Report No. IITKGP/BBM_SKP/2022/14

Final Project Report

SUBSIDENCE STUDY FOR SHAHPUR WEST COAL BLOCK IN SHAHDOL AND UMARIA DISTRICTS OF M.P.

(Ref. Work Order no. SEML/GKC/IIT-KGP/2022/Mar/011 dated 29.03.2022)

Submitted to

Sarda Energy & Minerals Ltd.

Raipur, Chhattisgarh, India

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DISCLAIMER

It is appropriate to mention here that neither the day-to-day mining operations would be under the control of the authors of this report nor it is possible to have any such control on the scientific execution of the method of working. The authors of this report would in no way be held responsible for any untoward incident, which might occur due to the implementation of the recommendations of this report. This report merely contains prediction of subsidence due to mining operations which is based on data supplied by the sponsor of the project. The modelling and analysis have been carried out using theoretically established methodology. Some essential geo-technical properties supplied by mine authority are used for modelling and interpretations of results. The uncertainty in these parameters, as expected in reality, may significantly change the prediction of structural behavior.

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1 INTRODUCTION

The Executive Director, Sarda Energy & Minerals Limited (SEML) requested the Indian Institute of Technology Kharagpur (IIT Kharagpur) to conduct a *Subsidence Study for Shahpur West Coal Block in Shahdol and Umaria Districts of M.P*. vide Work Order no. SEML/GKC/IIT-KGP/2022/Mar/011 dated 29.03.2022. Shahpur West coal block of Sarda Energy & Minerals Limited (SEML) is located in Sohagpur Coalfield, in the northern belt of the Son-Mahanadi basin. It is located in the Shahdol and Umaria districts of Madhya Pradesh. It is proposed to excavate coal by underground excavation following the Bord and Pillar method of mining.

A team from IIT Kharagpur visited the proposed mining site near Shahdol, Madhya Pradesh during the second week of June 2022 for observing the surface features, structures, villages, forest, waterbodies, roads, infrastructures etc. The team discussed with the SEML management throughout the implementation of the project in regard to the collection of relevant information for conducting scientific study.

Figure 1: Field visit by the team of IIT Kharagpur

1.1 Location

Shahpur West Coal Block area falls under the administrative control of Shahdol and Umaria districts in Madhya Pradesh state. It lies in the northwestern part of the Sohagpur coalfield, about 12 Km. South-West of Shahdol town, the district headquarters. The block is located at a distance of 75 Km. from Umaria town. The block covers an area of 619 sq. km falling in Latitude (N):

23°14'19" to 23°15'33" and Longitude (E): 81°17'10" to 81°18'49" (As per the Vesting Order issued by the Ministry of Coal, GoI) and lies in the Survey of India Topo sheet Nos. 64 E/7 and 64 E/8 (R.F.1:50,000). The block boundary limits of Shahpur West Block are given below:

North: Shahpur Block explored by GSI & West of Shahdol block explored by MECL.

East: Shahpur (East) block of SEML.

South: Block boundary supplied by SEML. Promotional exploration is in progress by CMPDIL /GSI.

West: Marwatola block of MECL & CMPDIL

Figure 2: Agricultural land (Right) and Ghoghra nullah

1.2 Communication

The block is well connected by road and rail. The nearest railway station is Shahdol, located 12 Km. south-east of the block on Anuppur-Chirimiri & Bilaspur - Katni broad gauge line of South-Eastern Railways. National highway No. 78 passes through Shahdol.

The Bilaspur–Katni section of the South Eastern railway passes through the important mining centres of Burhar-Amlai & Dhanpuri. The eastern part of the area is served by the Anuppur-Chirimiri branch lines which passes through Kotma, Bhadra, Yamuna & Bijuri Collieries.

A tar road from Shahdol to Malachua passes through the block & runs near Khamaria village situated in the block.

1.3 Climate

The area experiences three seasons during the year. The summer is from March to June when the day temperature varies from 25°C to 46°C and at night, it is between 18°C to 24°C. Mid-June to September is the rainy season and from October, the winter sets in and continues up to February. During the winter season, the maximum day temperature varies from 26°C to 31°C while the minimum night temperature shows variations from 7°C to 15°C. The average rainfall in the area varies from 1000 mm to 1700 mm annually.

1.4 Drainage

The main drainage in Shahpur West Block is Ghoghra nullah which flows northerly. The block has a maximum elevation of 503 m in the southwest corner of the block and a minimum elevation of 478 m in the northeast corner of the block. The general slope in the block can be observed towards Ghoghra nullah.

A dendritic pattern of Ghoghra nullah can be seen. A Number of small ponds are found within the block.

1.5 Forest cover

The Shahpur West Coal block is covered by protected forest in the north and by Reserve Forest in the south. The area of northern patch is of 12.248 Hectares and that of southern patch is 34.240 Hectares. The forest is deciduous and mixed. The common floras observed are mainly Sal, Kendu, Teak, Bija, Salai, Palas etc. Besides there are scattered patches of Revenue Forest measuring an area of 34.102 Hectares.

2 GEOLOGY

The Shahpur West Coal Block falls in the northwestern part of Sohagpur coalfield. The area explored is mostly covered by sandy soil and a few scanty exposures of Barren Measure sandstones are marked along the Ghogra nullah. A dolerite dyke outcrop is deciphered in the southeastern corner of the block.

The geological succession established in the block from the exploration data is given in *Table 1*.

Table 1: Geological Succession of Shahpur West Block

Age	Formation	Lithology
Recent	Soil	Soil & Alluvium
Mid. Permian	Barren Measures	Pink, buff, red sandstone, redshale etc.
Lw. Permian	Barakar	Coarse to medium grained sand-stone subordinate shales andcoal seams
Lw. Permian to Up.Carboniferous	Talchir	Greenish sandstone & siltstoneswith pebbles of Granite.
U n c o n f o r m i t y		
Pre-Cambrian	Metamorphics	Porphyritic granite gneisses

The thickness range of each formation within the block as intersected in theboreholes are given in *Table 2*.

Table 2: Thickness Range of Different Geological Formations Intersected in Shahpur West Block

Formation	Thickness Range (m)	
	Minimum	Maximum
Soil / Alluvium	3.00(MSSW-5)	7.75 (SSH-7)
WeatheredMantle	11.0 (MSSW-42)	28.50 (MSSW-1)
Barren Measures	9.00 (MSSW-23)	76.00 (MSSW -24)
Barakars	99.50 (MSSW -39)	239.00 (SSH- 30)
Talchirs	4.05 (SSH-30)	24.30 (SSH-29)
Metamorphics	Not drilled up to basement	

The sequence of coal seams, thickness ranges and range of intervening partingbetween the

seams as established in the block is presented in.

Table 3: Sequence of coal seams, shahpur west block

Sequence of Seam / Parting	Range of Seam Thickness (m)		No. of full intersections	Dominant thickness(m)
	Minimum	Maximum		
IV	0.15 (MSSW-21)	1.70 (MSSW-37)	60	0.50 – 1.50
Parting	41.03 (MSSW-56)	55.53 (MSSW-37)	-	-
L2	0.55 (MSSW-21)	3.16 (SSH-15)	63	0.50 – 2.00
Parting	9.58 (MSSW-14)	23.24 (MSSW-7)	-	-
III A	0.35 (MSSW-12)	2.84 (MSSW-11)	60	0.50 – 1.50
Parting	0.30 (MSSW-56)	2.93 (MSSW-25)	-	-
III B	0.14 (MSSW-32)	1.78 (MSSW-40)	35	0.50 – 1.20
Parting	0.72 (MSSW-30)	1.62 (MSSW-31)	-	-
III L	0.62 (MSSW-29)	1.40 (MSSW-58)	9	0.05 – 0.90
Parting	12.75 (MSSW-58)	20.32 (MSSW-29)	-	-
II	0.92 (MSSW-56)	4.16 (SSH-30)	62	1.50 – 3.00
Parting	18.54 (MSSW-24)	41.65 (SSH-17)	-	-
I	0.03 (MSSW-37)	1.25 (SSH-17)	29	<0.50–0.90
Parting	10.11 (MSSW-31)	25.76 (MSSW-38)	-	-
L1	0.10 (MSSW-37)	1.66 (SSH-30)	46	<0.50-0.90

3 METHOD OF WORKING

Conventional Board and Pillar system of mining will be adopted for excavating coal from Shahpur West Coal Block. Mine life is estimated to be 20 years.

4 PERIOD OF PREDICTION

The time period for the prediction of subsidence required is 20 years as given by SEML.

Stage-I	5 years
Stage-II	10 years
Stage-III	15 years
Stage-IV	20 years

5 FEM MODELLING FOR SUBSIDENCE PREDICTION

5.1 Introduction

For the subsidence prediction for Shahpur West block, three-dimensional finite element modeling (FEM) technique and software was used. *Figure 3* shows the plan of the area with important surface structures and the block boundary. The typical lithology of the area is shown in *Figure 4* which is around the central location of the mine. *Figure 5* to *Figure 7* show the depillaring areas in seam L2, IIIA, and II respectively at 5, 10, 15, and 20 years after the mining. This excavation sequence is in line with the approved Mining Plan (first modification), as provided by Sarda Energy and Minerals Limited. A similar extraction sequence was adopted in the FEM modeling for the subsidence analysis. The dimensions along the horizontal and vertical planes used for the analysis are 3729 m × 3265 m × 200 m (L ×W×H).

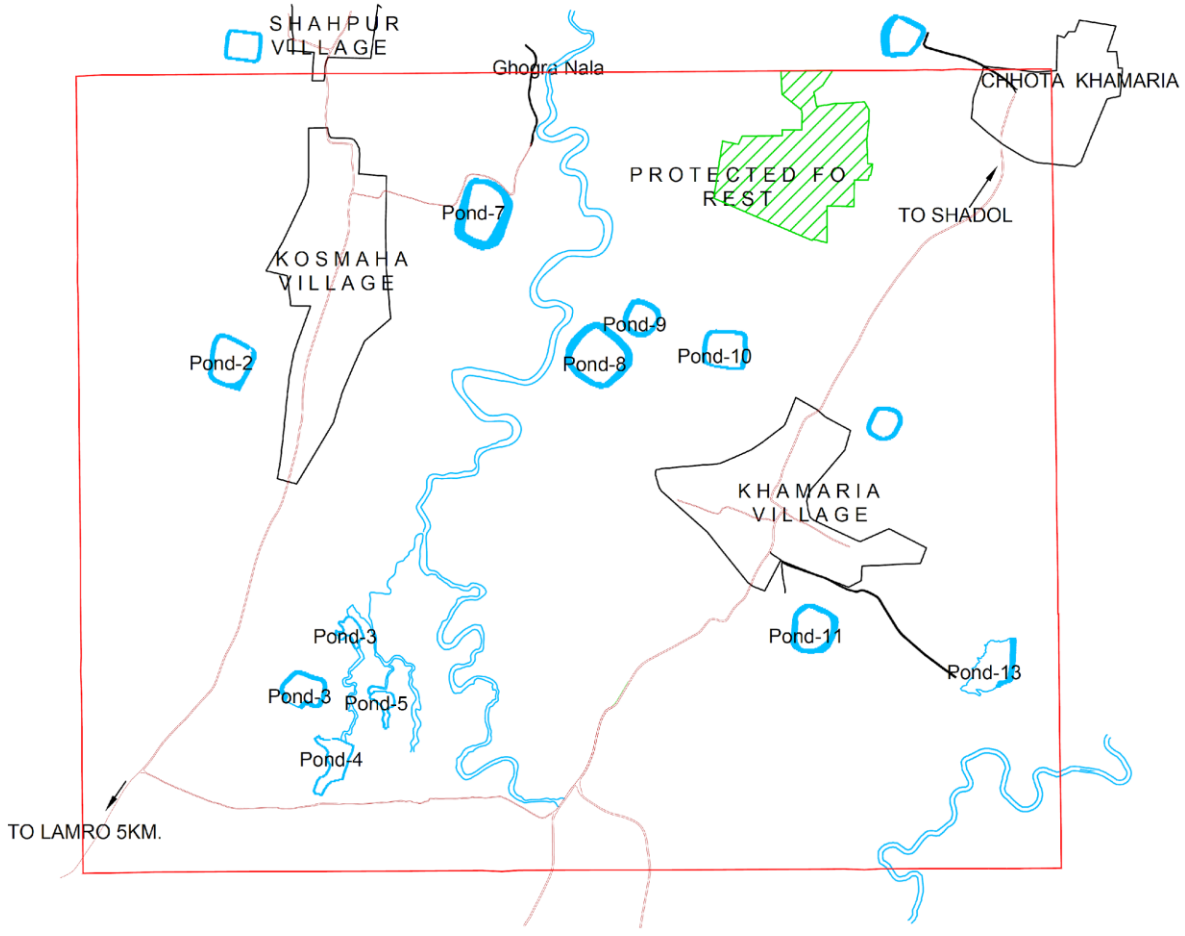


Figure 3: Important surface structures and the Shahpur West block boundary

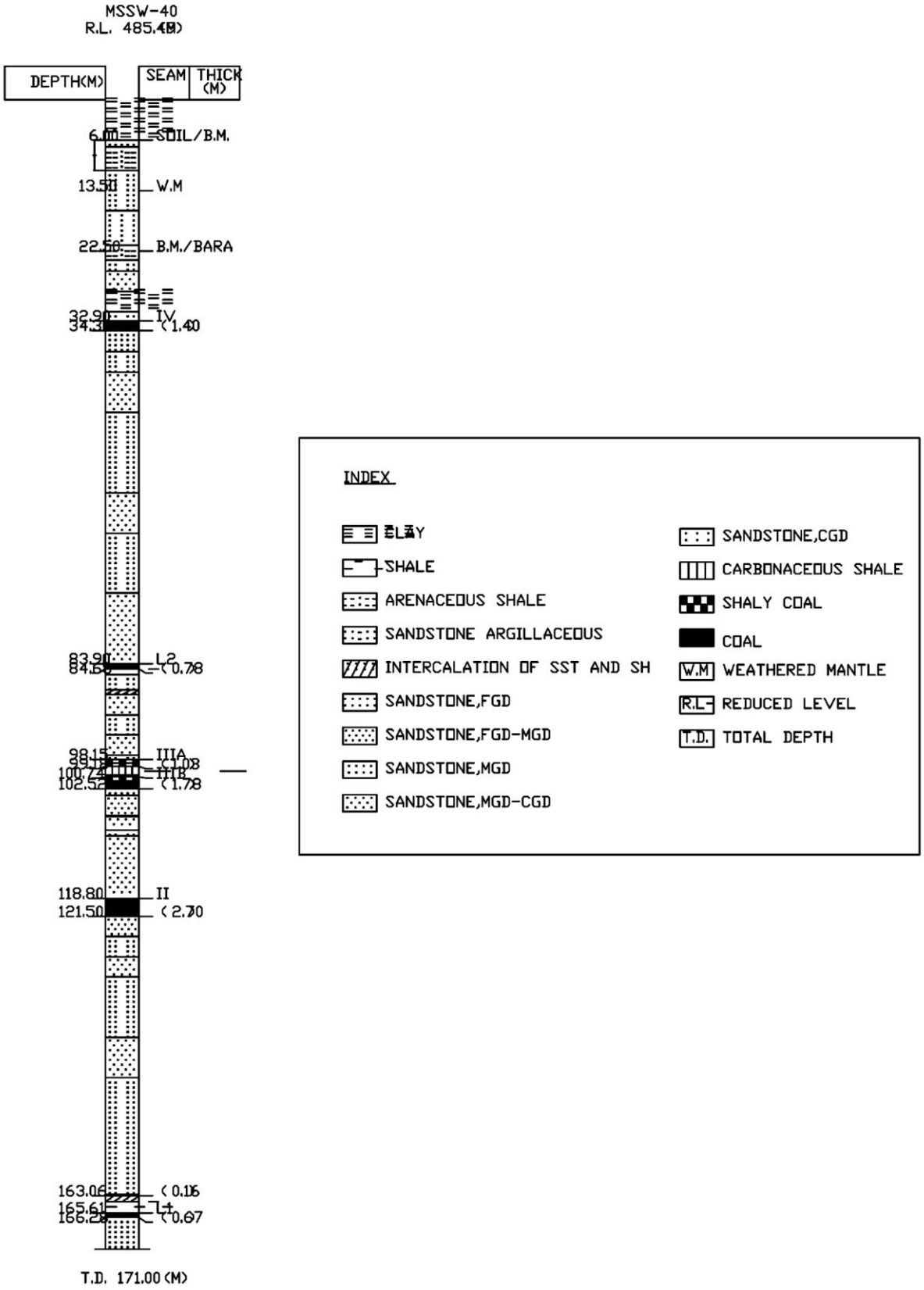
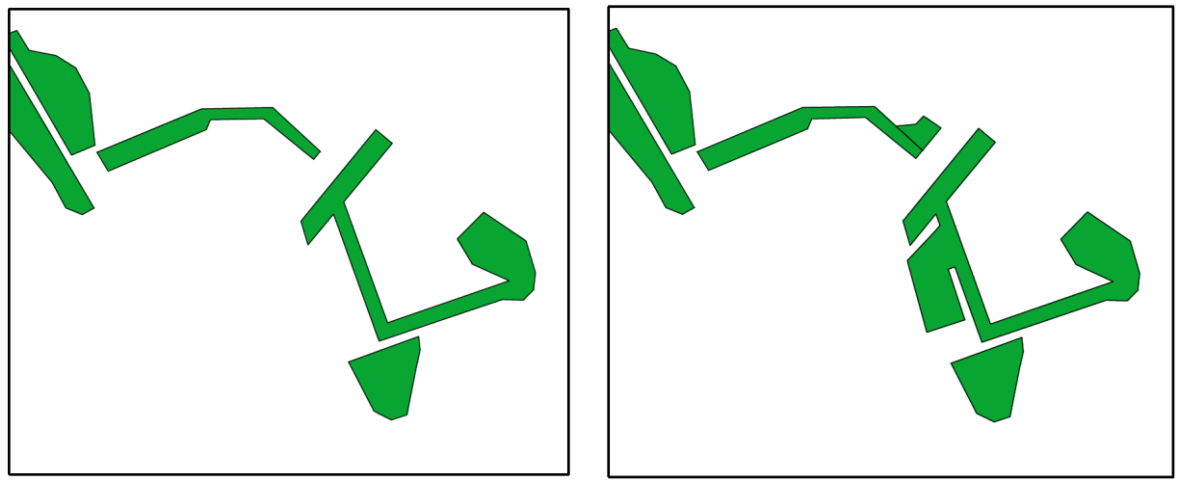
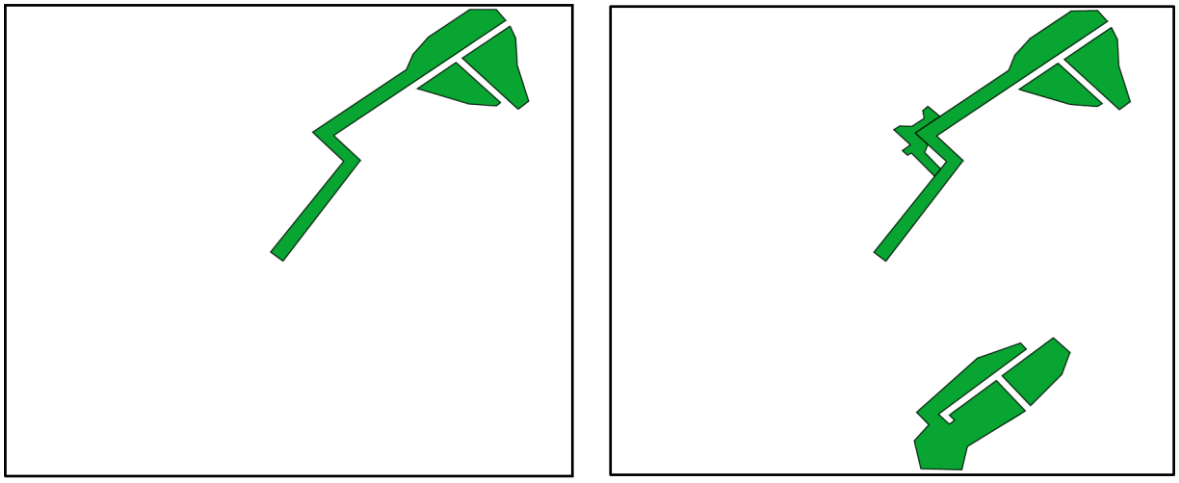


Figure 4: Lithology for a typical borehole MSSW-40 near the center of the block



(a) (b)

Figure 5: Depillaring area in seam L2: (a) after 5 years (b) after 10 years (end of seam)



(a) (b)

Figure 6:Depillaring area in seam IIIA: (a) after 5 years (b) after 10 years (end of seam)

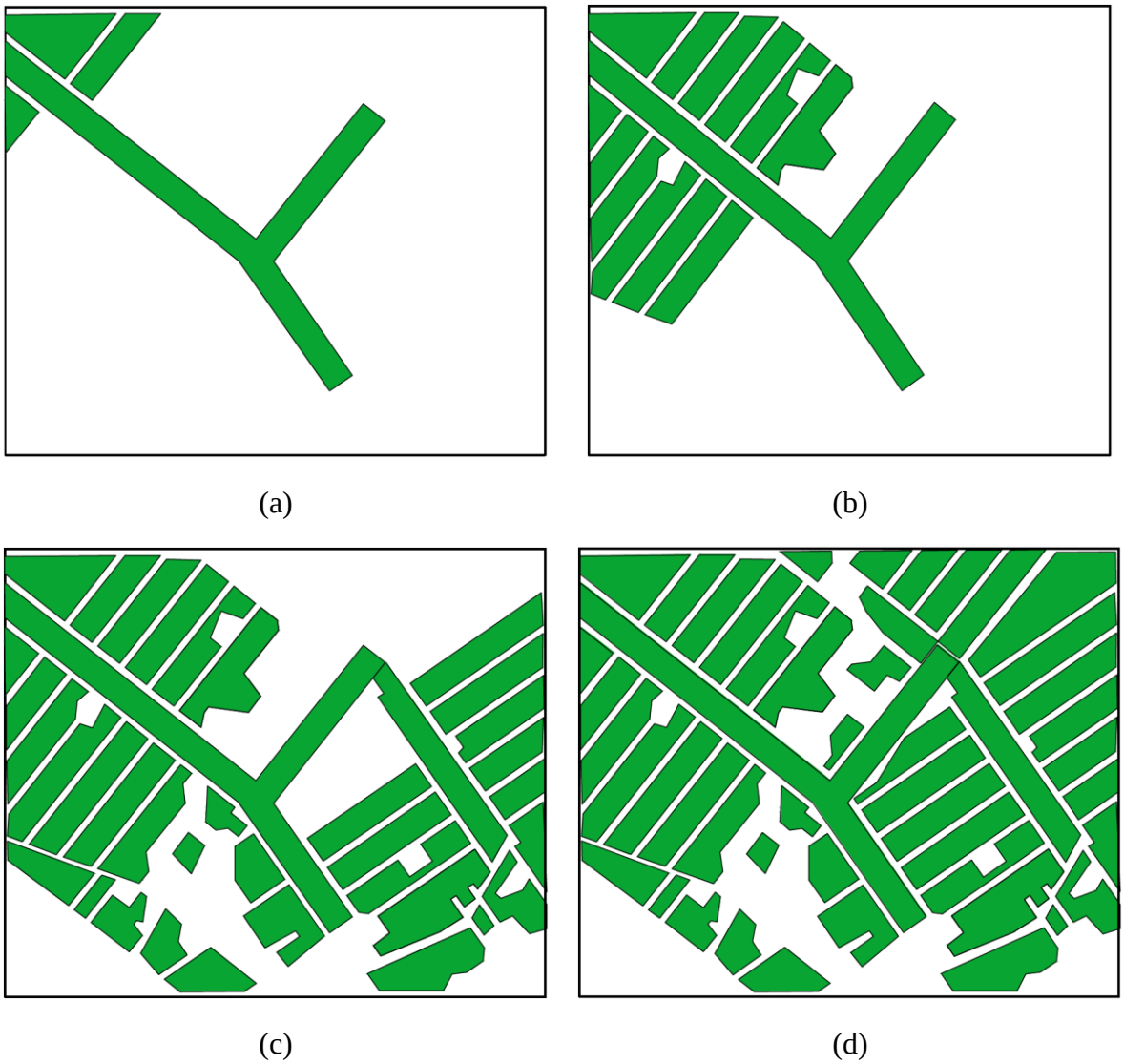


Figure 7: Depillaring area in seam II: (a) after 5 years (b) after 10 years (c) after 15 years (d) after 20 years (end of seam)

5.2 Rock mass properties

The borehole lithology near the central location of the Shahpur west block is shown in *Figure 4*. Three major types of rocks i.e. sandstone, shale, and coal are found in the block. The average elastic properties used in the analysis are shown in Table 4.

Table 4: Rock mass properties used for the numerical analysis

Rock	Density (kg/m^3)	E(GPa)	ν
Sandstone	2034	2.65	0.2
Coal	1340	1.63	0.13
Shale	2182	2.18	0.23

5.3 In-situ stress

The vertical stress was calculated using the following equation and as given by Hoek and Brown (1981):

$$\sigma_v = 0.027\ z\ \text{MPa}$$

where, **z** is the depth from the ground surface.

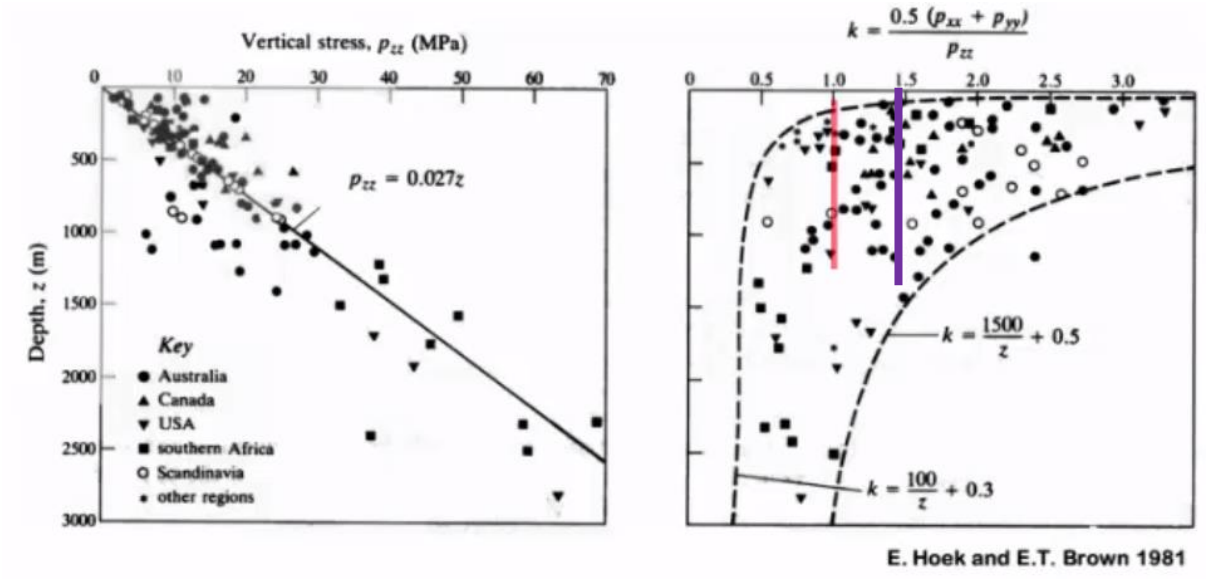


Figure 8: Horizontal and vertical stress with an increase in depth (Hoek and Brown 1981)

5.4 Prediction Technique

The FEM model was used to predict the subsidence of the coal block with time. The thickness of different rock layers was taken from the representative boreholes provided by the owner. As shown in *Figure 9*, the model created was 3729 m, 3265 m and 200 m in X, Z and Y direction respectively. The model generated was divided into 820000 elements with 1525000 nodes. The model was then run for in situ condition (no excavation). Coal seams were simulated to have been extracted sequentially from different seams for 5, 10, 15 and 20 years as per the plan provided by the Sarda Energy and Minerals Limited.

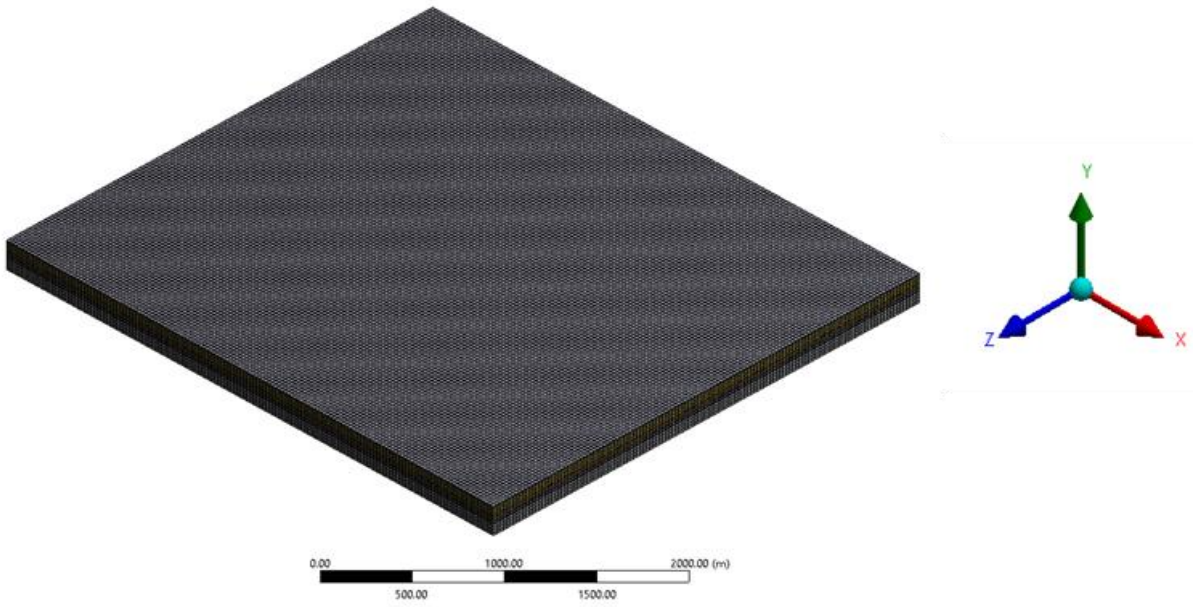


Figure 9: Visual representation of 3D Finite element model (FEM) used for prediction of surface subsidence with grid

6 RESULTS

6.1 Predicted Subsidence Contours

The subsidence values after running the model for different time periods were extracted from the FEM software. Figure 10 shows the subsidence contours after 5 years of mining. Similarly, Figure 11, Figure 12 and Figure 13 depict the subsidence contours at the end of 10, 15, and 20 years of mining respectively. The maximum values of the subsidence predicted at the end of each period are presented in Table 5.

Table 5: Maximum values of predicted subsidence at the end of mining.

Sl. No.	Year	Subsidence values (m)
1.	5	-0.71
2.	10	- 0.84
3.	15	- 1.22
4.	20	-1.63

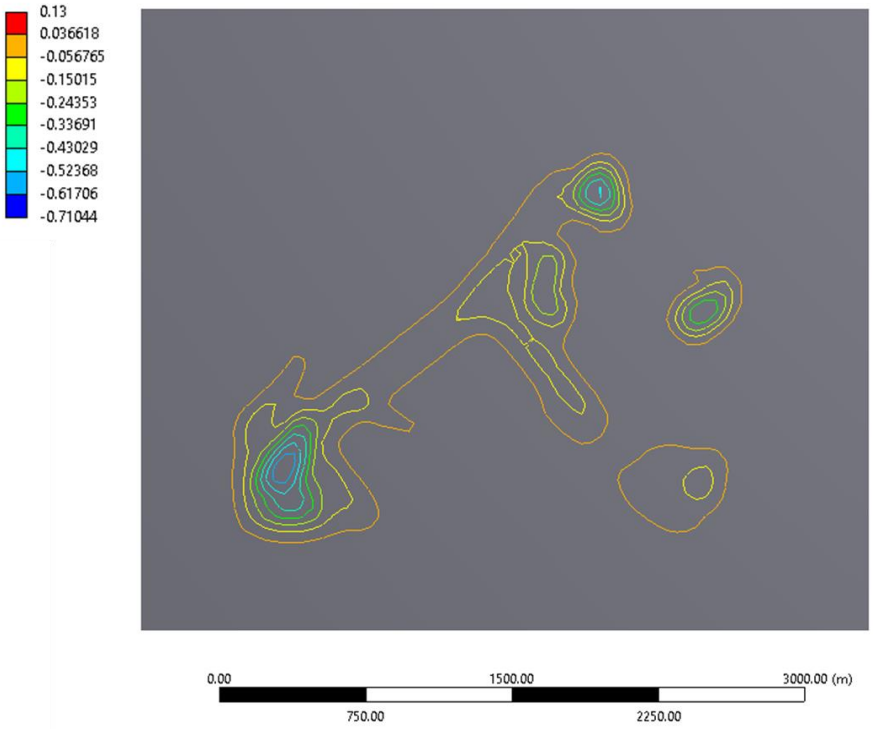


Figure 10: Subsidence contours after 5 years of mining (Shahpur west block)

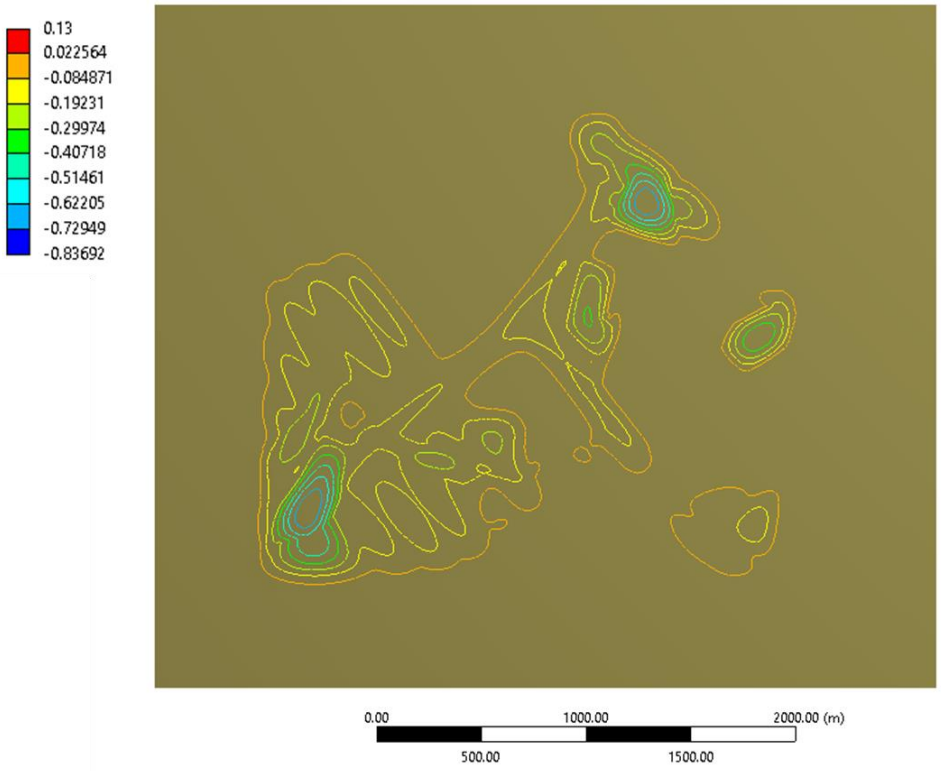


Figure 11: Subsidence contours after 10 years of mining (Shahpur west block)

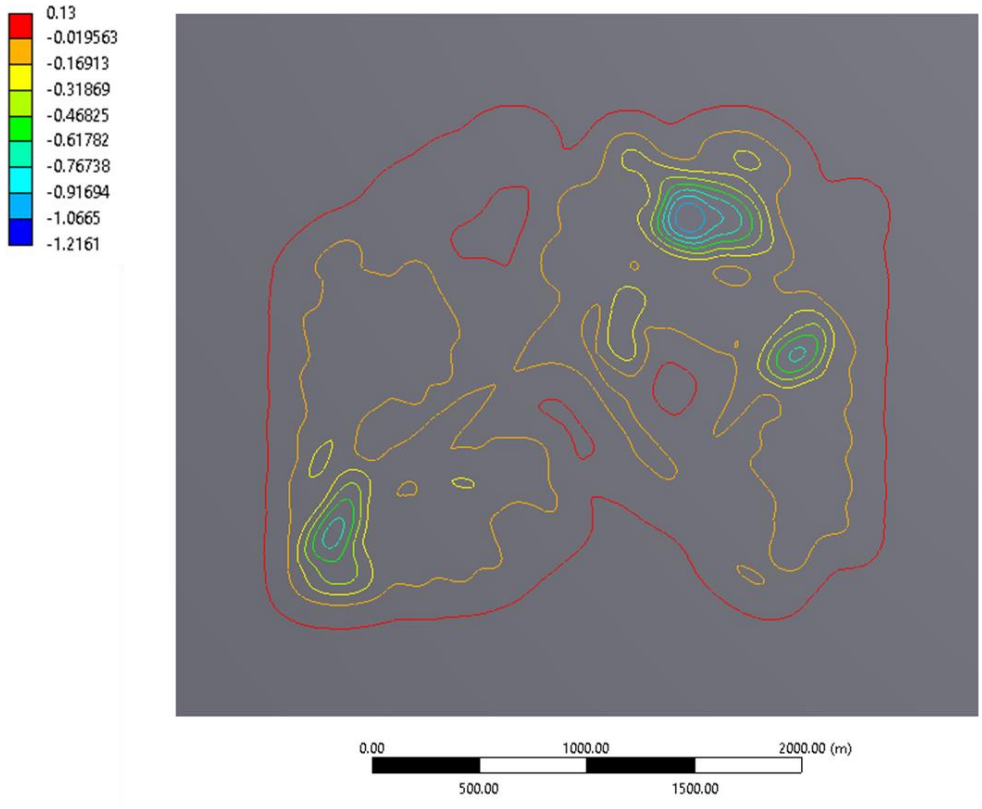


Figure 12: Subsidence contours after 15 years of mining (Shahpur west block)

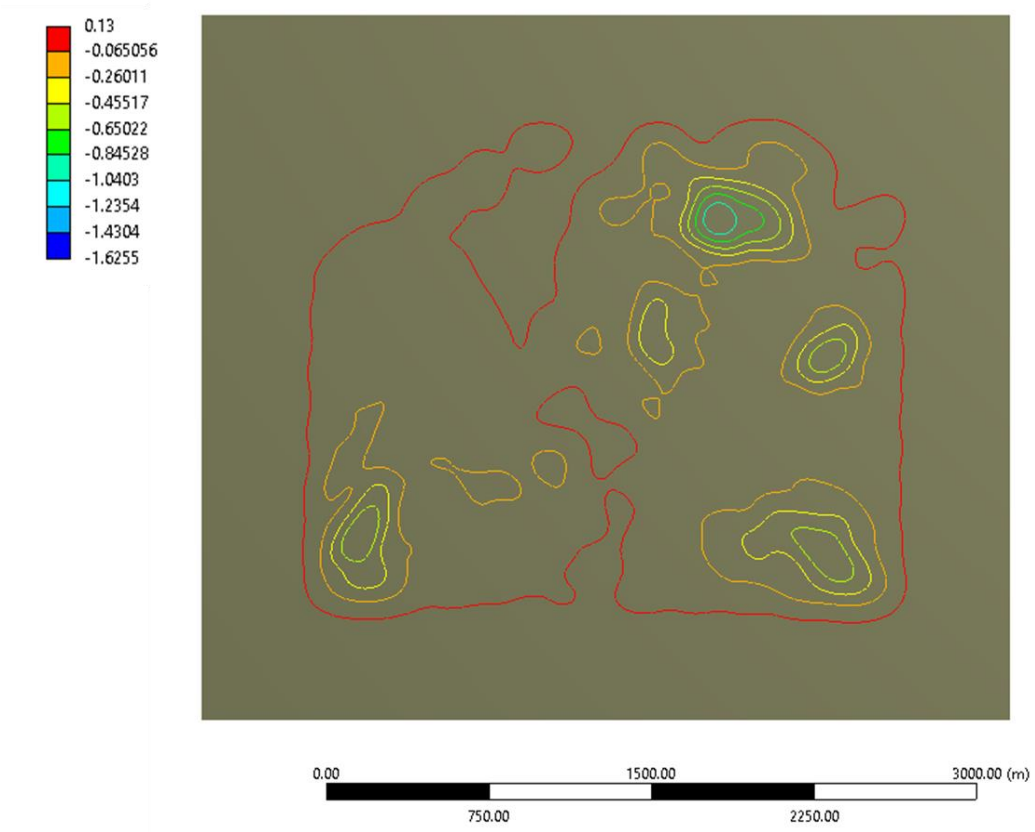


Figure 13:Subsidence contours after 20 years of mining (Shahpur west block)

6.2 Three Dimensional Projections of Subsidence

To get a 3-dimensional of the subsidence on the surface, the predicted subsidence has been projected for each of the block period based on X and Z coordinate defining the horizontal plane and 'Y' coordinate, the depth of the surface.

Figure 14 to Figure 17 give prediction of the subsidence at the end of 5, 10, 15 and 20 years of mining respectively, considering the surface to be horizontal before the mining. These figures give a realistic impression of subsidence as a result of the progression of mining with time. However, the subsidence values obtained were too low compared to the dimensions of the model. So, scale factor of 190 times of auto scale was used to visualize the subsidence at different locations of the block at different time. These drawings provide a fairly accurate idea about ground behavior after mining.

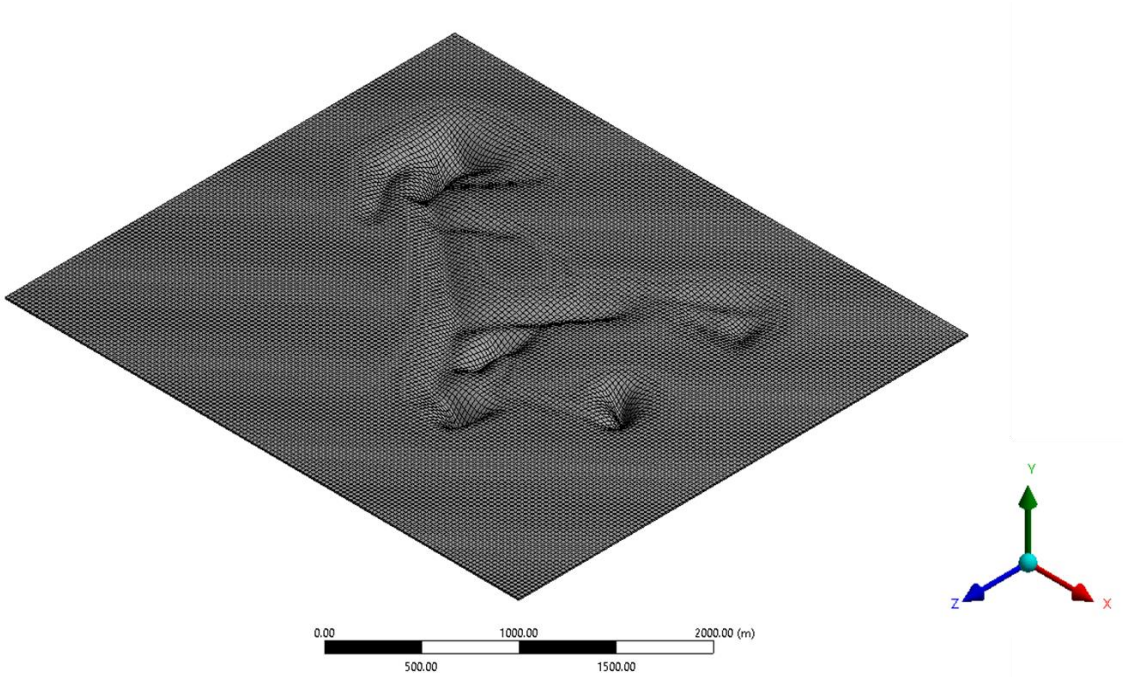


Figure 14: Subsidence profile after 5 years of mining (Shahpur west coal block).

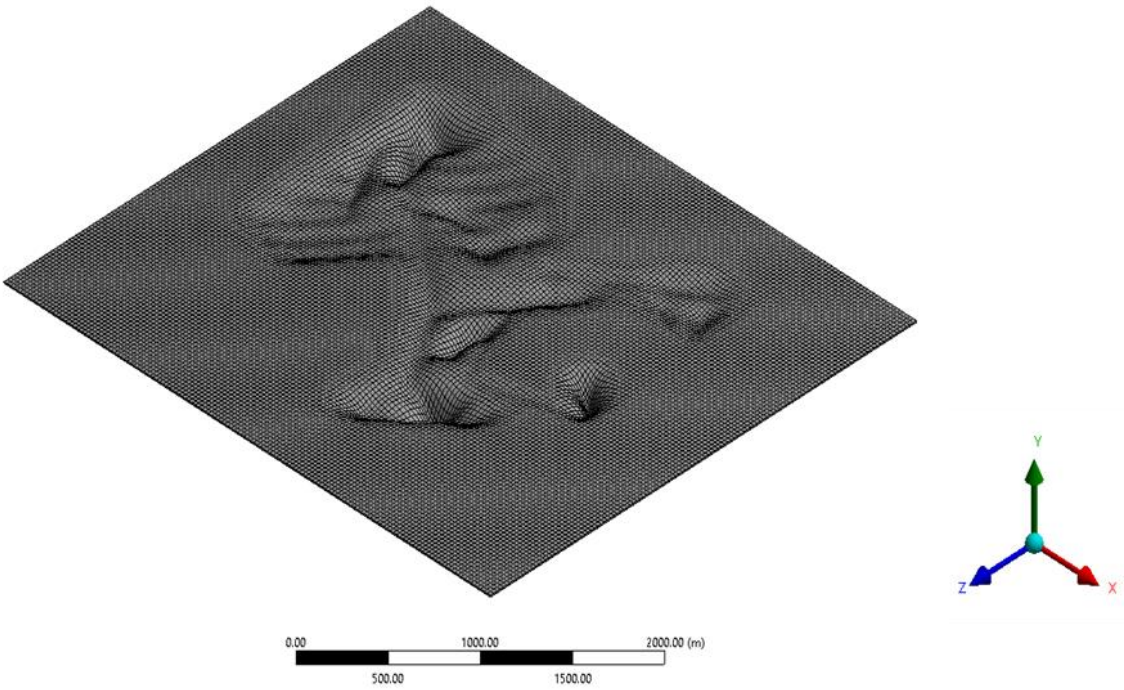


Figure 15: Subsidence profile after 10 years of mining (Shahpur west coal block).

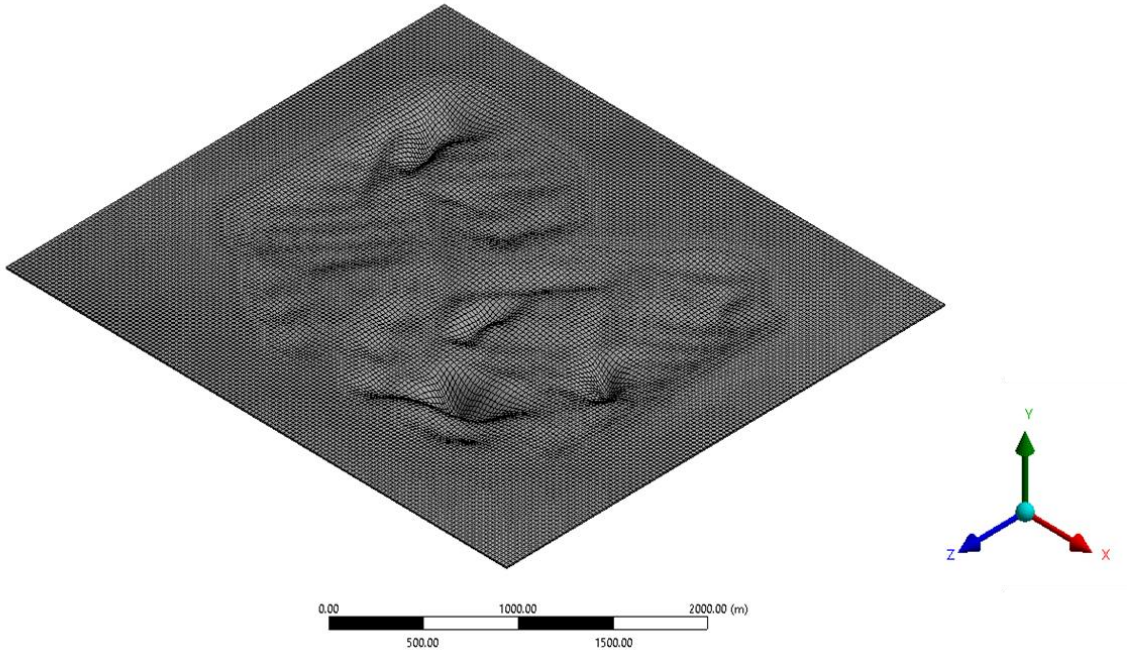


Figure 16: Subsidence profile after 15 years of mining (Shahpur west coal block).

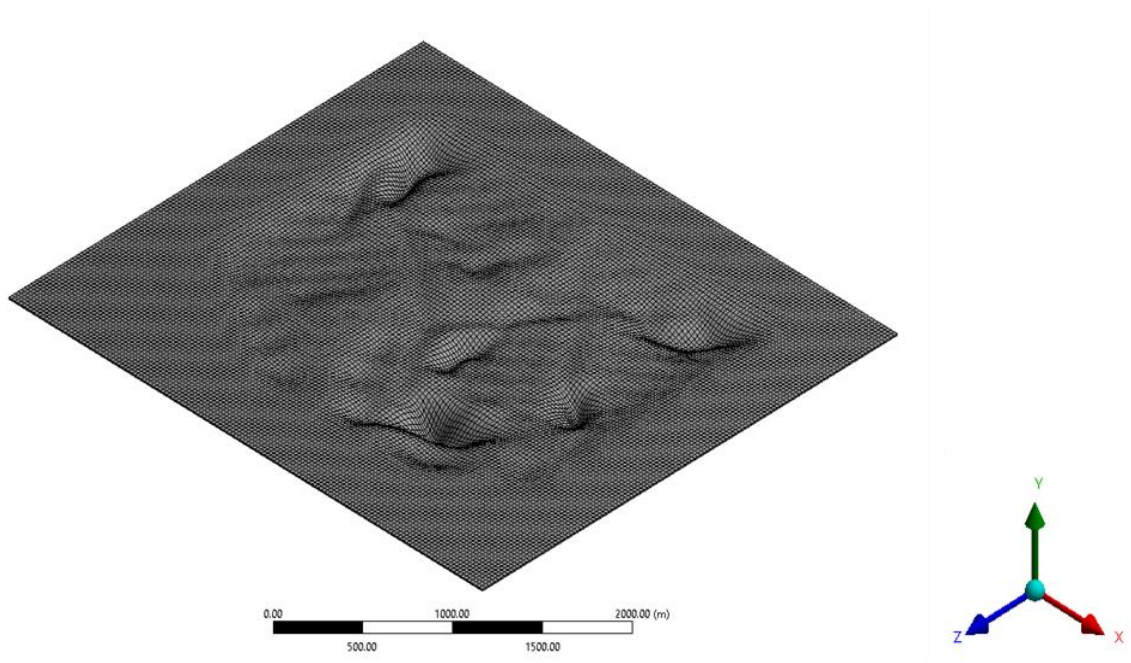


Figure 17: Subsidence profile after 20 years of mining (Shahpur west coal block).

6.3 Surface Profile/Subsidence near the important surface structures

To obtain the subsidence values near the important surface structures on the ground, the structures were superimposed over the predicted surface contours after 20 years of extraction (Figure 13). The results obtained is shown in Figure 18.

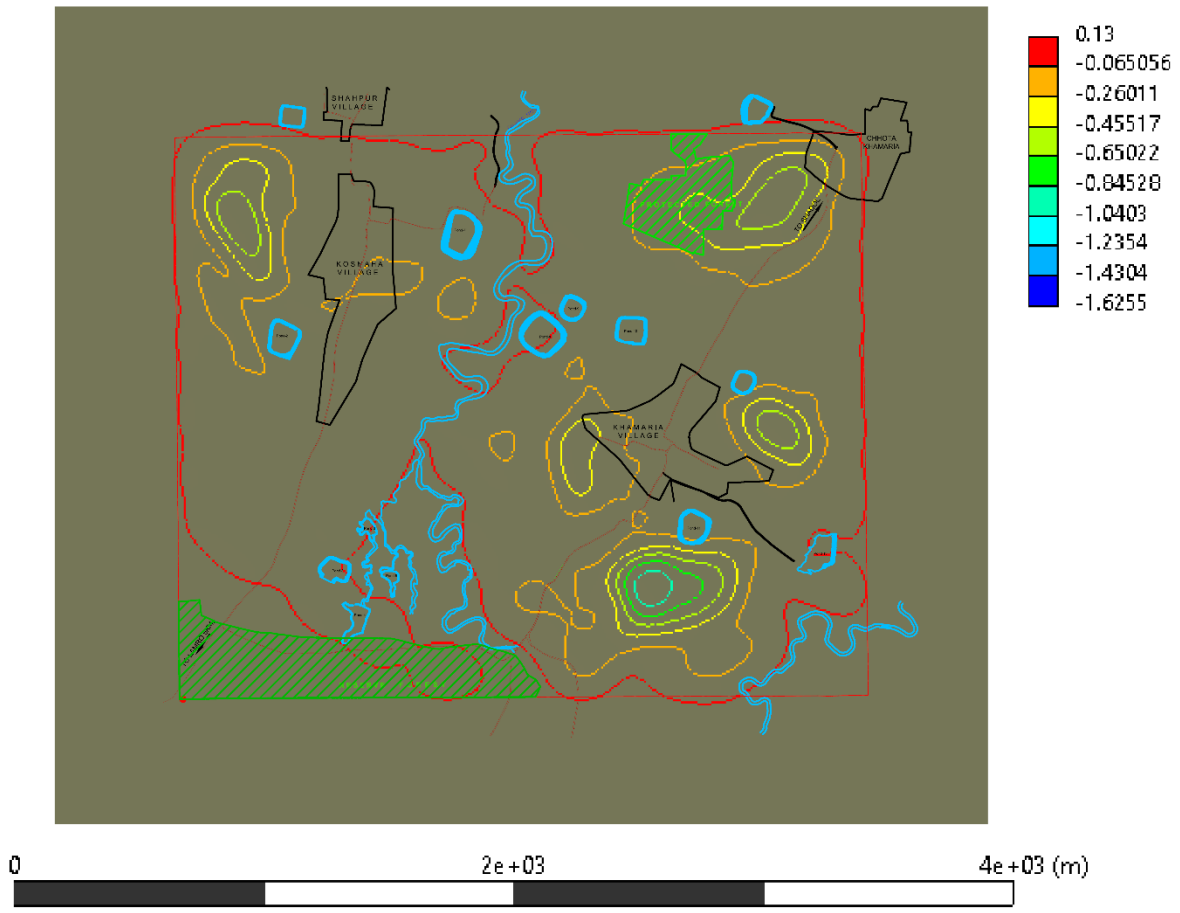


Figure 18: Subsidence contours superimposed with surface structures after 20 yrs of mining (Shahpur west block)

6.4 Tensile strain

The maximum predicted tensile strain on the surface of Shahpur West Block for various time blocks has been given below in Table 6.

Table 6: Predicted maximum tensile strain on the surface of Shahpur West Block at various time blocks

Sl. No.	Time Block (in years)	Tensile Strain (mm/m)
1.	5	3.17
2.	10	4.16
3.	15	7.06
4.	20	9.45

The maximum predicted tensile strain has been obtained for each time block separately and is 3.17 mm/m at the end of 5 years of mining. It slowly increases from 3.17 to 9.45 mm/m over the estimated life of mining.

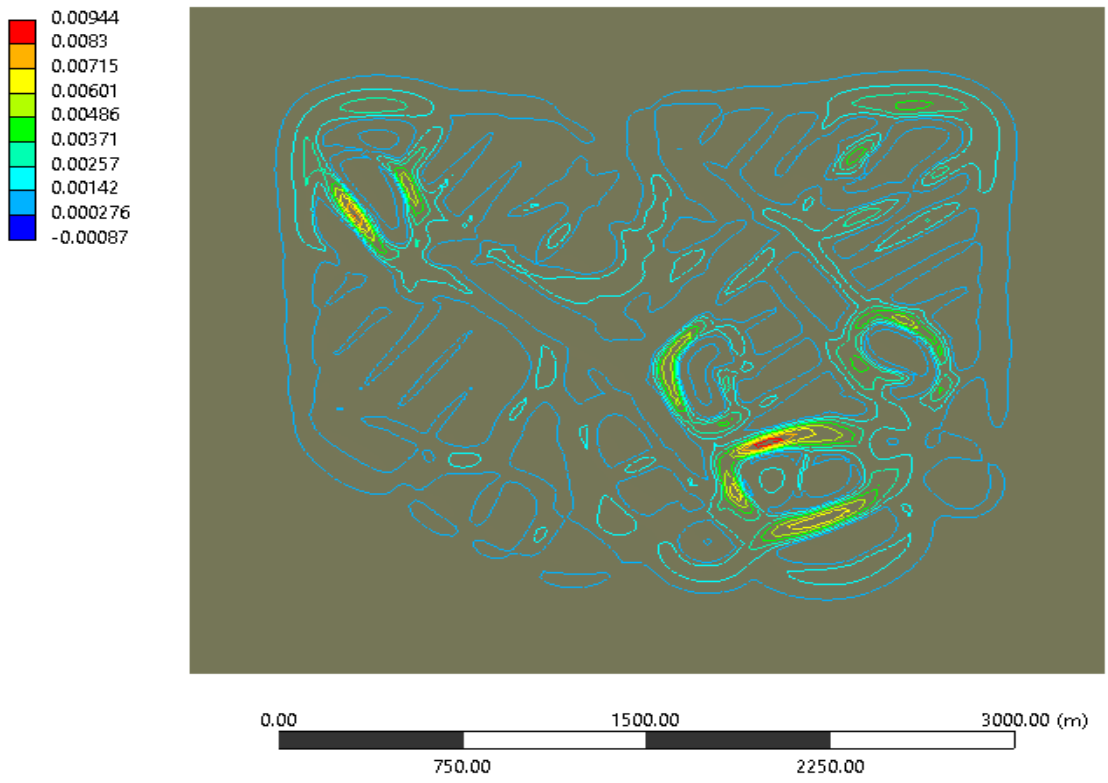


Figure 19: Tensile strain developed on the surface of the block after 20 years.

6.5 Crack width

It is well established from the coal mining practices that the cracks may occur under the condition of high tension and weak rock. The prediction of cracks width is associated with a high degree of uncertainty. Zones of possible cracks will be in the vicinity of weak rocks and near fault planes under high tensile strain. To have accurate prediction, the strain maps should be superimposed over the detailed geological plan with geotechnical data. Cracks are likely to be formed due to extraction of some of the panels. However, the areas having these cracks are very small in the north-western corner of the block.

7 DISCUSSION

Figure 14 through 17 shows the subsidence troughs formed at the end of each time block of 5 years of mining. The maximum predicted subsidence at the end of 5 years of mining is 0.71 m. The maximum predicted horizontal tensile strain is 3.17 mm/m. The subsidence troughs spread in area and depth at the end of 10 years of mining was found to be 0.84m. However, the maximum predicted horizontal tensile strain was 4.16 mm/m.

The predicted maximum subsidence and horizontal strain at the end of 15 years of mining were (1.22 m, and 7.06 mm/m). However, the subsidence troughs spread and cover more area after 20 years. The predicted maximum subsidence at end of 20 years of mining is 1.63 m. The predicted horizontal tensile strain was 9.45mm/m.

Effect of subsidence on structures present on the surface need careful examination. Two figures have been specially made for discussion purpose. Figure 18 is the superimposed subsidence contours at the end of 20 years of mining with important surface structures at the surface. Similarly, Figure 19 is the superimposed map of high tensile strain panels with important surface features. The subsequent discussion has been done using the above two maps.

1. ***Khamharia Kalan, Khamharia Khurd, Kushmaha Khurd And Shahpur Villages*****: -** Protection pillar of sufficient size has to be provided below Khamharia Khurd, Khamharia Kalan, Kushmaha Khurd and Shahpur villages. These are extra precaution to avoid any damage that may extend to the surface. There will not be any effect of subsidence on villages on the surface. Therefore, no subsidence management plan is specifically required for villages.
2. ***Ghogra Nullah*****: -** Ghoghra Nullah is passing in middle of the block flowing from south to north. Protection pillar of sufficient size has been provided below the above

mentioned Nullah. There will not be any effect of subsidence on the Nullah. Therefore, no subsidence management plan is required for Ghoghra Nullah.

3. ***Forest Area*: -** There are two major patches of forest covers viz protected forest that falls in the north eastern part of the block, covers an area of 12.248 Ha whereas, reserve forest lies in south western portion of the block, covers an area of 34.240 Ha only. Other than these patches, there are scattered patches of Revenue Forest measuring to 34.102 Hectares throughout the Coal Block.

   However, mining has been planned below the entire forest land except approx 18 hectares forest land situated in South Western part of Shahpur West Coal Block. It is evident from the Figure 17 that subsidence troughs having subsidence more than 1.5 m will be formed. Moreover, Figure 19 shows that tensile strain more than 9 mm/m will also result due to mining in forest area.

4. ***Roads:-*** There are two important roads passing on the block i.e., the road connecting KALYANPUR to SHAHPUR village and the other road on the eastern side passing through KHAMARIA village. Protection pillars of sufficient size have been left below the above-mentioned roads. There will not be any effect of subsidence on the roads. Therefore, no subsidence management plan is required for the above-mentioned two roads.

5. ***Water Bodies:-*** There are a number of water bodies on the surface. The study shows that the horizontal tensile strain is not high near water bodies. Therefore, it is likely that there will not be any damage to water bodies. However, care should be taken to observe cracks near water bodies due to the progression of mining.

Regular observation and inspection is a key idea to getting a prior indication of any changes that might occur on the surface due to mining. Precaution should be taken to regularly fill the cracks, if any and restore the land to its original position.

8 SUBSIDENCE MANAGEMENT PLAN

The following subsidence management plan is being is proposed for Shahpur West Coal block.

1. Some of the panels leading to tensile strain greater than 9 mm/m below the protected forest land should not be completely excavated. It should be partially excavated (during depillaring).
2. Visible cracks, if any, should be regularly filled and land be restored to its original position.

3. Vigil should be kept for likely cracks near water bodies.
4. No subsidence management plan is required for Khamaria Kalan, Khamharia Khurd, Kushmaha Khurd and Shahpur villages; Ghogra nullah and two roads passing over the surface as protection pillar of sufficient size have been provided in the mining plan below them.

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