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Reclamation of Abandoned Mined-Out Areas of BUKURU-RAYFIELD

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Abstract: *The Plateau tin fields have been subjected to mining activities and environmental degradation which spanned over a decade since mining started in 1902. Mining though an indispensable economic activity requires affective management, monitoring and control to forestall undesirable environmental degradation- This was not considered during the first 46 years of mining by the colonial government leading to the devastation of a substantial arable land. This paper examines the reclamation needs of tin fields of the Bukuru-Rayfield environs, and proposes necessary land reclamation methods and major land reclamation machineries and practice that would ensure proper management of mined-out areas and reduce risks of further environmental degradation. The study reveals that of the 9(nine) existing abandoned mine ponds and 5(five) mining spoils a total of about 22,237,380 m3 of earth material would be required for reclamation. This volume includes 435780 m3 of the available mining spoil. This therefore suggests that earth material would have to be moved from the several abandoned spoils of the Plateau tin fields to achieve a sustainable reclamation of the ponds. The study area which falls within the Jos-Bukuru Complex of the Younger Granites Province of the Jos Plateau was subjected to detailed geological investigation as part of initial surveys covering about 30km², between latitudes 9˚ 47' 58.3" and 9˚ 50' 43.6" North and longitudes 8˚ 51' 49.66" and 8˚ 55' 6.03" East (Sheet 168 Naraguta NE).*

KeyWords: *Abandoned, Environmental degradation, Mine ponds, Mine spoil, Reclamation, Geological mapping*

I. Introduction

Tin and allied metals mining on the Jos Plateau is over 100 years in Nigeria, having started about 1902. Within this span of time the tin fields have been subjected to a process of unregulated mining activity. The mining law only came to being in 1946 long after the erstwhile arable land had been devastated by intensive and extensive mechanized mining activities. All mining activities have very significant impacts on the environment. On the Jos Plateau tin fields, the major types of wastes and dumps are the mine pond, overburden (mine spoil) and processing mill wastes. These require careful management, especially since some of them may be hazardous while others are useful.

Environmental effects associated with mining operations are of particular concern to both the government agencies, planning authorities and the general public because of the destructions they have led to the surrounding. These destructions may result to the loss of land, provision of spoil tips, pollution of ground and surface water and may even cause damage to the ecosystem. There is, therefore, the need to develop appropriate reclamation and indeed rehabilitation measures to check furtherance of the menace.

The paper has examined the nature of the tin fields (by means of geological mapping) , the effects of past mining activities and identify reclamation needs of mined lands within the study area and thus has recommended further use of certain mine ponds that will ensure proper management and prevent land degradation.

II. Methodology

The procedures involved in this research included desk study and literature review where background information was collated from related journals, maps and bulletins. This was followed by orientation and reconnaissance geological and basic topographical survey. This involved demarcating field features such as nature of the terrain, damage caused by mining activities, measurements of the nature and offsets of the abandoned mine pond, spoils and the geological features of the area.

The geological mapping consist of study of different rock types and structural features such as strike and dip, it also locates the mine ponds and spoils on an enlarged map (Naraguta sheet 168NE) of area scale from 1:50000 to 1:12,500. The aim of this exercise was to produce a simple geologic base map of the area to show any recent features, geomorphology and structural changes in the affected area.

Further more, basic topographical and linear surveys were introduced in the research to calculate the surface areas of both the regular and irregular shapes of the mine ponds. Relevant data were gathered in the field

during this survey. These data were plotted into a plan from which the areas and volumes of the ponds and required earthwork were computed.

III. Results and Discussion

3.1 Geology

The geology of the study area falls within the Jos- Bukuru Complex which is predominantly of biotite-granite (Fig.1) type as exhaustively studied by Falconer (1911), Falconer (1921) and MacLeod et al. (1971). The geology of the Jos Plateau is made-up of the Precambrian Basement migmatite-gneiss-quartzite complex which underlies about half of the entire State and in some places has been intruded by Precambrian to the late Paleozoic Pan-African granite (Older Granite), diorite, charnockite etc. Intrusive into these Basement Complex rocks are the Jurassic anorogenic alkali Younger Granites. In association with the Younger Granites are volcanic rocks such as basalts and rhyolites that overly or cross-cut this formation as well as the Basement rocks. These volcanic rocks are believed to have been formed during the early Cenozoic (Tertiary) "Older Basalts" and Quaternary "Newer Basalts" (Macleod et al, 1971). The description of Macleod confirm the presence of minerals of economic importance such as tin and columbite which where extensively mined between 1902 and 1978. The present geological map and Satellite imagery (Fig.2) suggests and indicates that the mining activity has devastated the arable land. The study area is therefore littered with several mine spoils and ponds in addition to severe erosion of the landmass which potent serious limitation to urban expansion and agricultural development amongst others.

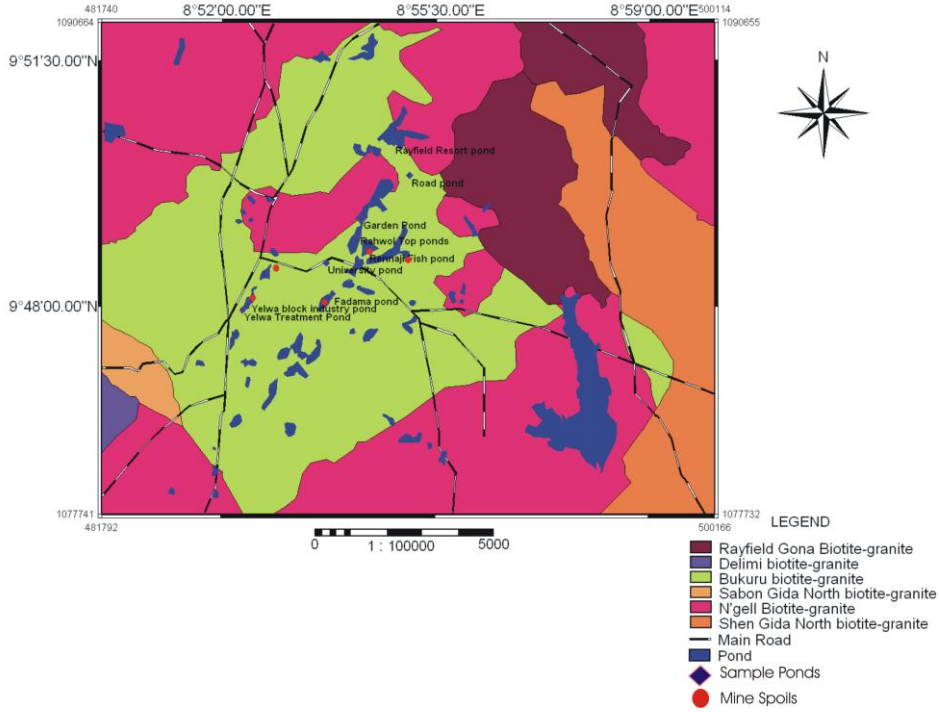

Fig.1.Geological map of the Study Area (Source: Modified after Macleod, 1971)

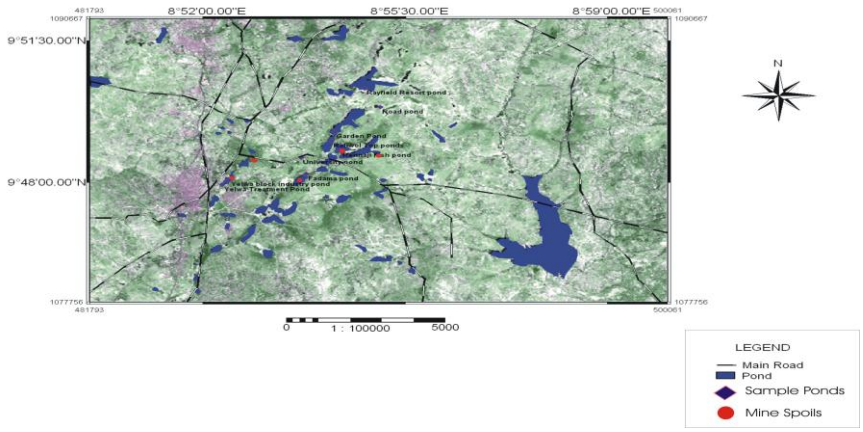

Fig.2: Satellite Imagery of the study Area (source: National Centre for Remote Sensing)

3.2 Abandoned Mine Ponds and Spoils

The existing mining ponds are relatively large pits of varying depths covered with water which resulted from excavation of the earth during mining. These ponds have been a major source of concern to both the Government and the general public due to the increasing rate of accidents and threat to life of humans and livestock alike over the years. Table 1 shows some data rescue operation (1980-1993) related to mine ponds, wells and rivers.

TABLE 1: Rescue Operations (1980-1993)

	MINE PONDS		WELLS		RIVERS	
YEARS	ALIVE	DEAD	ALIVE	DEAD	ALIVE	DEAD
1980	–	4	6	2	–	–
1981	–	20	25	4	–	–
1982	–	23	21	–	–	–
1983	–	20	37	3	–	–
1984	1	4	17	–	–	–
1985	–	2	16	–	1	–
1986	–	10	26	6	–	–
1987	–	3	10	5	–	–
1988	–	–	5	5	1	2
1989	4	5	17	14	1	2
1990	1	1	4	6	–	–
1991	–	–	10	4	–	–
1992	7	6	9	6	1	1
1993	–	8	10	–	–	–
TOTAL	13	106	213	61	4	5

SOURCE: Adiuku-Brown, 1999.

The danger posed by these mining derelicts forms the basic reason to reclaim a substantial percentage of the ponds, especially those without any socio-economic values. Mine ponds that contain much water have been used for several purposes such as agriculture, fishery, recreation etc.

The study identified some series of mine ponds and spoils which liter the Bukuru –Rayfied metropolitan areas. Nine groups of such mine ponds and five major mine spoils have been critically studied (Plates 1 to 8) and (Tables 2 and 3). The volumes of ponds were calculated, G.P.S. locations recorded, choice for reclamation method and equipment among other estimates were deduced.

3.2.1 MINE PONDS

a. Yelwa Treatment Plant Pond

It is an old mine pit that has been filled with water. It is located about 1km east of Bukuru town. Presently, it is used by the Plateau State Water Board to pump, treat and distribute water to the near-by communities for both domestic and industrial uses. For this reason, total reclamation is no more possible, thus, there is need for barricading the perimeter of the pond to prevent risk of drowning and pollution by run-off water. The excavated spoils or dumps during the mining of this pit were not seen around the perimeter of the pond at the time of field study. It must have been washed away by run-off water or probably used for building construction by the inhabitant of the area.

Plate 1: Yelwa Treatment Plant Pond

b. Yelwa Block Industry Pond**:** The pond is located about 300 meters north of Yelwa Treatment Plant Pond. It is used in block making by Jacob block industry. For proper management, the need for barricades is very necessary.

Plate 2: Yelwa Block Industry Pond

c. Garden Mine Pit (Pond)

Further north of pond 1 and 2 above (a distance of about 1-1.5km), a garden pond was observed. It was seen that the water in it is very shallow (low), consequently, the need for reclamation is recommended. For this reclamation operation, Backfilling method is suggested due to the abundant spoils seen around the perimeter of the pond.

Plate 3: Garden Pond

d. Rahwol Top Pond

Rahwol top comprises of two ponds separated by a minor road that link to Rayfield Resort. Some parts of the ponds were fenced with blocks to reduce the rate of inflow of water into near-by residents during the rainy season. These barricaded blocks are actually not good for embankment or as embankment material. Water from the two ponds is pumped using generating pumps to a close-by Rennajj Fish and integrated farm limited, where it is used for fishery. The ponds are therefore irreclaimable.

Plate 4: Rahwol Top Pond

e. Rennaj Fish and Integrated Farm Limited Pond

At this stop, about eight separated fish ponds have been observed. Only three of them contain water and are used for fish farming. As said earlier, the source of water for these fish ponds is the Rahwol top ponds. Six of the dried ponds were recommended for reclamation while the other remaining three should be rehabilitated by means of barricades.

Plate 5: Dry Fish Pond

Plate 6: Fish Pond

f. Fadama Pond
This pond is used for irrigation farming by local farmers. Total reclamation is therefore not recommended, however, there is need for barricades.

Plate 7: Fadama Pond

g. New University Pond
From this pond, water is pumped and use for the construction of near-by new University, it is equally use in civil engineering road construction. For this reason, the pond is irreclaimable.

h. Road Pond
Despite the abundance of water, Road pond was abandoned and left unsecured. However, industries are advice to be sited around the pond and make the best use of the water for productivity, or otherwise the pond should be reclaimed to minimize the danger of accidents.

i. Rayfield Resort Pond
At this stop, two major mine pits were observed and separated by a minor road. One of the ponds is completely filled with water of approximate depth of 12meters, and the other having very little water with inclusions of smaller ponds at the floor of the pit. The latter was observed to have been excavated in layers of four steps approximately 2m, 3m, 7m and 12.5m from the top respectively. For this reason, Terracing reclamation method is recommended for the closure of this pond. The former is actively use for recreational purposes; however, there is need for its rehabilitation.

Plate 8: Rayfield Resort Pond

A few industries and recreational outfits have already started using some of the observed mine pond water (such as Yelwa ponds, Rayfield pond etc) as highlighted above. For such, acquired pond-water total reclamation is no more possible (see table 7). In view of the current drive for industrialization, there still exists the possibility of the establishment of more industries that may require water from the mining ponds.

For reclamation purposes, the volume of mined pit must be calculated to give an idea of the amount of material needed to be moved for proper closure of the pit. This volume compared with that of the mined spoil (if available), will tell if additional spoil is needed or not for total reclamation of the pit. If the available spoil is not enough (which is the case in virtually all occasions), additional material must be sourced from other sources.

The volume of mined pit was calculated by dividing the shape of the surface of the pit into recognizable shapes such as rectangles, triangles, squares etc**.** For each shape, the surface area is calculated and recorded. The sum of the surface areas of all the divided shapes gives the total surface area of the pit. Finally, the product of the surface area of the pit and the depth of pit will give the volume of the pit.

Mathematically,

Volume of mine pit = Surface area of the pit X depth of pit

Table 2: Calculations of Volume of Mine Pond

S/N	NAME OF POND	G.P.S LOCATION	APPROXIMATE AREA(A) L X B (m^2)	APPROXIMATE DEPTH (D) m	APPROXIMATE VOLUME (V) m^3	RECLAMATION METHOD
1	Yelwa treatment plant (pond)	N09º48'01.6″ E09º52'28.6″	45,500m^2	9m	45,500m^2 x 9m =409500 m^3	(Irreclaimable) Presently use for water pumping station
2	Yelwa block industry pond	N09º48'06.1″E 08º52'29.8″	1,500m^2	6m	1,500m^2 X 6m =9,000m^3	(Irreclaimable) Presently use in block making
3	Garden pond	N09º48'06.1″ E08º52'29.8″	2800m^2	3m	2800m^2 X 3m =8400m^3	Backfilling method
4	Rahwol top ponds	N09º49'06.0″E 08º54'15.6″	45000m^2	7m	45,000m^2 X 7m =315,000m^3	(Irreclaimable). It supplies water to Rennajj Fish pond
			16,000m^2	7m	16,000m^2 X 7m =112,000m^3	(Irreclaimable). It is presently use for irrigation farming
5	Rennaj Fish Integrated Farms Limited ponds	N09º48'46.6″ E08º54'25.0″	20,000m^2	5m	20,000m^2 X 5m =100,000m^3	Backfilling method
	Pond 2		18,000m^2	1.5m	18,000m^2 X 1.5m =27000m^3	✓
	Pond 3		12,000m^2	1.5m	12,000m^2 X 1.5m =18000m^3	(Irreclaimable). Presently use in fish farming
	Pond 4		36,000m^2	1.5m	36,000m^2 X 1.5m =54000m^3	Backfilling method
	Pond 5		12,000m^2	2m	12,000m^2 X 2m =24000m^3	(Irreclaimable). Use as fish pond
	Pond 6		16,900m^2	2m	16,900m^2 X 2m =33800m^3	Backfilling method
	Pond 7		14,400m^2	1.5m	14,400m^2 X 1.5m =21600m^3	✓
	Pond 8		1,250m^2	1.2m	1,250m^2 X 1.2 m =1,500m^3	✓
	Pond 9		1,800m^2	1m	1,800m^2 X 1m =1,800m^3	(Irreclaimable) Use as Fish pond
6	Fadama pond	N09º48'03.2″ E08º53'40.8″	10,000m^2	6m	10,000m^2 X 6m =60000m^3	Backfilling method
7	New Private university Pond	N09º48'39.2″E 08º53'40.8″	6,000m^2	3.5m	6,000m^2 X 3.5m =21000m^3	(Irreclaimable) Currently use in civil engineering Constructions
8	Road pond	N09º49'48.1″ E08º55'04.2″	15,000m^2	1m	15,000m^2 X 1m =15000m^3	Backfilling method
9	Rayfield Resort pond	N09º50'15.9″ E08º54'46.7″	360,000m^2	12m	360,000m^2 X 12m =4,320,000m^3	(Irreclaimable) Use as a recreational centre
	Terrace Pond		1,300,000m^2	12.5m	13,00000m^2 X 12.5m =16,250,000m^3	The pit was excavated in layers as observed in the field, therefore, Terracing method of reclamation will be suitable

3.2.2 MINE SPOILS

Mine spoils are piles of "waste" rocks and soils left behind after excavation of mines. During the mining operation, overlying vegetations, soils and rocks are stripped off to access the removal of the ore. These stripped materials (spoils) are left over without actually filling back the opened mine. The quantity of mine spoil left after mining cease is also very important in reclamation consideration as already discussed earlier. Mine spoils are usually deposited in dump shapes like cones (Plat.9). The volume is therefore estimated by measuring the base area and height of the mine spoil. Mathematically;

Volume of mine spoil (Cone) = $1/3\ \pi D^2/4\ X\ h$

Where $\pi = 3.142$

D = the base area of the mine spoil

h = height of mine spoil

Plate 9: New Private University mined dump (spoil)

Table 3 shows the calculated volumes of spoil in the study area.

TABLE 3: ESTIMATED VOLUMES OF MINED SPOILS

S/N	NAME OF SPOIL	G.P.S LOCATION	BASE AREA OF THE SPOIL ($\Pi D^2/4$) {m^2}	HEIGHT OF SPOIL {m}	VOLUME OF SPOIL {m^3}
1	Yelwa block industry spoil	E09°48'O6.1″ N08°52'29.8″	4,830m^2	5m	8,050m^3
2	Garden spoil	E09°48'32.6″ N08°42'53.6″	4,009.1m^2	5.5m	7,350m^3
3	Rennajj fish and integrated farm ltd spoil	E09°48'46.6″ N08°54'25.0″	4,666.7m^2	4.5m	700m^3
4	Fadama spoil	E09°48'03.2″ N08°53'40.8″	5,090m^2	6m	10,180m^3
5	New Private university spoil	E09°48'39.2″ N08°55'03.7″	175,500m^2	7m	4,09500m^3

3.3. Reclamation

Environmental effects associated with mining operations are of particular concern to both the government agencies, planning authorities and the general public because of the destructions these have led to the surrounding (Ogezi, 2007). These destructions may result in the loss of land, provision of spoil tips, pollution of ground and surface water and may even cause damage to the ecosystem. There is, therefore, the need to develop appropriate reclamation and indeed rehabilitation measures to check furtherance of the menace. Nevertheless, the reclamation and rehabilitation of mined lands have become very important especially now that increasing population with associated diverging need for land use is placing tremendous pressures on existing industries, residential and recreational facilities/centers (Mallo,1999). Reclamation which is defined as the scientific restoration of devastated land due to mining activities into its former state for the purpose of socio-economic development can be accomplished through site preparation, backfilling, terracing and re-vegetation.

Restoration/reclamation is aimed at reducing the risk of water pollution, to restore the land and landscape to improve the aesthetics of the area and to prevent further degradation (Mallo, 2007). The resulting condition poses minimal risk to people and the environment both in the short and long term.

Land reclamation usually begins late in the mining cycle when most of the excavation phase is completed. However, there are several cases where the reclamation can be accomplished many years after extraction (as it is presently the case in the study area) hence the need for site preparation.

The degree of grading or earth moving required in reclamation of mined land is influenced by five factors that comprise:

1. The mining method;
2. The availability of reclaiming materials and machineries;
3. The cultural and topographic setting of the operations;
4. The climate; and
5. The intended end use of the land.

3.3.1 Reclamation Method

In relation to the study area, the necessary methods needed for the reclamation of abandoned mines include: Backfilling method and Terracing method.

As the name "Backfilling" implies, the excavated overburden or spoils are use directly to cover back the mine from which they are removed. It is important to do a certain amount of preplanning and site preparation before earth movement starts. This is necessary because the length, width and depth of the mine must have change over the years after mining cease. In such a case, additional materials such as mine refuse and slag of boulders exceeding a cubic meter in volume are employed, and small shrubs growth should be buried in the excavation so as not to interfere with the future use of the land.

Basically, Terracing is the alternation of short steep grades (or steps) and longer less steep grades which permits minimum grading of mines with maximum stabilization. However, in the course of terracing, additional materials (aside the excavated spoil) may be employ from other sources. And the end use of the land has implications on the type of material employed.

In general, in sparsely populated areas, it may be acceptable to leave the mine sites un-reclaimed, especially where valuable natural resources such as water exist. Ponds, usually generated from such site have several uses.

3.3.2 Reclamation Equipments

The equipment for reclamation does hardly differ much from the earth moving equipment used in alluvial mining. The important thing is for the company to incorporate in its financial projections a comprehensive plan for restoration and reclamation.

Major capital equipment used in reclamation is broadly classified under Excavation (Earth Moving Equipment) and Haulage Equipment as follows: Excavation include Power shovels, Draglines, Scrappers, Bucket-wheel Excavation, Dozers, Graders while Haulage Equipment consists of Bulldozers, Pay loaders, scrappers and Trucks (Taiwo, 2006).

The commonly used excavators in reclamation of mines are Dragline and Power shovel. The choice between them relies on some factors such as: Nature of the mine; the output; and Efficiency. Dragline can effectively be use to reclaimed deeper mines with softer overburden than power shovel however this machinery are currently being phased out. However, power shovel has greater loading efficiency, so that it clears material faster

IV. Summary And Conclusion

The study area was mapped by data acquisition and geological boundaries demarcation based on observations made in the field. The mapping was done on foot by systematically studying the area and traversing the locations of geological interest including outcrops, mining sites, ponds, mine spoils etc. Backfilling and Terracing have been found to be the most suitable methods for the reclamation of observed abandoned ponds under study. Prior to the selection of reclamation operation methods, the volume of pits and spoils was calculated to know if there is need for sourcing additional materials.

Presently the Jos-Bukuru urban areas and particularly the study area are greatly threatened by the presence of abandoned mine ponds and spoil. The only option available presently is the reclamation and possible restoration of the devastated land for socio-economic development. The area of study which covers about 10 square kilometers would have to be reclaimed thereby creating useful landscapes that can meet variety of goals, typically creating productive ecosystems from the devastated mine land. The reclamation of the study area shows that not all the mining ponds will require reclamation as some of the ponds are already being put to other socio-economic activities (Table 2). These mining ponds include the Rayfield Resort Pond which is being used for re-creational purpose, The Rennaj Fish ponds used as fish ponds, the garden pond for agriculture, the Bukuru (Yelwa Water Treatment) mining pond and the Du ponds which are being used as sources of urban water supply, the Yelwa Block Industry pond and the Rahol Top Pond.

The available options of ponds for consideration for reclamation are the Garden pond, Rainnaj Ponds 1, 2, 4, 6, 7, and 9, the Fadama pond, the Road Pond, and the Terrace pond (Table 2). The study reveals that a total volume of 22,237,380 m3 of devastated land would require reclamation/rehabilitation. Presently, of this volume there is indication 17,592,000m3 will not be subjected to reclamation as some of the areas are already being put to useful socio-economic uses such as re-creation, agriculture, and water supply for domestic and industrial uses. This leaves a balance of volume of about 4,645,380m3 of mining ponds and devastated area to be reclaimed with 435,780 m3 of the available mine spoil. From this study therefore there is indication that the required volume balance of 4,209,600 m3 of reclamation material would have to be moved from the Plateau mine fields such as Forom, Barkin Ladi and other surrounding fields.

The reclamation equipment shall include a combination of excavators, power shovels, Haulage dump trucks/pay loaders and bulldozer graders.

The equipment for reclamation does hardly differ much from the earth moving equipment used in alluvial mining. Major capital equipment for reclamation is broadly classified under Excavation and Haulage Equipment. For the purpose of this study the following equipment/machineries were recommended; power shovel, dragline, Bulldozers, Motorized graders, Pay loader, rollers, Dewatering pumps and supporting equipment such as low loaders, fuel tanker, generating plant, air-compressor etc.

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