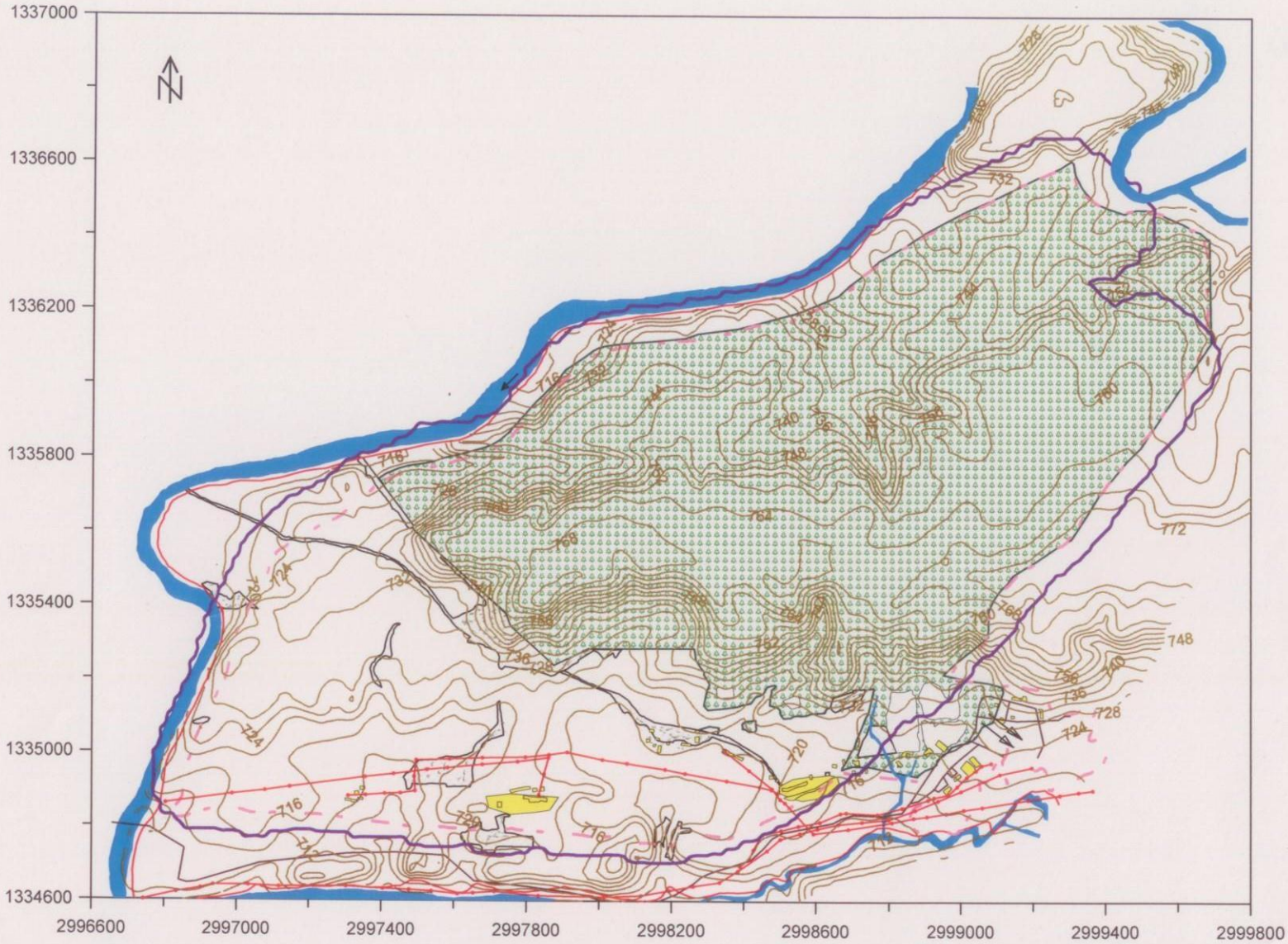
NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.0304161	
SUBJECT:Subsidence contours due to extraction of seam V only.	ACTIVITY	NAME	DESIG.	SIGN	D
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16-
	CHECKED	M.SAHAY	CH.MGR.		16
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 10 OF 18	
	DRG. NO. PLATE-10			REV. NO. 0	



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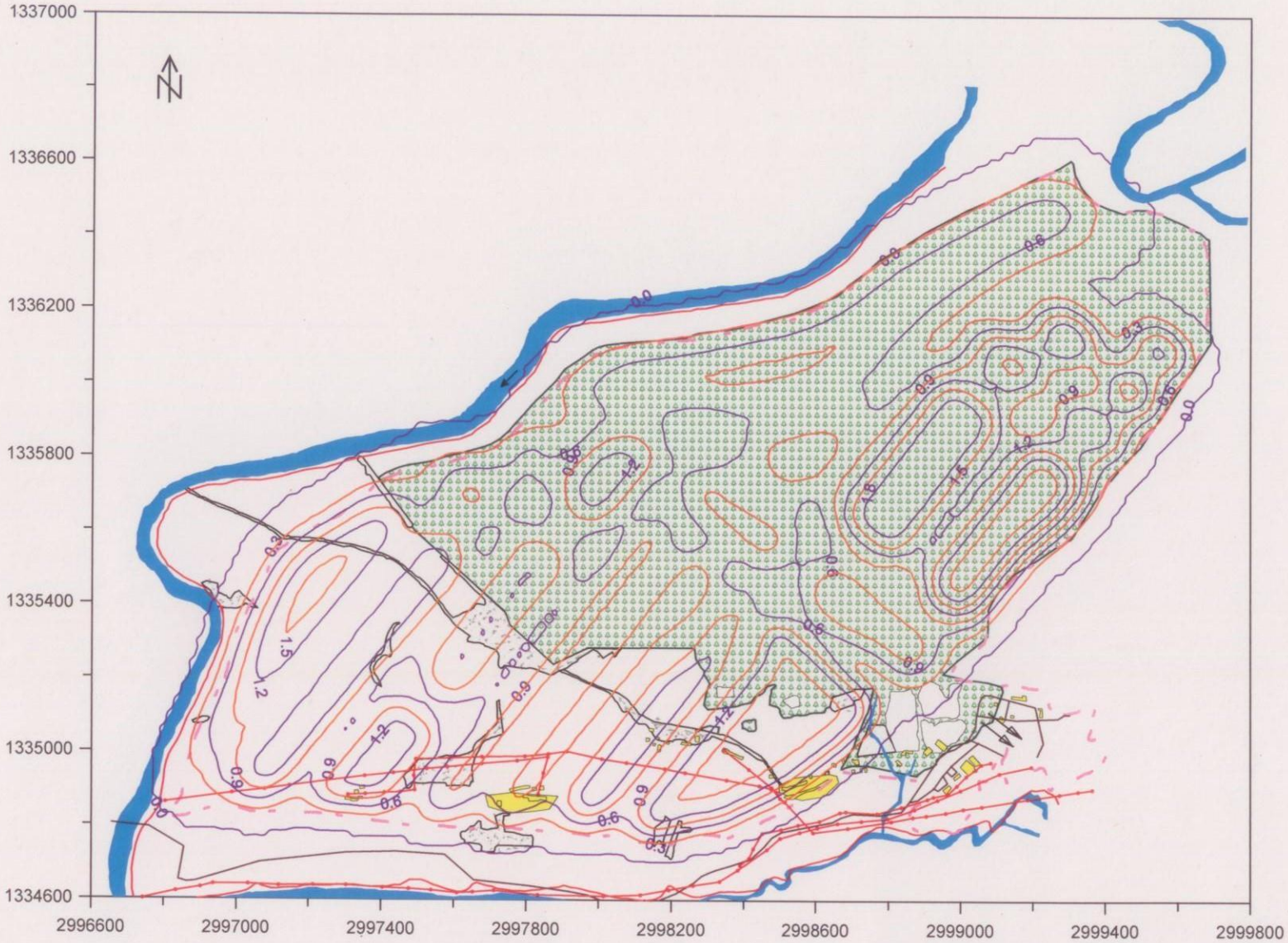
NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.0304161	
SUBJECT:Topography due to extraction of seam IV only.	ACTIVITY	NAME	DESIG.	SIGN	
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16
	CHECKED	M.SAHAY	CH.MGR.		
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 9 OF 18	
	DRG. NO. PLATE-9			REV. NO. 0	



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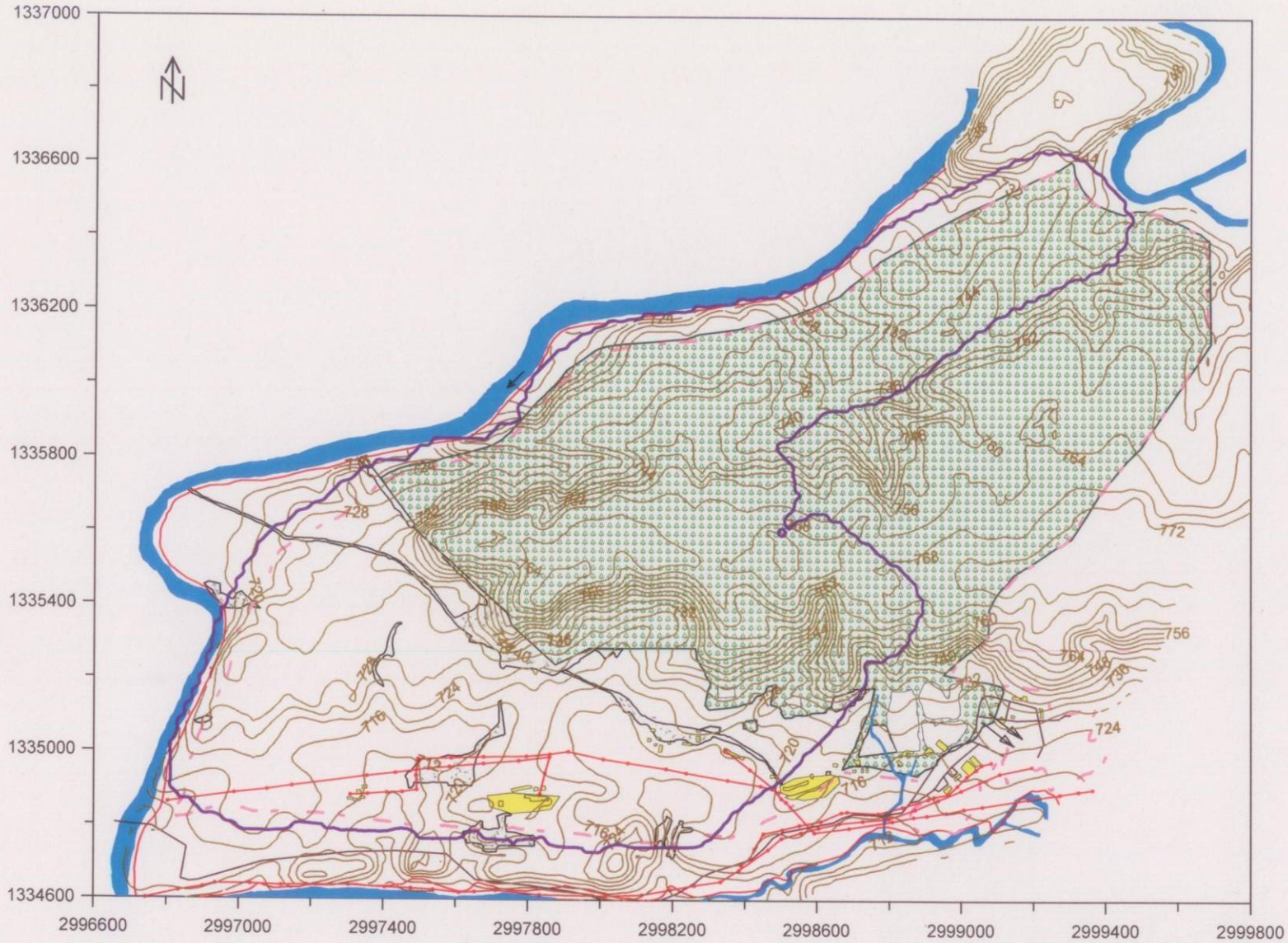
- HT LINE

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030416116	
SUBJECT:Subsidence contours due to extraction of seam IV only.	ACTIVITY	NAME	DESIG.	SIGN	DA
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16.
	CHECKED	M.SAHAY	CH.MGR.		16.
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 8 OF 18	
	DRG. NO. PLATE-8			REV. NO. 0	



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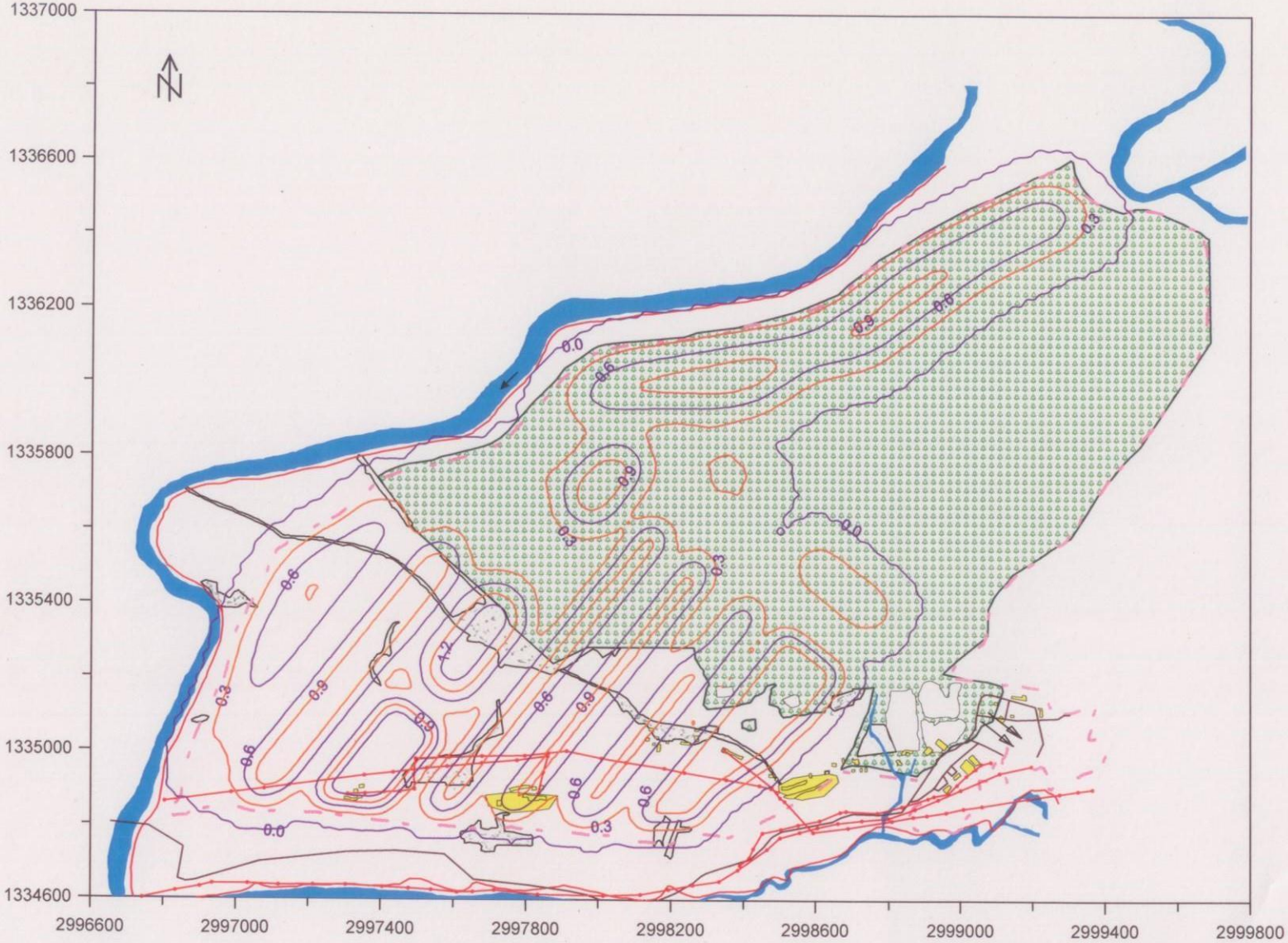
NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.03041611	
SUBJECT:Topography due to extraction of seam II only.	ACTIVITY	NAME	DESIG.	SIGN	DA
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16.
	CHECKED	M.SAHAY	CH.MGR.		16.
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 7 OF 18	
	DRG. NO. PLATE-7			REV. NO. 0	



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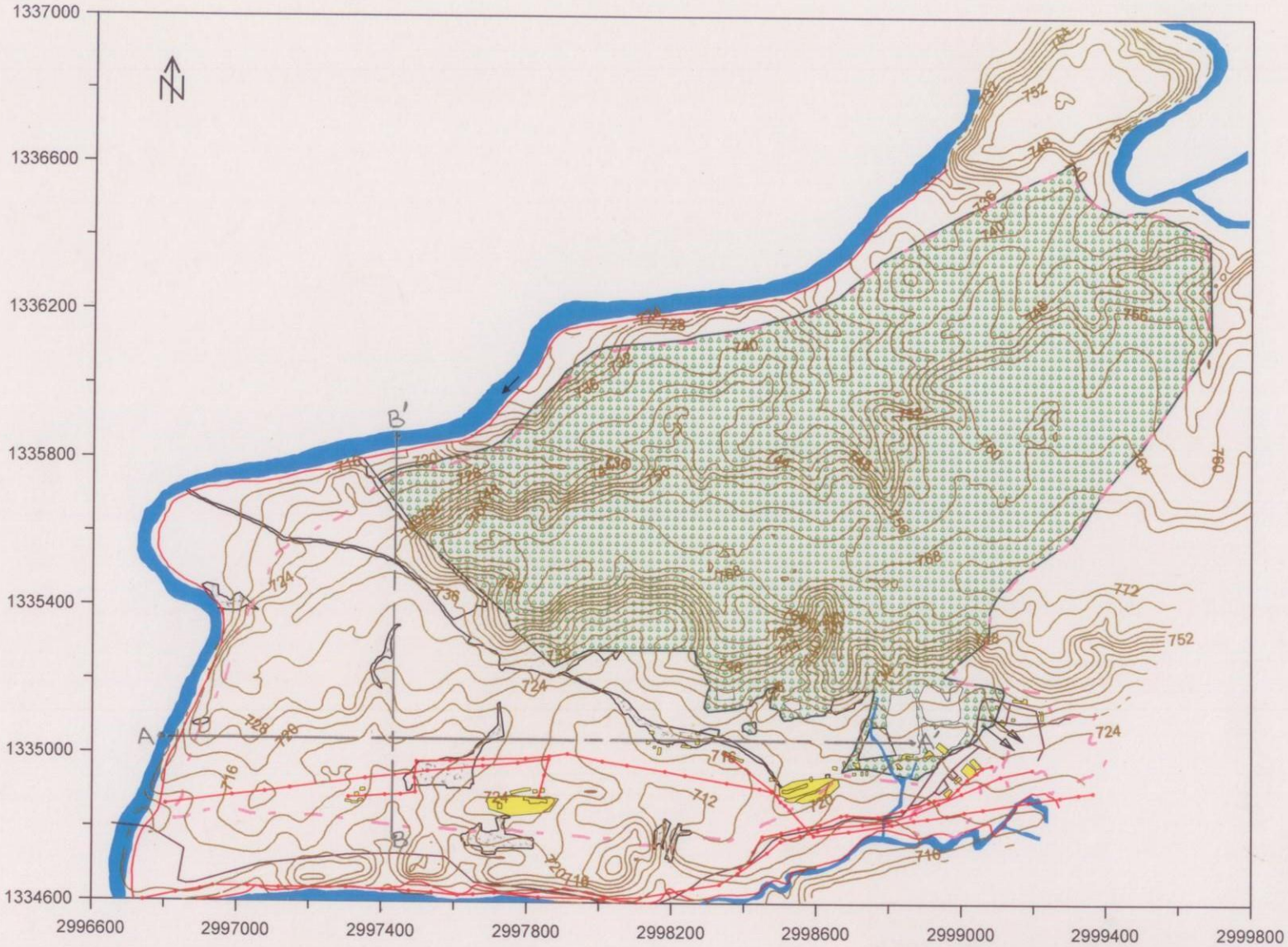
NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030416	
SUBJECT:Subsidence contours due to extraction of seam IC&II only.	ACTIVITY	NAME	DESIG.	SIGN	
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16
	CHECKED	M.SAHAY	CH.MGR.		
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 6 OF 18	
	DRG. NO. PLATE-6			REV. NO. 0	



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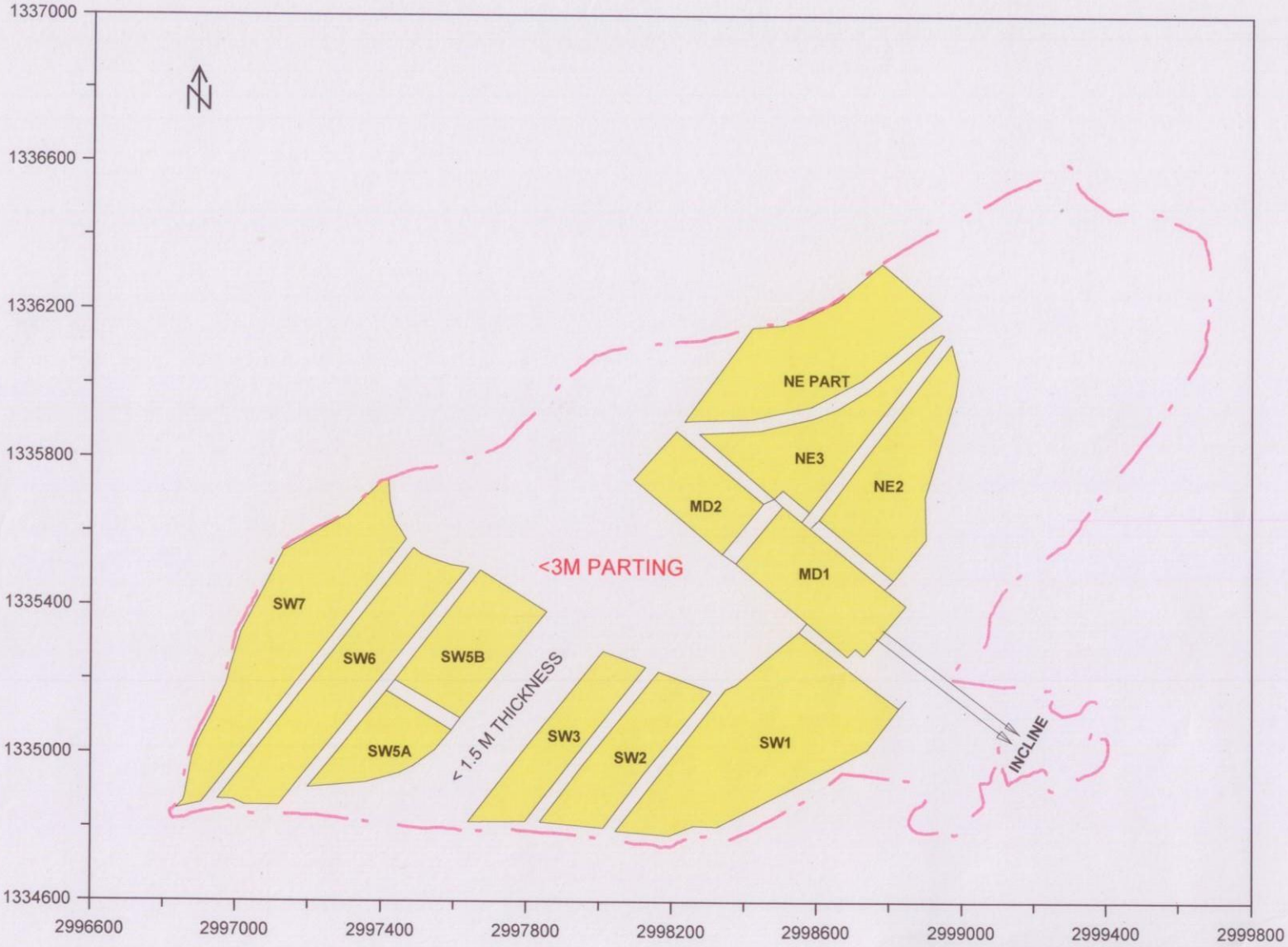
NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030416116	
SUBJECT:Topography before mining.	ACTIVITY	NAME	DESIG.	SIGN	DATE
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16.9.16
	CHECKED	M.SAHAY	CH.MGR.		16.9.16
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 5 OF 18	
	DRG. NO. PLATE- 5			REV. NO. 0	



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MINE BOUNDARY

PANELS PROPOSED TO BE DEPILLARED IN SEAM V

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED				
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.030
SUBJECT:Layout of underground workings of Seam V showing panels proposed to be depillared.	ACTIVITY	NAME	DESIG.	SIGN
	PREPARED	V.SINGH	SR.MGR.	
	PROCESSED	V.SINGH	SR.MGR.	
	CHECKED	M.SAHAY	CH.MGR.	
	APPROVED	A.K.RANA	GM	
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 4 OF 18
	DRG. NO. PLATE-4			REV. NO. 0

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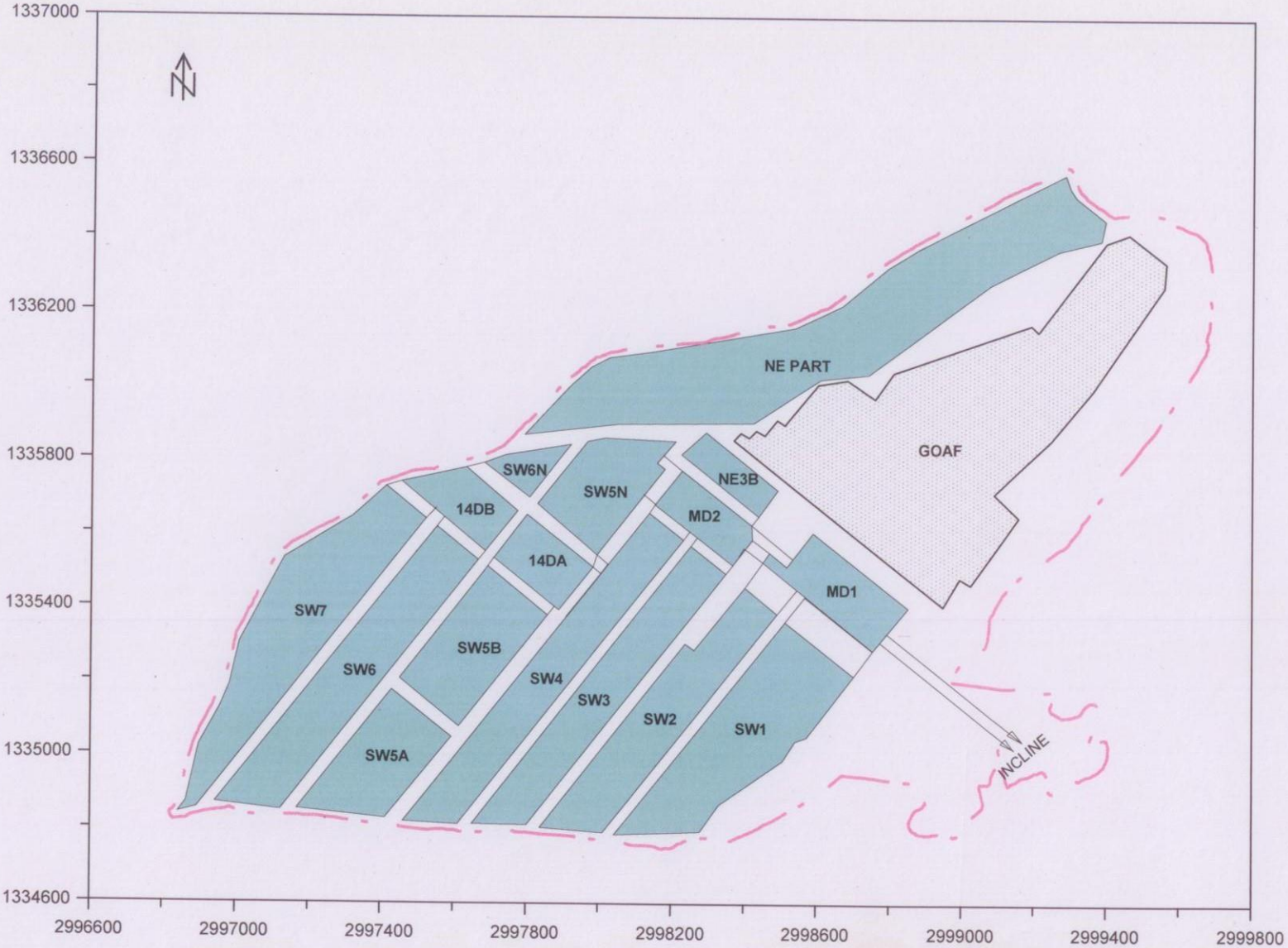
MINE BOUNDARY

PANELS PROPOSED TO BE DEPILLARED IN SEAM IV

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.03041611	
SUBJECT:Layout of underground workings of Seam IV showing panels proposed to be depillared.	ACTIVITY	NAME	DESIG.	SIGN	DA
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16-
	CHECKED	M.SARAY	CH.MGR.		16-
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 3 OF 18	
	DRG. NO. PLATE-3			REV. NO. 0	



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MINE BOUNDARY

PANELS PROPOSED TO BE DEPILLARED IN SEAM II

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : WESTERN COALFIELDS LIMITED					
JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE				JOB NO.03041611	
SUBJECT:Layout of underground workings of Seam II showing panels proposed to be depillared.	ACTIVITY	NAME	DESIG.	SIGN	DA
	PREPARED	V.SINGH	SR.MGR.		
	PROCESSED	V.SINGH	SR.MGR.		16·
	CHECKED	M.SAHAY	CH.MGR.		1c
	APPROVED	A.K.RANA	GM		
CMPDI ISO 9001 COMPANY	SCALE : 1:17000			SHEET 2 OF 18	
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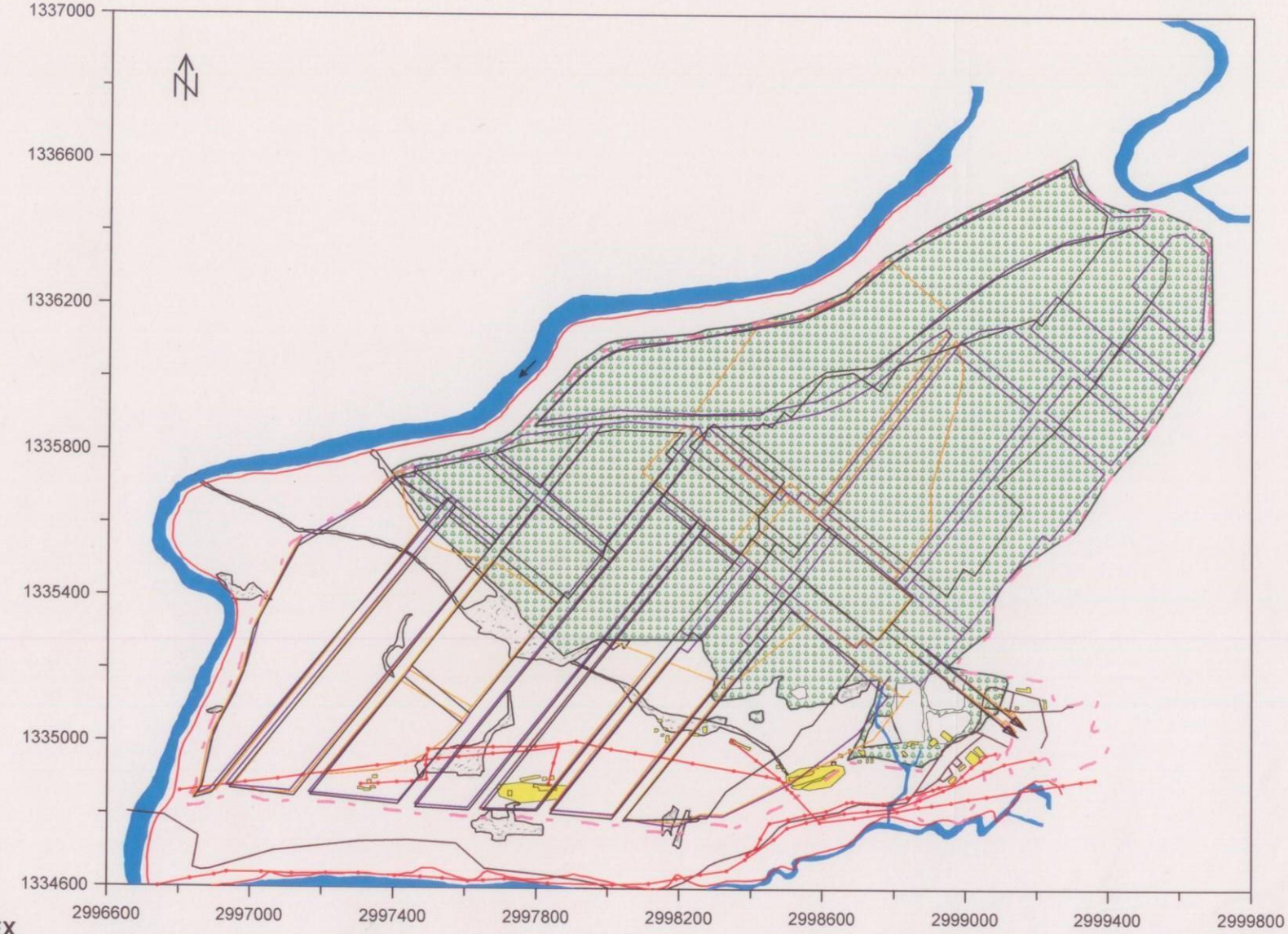

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- WORKINGS SEAM IV
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- HFL
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- ROAD
- HT LINE
- WORKINGS SEAM II

NOTE: ALL DIMENSIONS ARE IN METER

CUSTOMER : **WESTERN COALFIELDS LIMITED**

JOB TITLE :SUBSUDENCE PREDICTION FOR NAHERIYA UG MINE — JOB NO.0304161

SUBJECT : Layout of u/g workings of Seam II, Seam IV and Seam V.

ACTIVITY	NAME	DESIG.	SIGN	D
PREPARED	V.SINGH	SR.MGR.		
PROCESSED	V.SINGH	SR.MGR.		16
CHECKED	M.SAHAY	CH.MGR.		16
APPROVED	A.K.RANA	GM		

CMPDI
ISO 9001 COMPANY

SCALE : 1:17000

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DRG. NO. PLATE-1

REV. NO. 0