Environmental Impact Assessment

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Ensuring Safeguards Compliance

LOAN 3327 IND
ASSAM POWER SECTOR INVESTMENT PROGRAM – TRANCHE 2

Consulting Services for Supplemental Environmental Assessment for Lower Kopili Hydropower Project

<u>Final Report</u>
(Volume 4 - Water Quality Restoration Plan Report)

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µmhos/sec	-	micro Siemens per second
ABA	-	acid base accounting
ACMER	-	Australian Centre for Minerals Extension and Research
ADB	-	Asian Development Bank
Al	-	aluminium
ALD	-	anoxic limestone drains
AMD	-	acid mine drainage
AoC	-	Area of Concern
APDCL	-	Assam Power Distribution Company Limited
APGCL	-	Assam Power Generation Corporation Limited
ARD	-	acid rock drainage
BMPs	-	best management practices
$CaCO_3$	-	calcium carbonate
$CaMg(CO_3)_2$	-	calcium magnesium carbonate or dolomite
Cd	-	cadmium
CIA	-	cumulative impact assessment
Cr	-	chromium
Cu	-	copper
DO	-	dissolved oxygen
EC	-	electrical conductivity
EIA	-	environmental impact assessment
Fe	-	iron
$Fe(OH)_3$	-	ferric hydroxide or iron (III) hydroxide
Fe^{2+}	-	ferrous ion
Fe^{3+}	-	ferric ion
GIS	-	geographic information system
GoI	-	Government of India
H^+	-	hydrogen ion
Hg	-	mercury
HgS	-	mercury sulphide
ICP	-	inductively coupled plasma mass spectrometry
IWRMP	-	integrative water resources management plan
Kg	-	kilogram
kg/day	-	kilogram per day
KHEP	-	Kopili Hydro Electric Project
l/day	-	litre per day
L/m	-	litre per minute
L/s	-	litre per second
LKHEP	-	Lower Kopili Hydro Electric Project
M^3	-	cubic meter
Max	-	maximum
MFF	-	multitranche financing facility
mg $CaCO_3$/L	-	milligram of calcium carbonate per litre
Mg	-	magnesium
mg/L	-	milligram per litre
$MgCO_3$	-	magnesium carbonate
Min	-	minimum
Mn	-	manganese
MoEF&CC	-	Ministry of Environment, Forest & Climate Change, GOI

NAG	-	net acid generation
NEC	-	North Eastern Coalfields
NEEPCO	-	North Eastern Electric Power Corporation Limited
NEHU	-	North Eastern Hill University
NGT	-	National Green Tribunal
O_2	-	oxygen
OLC	-	open limestone channels
OLD	-	oxic limestone drain
Pb	-	lead
QA/QC	-	quality assurance/quality control
RAP	-	remedial action plan
Rs.	-	Indian Rupees
SEA	-	supplemental environmental assessment
SO_4	-	sulphate
Temp	-	temperature
ToR	-	term of reference
TSS	-	total suspended solids
VFW	-	vertical flow wetland
WQRP	-	water quality restoration plan
Zn	-	zinc

1. INTRODUCTION AND OBJECTIVES

1. This document is prepared in support of the Water Quality Restoration component of the Supplemental Environmental Assessment (SEA) Study for the proposed Lower Kopili Hydroelectric Power Project (LKHEP) in Assam State of India. The ADB requires, in advance of project approval and funding, that a remedial strategy be developed for implementation to reduce low-pH drainage into Kopili River and ultimately restore water quality in the Kopili River Catchment. During field visits and data analysis exercise for the Site Characterization Plan (summarized in Attachment 1), the Kharkar River was identified as the upstream source of Acid Mine Drainage (AMD) due to rathole coal mining practices. Confirmatory sampling and analysis was conducted in the Kharkar and Upper Kopili River. Additional limited mine site characterization was conducted in the Jaintia Hills District, within the Kharkar drainage basin. Results of these studies were used to produce this Water Quality Restoration Plan (WQRP).

2. The main objectives of the WQRP are to determine the sources of acidity due to rathole mining and to identify and design remedial alternatives based on feasibility, cost, and relative effectiveness.

3. The rathole mine areas site characteristics, as detailed in this report, were used to develop a conceptual design for AMD remediation, with the overall objective of restoring normal pH water in the Kopili Drainage Basin. Remediating the preliminarily-identified active and abandoned coal mine AMD discharges can use a combination of AMD isolating and passive treatment systems. Feasible active and passive treatment scenarios, a confirmatory pilot study and estimated costs are included. Data and information discussed in detail in this report which will be utilized in the mitigation methodology conceptual design process include:

- Preliminary evaluation of coal mine dimensions
- Local and regional geographic features
- Average discharge water quality, based on one sampling data set
- Average monsoon and dry season surface water flows
- Minimum, average and maximum AMD generation source area estimates

4. The overall objectives of mitigation planning are to:

i. Reduce and eventually eliminate AMD and consequent surface water contamination, up and downstream in the Kharkar and Kopili Rivers
ii. Remediate abandoned mine areas to isolate AMD-producing geologic material
iii. Restore coal mine-affected land to eventually support pre-mine land ecosystems including flora and fauna
iv. Restore pre-mining land use including agriculture, horticulture and grazing
v. Restore riverine systems to pre-AMD quality to support fisheries, and
vi. Guide eventual land use and local economy away from coal mining, to one that promotes sustainable development.

5. The Water Quality Restoration component considers possible active and passive remedial options which can be implemented to the extent possible at the rathole mine sites, to maximize mined land and water quality restoration at the lowest cost. At-source remediation and reclamation also offers the most efficient reduction in AMD generation and proliferation. Local workers will be utilized to construct, operate, monitor and maintain these systems, with the eventual goal of transferring the local economy and workforce away from coal mining, and

back to an agricultural-based livelihood. The Conceptual Mitigation Plan outlines long-term land restoration techniques and procedures that allow pre-mining land use to prevail, and establish local economic conditions that are not dependent on rathole mining.

2. PROJECT BACKGROUND

6. The draft EIA report prepared by WAPCOS for the LKHEP was reviewed by ADB and existing issues were identified, which require action by Assam Power Generation Corporation Limited (APGCL) before the project can be funded under the Investment Program. These issues include:

- Low pH in Kopili River, Khandong and Umrong Reservoirs is contributing to degradation of the existing KHEP. Source of low pH is presumed to be from rathole coal mining waste discharging acid mine drainage into tributaries to the Kopili River. Some of these rathole coal mine sites have been preliminarily identified but additional investigation and site characterization is needed to design a remedial strategy.
- Draft EIA prepared by WAPCOS (October 2016) requires three additional components in order to be finalized: a Cumulative Impacts Assessment (CIA), an Integrative Water Resources Management Plan (IWRMP) and a Water Quality Restoration Plan (WQRP) including a mitigation strategy.
- Further identification of rathole mine sites and pyritic rock exposures contributing to low pH drainage.
- Further identification of surface drainages and impacts.
- Mitigation and remediation plan needed, including a conceptual plan for a pilot study for anoxic limestone drains as a possible passive AMD treatment option.
- Comprehensive surface water treatment system needs to be designed and implemented based on above investigations and impact assessment.
- An additional Terms of Reference (TOR) issued by the Ministry of Environment, Forest, and Climate Change (MoEF&CC), Government of India (GoI) for the EIA, which included cumulative impact of operation of the LKHEP and existing HEP development. The EIA is also required to fulfil ADB requirements for sustainable hydropower development. Following review of WAPCOS EIA, ADB and APGCL identified additional studies required to complete the EIA to meet GoI and ADB's environmental safeguards requirements. APGCL invited consulting services proposals for Supplemental Environmental Assessment (SEA).

7. Subsequently, ES Safeguards Compliance Services Private Limited, India has been retained by APGCL as Consultant to undertake Consulting Services for Supplemental Environmental Assessment for Lower Kopili Hydropower Project. The Consultant is working with APGCL and other assisting consultants to conduct the Supplemental Environmental Assessment as detailed in the consultant's TOR.

8. The supplemental environmental assessment consulting services are being financed under Tranche 2 of the ADB's Multitranche Financing Facility (MFF) for Assam Power Sector Investment Program (APSIP). Lower Kopili Hydropower Project will be financed under Tranche 3 of APSIP MFF.

3. ASSESSMENT OF AMD SOURCES AND WATERSHED CONTAMINATION

9. This section presents a summary of AMD source and site characterization work done to date in support of the WQRP and remedial options assessment. This work has been presented in more detail in the Site Characterization Report for the LKHEP SEA (submitted separately and summarized in Attachment 1). Physical and geochemical characterization of AMD sources and impacted areas are crucial for developing a successful remediation program. Extremely limited access to the Kharkar River Basin and rathole mining areas precluded more robust data and information collection needed for detailed mitigation design. This WQRP Report evaluates the data and information available to:

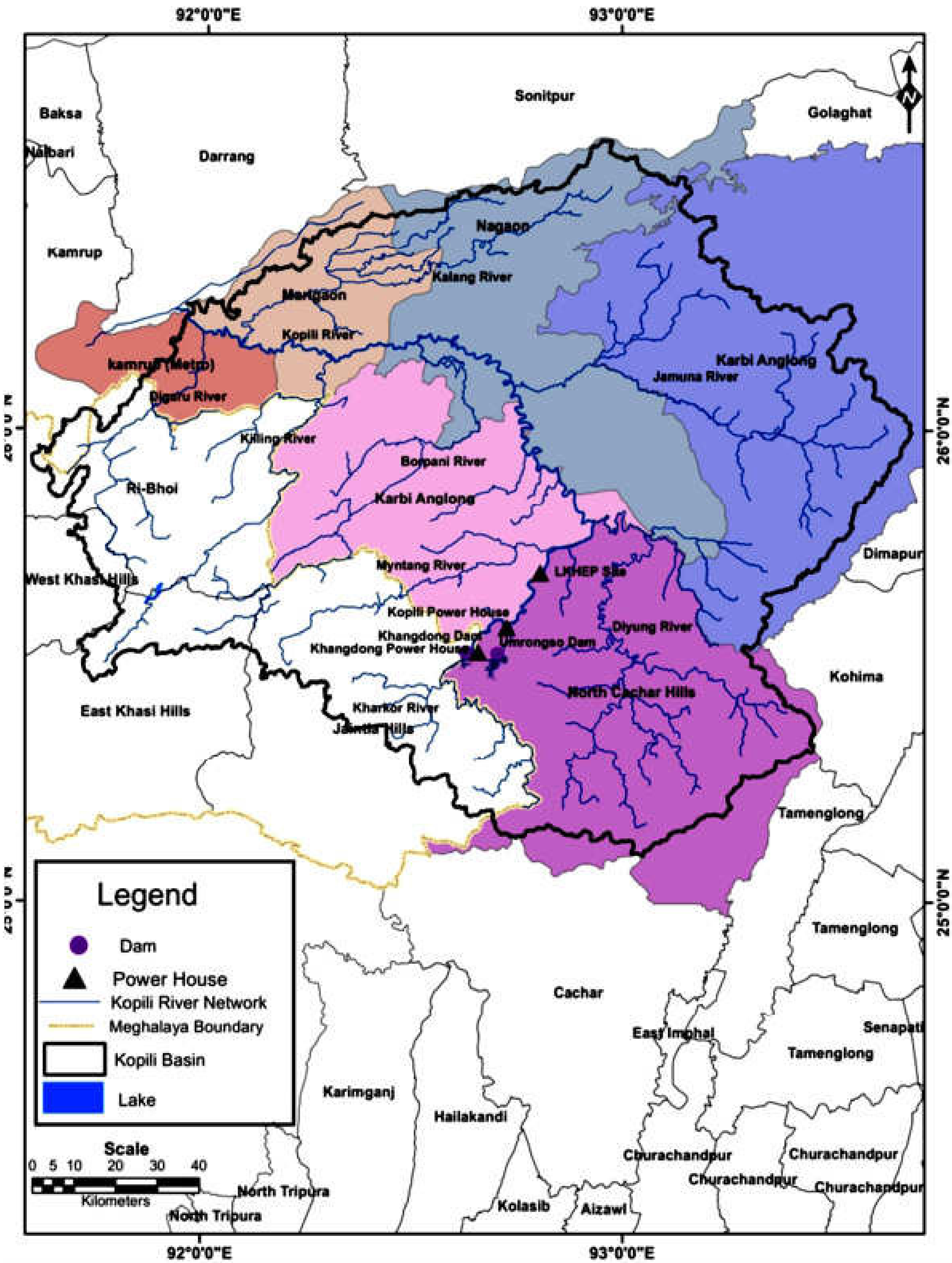
- Identify and design conceptual “at-source” active and passive treatment measures, discussed in detail in Section 4,
- Appraise the adequacy for various passive treatment options, as included in Section 5, and
- Develop an ALD Pilot Study concept to determine adequacy for pH neutralization from coal mine site discharge as contained in Section 6.

10. Preliminary detailed outlines for Stakeholder training and Environmental Awareness Programs were also developed to support the site-wide mitigation process and are presented in Attachments 3 and 4.

3.1 Coal Mining in Kharkar Basin

11. **Rathole Mining Areas** – One of the objectives of the SEA is to determine the sources of acidity due to rathole mining. Therefore, one of the tasks of the Work Plan is to verify and map, to the extent possible all the rathole mine sites/areas that contribute acidity within the Kopili Catchment Basin. During Phase 2, AMD source evaluation focused on the Kharkar River, Kharkar-Kopili confluence, and the Umrong Reservoir. The Kharkar River is a tributary to the Kopili River (as shown in Figure 1-1), which has been shown to be acidic (Sharma, et al, 2010). Access to conduct water quality sampling in the Kopili/Kharkar confluence area was obtained, and results confirmed that most AMD is being generated in the Kharkar River catchment.

Figure 3.1: Map of Kopili River Basin



12. Mitigation efforts must concentrate on remediating existing and abandoned coal mines in the Kharkar Basin. The following sections provide a basic understanding of the general physical locations, dimensions and geochemical characteristics of rathole mining in the Kharkar River basin, with a focus on Jaintia Hills District of Meghalaya State. This preliminary characterization is based both on collection and evaluation of salient existing data and information, and data collected during a brief field excursion into the Jaintia Hills conducted in July 2017, discussed in Section 5.1.1 of the Site Characterization Report and summarized in Attachment 1.

3.2 Rathole Mining – Location and Extent

13. Over 10,000 rathole mines, active and abandoned, have been identified in Meghalaya State as shown in Figure 3-1 (based on analysis of Google earth images). These open-pit, mostly hand-dug mines using pressure wash and hydraulic hoisting methods to extract coal, are the source of acidity in the Kharkar River. The mining activities in Jaintia hills district are small-scale ventures controlled by individuals who own the land. Coal extraction is done by primitive surface mining methods, or rathole mining where the land is first cleared by removing ground vegetation and then digging pits ranging from 5 to 100 m depth to the coal seam (Photo 3-1). Tunnels are then excavated into the seam to extract coal, which is removed from the pit in a conical basket or a wheel- barrow and then taken out and dumped on nearby storage area. The coal is carried by trucks to the larger storage areas near highways for export. Entire roadsides in and around mining areas are used for coal stockpiling, which is major source of air, water and soil pollution. Off road movement of trucks and other vehicles in the area causes further damage to the ecology of the area. Thus, a large area of the land is spoiled and denuded of vegetative cover not only by mining but also by dumping and storage of coal and associated vehicular movement (Photo 3-2).

Photo 3-1: An abandoned coal pit in Dkhiah village, Jaintia Hills District

Photo 3-2: Coal Stockpile area in Pamrapaithlu village. Note that no best practices are utilized to contain coal and prevent AMD runoff.

14. The majority of rathole mining occurs in the Jaintia hills districts of Meghalaya, lies between latitude $25^{o}5'$N to $25^{o}4'$N and longitude $91^{o}51'$E to $92^{o}45'$E. The district is bound by the state of Assam on the north and east, the East Khasi Hills on the west and Bangladesh in the south. The district covers an area of 3819 km^2 constituting 17.03 percent of the total area of the state. The topography of the district is composed of undulating hilly landscapes dissected by numerous rivers and streams. Jaintia hills is a part of the Meghalaya plateau which composed of rocks belonging to the age group of Archean and tertiary period[1] represented by granites, phyllite, gneiss, sandstone and limestone.

15. Due to the narrow nature of the coal seam in this area, large-scale mining is not economically profitable. Land owners' property rights give them the freedom to extract the coal from their property without using environmental or safety best management practices. As a result, tribal community land has been gradually privatized to reap the immediate benefit from mining without concern for the long-term environmental consequences. Economically, landowners compete to extract their coal as rapidly and as completely as possible to gain market value. Rathole mining was declared illegal in 2012, however mining is still occurring illegally.

16. The Jaintia hills districts of Meghalaya is a major coal producing area with an estimated coal reserve of about 40 million tonnes. Sutnga, Lakadong, Musiang-Lamare, Khilehriat, Ioksi, Ladrymbai, Rymbai, Byrwai, Chyrmang, Bapung, Jarain, Shkentalang, Lumshnong, Sakynphor etc. are the main coal bearing areas of the district. Areas under coal mining in Jaintia hills districts are shown in Figure 3-2. The coal seams varying from 30 to 212 cm in thickness occur embedded in sedimentary rocks, sandstones and shale of the Eocene age[2]. The main characteristics of the coal found in Jaintia hills are its low ash content, high volatile matter, high calorific value and comparatively high sulphur content. The coal is mostly sub-bituminous in character. The physical properties characterize the coal of Jaintia hills district as hard, lumpy bright and jointed except for the coal in Jarain which is both soft and hard in

nature. Composition of the coal revealed by chemical analysis indicates moisture content between 0.4% to 9.2%, ash content between 1.3% to 24.7%, and Sulphur content between 2.7% to 5.0%. The calorific value ranges from 5,694 to 8,230 kilo calories/Kilogram (Directorate of Mineral Resources, 1985).

17. During recent years, rathole coal mining in the area has resulted in soil erosion, scarcity of water, pollution of air, water and soil, reduced soil fertility and loss of biodiversity.[3] Continued soil acidification due to acid mine drainage and release of excess metals including Al, Fe, Mn, Cu have caused enormous damage[4] to plant biodiversity in this area. Due to mining-induced changes in land use pattern and soil pollution the area of fallow land has steadily increased. Between 1975 and 2007, there has been decrease in forest area by 12.5%, while area under mining has increased three-fold.[5] Thirty one percent of the land in Jaintia districts has been made barren due to coal-mine contamination, the highest of all districts in Meghalaya.

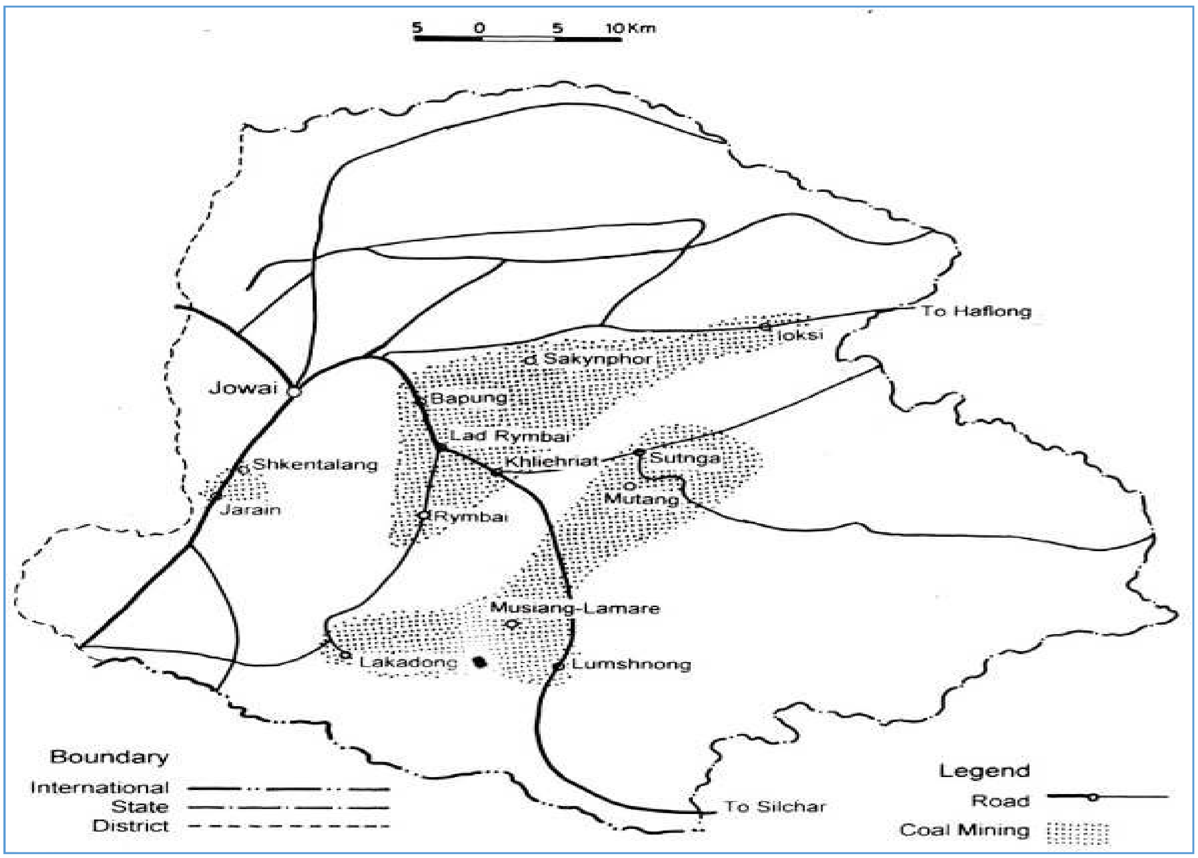
[1] Swer and Singh, 2003
[2] Chabukdhara and Singh, 2016
[3] Das Gupta et. al., 2002
[4] Sarma, 2005
[5] Sarma et.al, 2010

Figure 3.2: Google Earth Image of Rathole Mines in the Kharkar River Valley, Meghalaya State

18. As shown on Figure 3-1, the entire Jaintia hills area has become infested with coal mine pits and caves. These open, unfilled pits allow surface water percolation into the groundwater. As a result, smaller streams and rivers of the area are either completely disappearing or becoming seasonal. Consequently, the area is facing acute shortage of clean drinking and irrigation water. Besides, a vast area has become physically disfigured due to haphazard dumping of overburden and mined coal, and caving in of the ground and subsistence of land.[6]

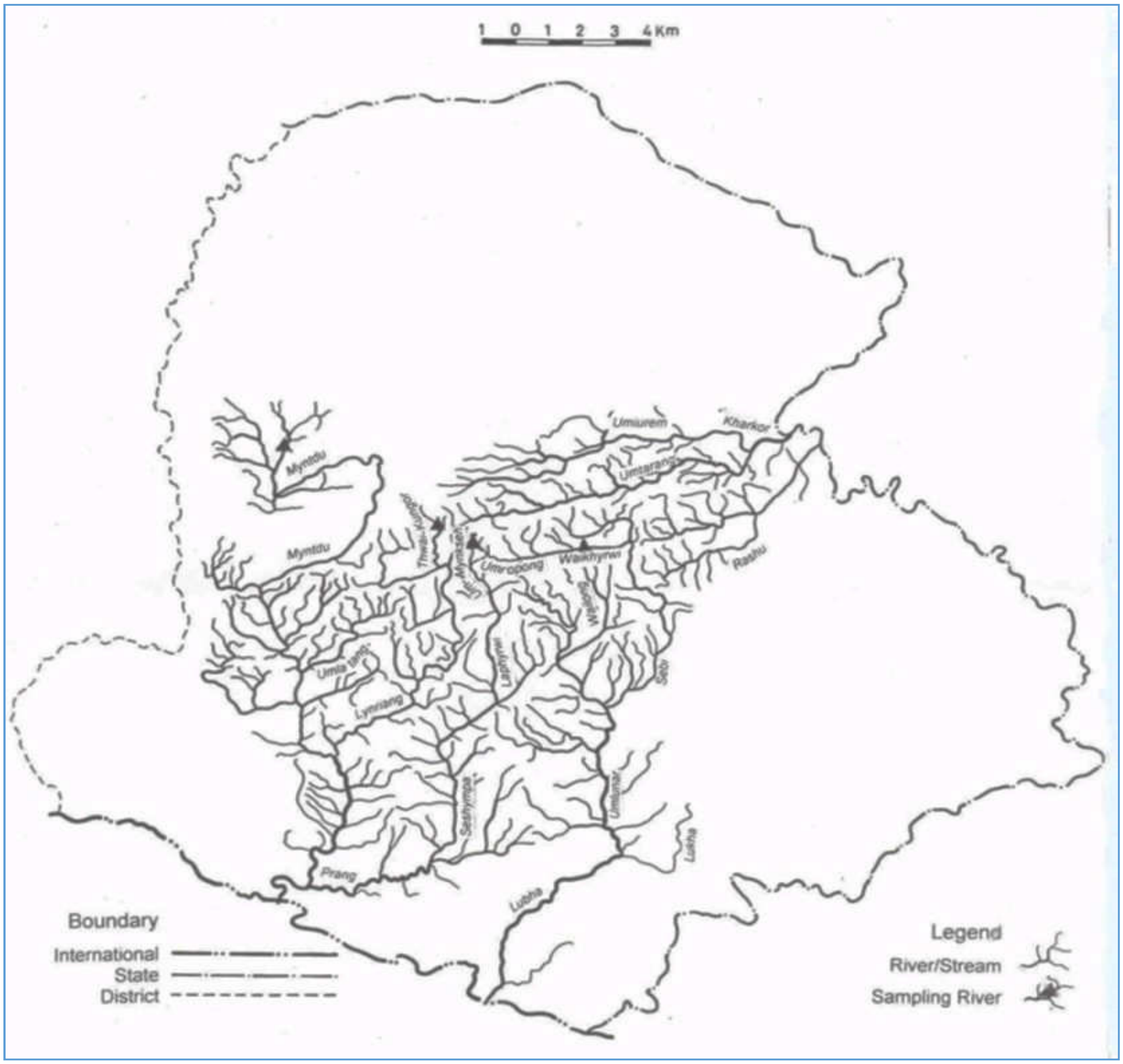
19. Existing Data from NEEPCO and Others - As access to the rathole mining areas in Meghalaya is not available to the Team at this time, AMD source characterization will begin with data collection and evaluation concentrating on the upper Kopili Catchment, specifically the Kharkar River. Two research papers provided by Dr. Singh (Swer and Singh, ENVIS Bulletin Vol 11(2) and Chadbrukdhara and Singh, (2016) were reviewed for data and information pertinent to AMD sources and coal mining in Meghalaya State. Neither document provided Kharkar River catchment data, or information specific to rathole mining in Meghalaya. Of note were two maps provided in Swer and Singh, as shown below.

Figure 3.3: Coal Mining Areas of Jaintia Hills, Meghalaya



[6] Swer and O.P. Singh, 2003

Figure 3.4: Map Showing Rivers/streams of Coal Mining Areas, Jaintia Hills District, Meghalaya



20. The first map (Figure 3.2) shows the extent of coal mining activities in Meghalaya State and the second map (Figure 3.3) shows the tributaries to the Kharkar River including the Umiurem River, which Dr. Singh states is affected by AMD drainage from mining areas to the north and west. It is obvious from inspection of both maps that AMD is emanating from the coal mining areas. These two maps should be used as a base for investigating the extent of AMD drainage into the upper reaches of the Kharkar River Catchment. The coal mining areas shown above should be updated to include the rathole mining areas to the north and east. Also of note, the coal quality in Meghalaya is generally high-sulfur with imbedded silt layers, which increases ash content upon burning. The sulfur content is the contributor to AMD and coal ash causes increased air and water pollution as well.

21. After sufficient Kharkar River water quality data is identified and collected, a trend analysis and contaminant loading calculation can be done to determine if pH loading is continuing to rise, that is, if low pH AMD-laden water influx into the Kharkar River is

increasing. Metals, dissolved oxygen (DO) and conductivity trends should also be evaluated in advance of decision-making processes for determining the best passive or active treatment alternative(s).

3.3 Kharkar Watershed Characterization

22. No recorded data exists on the extent of active rathole mining in the Kharkar catchment, but several rathole mines were inspected on the Assam side of the Kharkar-Kopili confluence to capture a sense of the scope of mining activities, including pit depth, process water use and overburden storage, among other mine site characteristics. An on-site data gathering scheme was developed to collect information on the nature and extent of mining activities at some accessible mine sites in the Jaintia Hills (Attachment 1). This information was used to create a schematic of representative mine site dimensions and discharge water quality and quantity. The Mine Site Inventory Field Trip Report is contained in Attachment 2 of the Site Characterization Report, August 2017 (provided as Appendix 1).

23. Data collected during this field effort was used to develop a conceptual design for general site remediation strategies including costs and schedule. It is obvious, given the relative inaccessibility of the Meghalaya coal mining areas, that only a very small number of the actual active and closed mines could be assessed. Therefore, the results of our preliminary mine site assessments will be considered as representative of the general conditions of the over 10,000 mine sites located in the Kharkar River basin.

24. For each mine site visited the following data was collected:

- GIS Coordinates
- Landowner identification
- Lawful occupier on the property other than the Landowner
- Tribal authority or host community that may be affected
- Number of workers at the site
- Power, water and other infrastructure
- Public roads
- Pit active or inactive
- Pit dimensions – depth, width and length
- Coal seam depth and width
- Groundwater present
- Pit pumping and pit water disposal
- Volume of coal produced per day
- Closest tributary and distance to Kharkar River
- Volume of water used and released per day
- Field measurement of mine water acidity
- Volume estimate of waste rock displaced

25. The physical extent of the survey is shown on Figure 3-4 below. Numeric minimum, maximum and average dimensions of salient mine area features needed to design a conceptual mitigation plan are included in Table 3-1. Note that all mine discharge areas but one had acidic pH. Discharges for winter, rainy and dry seasons are included as well to incorporate monsoon discharge remediation design into the overall mitigation strategy.

Figure 3.5: Jaintia Hills Mine Site Discharge Sample Locations – July 2017

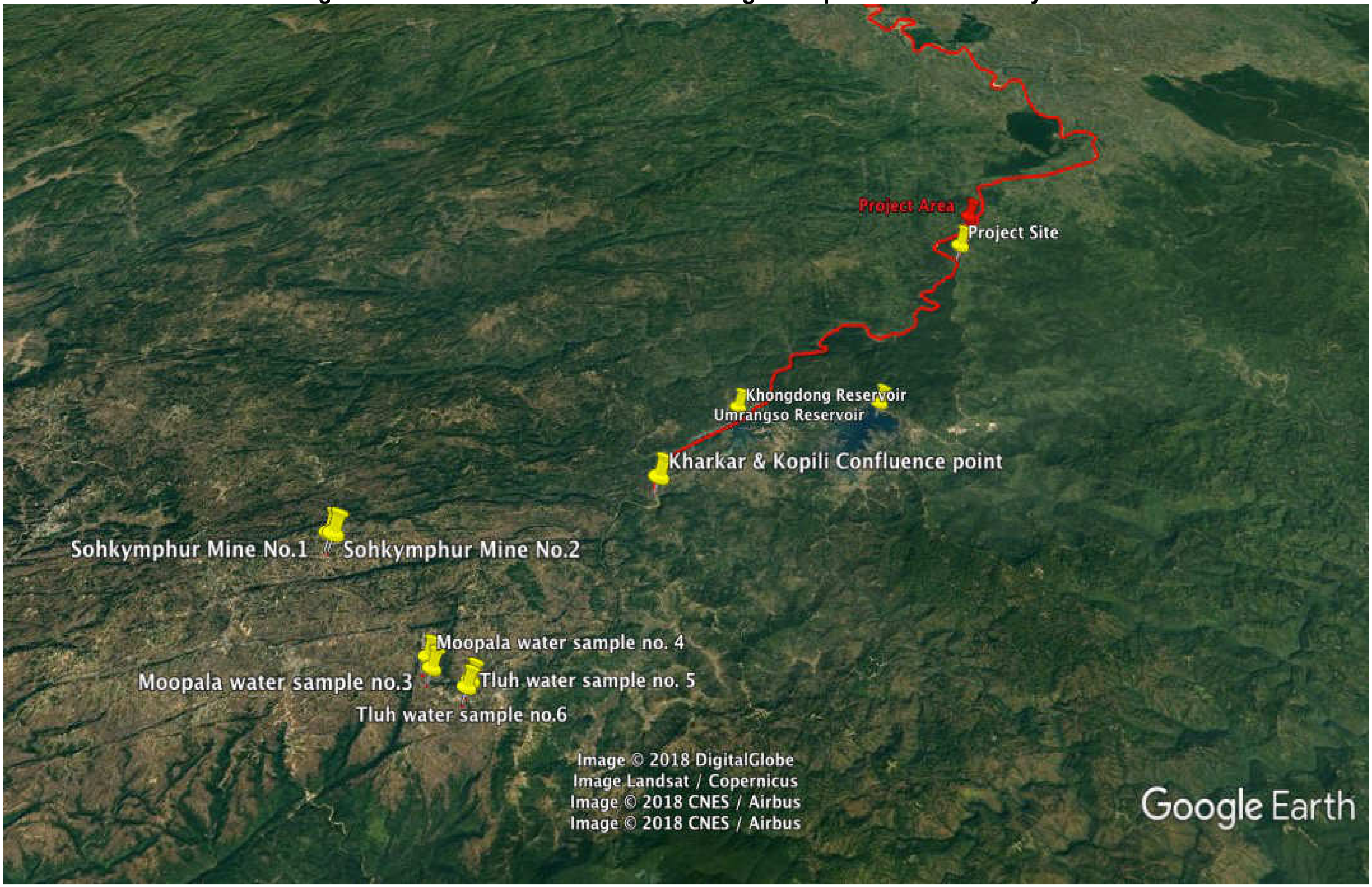
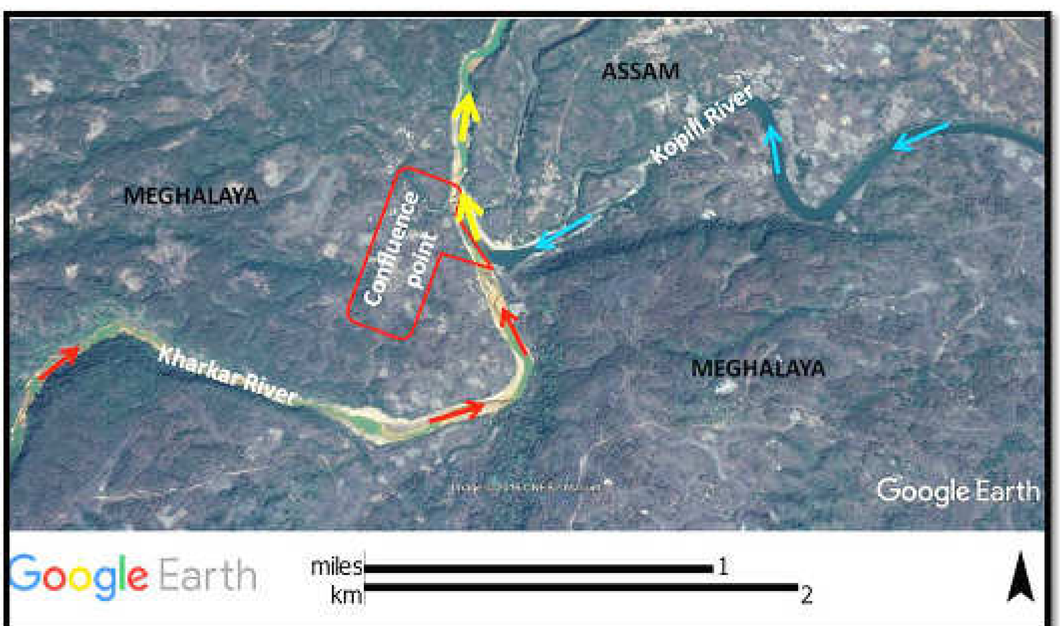


Table 3.1: Mine Site Inventory Summary

		Min	Max	Average
Pit Dimensions (meters)	Pit Radius	1.5	8	6.2
	Pit Depth	4	52	30.3
Coal Seam (meters)	Coal Seam	3	50	28
	Pit Depth	0.25	1.2	0.71
Coal Storage (m^3)		300	10,000	5998
Overburden	Height	2	4	2.7
	Area (meters)	10	100	66.7
Water Discharge (l/day)	Winter	1120	20,150	5544
	Summer	0	13,700	3796
	Rain	0	5,400	1541
Discharge Quality	pH	2.4	6.8	3.2
	EC	1	63	22.7

26. Previous studies indicate that water quality in the Kopili River is affected by low-pH water from the Kharkar River (Site Characterization Report, August 2017 – Appendix 1). Photo 3-3 is a Google Earth photo of the confluence of the Kharkar River with Kopili River. Of note is the obvious metal oxide staining and precipitation in the Kharkar River channel that continues in the Kopili River downstream of the confluence. Photo 3.3 shows that the Upper Kopili River above the confluence is unaffected by AMD. Sulfide levels are highest in the Kharkar River and in the Upper Kopili. Aluminum levels are highest in the Kharkar River (1.1 mg/L) but are lower than the maximum amount recommended for successful ALD and other passive treatment technologies (less than 25 mg/L). Total iron in all samples is also less than recommended maximum for passive treatment (10 mg/L). These initial results of all the river samples indicate that water quality is suitable for passive treatment design with some oxide flocculation collection and management necessary to maintain low turbidity and sedimentation accumulation.

Photo 3-3: Google Earth Photo of the Confluence of the Kharkar and Kopili Rivers



27. During the Jaintia Hills mine site Survey, discharge water samples were collected from six mine discharge locations as shown on Figure 3-4, and results of analysis are included in Table 3-2. Results were used to model theoretical input parameters for design of passive oxic/anoxic limestone drains as discussed in Section 5.

Table 3.2: Jaintia Hills Coal Mine Discharge Analytical Results-August 2107

Sampling location	#1 Sohkymphor	#2 Sohkymphor	#3 Moopala	#4 Moopala	#5 Tulh	#6 Tulh
Sampling date	7/30/2017	7/30/2017	7/30/2017	7/30/2017	7/30/2017	7/30/2017
Lab pH	3.3	3.7	2.4	2.6	2.2	2.5
Lab EC	80	180	270	280	630	400
Total Solids (mg/L)	55	142	190	196	494	279
Total Suspended Solids TSS (mg/L)	62	83	112	110	144	121
Acidity (as $CaCO_3$)	32	44	46	48	52	44
Total Alkalinity as $CaCO_3$ (mg/L)	55	96	130	136	320	222
Chloride (mg/L)	16	28	42.5	44.2	180	110
Sulfide (mg/L)	0.2	0.45	0.28	0.72	0.75	0.39
Sulfates (SO_4) (mg/L)	18	34	36	32.2	68.8	52.7
Total Al (mg/L)	0.08	0.09	0.11	0.13	0.15	0.11
Total Mn (mg/L)	0.12	0.21	0.22	0.28	0.26	0.24
Total Fe (mg/L)	1.23	1.91	2.14	2.67	6.2	5.12
Ferric Iron -Fe^{3+} (mg/L)	0.623	1.22	1.1	1.48	4.21	3.1
Ferrous Fe (Fe^{2+}) (mg/L)	0.607	0.69	1.04	1.19	1.99	2.02
Ca as $CaCO_3$ (mg/L)	12.8	22.4	28.8	29.6	67.2	48.8
Mg (as $CaCO_3$) (mg/L)	6.3	12	15.6	18	36	26
Organic Content (mg/L)	2.8	3.1	3.4	3.3	6.8	5.2
Inorganic content (mg/L)	12.8	15.2	16.2	12.8	70.4	54.7

3.4 Remedial Alternatives Summary

28. During the interim phase work of SEA study (in the process of data collection, stakeholder consultations and site visits) seven remedial alternatives were identified and evaluated based on whether access to the Kharkar mining areas can be obtained. These are listed in Table 11 of the Interim Report (April 2017), along with data needed to develop each alternative, technical approach and effectiveness. The potential locations for each option were identified and scoped as part of the AMD remedial design process, as listed in the alternatives summary Table 3-3.

Table 3.3: Summary of AMD Remedial Options Based on Site Access

Alternative Number	Site Accessibility Access Constraints	Source Treatment Options	Technical Approach
A1	**Full Source - Mine Site Access length of Kharkar mine sites minor tributaries cooperation of Meghalaya**	1.AMD 2.ALD 3.Pit backfilling 4.spot-treatment of minor on-site AMD 5. Wetlands polishing Alternatives based on flow model chemistry inputs	ALD/OLD based on data and decision-making flowcharts. Pit backfilling with overburden based on cooperation with miners/landowners Acquire land to install and operate ALD/OLD and wetlands sites in optimal areas prior to discharge back to Kharkar
A2	Limited AMD source access **Kharkar only- Up-and downstream (no minesite access) cooperation of Meghalaya**	Series of OLD channels in-stream with settling ponds in point- bar areas Alternatives based on flow model chemistry inputs	Hydrograph analysis of up and downstream Kharkar including point loading pH source tributaries. Design in-stream limestone channels to incorporate low flow, and monsoon with flocculent settling areas
A3	Limited AMD source access **Entire Kharkar River upstream of Confluence with Kopili cooperation of Meghalaya**	Series of in-stream limestone porous dams to promote alkalinization.	Number of dams based on chemistry and alkalinization to be achieved and flow-through. Dam design based on balance between porosity and flow- through and degree of armoring during flow. Will need dual-design to incorporate monsoon flows.
A4	Limited AMD source access **Downstream Kharkar Only before confluence cooperation of Meghalaya**	Minor stream diversion to ALD/OLD based on low-flow/non-monsoon	Divert Kharkar River Channel to point bar area with low elevation. ALD/OLD systems designed as above.
A5	No Access to Kharkar **Downstream of Kharkar-Kopili Confluence on Kopili (Assam) side**	Major stream diversion to ALD/OLD based on low-flow/non-monsoon	Considered minimally feasible to infeasible based on: 1-amount of water to be treated doubles due to mixing of Kopili (normal pH) at confluence and 2-access to stream channel is difficult 3-may need pumps and electric source to pump water from river channel to ALD/wetlands.

Alternative Number	Site Accessibility Access Constraints	Source Treatment Options	Technical Approach
A6	No Access to Kharkar **At Kopili outfall into Khandong Reservoir**	Minor stream diversion to ALD/OLD based on low-flow/non-monsoon	Construct ALD and OLD channels in accessible areas upstream or at the reservoir bank. Water diversion will depend on flow and grade of river channel and access to reservoir bank for series of short/small ALDs and OLDs for monsoon flow.
A7	No Access to NEEPCO or Assam Land **Upstream of LK HEP dam site/reservoir**	Active water treatment plant	WTP design based on best engineering treatment models and standard WTP construction and operation criteria

29. These alternatives were further evaluated to determine overall feasibility based on anticipated costs, long-term effectiveness and applicability to the final mitigation strategy for prevention of AMD formation. Alternative A1, (the “at-source” remedial alternative) despite the possibility of limited mine site access; is the only feasible option to ensure long-term remediation and restoration of pre-mining land use, which will in turn, ensure viable economic growth and stability for the Kharkar region. Without implementation of Alternative A1, rathole mining is likely to continue unabated along with AMD generation and propagation into the Kopili River system.

30. These remedial alternatives were discussed with APGCL during the interim workshop and agreement was reached to design the conceptual plan using at-source AMD remedial measures.

31. Alternative A1 requires access to the majority of rathole mine sites and AMD drainages to allow installation of active and passive remedial measures, as discussed further in Section 4. Site access and landowner cooperation can be obtained as part of Stakeholder communications efforts as discussed in Section 7. Long-term mine site management and mitigation efforts are further discussed in Section 7 and in Attachment 4.

4. TECHNICAL APPROACH FOR AT-SOURCE REMEDIATION

32. The requirement for remediation of acid mine drainage (AMD) impacted water from the rathole coal mine sites upstream of the LKHEP is to provide an acceptable long-term plan for managing the discharge and minimizing the risk of further discharges to and effects on the Lower Kopili River and Reservoir. Assam Agency, who are responsible for the project, have the added requirements to firstly provide for a long-term solution with minimal ongoing maintenance and operation costs and, secondly, to minimize capital to that required to ensure that the operating cost objective can be met while restoring quality of discharges into the Lower Kopili River.

33. Since submittal of the ES Safeguards Interim Report in April 2017 (discussing various possible remedial options as summarized in Table 3.3), it has been determined that only "at-source" active and passive mitigation measures are possible at this stage and the same will be developed further in detail due to cost constraints, site availability limitations and mitigation effectiveness. These include but are not limited to: oxic and anoxic alkaline limestone drains, constructed wetlands, storm water diversion measures, pit backfilling, waste rock capping, and pit wall shotcreting. Besides these structural measures, non-structural measures such as best practices guidelines for mine operations, awareness programs, alternate livelihood programs etc. are also proposed.

34. AMD source areas must be identified, characterized and remediated as soon as possible, using "active" technologies such as soil covers, pit wall covering with sprayed liquidized concrete (shotcrete), surface water runoff channeling, and other earthworks management to isolate pyritic material from precipitation and surface water, thus allowing surface water in the catchment to return to normal pH prior to or concurrent with installing passive treatment. Interim AMD management strategies including the use of holding ponds for evaporative purposes, localized limestone application and short-term waste rock and coal storage and management techniques. This document considers possible passive remedial options, including either oxic or anoxic limestone drains and passive wetland "polishing" systems to be the optimal remedial alternative for this project as this technology can be applied at low cost to provide a minimal-care water quality restoration device for areas with acid drainage that cannot immediately be mitigated using active control methods.

35. Three AMD minimization steps are considered as paths forward for the technical approach to the WQRP work plan:

- **Step 1** – Minimization of AMD discharge using operational control at the origin, including use of best practices for waste rock disposal, mine water management and coal handling and transport. Stakeholder engagement to disseminate educational materials and obtain site access.
- **Step 2** – Active treatment of discharge at the mine pits, including mine water transfer to limestone channels (ALD and/or OLD) prior to discharge to surface water.
- **Step 3** – Active collaboration with the mining community and local and State governments to plan a combined approach to AMD minimization and prevention integrating both options and ensuring ongoing acid-neutral discharge, environmentally sound mining practices, and ultimately, restoration to pre-mining land use.

36. This three-step approach provides the most robust long-term solution to the ongoing rathole mining activity in the upper reaches of the Kharkar Catchment, but also requires complete Stakeholder participation and coal mine owner/operator engagement to produce results. The data and information required to produce technical detail for each Step is outlined below.

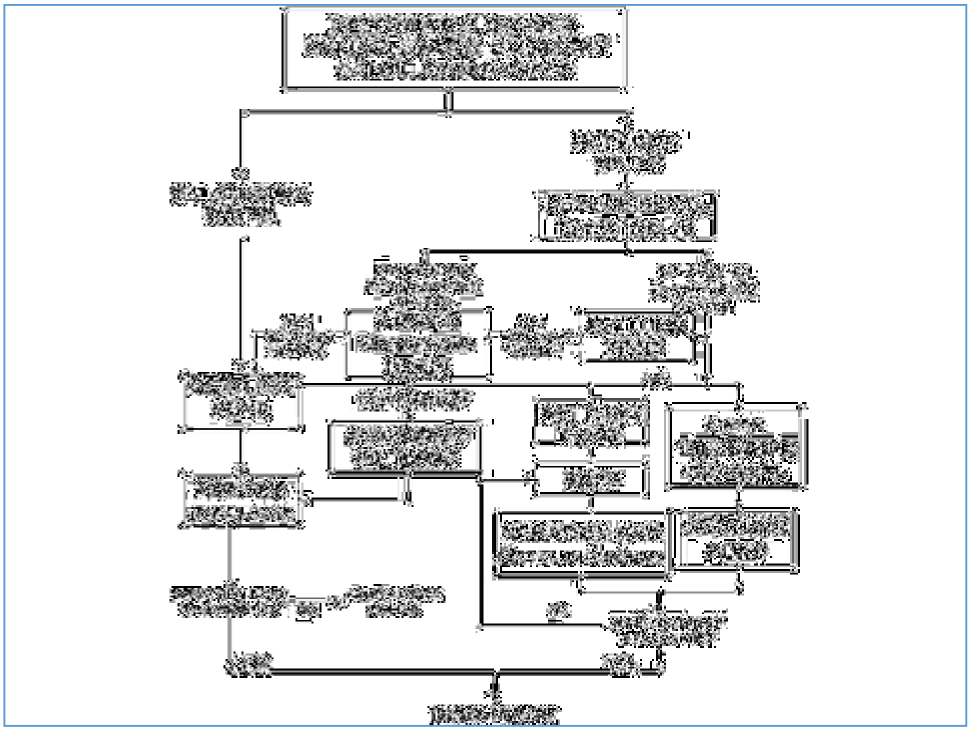
4.1 Passive Treatment

37. Passive treatment refers to AMD remedial processes that do not require regular human intervention, operations, or maintenance. Passive processes typically employ natural construction materials, including easily available soils, clays, limestone and broken rock, natural materials (plant residues such as straw, wood chips, manure, and compost) and promote the growth of natural vegetation. Passive treatment systems use gravity flow for water movement. In some climates, evaporation or infiltration (e.g., soil amelioration and neutralization) can be used to treat smaller volumes of AMD.

38. Passive systems rely on natural physical, geochemical and biological processes but can fail if not carefully selected and designed[7]. Unlike active treatment systems, which add neutralizing material on a regular basis to neutralize the acidity in AMD indefinitely, passive systems are usually constructed with a lifespan of neutralizing material such that no additional inputs are necessary. Most passive treatment systems rely on the dissolution of a neutralizing material (usually limestone) to neutralize the acidity in AMD and sufficient residence time in the systems is necessary for this dissolution to occur. As such, passive systems typically require large areas of land and are more suited to complement active systems or remediate closed mine sites. Long term treatment using passive systems is often more economical than implementing active systems, particularly after mine closure.

39. The flow chart contained in Figure 4-1 below shows the determination process for use in assessing AMD remedial options. Generally, mine water quality that falls within the right side of the flow chart can be treated using passive treatment technology. Mine discharge water chemistry from recent sampling in the Jaintia Hills has undergone a geochemical assessment, in comparison to Figure 4-1, to ascertain the most viable passive treatment options, as discussed further in Section 5.

Figure 4.1: Flow Chart for Selecting a Passive AMD Treatment System Based on Water Chemistry and Flow



(Source: From Gusek and Wildman, 2002)

4.1.1 Anoxic Limestone Drains

40. Anoxic limestone drains (ALD) are a passive form of alkalinity addition for AMD having a net acidity. ALDs are essentially underground limestone beds through which an un-aerated effluent or discharge stream flows by gravity. As the effluent flows through the system, limestone is dissolved, and calcium and bicarbonate are introduced, adding alkalinity and increasing the pH of the stream. Key to the performance of the drain is the exclusion of oxygen. In the presence of oxygen, metal hydroxides are formed which may armour the surface of the limestone or plug spaces between limestone, making the drain ineffective and subject to failure. Iron is the most difficult metal to remove from AMD using passive treatment technology, particularly ALDs, largely due to coating or armouring of limestone, the most commonly used neutralising agent, by Fe oxides and oxyhydroxides. This armouring reduces the dissolution rate of the limestone and hence, neutralization of the AMD. Photo 4-1 shows a typical ALD being constructed.

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[7] Skousen et al. 2000

Photo 4-1: Limestone gravel being placed in lined ALD trench

Source: Skousen et al, 2016

41. To reduce the potential for failure, experience suggests that ALDs only be used to treat effluent having dissolved oxygen, ferric iron and aluminum concentrations below 1 mg/L, and water intercepted after it contacts the atmosphere may not fulfill these criteria. In an ALD, alkalinity is produced when the acidic water contacts the limestone. It is considered important to use limestone with a high $CaCO_3$ content because of its higher reactivity compared to a limestone with a high $MgCO_3$ or $CaMg(CO_3)_2$ content.

42. Most effective systems have used 3-15 cm diameter (baseball size) limestone. Some systems constructed with limestone powder and gravel have failed due to plugging of the pore spaces between limestone gravel, reducing effluent flow-through. The ALD must be sealed so that inputs of atmospheric oxygen are minimized and the accumulation of carbon dioxide within the drain is maximized. This is usually accomplished by burying the ALD under several cm of clay. Plastic is commonly placed between the limestone and clay as an additional gas barrier. In some cases, the ALD has been completely wrapped in plastic before burial.[8] The ALD should be designed so that the limestone is always inundated with water. This has been accomplished with clay dikes within the drain or riser pipes at the outflow of the drain. AMD should contain sulphate concentrations below 2,000 mg/L.

43. The proper sizing of ALDs is uncertain. Theoretical calculations can be performed to estimate the mass of limestone required to neutralize a certain discharge for a specified period of time. Important to these calculations is the alkalinity concentration expected to be produced by ALDs. A maximum value of approximately 300 mg/L has been observed at ALDs constructed recently. The minimum mass of limestone needed to treat a year's flow of mine water can be calculated from the flow rate and an assumption that the drain will produce 300 mg/L alkalinity.

yearly $CaCO_3$ = flow (L/m) X 158 consumption (kg)

44. Questions about the ability of drains to maintain un-channelized flow for a prolonged period, whether 100% of the $CaCO_3$, content of the limestone can be expected to dissolve, whether the drains will collapse after significant dissolution of the limestone, and whether inputs of DO that are not generally detectable with standard field equipment (0- 1 mg/L) might result in armoring of the limestone with ferric hydroxides, may need to be addressed as passive treatment proceeds.

4.1.2 Oxic Limestone Drains

45. Oxic limestone drains (OLD) or channels treat AMD that is generated through an oxidation process, which results in the dominant contaminant, Fe, being present in two states, ferrous (Fe^{2+}) and ferric (Fe^{3+})[9]. Oxidising systems remove Fe from the AMD by continuing the oxidation process such that all Fe^{2+} is oxidised to Fe^{3+}, and once the pH has been raised sufficiently, precipitated out of the AMD as ferric hydroxide ($Fe(OH)_3$).

46. Oxic limestone channels are constructed similarly to ALDs but typically require a steep topography and high flows to generate the necessary aeration and to prevent armouring of limestone by metal hydroxides, which can inhibit the dissolution of limestone.[10] Iron or aluminum hydroxides form within them, and these solids can be periodically flushed out by temporarily increasing the pressure or head, then releasing water from the drain rapidly.

47. Open limestone drains can be effective for neutralizing oxic, relatively dilute AMD (O_2 >1 m L-1; acidity <80 mg L-1) and decreasing concentrations of dissolved $A1^{3+}$, Fe^{3+}, Fe^{2+}, Mn^{2+}, and trace metals (<5 mg L-1). Previous studies have shown that in less than 3 hours residence time, limestone dissolution within OLDs increased pH from 3.5 to >6.2, producing net alkaline effluent[11]. OLDs are considered as an optimal passive treatment for high flow, highly diluted, low-metal drainage such as occurs during monsoon season. OLDs are proposed to treat monsoon mine discharge flow as discussed in Section 6. There is some concern that low-acidity raw water (both discharges averaged less than 50 mg/L acidity) may be unable to dissolve the limestone to the extent that more highly acidic water does, even when influent pH is similar. The pilot study detailed in Section 6 incorporates an OLD component which will determine whether low-acid diluted monsoon discharge can produce an effective amount of alkalinity.

[8] Skousen and Faulkner, 1992

[9] PIRAMID Consortium, 2003

[10] Trumm, 2010

[11] Cravotta, 1998

4.1.3 Constructed Wetlands

48. As the name implies, constructed wetlands are engineered ecological systems, which use the biological processes commonly found in natural wetlands to modify effluent such as AMD. The effluent treatment reactions most commonly attributed to constructed wetlands include:

- exchange of metals by an organic-rich substrate;
- sulphate reduction and precipitation of iron and other sulphides;
- precipitation of ferric and manganese hydroxides;
- adsorption of metals by ferric hydroxides;
- metal uptake by living plants;
- filtering of suspended and colloidal material; and,
- adsorption or exchange of metals on algal material.

49. Wetlands can be designed and constructed to provide the aerobic and anaerobic conditions to support these microbial and abiotic reactions. A consideration of the hydraulics of flow is important to the effectiveness of the system. In the aerobic cells surface flow is promoted to maximize oxygen contact, while in the anaerobic components downward flow is maximized to minimize oxygen contact[12].

50. Sizing influences the design and cost of the wetland operation. Published data shows that efficiency is not a function of sizing. Wetlands differ greatly in terms of substrate chemistry, plant coverage and density, open areas, flow hydraulics, retention time, and other design characteristics[13].

51. Wetland design should consider the impact of precipitation and the spring runoff on the flow velocities in the wetland. It is necessary to control the turbulence and prevent the establishment of preferred channels to minimize or eliminate erosion. Since, metal removal and neutralization rates depend significantly on these design parameters, it is not appropriate to define or recommend a sizing for wetland construction unless the system components are standardized. Several sizing recommendations have been proposed based on criteria such as hydraulic loading and influent pH, Fe and Mn values (as listed in MEND, 2004) recommended a composite sizing index based on the combined requirements of influent acidity, Fe and Mn loadings. These recommendations, however, refer to coal mine drainage where iron and manganese are often the only metals observed above regulatory limits.

52. Table 4-1 summarizes the necessary wetlands system requirements in existing operations as detailed in MEND, 2004.

Table 4.1: System Parameters for Constructed Wetlands

Category	Factors to be Considered
Input to the Wetland	Hydraulic Loading Chemical Loading Chemical Species in the influent Chemical Water Quality
Wetland System	**Wetland Plants:** Plant Species, density and coverage Nutrient supply to plants **Wetland Construction:** Shape and configuration (serpentine channels, lagoons, bottom slope, depth) **Substrate:** Vertical and horizontal permeability **Non-Wetland Areas:** Open ponds, ditches
Hydraulics of Flow	**Flow velocities, flow depth, flow paths through the substrate, short-circuiting of flow, clogging of vertical percolation, development of preferred channels of flow in the substrate, erosion, variation in the residence times**
Operations Mode	**Variable hydraulic and chemical loading to synchronize with the seasonal variation in the wetland capacity, dilution due to precipitation, temperature effects**

Source: from MEND 2004

53. Analytical results of the Jaintia Hills discharge water quality indicate the net acidity of the mine water < 300 mg/L, therefore, an ALD will add enough alkalinity to the water to make the effluent of the drain net alkaline. The drain effluent can then be treated with a constructed aerobic wetland. If possible, the water should be aerated as soon as it exits the ALD and directed into the wetland. A conceptual constructed wetland polishing system is included in the Pilot Study as detailed in Section 6. The post- ALD system will be sized according to the criteria provided in Section 6. The constructed wetland will function to remove precipitates and sediments as the treated effluent exits the ALD/OLD system and percolates through the organic substrate.

4.2 Active Treatment Technologies

54. Active treatment technologies for AMD mitigation require reagents and/or energy on a regular basis and the process usually requires routine maintenance and monitoring. Active treatment in this case entails on-site engineering and construction to immediately reduce the exposure of pyritic material, and prevent AMD-laden discharge from entering surface water. Three main active technologies are described below and will be discussed further in the Mitigation Plan, Section 7.

[12] Wildman et al, 1991

[13] MEND 2004

4.2.1 Stormwater Management

55. Stormwater management consists of construction of collection ditches and diversions, either lined or unlined to collect and divert clean stormwater/surface water away from pits, coal piles or waste rock dumps to avoid contact with pyritic material and AMD formation. AMD-contaminated water should be diverted into a lined holding pond for storage and/or discharge into a passive treatment system. It is anticipated that holding ponds can also be constructed for evaporative purposes. The design costs and details are site dependent and predicated upon the nature of mine infrastructure location, available space, surface and stormwater conditions and volumes. Stormwater/surface water management should be included as a component of each mine site remedial action plan.

4.2.2 Pit Backfiling and Pit Wall Isolation

56. Mine pit walls can be a considerable source of AMD generation and release. As noted in Photo 3-1, surface water drains down the pit walls and contacts pyritic material within the wall rock. Groundwater can seep through the joints and partings in the pit wall rock and contact pyritic materials to generate AMD, then seep down the wall rock into groundwater, or be discharged back to the surface during active mine dewatering. Actively backfilling all accessible pits is the best way to remediate this source of AMD, if possible.

57. Conversely, some issues of pit backfill include potential groundwater quality impacts (especially if AMD is already occurring in mine wastes and there is migration of solutes from the mine wastes into the surrounding groundwater), costs involved, and the expansion of volume in rock when it is blasted and mined—meaning that waste rock may occupy a greater volume than the original pre-mined rock and some sulfidic wastes may still sit above the post-mining groundwater table and be subject to oxidation and AMD risks.

58. Overall, it is important to consider all impacts and risks and contrast above ground rehabilitation of mine wastes with the costs and benefits of pit backfill, even if only partial.

59. Pit backfilling should be conducted to the extent possible at all mine sites once site access is granted. Pit backfilling achieves several remedial objectives:

- waste rock is moved from the surface back into the pit, thereby removing the need for waste rock covers to isolate pyritic material in the waste rock.
- groundwater is protected from exposure to air and pyritic rock, thereby reducing and/or eliminating AMD production in the pit which impacts groundwater quality.
- If pit backfilling can be achieved to the top of the pit, then pit walls will be isolated from air and seepage, thereby eliminating AMD formation on the pit walls and AMD seepage to groundwater.
- Pit backfilling allows the surface to be re-graded and re-vegetated to achieve eventual pre-mining land use.
- The dangers inherent in open pits are removed.

60. If there is insufficient waste rock to completely backfill the pit, shotcreting can be conducted with relatively little expense and can provide a longer-term isolating effect. Shotcreting consists of spraying either wet or dry cement onto the pit walls. This involves a premix of sand and cement, which is fed into a hopper. Compressed air is then used to drive the mix in a stream through a hose to a nozzle where water is added. The wet mix method, introduced in the 1970s, involves premixing sand, aggregate, cement, water and an additive in a concrete plant. This mix is then conveyed by piston pumps through the hosing system to the nozzle where compressed air is used to accelerate the concrete to a speed suitable for

positioning the nozzle 1.5 m from the rock surface. Special chemicals known as accelerators are frequently added to speed up the hardening of the sprayed concrete.

61. The dry mix system tends to be more widely used in mining as it uses smaller trucks and more compact equipment and is therefore the best option for the rathole pit wall treatment.

62. Costs associated with shotcreting can be developed on a per-square meter basis including labor, equipment, and cement/aggregate/sand/aggregate costs. A test pit wall can be treated as a test model to determine optimal coverage and mixing components as well as durability. Cement and aggregate are readily available in Jaintia Hills and other parts of Meghalaya, therefore ensuring that materials costs will not be prohibitive and only the applicating equipment and expertise are needed to ensure success of this treatment method.

4.2.3 Waste Rock Covers

63. Soil covers should be placed over acid-generating waste rock dumps as part of the catchment remediation plan. Soil covers generally involve the use of granular earthen materials placed over mine wastes[14]. The benefits of soil covers generally include (i) dust and erosion control; (ii) chemical stabilization of acid-generating mine waste (through control of oxygen or water ingress); (iii) contaminant release control (through improved quality of runoff water and control of infiltration); and/or (iv) provision of a growth medium for establishment of sustainable vegetation[15].

64. After the mine waste areas are characterized, the following considerations will be given to design and installation of soil covers, alone or in tandem with pit backfilling, shotcreting and runoff management, to isolate AMD material in the catchment area.

- Cover systems may be designed to release alkalinity to infiltrating waters, should the geochemical assessment of waste material prove the presence of AMD. Alkalinity generally consists of dissolved carbonate species that are derived from the dissolution of limestone ($CaCo_3$).
- Organic Covers – Covers consisting of organic material that may act as a reductant (electron donor) that can scavenge or remove oxygen and possibly drive other reducing reactions such as sulfate reduction.
- Cover layer(s) should be constructed with locally-sourced natural earth materials.
- Synthetic cover systems may be considered if naturally-occurring pH neutral material is not available. These are constructed with synthetic layers such as geo- synthetic clay layers, various plastics or bitumen. The primary objective of such covers is to reduce net precipitation infiltration.

65. Key factors to consider in the design of a soil cover include:

- The climate regime at the site
- The reactivity and texture of the mine waste material
- The geotechnical, hydrologic, and durability properties of economically available cover materials
- The hydrogeologic setting of each waste area – if the area is subject to inundation by surface water, and therefore creates a surface water-groundwater interaction, which could facilitate transport of AMD and leachate into down gradient flow.
- Long-term erosion, weathering, and evolution of the cover system, if necessary.

66. Data and information collected during catchment and AMD source characterization has been used to assess these key factors and design robust covers for AMD source materials. A mine waste isolation plan will be included in the Remedial Action Plan for each site, as discussed in Section 7.

[14] MEND, 2001

[15] MEND, 2004a

5. AT-SOURCE ASSESSMENT FOR REMEDIAL DESIGN

67. The Kharkar River Basin has been confirmed as the transport mechanism for contaminated discharge to the Kopili River; and a preliminary Jaintia Hills mine site assessment has been conducted and AMD drainage, locations, water quality and flow- rate quantified, the design process can begin in earnest. At-source active mitigation measures should be implemented immediately upon granting of site access and landowner cooperation. Meanwhile, the design of a passive treatment methodology is generally a somewhat iterative process, in that it may be necessary to proceed with some of the data-gathering before a design constraint becomes apparent. In some cases, the constraint may be so serious that it is necessary to return to the drawing board, selecting a new site for the scheme, and repeating tasks such as the topographical survey and walkover surveys. This process can be made more efficient by utilizing a pilot study to confirm the optimization criteria for long-term, site-wide treatment design and construction. A Pilot Study is suggested to evaluate the adequacy of passive treatment for mitigation planning. Due to the extensive area to be remediated, and the paucity of existing site data, this Pilot Study is conceptual in nature and should be verified with additional site data as detailed in this section. The pilot study conceptual design for the Jaintia mining region is discussed in detail in Section 6.

68. Prior to designing a pilot study, an appropriate and representative mine site must be chosen. The physical and geochemical parameters involved in this process are discussed further below.

5.1 Mine Site Appraisal

69. At the onset of the Pilot Study Project, a walkover of potential sites should be made to identify and record features of geological and topographical interest. Information on groundwater levels, water features and hydrological information for the site should also be acquired. Data collected from a site survey can then be used to supplement and clarify data collected in the preliminary mine site inventory. The details should ideally be noted on a large-scale plan at 1:200 or larger.

70. The Passive In-situ Remediation Consortium of Acidic Mine Drainage[16] discusses how proposed pilot study sites, and all sites needing remediation, should be inspected carefully and methodically for conditions that might cause construction difficulties. Topography is important. Slopes greater than 1 in 10 may be subject to soil creep as indicated, for example, by tilting walls, fences and trees. Abrupt changes in local topography may indicate changes in ground type and a consequent variation in soil characteristics across the site. The extent of flat areas in the bottom of a valley should be identified, as these may delineate the extent of softer or weaker material infilling a valley floor and lowlands may also be subject to monsoon flooding.

71. Vegetation is an important indicator of soil types and groundwater levels. Reeds, rushes and willows indicate a shallow water table, whereas bushes and trees may denote a well-drained soil with a low water table. Abrupt changes in vegetation may indicate important variations in ground or groundwater conditions. The extent and type of vegetation across the site should be recorded and linked, where possible, with topography amongst other features.[17] Additionally, wetland plants should be noted as possible sources for use in constructed wetlands for the pilot study as well as long-term treatment systems.

[16] PIRAMID, 2003

72. Removal of vegetation, particularly mature trees and large shrubs, for rathole mining or other earth-disturbing activity, may lead to groundwater level changes and ground movement. Evidence of past ground deformations due to soil moisture changes and movements may be revealed in existing buildings or structures on each site. Current and past land use, where known, should be noted. Previous land use, particularly agricultural, may have resulted in realigned watercourses, areas of stockpiled rock or abandoned underground workings.

73. PIRAMID Design Guidelines, 2003 lists site features that should be identified during a field survey, which should be carried out on foot. The field information to be collected is listed in Table 5-1. Useful items to be carried by the field surveyor are shown in Table 5-2.

Table 5.1: Items to be Investigated During a Site Appraisal

Item	Details
Information requirements	• collect and assess data about the ground conditions of the site and adjacent areas from existing records. • seek information on buried and other services. • establish land ownership if in doubt and confirm rights of way
Site survey	• Walkover of the site to record the topography, vegetation and general ground conditions. • carry out level survey by specialist surveyor.
Ground investigation	• Establish the soil profile and groundwater conditions beneath the site using exploratory holes. • Carry out laboratory testing if required.
Assessment	• Determine whether the site is suitable. • Prove sufficient and suitable construction materials. • Establish that there is sufficient information for the design.

Table 5.2: Detailed Investigative Requirements for Construction of a Passive Water Treatment System

Item	Details
Foundation	• Confirm the ability of the ground to support an embankment and prevent excessive seepage from occurring through the foundation.
Construction materials	• The hydraulic conductivity of all potential fill materials should be assessed to establish the suitability for embankment construction.
Stability requirements	• Ensure the pond system and land adjacent will remain stable after commissioning.
Access requirements	• Ensure suitable access for construction plant and imported materials.

74. All collected data will be tabulated and mapped, and incorporated into the mine site inventory. This database will be used to choose the most appropriate location for a pilot study. In addition, the pilot study must be located in a relatively safe and secure area. The local population must be supportive of the study and able to provide a work force for construction, operation, maintenance and monitoring of the pilot study program.

[17] PIRAMID Design Guidelines, 2003

5.1.1 Mine Site Dimensions

75. The mine site inventory conducted in July 2017 provided a useful database of mine site physical dimensions that have been used to develop the conceptual passive treatment pilot study design, operation and anticipated construction and operation costs. Table 5-3 lists a summary of the data used in design of the pilot study and is based on mine site inventory data collected in July 2017. Additional topographic mine site data needed for long-term detailed remedial design include:

- Levels of all rivers or streams to which treated effluent could be discharged, with focus on monsoon versus dry season flows so that highest flow and lowest flow levels are measured.
- Elevation of proposed inlet pipe to treatment system.
- Elevation of existing outlet point of discharge.
- Location of any infrastructure such as water piping or electricity pylons.
- Location and extent of any substantial stands of trees.
- Overall site dimensions.
- Pipe and/or pump dimensions, if present, should also be recorded.

Table 5.3: Mine Site Inventory Summary

Item	Unit	Min	Max	Average
Pit Dimensions (meters)	Pit Radius	1.5	8	6.2
	Pit Depth	4	52	30.3
Coal Seam (meters)	Coal Seam	3	50	28
	Pit Depth	0.25	1.2	0.71
(m^3)	Coal Storage	300	10,000	5998
Overburden (meters)	Height	2	4	2.7
	Area	10	100	66.7
Water Discharge (l/day)	Winter	1120	20,150	5544
	Summer	0	13,700	3796
	Rain	0	5,400	1541
Discharge Quality	pH	2.4	6.8	3.2
	EC (µmhos/sec)	1	63	22.7

5.1.2 Mine Site Discharge Chemistry

76. As discussed in Section 3, discharge water samples were collected from six mine site discharges in the Jaintia Hills mining area. Results have been used to model input parameters for design of passive oxic/anoxic limestone drains as a pilot study. It must be stated that six samples collected during monsoon season is not sufficient to design a functional regional AMD mitigation operation. Many geochemical assumptions have been made, which, if proven to be wrong, could set back the remedial planning process and delay water quality restoration efforts. A detailed proposed mine site characterization is necessary before detailed mitigation planning can begin. A proposed work plan to conduct mine site characterization is included in Attachment 2.

77. The importance of mine water sampling and analysis cannot be over-emphasised. No matter how well constructed, a passive treatment system that has been designed using inaccurate or unreliable hydrochemical data may well fail to treat the mine water effectively. To use most of the engineering guidelines that follow, it is essential to have reliable flow-rate and water quality data. While flow-rate data are essential in determining the size (and ultimately cost) of a scheme, it is the hydrochemical data that will determine what type of treatment units are required, how many of them are required, and where they should be placed on site.

78. Based on existing monsoon and dry season flow determinations for the Kopili and Kharkar drainage basins, it is guaranteed that the mine site discharge flow rates will also vary. Therefore, assumptions have been made as to the relationships between seasonal flow and acid and metals loading based on existing water quality data. A simultaneous measurement of flow-rate needs to be made at the time of sampling. It is the contaminant load (i.e. flow-rate x concentration) that ultimately determines the system type and size. Since contaminant concentrations invariably change with flow-rate, it is not possible to reliably calculate contaminant load unless a water sample is collected and flow rate measured at the same time. Once the nature of particular water has been established from repeated sampling and analysis, it may be possible to eliminate certain determinants from the standard suite. This is typically so in relation to Al in waters with pH > 5.5, and for Zn in many coal mine waters. On the other hand, it may also be necessary to add further parameters to the suite. Which parameters to be added to an initial analyte list will be depend to a considerable extent on the local mining geology. Metals which are often added to the standard suite include copper (Cu), cadmium (Cd), nickel (Ni), lead (Pb) and chromium (Cr). Other metals, such as mercury (Hg), are principally found in effluents from mines which either exploited the mineral cinnabar (HgS) or else encountered it as a gangue (commercially-worthless) mineral, and are very rarely found in mine waters.[18]

5.2 Geochemical Assessment for Remedial Treatment Design

79. Existing Jaintia Hills discharge water quality data, as listed in Table 3-2, provides the only current geochemical conditions on which to model a conceptual pilot study, therefore several assumptions have been made, as will be noted throughout the following sections. The minimum, average and maximum for selected constituents and calculated mass loadings are included in Table 5-4.

80. As previously discussed, ALDs will generally not be successful if concentrations of Fe, Mg and Al are too high. Figure 5-1 shows a flow chart for determining whether discharge chemistry is suitable for passive treatment. A high acid load (acidity x flow rate -generated by high acidity and/or high flow) consumes the neutralising material faster, and in a passive system this can limit life expectancy. In addition, high flow rates require construction of very large systems that can be prone to short-circuiting and failure[19]. Acid load is calculated as acidity (mg $CaCO_3$/L) x flow rate (L/s) x 0.0864.

81. Acidity Load discussion (from a discussion in Australian Centre for Minerals Extension and Research (ACMER) 2005): *Understanding the difference between "acid", "Acidity" and "Acidity* Load*" is important for quantifying AMD treatment requirements, and therefore choosing appropriate treatment systems. "Acid" is a measure of hydrogen ion (H+) concentration which is generally expressed as pH (pH = -log10[H+]), whereas "Acidity" is a measure of both hydrogen ion concentration and mineral (or latent) Acidity. Mineral or latent Acidity considers the potential concentration of hydrogen ions that could be generated by the precipitation of*

various metal hydroxides in solution at a given. It is not unusual for AMD to contain iron (Fe), aluminum (Al), manganese (Mn), copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), nickel (Ni) and other metals, and some of these metals can remain in dissolved form even in near neutral solutions. As such, it is possible to have AMD with an elevated Acidity but neutral pH values. In general, Acidity increases as pH decreases (ie. H+ concentration increases), but there is not always a direct relationship between Acidity and pH. It is therefore important to quantify the contributions of both hydrogen ion concentrations ("acid") and mineral contributions ("latent" Acidity), in order to determine the total "Acidity" (ie. "acid" + "latent" Acidity) of a stream or water body. Acidity is generally expressed as "mass $CaCO_3$ equivalent per unit volume" (i.e. mg $CaCO_3$/litre). "Acidity Load" refers to the product of the total "Acidity" (ie. "acid" + "latent" Acidity) and flow rate (or volume) and is essentially equivalent to "ideal" treatment requirements expressed as "mass $CaCO_3$ equivalent per unit time" (or mass $CaCO_3$ equivalent for a given volume of water). Other factors such as reagent purity and dosing efficiency also need to be considered when estimating AMD treatment requirements."

82. Contaminant (Fe, Mn, Mg, Al and acidity) loads were calculated by multiplying contaminant concentrations by the flow rate as shown in Table 5-4. If the flow is measured in liters per minute (l/m), the calculation is:

[Fe, Mn, Al, Mg, Acidity] grams/day = flow (l/m) X [Fe, Mn, Al, Mg, Acidity] (mg/l) X 1.44

83. The following effluent chemical conditions are generally necessary to achieve success with use of an ALD as a passive treatment option:

- Sulfate Concentrations below 2,000 mg/l
- Acid load below 150kg/day
- Total Fe below 10 mg/l
- Total Al below 25 mg/l
- Dissolved oxygen (DO) less than 20% (DO values are not available for this data set)
- Long narrow land area with low to moderate slopes

84. Although DO was not measured for the Jaintia Hills discharge water quality assessment, existing data from Swer and O.P. Singh, (2003) report DO concentrations in some Jaintia rivers as being between 4.24 and 10.2 mg/l. The initial Jaintia hills site database indicates low relative flow rates during dry season and very low acid loads, indicating AMD discharges would be amenable to passive treatment. Fe and Al concentrations are also below maximum levels for successful passive treatment indicating that ALD/OLD combinations may well be a successful strategy for the Jaintia Hills District.

85. Hedin and Nairn (2003) allow that when net acidity is less than alkalinity, as is the case for each of the Jaintia Hills mine discharge analyses listed in Table 5-4, then polishing aerobic wetlands alone would suffice for removing Fe, Mg and Mn. However, to raise pH in the larger discharges into Kharkar River, it is recommended that influx of produced alkalinity from passive treatment systems be utilized wherever possible to treat mine discharges.

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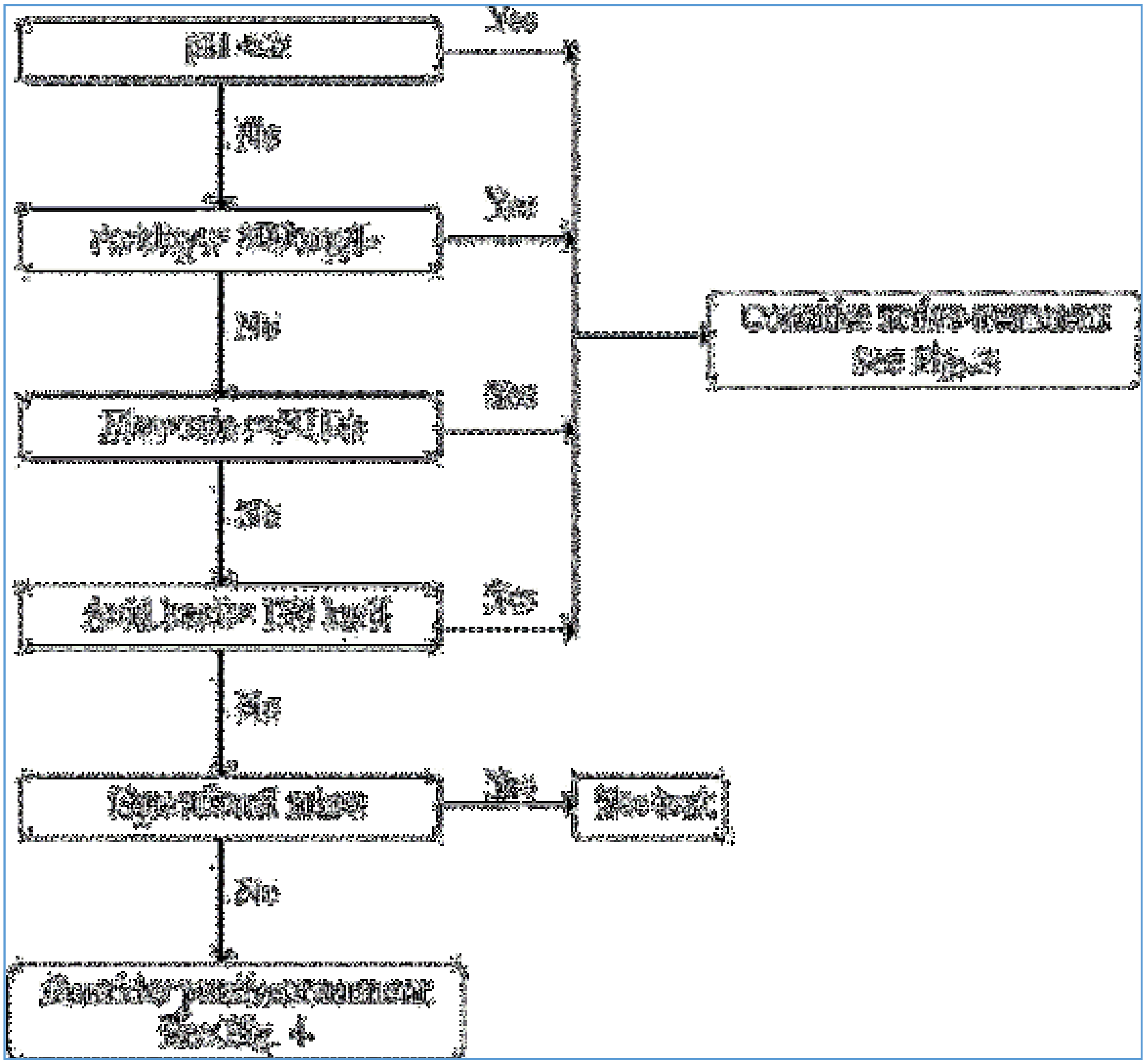
[17] PIRAMID, 2003

[18] Trumm, 2010

Table 5.4: Average Influent Quality for Passive Design from Jaintia Hills Mine Discharge (compiled from data contained in Table 3-2)

Parameter	Minimum	Average	Maximum
Field pH	2.4	3.2	6.8
Field DO	1	2.7	6.3
Net Acidity (as $CaCO_3$)	32	44	52
Alkalinity (as $CaCO_3$)	55	160	320
Sulfate (mg/l)	18	40	68.8
Total Fe (mg/l)	1.23	3.2	6.2
Total Mg (mg/l)	6.3	19	36
Total Al (mg/l)	0.08	0.11	0.15
Acid Load (kg/day)	0.04	0.23	1.03
Fe Load (kg/day)	0.0015	0.0166	0.1232
Mn Load (kg/day)	0.0001	0.0011	0.0056
Mg Load (kg/day)	0.0076	0.0985	0.7154
Al Load (kg/day)	0.0001	0.0006	0.0030

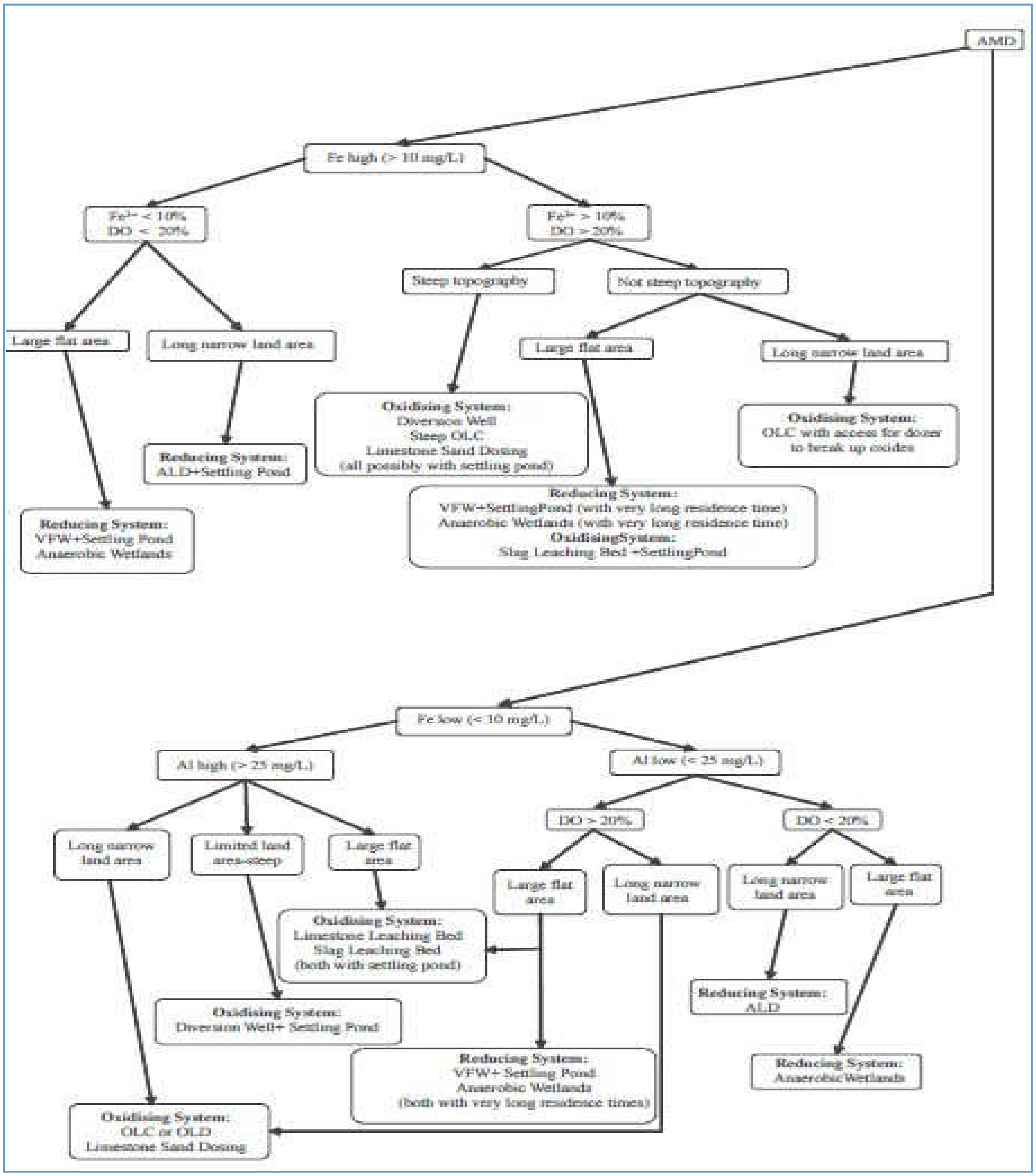
Figure 5.1: Flow Chart for Making a Choice Between Active and Passive Treatment for AMD



Source: (Trumm, 2010).

86. Active treatment system is using chemical, energy, labor and infrastructure to produce clean water in a shortest time with a lowest footprint. Passive treatment system is capitalizing on low energy dynamics employed in natural, biological and geochemical process at a ambient temperature From comparison of data from Table 5-4 with analytical dimensions shown in Figure 5-1, it is apparent that Jaintia Hills mine drainage is suitable for ALD treatment. Figure 5-2 further allows decision-making for passive treatment options based on topographic conditions and available land area. Based on the preliminary Jaintia Hills mine site inventory and inspection of available maps and geological information, it appears that most of the mine sites would be amenable for installation of passive treatment systems if AMD discharge cannot be eliminated with implementation of active measures alone and/or if monsoon moisture produces quantities of stormwater that is contaminated with AMD necessitating additional AMD discharge treatment in some areas. This should be confirmed during the proposed regional mine site inventory (Attachment 2).

Figure 5.2: Flow Chart to Select Among AMD Passive Treatment Systems



Source: Trumm, 2010.

6. CONCEPTUAL PILOT STUDY DESIGN DETAILS

6.1 Trench Size

87. Use of passive systems for the Kharkar rathole mining district discharge is made more complex by the large difference in seasonal flow, with the monsoon precipitation and surface water flow being over three times that of winter and dry season precipitation and flows. To effectively treat both flow and discharge extremes, a dual-system limestone trench is proposed, where the ALD is at the bottom of the trench and therefore able to be kept continually saturated. An OLD will be constructed in the upper part of the trench to capture and treat monsoon and other flows in excess of the ALD component volume. A conceptual trench layout is shown in Figure 6-1. This will require some oversight and management of flow and precipitation conditions, as well as flow and saturation in the ALD so that the OLD can be activated if needed and the ALD can be kept saturated by shutting off the exit flow valve, as shown in Figure 6-2. This design enables both passive components to be constructed and operated in one trench with one discharge inlet, thereby saving construction and operating costs. The presumed low-metals content of the discharge based on existing data and high monsoon volumes, should reduce the likelihood that the OLD limestone will armor over, or that sediment will deposit in the limestone gravel interstices. ALD/OLD design assumptions and calculations are discussed further below.

6.1.1 Anoxic Component

88. An anoxic limestone drain is essentially a trench filled with crushed limestone, sealed under plastic and geotechnical fabric, and covered by soil through which a contaminated effluent stream flows by gravity. Figure 6-1 provides a schematic representation of a typical ALD.

89. The dimensions of anoxic limestone drains vary from site to site-based on dimensions such as topography and distance to surface drainage. ALDs are generally shallow in depth, and contain an effective limestone thickness of 1 m to 2 m which is covered by a minimum of 0.6 m of soil. Traditionally, ALDs have been narrow in width (0.6 m to 1.0 m), with sufficient length to provide the retention time required to reach chemical equilibrium based on the predicted flow regime. Drains of up to 20 m wide have also been shown to be effective, and produced alkalinity concentrations similar to more conventionally shaped systems (Hedin et al. 1994).

90. Dimensions for construction of an ALD at a specific location can be established once the volume of limestone required is determined. An equation that is commonly used in ALD design is as follows:

$$M = [Q * \rho * t / V] + [Q * C * T / x]$$

91. In this equation, M represents the mass of limestone to be used to construct the drain. The first bracketed term represents the volume of limestone required to achieve the design retention time, while the second bracketed term represents the volume of limestone expected to dissolve over the design lifetime. Adding the two quantities is intended to assure that the mass of limestone remaining in the drain throughout its design lifetime is adequate to achieve the design retention time. To calculate the first bracketed term:

Q = water flow rate; ρ=
limestone density;
t = design retention time;

and V= bulk void volume of the limestone gravel, expressed as a percent of total volume.

92. To calculate the second bracketed term: Q = influent flow rate; C = expected rate of alkalinity generation, expressed on an mg- $CaCO_3$/L per unit time basis; T = the design lifetime; and x = the $CaCO_3$ content of the limestone, for which 90% or greater is recommended.

93. The most recent literature based on a variety of different case studies, suggests the following retention times (tr) are generally appropriate, as discussed in Section 6.3:

- Faulkner and Skousen (1994) 15 to 20 hours
- Hedin and Watzlaf (1994) 14 to 23 hours, 15 hours recommended
- Hedin et al. (1994) 14 hours

94. Limestone used in ALDs has an average density of about 1.5 to 1.6 kg/m^3. To determine the total mass of limestone needed in the drain, the above calculation must be adjusted for the $CaCO_3$ content of the limestone and the projected lifetime of the ALD. When these calculations are done properly and carried through into the actual construction of the ALD, they assure that there is theoretically enough limestone in the drain to generate alkalinity for the time considered. Because the oldest ALDs are only 15-20 years old, it is difficult to assess how realistic these theoretical calculations are although new research is available (Skousen et al, 2016, 2017). Questions about the ability of drains to maintain unchannelized flow for a prolonged period, whether 100% of the $CaCO_3$, content of the limestone can be expected to dissolve, whether the drains will collapse after significant dissolution of the limestone, and whether inputs of DO that are not generally detectable with standard field equipment (0- 1 mg/L) might result in armoring of the limestone with ferric hydroxides, have not yet been addressed. (Hedin and Nairn, 1994)

95. The minimum mass of limestone needed to treat a year's flow of mine water can be calculated from the flow rate and an assumption that the drain will produce 300 mg/L alkalinity.

96. The average mass of limestone calculated for the Pilot Study is 22 tonnes, based on the following formula inputs: Flow rate (average) 210 l/hour; retention (residence) time of 15 hours; bulk density of limestone 90%; void volume 40%; design life of 10 years; and a very conservative $CaCO_3$ limestone content of 80%. Minimum and maximum limestone volumes were estimated based on minimum and maximum flow rates, respectively with all other inputs remaining the same. These limestone mass estimates are included in Table 6- 1.

97. The ALD should be designed to accommodate the maximum expected flow to prevent hydraulic failures and to ensure that the minimum residence time is maintained at all times. Trench sizing for the Conceptual Pilot Study was determined based on anticipated average flow volumes for dry season discharges of 210 l/hour, as shown in Table 6-1.

98. If the rate of AMD discharge flow into the drain is such that insufficient water is available for complete saturation, the exit flow will be shut off at the base of the ALD, as shown in Figure 6-2. This will hold the AMD effluent in the ALD to maintain saturation until discharge flow resumes. Once seasonal flow resumes, the flow valves can be opened again.

Figure 6.1: Conceptual Layout- Pilot Passive Treatment Components (not to scale)

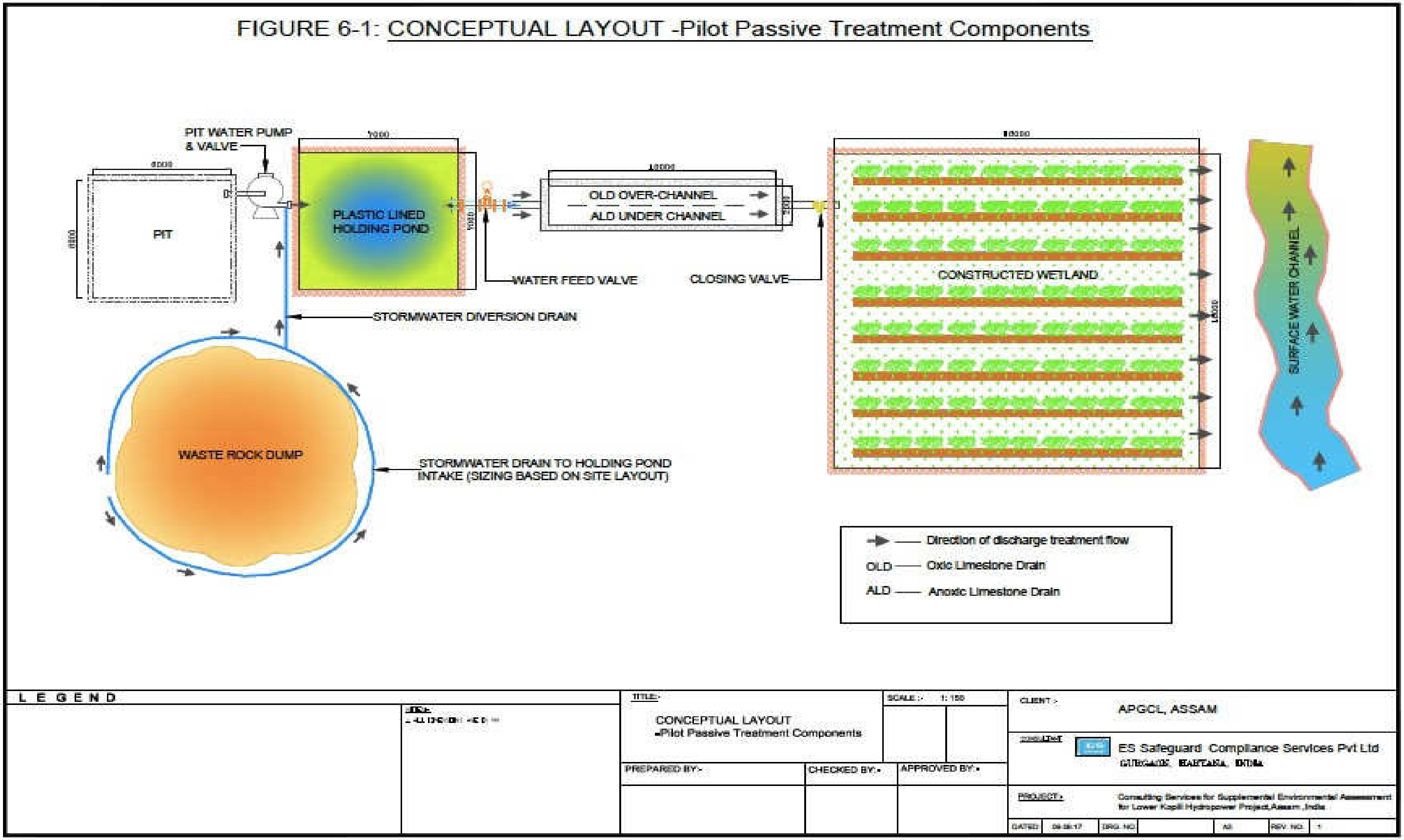
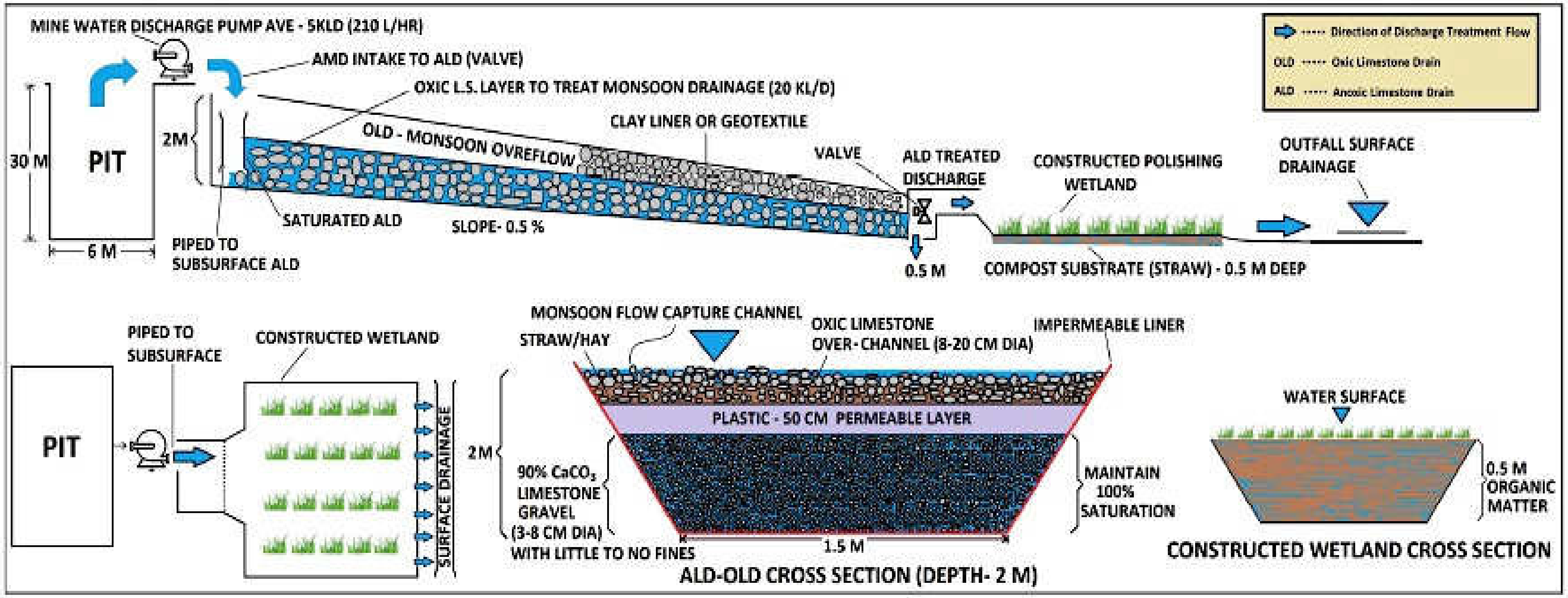


Figure 6.2: Preliminary Design – ALD Pilot Study (not to scale)



6.1.2 Oxic Limestone Drain (OLD) Component

99. The upper trench channel comprises the OLD component. Limestone mass for the OLD channel was calculated based on the volume of the remaining upper portion of the trench and expected monsoon discharge volumes as listed in Table 6-1. Limestone will be placed on top of the clay/plastic impermeable liner.

Table 6.1: Pilot Study and Passive Treatment Site Parameters

Parameter	Unit	Min	Average	Max
Pit Dimensions (meters)	Pit Radius	1.5	6.2	8
	Pit Depth	4	30.3	52
Coal Seam (meters)	Coal Seam	3	28	50
	Pit Depth	0.25	0.71	1.2
(m3)	Coal Storage	300	6,000	10,000
Overburden	Height	2	2.7	4
(meters)	Area	10	66.7	100
Water Discharge (l/day)	Winter	1120	5,500	20,000
	Summer	0	3,800	13,700
	Rain	0	1,500	5,400
Discharge Quality	pH	2.4	3.2	7
	EC	1	22.7	63
Average Discharge (All seasons average)	l/hour	50	210	850
Acid Load				
ALD Volume	m^3	60	90	120
ALD Dimensions	m^3	10x3x2	12x3x2	15x3x2
Holding Pond volume	m^3	72	130	200
Holding Pond Dimensions	m^3	6x6x2	7x7x2	8x8x2
Constructed Wetland Dimensions	m^3	12x12x0.5	16x16x0.5	20x20x0.5

Note: holding pond volume estimated to hold 110% of average flow
Constructed wetland dimensions constructed to hold 110% of average discharge.

6.2 Limestone Gravel Quality and Dimensions

100. Generally, high calcium limestone is the most effective material for ALD construction. This is supported by Watzlaf and Hedin (1993) who conducted an experiment to assess the effectiveness of seven different qualities of limestone and dolomite. The limestone samples had a $CaCO_3$ content ranging from 82% to 99% and a $MgCO_3$ content of between 0.4% and 4.5%. The dolomite sample tested had a $CaCO_3$ content of 46% and $MgCO_3$ content of 38%. All the limestone samples dissolved faster and produced higher alkalinity than the dolomite sample; however, among the limestone samples there was no correlation between $CaCO_3$ content and alkalinity produced.

101. In general, the size of crushed limestone chosen to construct the drain should be a compromise between allowing free flow and sufficient surface area for dissolution to occur. In most of the ALDs reviewed, limestone crushed to between 2 cm to 4 cm was used. Smaller sizes were anticipated to clog too readily, and hamper flow through the ALD. Hedin et al. (1994) reported that many ALDs constructed with limestone fines and small gravel failed by plugging. As a result, two recent articles suggest that larger particle sizes (8-25 cm, Faulkner and Skousen 1994; 'baseball sized', Hedin et al. 1994) should be used in ALD construction to increase hydraulic conductivity and reduce the potential for plugging.

102. Preliminary identification of limestone from a quarry in Jaintia Hills showed that gravel sizes of 2-5 cm can be obtained. There was no available data on the purity of $CaCO_3$ or limestone dissolution rates for these particular samples, however data on limestone mineralogy and purity from several deposits in the Jaintia Hills area is contained in Bandyopadhyay et al, 2009 which supports the assumptions made to calculate alkalinity loadings and limestone quantities. For the purposes of modeling alkalinity production and residence time, a conservative estimation of 80% $CaCO_3$ was used

6.3 Determination of Residence Time

103. The residence time for water in limestone drains is a critical factor affecting their performance because of kinetic controls on dissolution, precipitation, and sorption reactions that control pH and dissolved ion concentrations. Standard design guidelines for ALDs generally recommend that drains be constructed to achieve 15-hour retention times over their design lifetimes (Zipper et al, 2011). Experience has shown that beyond these residence times, the ALD will not achieve further alkalinity. These retention times were generally not used in the early ALDs represented in the literature. A design life (T) is chosen based on the expected period of treatment required.

104. Data for the porosity and flow rate were used to compute the residence time for water within the ALD pilot trench. Based on the known drain volume (assumed 5,000 l and measured velocities for specific flow rates, (Cravotta and Trahan (in press)) estimated porosity to be 0. 14 for the OLDs. According to Darcy's equation (Freeze and Cherry, 1979), the velocity of flow through a porous medium is:

$$V = Q/(A \times n)$$

105. where Q is the volumetric flow rate, A is the cross-sectional area perpendicular to flow, and n is the porosity. Assuming constant values for the cross-sectional area for the pilot trench, $A = 0.84m^2$, and the porosity, $n = 0.14$ -velocity through the channel is 0.25 m/hour. As the limestone dissolves, the hydraulic integrity of the drain should decrease but it is difficult to predict the reduced performance. Furthermore, the equation does not account for the demands of reactions generating alkalinity through retention of Fe^{3+}, Mg, Mn and Al, which have the potential to significantly and adversely affect the performance of limestone drains by clogging the drain with secondary mineral precipitates (Hedin et al. 1994). Hence, although this calculation of residence time is useful for the design stage, monitoring is important to evaluate the actual ALD efficiency and its evolution over time. This is discussed further in Section 6.9, regarding Pilot Study monitoring requirements.

6.4 Holding Pond

106. A lined holding pond will be constructed near the discharge point for the pit dewatering pump and pipework. The pond will be lined with neoprene plastic or a 10-cm compacted clay liner, whichever is more readily available. The pond dimensions for the pilot study will be

7x7x2 meters – a volume sufficient to hold at least 15 days of discharge. The pond will serve a dual purpose of settling solids and metal precipitates prior to entering the limestone channel and facilitating evaporation to decrease discharge volume. Holding ponds will also be constructed as components of active treatment for stormwater/surface water discharge as discussed in Section 4.2.1 and Section 7.4.1.

6.5 Constructed Wetland Design

107. Treated flow from the pilot channel, both the ALD and OLD sub-trenches, will flow directly into a constructed wetland. The dimensions of this pilot wetland (16m x 16m) are designed to provide sufficient post-treatment effluent aeration and measured flow into the local surface water drainage. The constructed wetland will serve to percolate this flow through the wetland organic substrate with the effect of aerating the water to facilitate settling metals precipitates and providing additional alkalinity to the treated water before it is released to surface water drainage.

6.6 Pilot Study Construction Details

108. As a physical location for construction and operation of a pilot passive system has not yet been determined, a representative schematic of anticipated average mine site conditions has been utilized based on results of the Jaintia Hills mine site survey as discussed in Section 5.0. The following are anticipated details as related to the pilot system construction. These details are expected to be relevant to a region-wide mitigation effort and are therefore pertinent for use in planning mine site AMD remediation/mitigation efforts in support of the LKHEP.

- ALD/OLD systems will be located to utilize a minimum 2-5% grade to maximize use of gravity to feed and maintain saturation in the limestone beds.
- Water will flow from the pit through pipework to the valved intake from the pit water containment to the ALD. Flow will be induced and maintained via gravity flow. For a gravity flow system to work, the intake must be higher in elevation than the outflow and no air must be allowed to enter the system.
- Limestone beds will be sized based on AMD discharge flow rate during the dry season so that saturation can be maintained. Monsoon flow will be managed utilizing holding pond storage and OLD over-channels. If necessary, holding ponds can be lined with limestone gravel to generate alkalinity during monsoon flows, but it must be anticipated that armouring of limestone liners will occur. The armouring rate will be dependent on Fe, Mg and Mn content of the AMD discharge. Site monitoring and maintenance will include regular inspection of all limestone placements to note the degree of armouring, which will isolate the $CaCO_3$ surface from AMD water and decrease alkalinity production.
- Limestone gravel must be well graded to maximize pore space. Grade size should not be larger than 15 cm.
- Local wetland plants should be utilized in the constructed wetlands bedding to reduce need for maintenance and optimize success of the beds.
- Organic material to line the base of the constructed wetland can contain the following material: locally-sourced manure, wood chips, wood ash, peat and plant detritus. The base of the wetland will be below water surface and will consist of a mix of the above materials with sand and pebbles to form a permeable matrix into which plants can take root.
- Drainage from the wetland should be constructed to minimize erosion and maximize

the opportunity for additional sediment settling prior to entry to the surface water channel.

- Either a 10-cm base of impermeable clay or neoprene plastic will be used as a base for both the ALD and the holding pond. This is to ensure that seepage to groundwater does not occur and in the case of the ALD to maintain total saturation. A 10-cm overliner of clay or plastic will be used to cover the ALD surface and separate the ALD from the OLD over-channel. Again, this is to maintain total saturation of the ALD channel.
- Stormwater diversion drains will be constructed around the base of all site waste rock piles, to a size adequate to collect maximum stormwater from the piles. The size of the diversion drains will be based on surface area of the waste rock piles. The drains will drain down gradient to the holding pond for collection and treatment. The drains should be lined with gravel and/or riprap, limestone if possible to maximize alkalinity production.

6.7 Costs

109. Table 6-2 lists some of the anticipated estimated costs per passive treatment system for three Scenarios, based on discharge volumes and corresponding treatment component sizes (minimum, average and maximum).

Table 6.2: Estimated Construction Costs (in INR) Per Passive Treatment System for Three Scenarios

Items	Scenario 1 - Minimum		Scenario 2 - Average		Scenario 3- Maximum	
	Unit Cost	Total Cost	Unit Cost	Total Cost	Unit Cost	Total Cost
Design and Engineering						
Labor-ALD Labor-wetlands construction Labor - holding pond Labor - Stormwater diversions and misc.		24,897		29,158		34,040
Equipment						
Dozer	2,850	34,200	2,850	51,300	2850	85,500
Loader	1,787	21,444	1,787	32,166	1787	53,610
Misc. tools (hoses, shovels, etc.)	30/Cum	10,200	30/Cum	15,120	30/Cum	21,060
Limestone (5-15 cm dia)	250	5,000	250	10,000	250	15,000
Valves (2 L/sec max flow capacity)	6,500	13,000	6,500	13,000	6500	13,000
6cm PVC pipe	107	3,210	107	4,280	107	6,420
10 cm PVC pipe	216	6,480	216	8,640	216	12,960
Impermeable plastic liner	319	22,330	319	41,470	319	57,420
Seed/mulch/fertilizer		6,970		13,090		19,210
Straw or hay	400	100,000	400	160,000	400	220,000
Clay	100	500	100	1,000	100	1,000
Shotcrete application (pit dimensions depth x width x 4 walls)	542	13,017	542	407,862	542	902,503
Total (INR)		**261,248**		**787,086**		**1,441,723**

110. Based on estimated per-site costs, preliminary costs can be determined and a budget prepared, as the regional mine site survey is conducted and mitigation-planning processes unfold. For example, once the mitigation progresses to the point where a major regional mine site inventory has been conducted and site access and landowner cooperation is obtained, a conceptual remedial cost and budget scenario can be developed as follows:

- Approximately 5,000 mine sites are accessible.
- All 5,000 sites have pits. 1500 sites have small pits with no need for on-site AMD drainage management. Small holding ponds will be constructed.
- 2,000 sites have average size pits to be backfilled and of these 100 will require ALD/holding pond/drainage installation for additional AMD drainage treatment.
- 1500 sites have large pits, and, of these, 50 sites will require maximum size ALD/holding pond/drainage installation.

111. Table 6-3 presents approximate construction costs associated with this conceptual remedial action scenario. Total estimated remedial construction costs for this scenario are estimated at 252,300,000 rupees, or 4,000,000 USD. This initial cost estimate would be reduced based on the assumption that efficiency in site access, equipment purchase and management, labor and supplies will increase as site remediation progresses. As an example, construction material can be purchased in bulk and fuel needs can be reduced by conducting remedial activities in geographic "clusters" allowing equipment to be used and transported more efficiently. Also, landowners can undertake some of the construction work themselves thus reducing earthworks costs considerably.

112. Management and monitoring costs for pilot study operation are included in Section 6.9.

Table 6.3: Regional Mitigation Cost Estimate

Remedial Component	Number of Units	Unit Cost	Cost (INR)
Small pits	1,500	2,000	3,000,000
Average pits	2,000	4,000	8,000,000
Large pits	1,500	8,000	45,000,000
2,000 average ALDs	100	788,000	78,800,000
1,500 large ALDs	50	1,440,000	72,000,000
Shotcrete for med and large pits	3,500	13,000	45,500,000
Total Estimated Remediation Construction Cost (INR)			**252,300,000**

6.8 Operation and Management Requirements

113. As the purpose of the Pilot Study ALD/OLD system is to collect data on the efficacy of acid load removal and water quality restoration, the system must be monitored and maintained on a regular basis. Water discharge management is paramount to the success of the system; therefore, the site should be checked at least weekly and more often during storm events. The most important task is to ensure that the ALD remains saturated and if the holding pond is running dry, to close the effluent discharge valve at the base of the ALD

so that water is contained in the ALD system. When water is flowing in excess of 210 l/hour, the holding pond will contain excess flows which will then drain into the OLD over channel and then to the constructed wetlands.

114. The performance and geochemical data collection requirements to operate and maintain the Pilot Study are detailed below.

6.9 Performance Monitoring and Data Collection for Mitigation Planning

115. Operation of the Pilot Study will produce data that is invaluable for long-term site wide mitigation planning. System monitoring, data collection and analytical modeling will be used to determine the effectiveness of the ALD/OLD system in reducing discharge acidity, normalizing pH and reducing metals loading into regional surface and groundwater. As well site remedial data will be used to plan a region-wide mine site restoration plan, including estimated costs, schedules, and water treatment expectations. Data on discharge and effluent flows, treated effluent chemistry, monsoon vs. dry season operational effectiveness and passive treatment operational efficiency and maintenance requirements can all be estimated and included in the Site Mitigation Plan, a detailed discussion of which is included in Section 7. Details of Pilot Study performance monitoring and management aspects are discussed below.

6.9.1 Seasonal Discharge Flow Rates

116. The most influential aspect of technical mitigation planning is the dichotomy of seasonal precipitation and surface water flow systems in the Kharkar region. Monsoon moisture has been shown to increase local and regional surface water flows up to four times the dry season minimum flows. Therefore, passive treatment technologies for mine waste discharge must consider a dual-flow treatment system that can handle extremes in flow rates. The Site Characterization Report demonstrated that monsoon moisture does not necessarily provide dilution effects to Kharkar and Upper Kopili River pH levels. At present, no data exists to confirm pH fluctuations with seasons at the rathole mine sites, therefore a robust site discharge flow monitoring plan will be implemented during the Pilot Study. Data collected will include:

- Discharge flow rate from the mine pit
- Discharge flow rate into the ALD
- Discharge flow rate from the ALD flow release valve at the end of the trench
- Discharge flow rate at the surface water system nearest to the constructed wetlands release area.

117. This data should be collected at least twice per month and logged into a spreadsheet.

6.9.2 Seasonal System Discharge Water Quality

118. Treated discharge water chemistry analysis and evaluation is the most important aspect of this Pilot Study program. Sampling of treated effluent, performed at least once per month for the first year of operation will provide invaluable data to ascertain the effectiveness of the ALD/OLD system, seasonal and/or other changes to mine discharge chemistry itself, limestone dissolution chemistry and the effectiveness of the constructed wetlands in providing additional oxygenation, pH reduction and metals precipitation. Periodic sampling and analysis of downstream water quality both in the receiving stream and at the Kharkar River will allow modeling of water quality trends and the effectiveness of passive treatment overall.

119. Water samples will be collected monthly at a minimum, at the same time as flow measurements are taken, at the discharge points listed above: mine discharge, ALD channel inflow valve, OLD channel outlet (when receiving water) ALD channel outlet to the wetlands, and the receiving stream. Parameters measured during field sampling to evaluate the drain performance will include: pH, temperature, redox, conductivity, flow rate, dissolved oxygen (DO), and electric conductivity (EC). Water samples laboratory analyses include: alkalinity, acidity, hardness and ICP multi-elements including Fe, Mn, Mg, and Al. The effluent variation in pH and alkalinity is a good indication of the passive treatment efficiency in treating AMD.

120. The pH is an intensity indicator whereas alkalinity is a neutralising capacity indicator. The variation in pH, acidity and alkalinity with time will be compared. Data evaluation will determine if the pH of the treated effluent is much higher than the influent, whether it has continuously increased during the first season of passive treatment and if the OLD component is successfully adding alkalinity during monsoon flows.

6.9.3 Limestone Dissolution Rates

121. An important monitoring result of the Pilot Study is to determine the dissolution rate of limestone used in the pilot channels. The dissolution rate will be expected to vary both seasonally and within the ALD and OLDs. The OLD will be inspected during and between monsoon seasonal flow to determine whether limestone armoring has taken place and if sedimentation is occurring within the limestone aggregate. If this is occurring, then a comparison of alkalinity production versus time should be undertaken to determine whether the OLD is operating with any degree of efficiency, and if not, consideration should be given to re-loading the OLD with fresh limestone and perhaps vary the gravel grade.

122. Inspecting the ALD for limestone dissolution, armoring and sediment accumulation will be more difficult as it necessitates removing a portion of the impermeable trench cover to expose the ALD limestone bed. Conducting an ALD channel inspection should be considered if flow rates and/or alkalinity production, and pH increase rates are not within expected results. If the residence time through the trench is shown to be decreasing with time, this may indicate that an accumulation of sediment and metals precipitates are clogging the limestone bed interstices. Likewise, if pH neutralization rates are decreasing, and alkalinity levels are leveling or reducing, then armoring of the limestone gravels is suspected and the ALD channel should be opened for inspection. In all cases of channel inspection, detailed notes and photo records should be taken to facilitate evaluation of the ALD/OLD malfunction and to consider limestone bed replacement.

6.9.4 Regional Surface Water Flow and Quality

123. During the duration of the Pilot Study, flows and field water quality should be taken downstream of the Study area as well as at the confluence with the Kharkar River. This data will be used to evaluate whether influx of alkalinity-laden water will influence pH in the surface water systems draining into the Kopili River. It’s not expected that just one passive treatment system will change pH levels beyond the immediate receiving drainage, however collection of this data will be invaluable for mitigation action planning and eventual water quality restoration.

6.9.5 Pilot Study Maintenance and Monitoring Costs

124. Table 6-4 lists anticipated and estimated costs to conduct periodic sampling and maintenance of the pilot study components as detailed in the above sections.

Table 6.4: Estimated Maintenance and Monitoring Costs

Maintenance and Sampling Costs	Quantity	Rate (Rs.)	Amount (Rs.)	Remarks
Labor (2 days/event) sampling & inspection	1 manday of skilled workman + 1 manday of unskilled workman	{(360.39 + 257.4) + 20%} x 30 days =741x30	22,230	Per month
	1 event/month	Included above		
Field & Sampling Equipment				
Sampling equipment & bottles	1	8,000	8,000	1 Kit containing 24 bottles including: 12-1 litre HDPE bottles, 12- 200 ml small HDPE bottles for heavy metals, Icebox, gloves, apron, 200 ml Preservative for heavy metals etc.
Flow meter	2	15,000	30,000	Digital flow/velocity meter
pH/DO/EC meter	1	65,000	65,000	HANNA Multi Parameters Portable Meter
Transportation/lodging	LS		60,000	Total 6 visits considering Rs.10,000 per visit
Laptop			25,000	
Laboratory (six samples)	6	6,000	36,000	Considered rates are based on market rate for analysis of parameters viz. alkalinity, acidity, hardness and ICP multi-elements including Fe, Mn, Mg, and Al
Miscellaneous	LS		25,000	
		Total (INR)	**271,230**	

7. CONCEPTUAL MITIGATION PLAN

125. This section outlines the elements needed to develop a robust mitigation process for the Meghalaya rathole mining areas that are contributing low-pH, elevated metals concentrations to the Kharkar River, and ultimately the Kopili River system. This Mitigation Plan is conceptual in nature and can be used as a framework for planning actual remediation and restoration activities in the Kharkar Valley rathole mining areas, once Stakeholder engagement and financial sources are obtained.

7.1 Objectives

126. The overall objectives of mitigation planning are to:

- Reduce and eventually eliminate AMD and consequent surface water contamination, up and downstream in the Kharkar and Kopili Rivers.
- Introduce preventative measures to protect natural water quality.
- Remediate abandoned mine areas to isolate AMD-producing geologic material.
- Restore coal mine-affected land to eventually support pre-mine land ecosystems including flora and fauna.
- Restore pre-mining land use including agriculture, horticulture and grazing.
- Restore riverine systems to pre-AMD quality to support fisheries.
- Guide eventual land use and local economy away from coal mining, to one that promotes sustainable development.

127. Prevention is a proactive strategy that obviates the need for the reactive approach to mitigation. Mitigation will be the usual initial course of action for an existing case of mine drainage that is adversely impacting the environment. Despite this initial action, subsequent preventative measures may also be considered in the context of reducing future contaminant load, and thus reducing the ongoing need for mitigation controls. For example, the amount of seepage requiring treatment may be reduced if the current source strength is reduced. Meghalaya has introduced the first step of banning rathole mining, however it is still occurring, as was evidenced during the July 2017 Jaintia Hills mine site inventory, as discussed in the LKHEP Site Characterization Plan Summary (Attachment 1). For both prevention and mitigation, the strategic objectives must be identified because, to a large extent, these strategic objectives will define the control methods that need to be used. The process of identifying the strategic objectives should consider the following:

- Quantifiable risks to ecological systems, human health, and other receptors
- Site-specific discharge water quality criteria
- Capital, operating, and maintenance costs of mitigation or preventative measures
- Logistics of long-term operations and maintenance
- Required treatment system longevity
- Risk of passive treatment system failure and identification of potential modes of failure

128. AMD prevention is the key to avoiding additional costly mitigation. The primary goal of the prevention is to stop contaminated drainage from leaving the mine site at its source by

minimizing reaction rates, leaching, and the subsequent migration of weathering products from mine waste to the environment. As the Stakeholder engagement process unfolds, information dissemination on best practices to prevent AMD formation will be incorporated into the landowner education on best practices and long-term site mitigation strategy. This serves to both reduce costs associated with mine site remediation and to engage landowners in practicing good environmental hygiene.

129. The primary objective for ARD control is to satisfy environmental criteria using the most cost-effective technique. Within the Meghalaya rathole mining areas, a two- pronged approach is needed: first is to immediately apply active and passive treatment to existing mining areas with identified AMD, once landowner cooperation is ensured. Second is to incorporate best practices for AMD prevention at all sites, including those with little to no existing AMD, but with potential to produce AMD in the future.

7.2 Organization

130. The requirement for remediation of acid mine drainage (AMD) impacted water from the rathole coal mine sites upstream of the LKHEP is to provide an acceptable long-term plan for managing the discharge and minimizing the risk of further discharges to and effects on the Lower Kopili River and Reservoir. Due to cost constraints, unreliable power supply, site access limitations and mitigation effectiveness only “at-source” mitigation measures will be developed further. This conceptual mitigation plan will provide a long-term solution with minimal ongoing maintenance and operation costs and, secondly, to minimize capital to that required to ensure that the operating cost objective can be met while restoring quality of discharges into the Lower Kopili River. Other actions include provisions of educational mechanisms that will impart post-mining restoration best practices and AMD prevention measures as discussed above.

131. Three AMD discharge remediation steps are considered as paths forward for the technical approach to the WQRP Mitigation Plan:

132. **Step 1** – Minimization of AMD discharge using operational control at the origin, including use of best practices for waste rock disposal, mine water management and coal handling and transport. This step will be activated in two phases. First Stakeholder engagement will be initiated to provide education on AMD prevention and mitigation and to obtain mine site access. Second, a comprehensive mine site inventory in the Kharkar River basin will be undertaken once landowner permission is granted and worker safety is ensured.

133. **Step 2** – Active treatment of discharge at the mine pits, including mine water isolation in holding ponds, pit backfill, pit wall shotcreting and waste rock covering, followed by ALD/OLD installation if needed for AMD discharge treatment. Active mitigation measures should be undertaken as soon as possible after mine site access is acquired. Further acid drainage treatment will be planned and initiated once sufficient data is collected from the Pilot Study operation and analyzed for AMD removal effectiveness. Based on activation of Step 1, the mine site inventory will be used to identify sites with the most egregious levels of AMD and those most amenable to passive treatment. Generally, these sites will also be the ones most immediately impacting the Kharkar River.

134. **Step 3** – Ongoing and active collaboration with the mining community and local and State governments to plan a combined approach to AMD minimization and prevention integrating all treatment options and ensuring ongoing acid-neutral discharge, environmentally sound mining practices, and ultimately mined land restoration. This Step will assure that long-term land restoration is implemented along with AMD remediation with the

goal of returning the mined land to pre-mining land uses including agriculture, horticulture, forestry and fisheries restoration in the Kharkar and Kopili Rivers.

135. Implementation of each of these Steps in tandem provides the most robust long- term solution to the current increase in rathole mining activity in the upper reaches of the Kharkar Catchment, but also requires complete Stakeholder participation and coal mine owner/operator engagement to produce results.

136. Long-term mitigation measures include ongoing Stakeholder engagement to encourage individual responsibility for land reclamation management and restoration. Additionally, mine sites that have minor surface water impacts and/or are further away from the Kharkar drainage basin will be targeted for passive and active AMD remediation and prevention measures. Long-term water quality restoration activities will include:

- **Continued implementation of restoration/remediation/prevention measures** at sites in more remote and/or less impactful to Kharkar Drainage. Remediation measures will be same as listed above, based on individual site characteristics.
- **Stakeholder engagement**: Continue collaboration with the mining community and local and State governments to plan a combined approach to AMD minimization and prevention integrating all techniques listed above, as based on each mine site's characteristics and degree of contamination.
- **Ensure ongoing acid-neutral discharge** by instituting environmentally sound mining best practices, and ultimately mine worker safety and best practices. These include acid-producing rock encapsulation and isolation methods for waste rock, coal storage and transport practices that prevent exposure to precipitation and surface water, AMD prevention by surface water drainage control on site and reducing environmental degradation by resurfacing and re-vegetating disturbed areas. Open pits must be backfilled while mining, or post-mining, to the extent possible to reduce impacts to ground and surface water.
- **Coordinate with Meghalaya Government** to monitor rathole mining areas to ensure that mining is NOT occurring, as per State Law. If mining is occurring, instituted mandated best practices and activate AMD prevention measures as listed above.
- **Long-Term Regional Monitoring** of Kharkar and Upper Kopili Drainage basins to collect water quality data and information for use in scientific and technical study as well as ensuring restoration of riverine and riparian ecological health.

137. An outline of short-term mitigation, long-term remediation, and regional land-management and restoration measures is provided below.

7.3 Stakeholder Engagement and Regional Site Inventory

138. The goal of the Water Quality Restoration Plan and Mitigation Plan is to restore mined land areas to pre-mining conditions to promote original land use activities including: agriculture, horticulture, forestry, ranching, fisheries, etc. Stakeholder participation is mandatory to ensure this goal is attained. There are three outcomes needed from Stakeholder engagement to allow the Mitigation Plan to proceed smoothly. They are:

i. Educate Stakeholders and the residents of mining areas affected by AMD
ii. Permission to access rathole mine areas
iii. Solicit participation in site remediation process and land restoration

139. The stakeholder process began with an educational session held near Shillong,

Meghalaya on October 7, 2017. A State level consultation workshop was organized to disseminate and discuss findings of the SEA. The participants involved key stakeholders from Assam and Meghalaya State as well as representatives from ADB and Central Government agencies. During this initial workshop, experts provided basic information on how AMD forms, how rathole mining practices exacerbates AMD formation, and how remedial action and preventative measures can be put in place to reduce and eventually reverse acid-production. Stakeholders were informed about how the regional mine site inventory might be undertaken and participation and permission would be solicited from Stakeholders, as discussed below.

7.3.1 Stakeholder Engagement

140. All remedial options and planning can only be implemented if access to the rathole mining areas in Meghalaya is obtained. Stakeholder discussions and engagement must continue with ongoing meetings to include the essential participation of Meghalaya government representatives and landowners managing rathole mining activities. It is imperative to the successful outcome of this project that NEEPCO, the governance of Meghalaya and Assam States and mined land owners participate in public education, data collection, scope determination and remedial planning and implementation of a focused water quality restoration and mitigation plan. A detailed outline of the proposed Stakeholder engagement process for the WQRP component is included in Attachment 3. An overview of ongoing Stakeholder engagement process is discussed below:

141. The Stakeholder engagement process will include the following components:

- **Site Access** - The passive remedial systems listed in Section 4 rely on site access, including as many of the operational and abandoned rathole mines as possible. Mining operation best management can and should be instituted, if possible, with education, organization and coordination efforts being paramount to successful revision of mine waste handling and AMD production abatement.
- **Stakeholder Educational Seminar** – Concurrent with obtaining site access agreements, all Stakeholders will be given an educational seminar on the formation of AMD, the effects of AMD contamination in the mined lands and in surface waters downstream, including the Kopili River. The educational process will evolve to an overview and instruction on how to instill preventative measures to prevent AMD formation and to restore healthy ecosystems.
- **Best Practices for Mining Operations** – A detailed plan to develop and implement feasible best management practices (BMPs) for mining operations including mine water management and storage, proper waste rock storage and mine pit abandonment techniques, is necessary as part of a robust plan to reduce and ultimately eliminate deleterious effects of rathole mining activities. Preventative planning and measures will be provided to landowners for implementation. Worker health and safety best practices should also be implemented to protect the lives and livelihood of the mine-workers. This will require the assent of Meghalaya environmental and Health and Safety governmental departments. A preliminary detailed outline of an Environmental Awareness Plan is included in Attachment 4.

7.3.2 Kharkar Basin Site Inventory and Site Characterization

142. To facilitate Steps 2 and 3 of the Mitigation Plan, a robust mine site inventory, including a field mapping effort must be conducted. The results of this effort to determine the locations of active and abandoned rathole mines within the Kharkar River Catchment, discharge flows

and qualities will be used to diagnose the degree of contamination emitted from each mining area and which AMD treatment alternative can best be implemented. This work can be done in combination with aerial photography, Google Earth Imagery, Meghalaya State Coal Company and Government official documentation. The largest pits nearest to Kharkar tributaries and those that are actively contributing to those tributaries should be identified and characterized as a precursor to AMD discharge control planning and to design remedial strategies for each site.

143. As access to Kharkar Basin mine sites is granted, the mine site inventory started in Jaintia Hills in July 2017 should be continued using the list of site inventory details included in Attachment 2. As the inventory progresses, each site will be evaluated based on field water quality data, pH, discharge water flow, distance from the Kharkar River, and overall acceptability for passive drainage. Each site will have a proposed remedial action plan (RAP) developed. Implementation of each RAP will be dependent on-site access, landowner approval and participation and available funding.

144. The best way to conduct robust AMD remediation is to identify and characterize the source areas in the rathole mining areas of Meghalaya State. Highlights of the technical approach are listed below. Results of data collection and evaluation will be categorized while initiating mitigation and RAP activities on a mine site-by-mine site basis:

- **Rathole Mine Site Identification and Mapping** - Mapped location of all rathole mines in the Kharkar catchment area. Mines should be identified as "active" or "abandoned". If possible, surface drainages from these areas to the Kharkar River should be identified and mapped.
- **Rathole Minesite Characterization** – Rathole mines and pits identified as being closest to surface water drainage, and those that contribute the highest quantities of AMD-affected water into the surface water drainage will be identified and characterized. Data to be collected and collated include pit depth and dimensions, coal seam dimensions, depth to groundwater, groundwater pumping rates, and analytical results of pit rock and water samples.
- **Contaminant-generation ranking** - Mine sites will be ranked by the degree to which they are actively contributing AMD to the Kharkar drainage. Ranking will be made by volume and pH of discharge, active flow off-site and proximity to the Kharkar River.
- **Passive Remedial Treatment System Evaluation** - On-site investigation to identify best areas for installation of ALDs/OLDs and/or wetlands for passive treatment will occur either when the initial mine site inspection is made, or as a result of the site evaluation process. Site photos, maps and sketches will allow RAP managers to develop a remedial strategy for each site which will allow the WQRP Team and Stakeholders to plan, schedule and cost RAP activities.

145. Field identification and characterization of rathole mines should begin with mines closest to the Kharkar River above the confluence with the Kopili River, then work inland along all tributaries identified as contributing acidity to the Kharkar. A compilation of field data can be tallied using the table contained in Attachment 2.

7.4 Short-Term Active Mitigation Measures

146. Active mitigation is dependent on obtaining access to the mining areas adjacent and contributing AMD to the Kharkar River drainage. Active and immediate mitigation efforts will aim to provide physical isolation and barriers to either prevent or curtail AMD as quickly as possible as access to each mine site becomes available. Active mitigation methods

(previously discussed in Section 4) include:

- **Field identification** of highest concentrations of AMD discharge draining into Kharkar River
- **Construction of stormwater diversion channels** to divert clean water from AMD sources
- **Application of limestone gravel or powder** to neutralize existing AMD
- **Construct AMD discharge holding ponds** for evaporative purposes
- **Capping waste rock piles** with actively leaching AMD using alkalinity-producing covers and other earthworks to isolate pyritic material from contact with precipitation and surface water. Specific soil cover construction details are detailed below.
- **Backfilling abandoned pits** to isolate groundwater from AMD-producing rock in the pit walls and floor
- **Shotcreting pit walls** that are actively leaching AMD and that cannot be covered/isolated by backfilling. This entails spraying pit walls with liquid concrete to both isolate and neutralize AMD leachate forming on pit walls.
- **Revise coal storage and transport areas t**o minimize contact with precipitation and surface water sources

7.5 Long-Term Mine Water Remediation and Mine Closure

147. Passive remedial technology can be applied at low cost to provide a minimal-care water quality restoration device allowing influx of pH-nneutral surface water in the catchment; and ongoing minimal monitoring and maintenance at sites that are 1) more accessible, 2) have high AMD discharge and 3) have cooperative landowners who will take responsibility for maintenance and monitoring. Passive treatment will be initiated as follows:

- **AMD source areas** must be identified and characterized for local geochemistry, drainage flow and volumes and topographic conditions
- **Landowners** will be involved in site remediation/mitigation planning processes to maximize stakeholder cooperation and ownership in managing active and passive treatment system installation, operation and monitoring, thus ensuring increased land restoration success. Each site's topography and layout will be evaluated for locating passive and active treatment and mine site-specific plans will be designed for each site.
- **Targeted high AMD discharge areas** for priority in initiating remedial activities to maximize pH restoration in Kharkar drainage.
- **Results of the pilot study** will be used to confirm the degree to which oxic and anoxic limestone drains (OLD/ALD) are effective for long-term treatment of AMD drainage from active and abandoned rathole mining areas. Passive treatment is best suited to sites with low acidity and low flow rates so must be carefully designed to incorporate monsoon conditions.
- Once enough data is collected from the pilot study, a **site-wide mitigation plan** can be developed to target sites amenable to AMD/OLD treatment.
- **Monsoon conditions must be characterized** to determine optimal management of discharge flow increases and AMD migration.
- **Interim AMD management strategies** including the use of short-term waste rock and coal storage and management techniques to reduce contact with precipitation

and surface water.

- **Construct wetlands areas** to collect and precipitate treated AMD as well as minimally-affected mine discharge water. Wetlands areas can be constructed in riparian areas alongside any AMD-affected drainage into the Kharkar River. These wetland areas should be tiered in design to allow for monsoon flow conditions.

7.6 Mined Land Restoration

148. Restoration of mined land is the last step in the remedial process. Once discharge water is pH neutral, and all mining waste and pits have been reclaimed, surface soil restoration and revegetation can be initiated. The goal of mined land restoration processes is to return the land to pre-mining ecosystems to the extent possible. Long-term land restoration involves re-establishing vegetation appropriate and amenable to the remediated area and providing long-term care to the area to ensure establishment of a self-sustaining and healthy environment that no longer contributes contaminants to the surface water system.

149. Ongoing and active collaboration with landowners, communities and local governments to integrate restoration efforts with pre-mining land uses that allow healthy economic development and sustainability. Pre-mining land uses will be identified and recommended for each remediated area, and may include agriculture, horticulture, forestry and fisheries restoration in the Kharkar and Kopili Rivers.

150. Once mining is complete, the mined lands are restored to create rangeland, prime farmland, wildlife refuges, horticultural areas, wetlands, or recreation areas. Land restoration may require assistance from local experts including engineers, biologists, hydrologists, range scientists, and other environmental experts to return the land to productive use.

151. The long-term goal of restoring healthy pre-mining vegetation with concurrent and stable economic sustainability will provide the most robust long-term solution to the current increase in rathole mining activity in the upper reaches of the Kharkar Catchment.

8. REFERENCES

- Bandyopadhyay, KP., S. Sekar, S. Rajakrishnan and J. K. Angami, 2009. Investigation for Limestone in Um-Maju Block, West of Litang River, Jaintia Hills, Meghalaya, (E-II Stage) Final Report for the Field Seasons 2003-2004 and 2004- 2005. Meghalaya Mineral Investigation Project, Geological Survey of India, Northeastern Region, Shillong.
- Chabukdhara, Mayuri and O. P. Singh. 2016. “Coal Mining in Northeast India: An Overview of Environmental Issues and Treatment Approaches”. International Journal Coal Science and Technology 3(2):87–96
- Christensen, E. 2005 Assessment, Water-Quality Trends, and Options for Remediation of Acidic Drainage from Abandoned Coal Mines Near Huntsville, Missouri, 2003—2004. United States Geological Survey Scientific Investigations Report 2005-5202.
- Cravotta, C. 1998. Oxic Limestone Drains For Treatment of Dilute, Acidic Mine Drainage. Paper presented at the Annual Symposium of the West Virginia Surface Mine Drainage Task Force, April 7-8,1998
- Groundwater Information Booklet, Jaintia Hills District, Meghalaya, Government of India, Ministry of Water Resources, Central Groundwater Board, Technical Report Series: No: 49/2011-12 Dhttp://cgwb.gov.in/NEW/District_Profile/Meghalaya/Jaintia.pdf
- Freeze, A and J. Cherry, 1979. Groundwater. Prentice-Hall, Inc. Publishers.
- Gusek, J., and T. Wildman, 2002. Passive Treatment 101: An Overview of the Technologies, A New Millennium of Passive Treatment Of Acid Rock Drainage: Advances In Design And Construction Since 1988. Proceedings America Society of Mining and Reclamation, 2002 pp 935-952 DOI:10.21000/JASMR02010935
- Hedin, R., Watzlaf, G. and Nairn, R. 1994. Passive Treatment of Acid Mine Drainage with Limestone, Published in J. Environ. Qual. 23:1338-1345 (1994).
- Hedin, R. and R. Nairn, 2015. Designing and Sizing Passive Mine Drainage Treatment Systems, U.S. Bureau of Mines, Pittsburgh Research Center
- Mukhopadhyay, Lekha (2013). “Sustainable Development - A Path Dependent Analysis to the Rathole Coal Mining in Jaintia Hills District, India”. Indian Society for Ecological Economics (INSEE) Global Change, Ecosystems, Sustainability. Seventh Biennial Conference
- Mine Environment Neutral Drainage, MEND, 1996. Evaluation of Field-Scale Application of a Shotcrete Cover on Acid Generating Rock. MEND Project 2.34.1.
- Mine Environmental Neutral Drainage (MEND) Program, 2004. Review of Passive Systems For Treatment Of Acid Mine Drainage, Nedem, Gard Guide (Global Acid Rock Drainage Guide).
- PIRAMID Consortium, 2003. Engineering Guidelines for the Passive Remediation of Acidic and/or Metalliferous Mine Drainage and Similar Wastewaters, A Research Project of the European Commission 5th Framework Programme (Key Action 1: Sustainable Management and Quality of Water) Contract Number EVK1-CT-1999- 000021.
- Sarma, K (2005). “Impact of coal mining on vegetation: a case study in Jaintia district of Meghalaya, India” Thesis submitted to the International Institute for Geo- Information Science and Earth Science (ITC).
- Sarma, K., Tripathi, R.S. and S.P.S. Kushwaha, (2010). “Land use/land cover change analysis in coal mine affected areas in Jaintia Hills district of Meghalaya, northeast

India using remote sensing and GIS technique." Indian Journal of Tropical Biodiversity, 16(1), 43-50.

- Sharma, P, Sameer Vyas, Sharma S., Mahure N., Anil Rustagi, Sivakumar, Murari Ratnam. (2011). "Acid mine discharge – Challenges met in a hydro power project". International Journal of Environmental Sciences Volume 1, No 6, 2011
- Singh G, Sinha DK (1992). "The problem of acid mine drainage its occurrence and effects". Proceedings of Environment Management of Mining Operations, Department of Environment and Forest Government of India, pp 156–167
- Skousen J, Sexstone A and Ziemkiewicz,PF. 2000. Acid mine drainage treatment and control, in: Barnhisle R, Daniels W and Darmody R (eds). Reclamation of Drastically Disturbed Lands. American Society of Agronomy. Madison, WI. pp. 131— 168.
- Skousen, J. 2003. Anoxic Limestone Drains for Acid Mine Drainage Treatment. Greendlands, ALD- 91.
- Skousen, J., Zipper, C., Rose, A., Ziemkiewicz P., Nairn, R., Mcdonald L., Kleinmann, R., 2016. Review of Passive Systems for Acid Mine Drainage Treatment. Mine Water and the Environment. . 10.1007/s10230-016-0417-1.
- Skousen,J., Zipper, C., Rose, A., Ziemkiewicz P., Nairn, R., Mcdonald L., Kleinmann, R., 2017. Review of Passive Systems for Acid Mine Drainage Treatment, Mine Water and the Environment, March 2017, Volume 36, Issue 1, pp 133–153
- Swer, Sumarlin and O.P. Singh 2003 "Coal Mining Impacting Water Quality and Aquatic Biodiversity in Jaintia Hills District of Meghalaya". ENVIS Bulletin Vol 11(2) : Himalayan Ecology
- Taylor, J., Pape, S. and Murphy, N. 2005. A Summary of Passive and Active Treatment Technologies for Acid and Metalliferous Drainage (AMD) Prepared for the Australian Centre for Minerals Extension and Research (ACMER). Fifth Australian Workshop on Acid Drainage 29-31 AUGUST 2005, Freemantle, Australia
- Trumm, D. 2010. Selection of active and passive treatment systems for AMD—flow charts for New Zealand conditions, New Zealand Journal of Geology and Geophysics, 53:2-3, 195-210, DOI: 1 C. Zipper, Extension Specialist, Crop and Soil Environmental Sciences, Virginia Tech
- Wildeman, T., J. Gusek, J. Dietz and S. Morea. 1991. Handbook for Constructed Wetlands Receiving Acid Mine Drainage. US EPA, Cincinnati, OH.

  Watzlaf, G. R. and R. S. Hedin. 1993. A method for predicting the alkalinity generated by anoxic limestone drains. In Proceedings of the 14th Annual West Virginia Surface Mine Drainage Task Force Symposium. WV Univ., Morgantown, WV.
- Zipper, C. J. Skousen and C. Jage, 2011. Passive Treatment of Acid-Mine Drainage. Powell River Project, Reclamation Guidelines for Surface Mined Land. Virginia Cooperative Extension, PUBLICATION 460-133.

ATTACHMENT 1: Site Characterization Report Summary

This Attachment presents a summary of the outcome of technical research and data collection processes (both existing data and field data collection) to characterize surface water quality and hydrology in the Kopili and Kharkar Catchments as contained in full in the Site Characterization Report, August 2017.

The work was conducted as below:

1) **Existing Data Collection**
2) **On-Site Data collection and analysis**
3) **Review Regulatory Framework for Surface Water Quality**
4) **Prepare Kopili and Kharkar River Catchment**
5) **Catchment Basin Characterization**

The site characterization work, including identifying and locating sources of AMD, was conducted in both the Kopili and Kharkar River Catchment areas. We have preliminarily identified rathole mining areas, including pits and waste rock dumps, and tributaries into the Kharkar River which may be affected by AMD. The Report compiles existing data and information and the limited field data collected in January 2017 as well as a limited mine site inventory in the Jaintia Hills area of Meghalaya in July 2017,

Upstream rathole coal mining areas are generating acid mine drainage (AMD) which has significantly deteriorated water quality and aquatic ecology in the Kopili River. The AMD pollution from upstream rathole coal mining should be considered a cumulative impact when considered in conjunction with the water quality impacts anticipated to be generated directly by the proposed LKHEP. The LKHEP water quality impacts are described in detail in the WAPCOS EIA and the ADB EIA for the LKHEP project.

Rathole coal mining upstream of the KHP project in Assam and especially Meghalaya State does not appear to be abating and, while there is a legal battle ongoing over the cessation of rathole coal mining in the state, no remedial efforts are currently underway or planned to manage and mitigate rathole mining in Meghalaya. Therefore, the safe assumption is that AMD pollution will continue to occur and possibly increase, with the only relief possibly coming in the form of dilution during the annual monsoon season, although this has not been the case in the Umrong and Khandong Reservoirs, where pH remains consistently low through monsoon season.

Water Quality - The pH measurements obtained from NEEPCO for the Khandong and Umrong Reservoirs for the period 2007-2015 indicate that pH ranges between 3 and 5 with little to no seasonal variation. Water quality in the lower Kopili does vary seasonally, due to influx of precipitation during monsoon rains. The pH in the Lower Kopili Project Area varies between from 3.2 to 5.2 (WAPCOS EIA). There inadequate data to evaluate seasonal variations in Upper Kopili and Kharkar Rivers, or whether pH levels are trending down due to increasing rathole mining activity.

General Water Quality – Other than low pH, there are no major sources of pollution loading in the basin. The catchment has low population density and little agricultural activity. Other than rathole mining there are no other industrial sources of contaminant discharge into the Kopili drainage other than total suspended solids.

Kharkar River - The Kharkar River drains the Jaintia Hills District of east Meghalaya State. The topography of the district is composed of undulating hilly landscapes dissected by numerous rivers and streams, many draining to the Kharkar River. On the northern and western borders, these hills take the form of north- south trending hilly ranges, and ranging two to three thousand feet in height.

The drainage system of the district is controlled by topography. Broadly, there are mainly two watersheds in the district, one river flowing in the northern direction toward the Brahmaputra and the other in the south, towards the Surma valley in Bangladesh. The drainage pattern is sub parallel to parallel and is controlled by joints and faults as indicated by the straight courses of the rivers and streams with deep gorges.

The Kharkar River is the main contributor of low-pH surface water into the Upper Kopili River. Previous investigations, including a brief trip to the confluence of the Kharkar River and Kopili River in January 2017 (ES Safeguards Interim Report, February 2017) confirmed the low-pH conditions. Extremely limited access to the Kharkar Valley precluded collection of any additional data from the site. The data and information available for the Kharkar River has been evaluated in this section to give a preliminary assessment of Kharkar River flows and quality.

Kharkar River discharge has been estimated by extrapolating Kopili River discharge data, catchment area of LKHP dam site and Kharkar River catchment areas. Based on last 18 years' discharge data (from Year 1999-2016), the annual mean Kharkar River discharge is estimated at 21.49 Cumecs. Variation in estimated monthly maximum, minimum and average discharge for the Kharkar River is summarized in the table A-1 below.

Table A-1: Estimated Discharge Data of Kharkar River

Months	Monthly Maximum	Monthly Minimum	Monthly Mean
Jan	12.19	7.39	9.69
Feb	11.72	6.38	8.51
Mar	13.78	6.33	7.92
Apr	18.67	7.67	11.28
May	42.44	11.82	18.77
Jun	84.90	17.20	35.93
Jul	111.14	20.71	40.74
Aug	99.86	20.85	35.08
Sep	61.09	21.33	32.70
Oct	55.05	18.23	26.40
Nov	27.08	12.58	18.34
Dec	16.40	9.70	12.56
Annual Mean (Cumecs) Cubic Meter/Sec.			21.49

Hydrogeology: The Ground Water Information Booklet, Jaintia Hills District, Meghalaya reports the following information on groundwater:

- Hydrogeologically, the district can be divided into three units, namely consolidated, semi consolidated and unconsolidated formations.
- The major water bearing formation in the Jaintia Hills District occurs in Tertiary sedimentary rocks, including sandstones and shales and alluvium valley fill deposits.
- Depth to Water Level: Pre-monsoon depth to water level during 2011 - 0.77 to 2.86m below ground level (bgl); Post-monsoon during 2011 - 0.57 to 1.40 m bgl; long term water level trend in 10 years (2001 – 2010) in m/yr - 0.186 to 0.26 m rise in post-monsoon
- Ground water occurs under both unconfined and semi-confined conditions in the hard rocks controlled mostly by topography and secondary porosities of weathered residuum and in joints and fractures.
- Groundwater quality - Higher concentration of Fe is observed in few pockets in deeper aquifer of the district (higher than permissible limit prescribed by Bureau of Indian Standards (BIS), World Health Organization).
- Management and utilization of Groundwater. Coal mining, limestone quarries and cement factories affecting the water quality and the environment particularly the water bodies.

The entire coal mining area of the Jaintia hills has become full of mine pits and caves. These open, unfilled pits allow surface water percolation into the aquifer systems. As a result, not only is surface water disappearing, groundwater quality is most likely being degraded also. Groundwater impacts are twofold: degradation due to infiltration of contaminated surface water, and contact of groundwater with air and exposed pit wall rock containing sulfidic minerals, causing sulfuric acid to form and percolate into the aquifer. Ground caving and subsistence of land due to underground mining is also impacting surface and groundwater quality and availability, the extent to which is not yet known.

As a result of disappearing and/or contaminated surface water, and degradation of groundwater resources, the area is facing an acute shortage of clean drinking and irrigation water.

Rathole Mining – Location and Extent - Over 10,000 rathole mines, active and abandoned, have been identified in Meghalaya State. These open-pit, mostly hand-dug mines using pressure wash and hydraulic hoisting methods to extract coal, are the source of acidity in the Kharkar River. The mining activities in Jaintia hills district are small scale ventures controlled by individuals who own the land. Coal extraction is done by primitive surface mining methods, or rathole mining where the land is first cleared by removing ground vegetation and then digging pits ranging from 5 to 100 m^2 to reach the coal seam. Tunnels are then excavated into the seam to extract coal which is removed from the pit in a conical basket or a wheel barrow and then taken out and dumped on nearby storage area. The coal is carried by trucks to the larger storage areas near highways for export. Entire road sides in and around mining areas are used for coal stockpiling, which is major source of air, water and soil pollution. Off road movement of trucks and other vehicles in the area causes further damage to the ecology of the area. Thus, a large area of the land is spoiled and denuded of vegetal cover not only by mining but also by dumping and storage of coal and associated vehicular movement.

The majority of rathole mining occurs in the Jaintia hills districts of Meghalaya, lies between latitude 25°5'N to25°4'N and longitude 91°51'E to 92°45'E. The district is bound by the state of Assam on the north and east, the East Khasi Hills on the west and Bangladesh in the south. The district covers an area of 3819 km^2 constituting 17.03% of the total area of the state. The topography of the district is composed of undulating hilly landscapes dissected by numerous rivers and streams. Jaintia hills is a part of the Meghalaya plateau which composed of rocks belonging to the age group of Archean and tertiary period represented by granites, phyllite, gneiss, sandstone and limestone (Swer and Singh, 2003).

Due to narrow nature of the coal seam in this area, large scale mining is not economically profitable. Landowners property rights give them the freedom to extract the coal from their property without using environmental or safety best management practices. As a result, tribal community land has been gradually privatized to reap the immediate benefit from mining without no concern for the long term environmental consequences. Economically, landowners compete to extract their coal as rapidly and as completely as possible in order to gain market value. Rathole mining was declared rathole in 2012, however mining is still occurring and it is reported that the government collects revenue in the form of royalty and transport tax from mine owners (Mukhopadhyay 2013).

The Jaintial hills district of Meghalaya is a major coal producing area with an estimated coal reserve of about 40 million tonnes. Sutnga, Lakadong, Musiang-Lamare, Khilehriat, Ioksi, Ladrymbai, Rymbai, Byrwai, Chyrmang, Bapung, Jarain, Shkentalang, Lumshnong, Sakynphor etc. are the main coal bearing areas of the district. The coal seams varying from 30 to 212 cm in thickness occur imbedded in sedimentary rocks, sandstones and shale of the Eocene age (Chabukdhara and Singh, 2016). The main characteristics of the coal found in Jaintia hills are its low ash content, high volatile matter, high calorific value and comparatively high sulphur content. The coal is mostly sub-bituminous in character. The physical properties characterize the coal of Jaintia hills district as hard, lumpy bright and jointed except for the coal in Jarain which is both soft and hard in nature. Composition of the coal revealed by chemical analysis indicates moisture content between 0.4% to 9.2%, ash content between 1.3% to 24.7%, and Sulphur content between 2.7% to 5.0%. The calorific value ranges from 5,694 to 8230 kilo calories/Kilogram (Directorate of Mineral Resources, 1985).

During recent years, rathole coal mining in the area has resulted in soil erosion, scarcity of water, pollution of air, water and soil, reduced soil fertility and loss of biodiversity (Das Gupta et. al., 2002). Continued soil acidification due to acid mine drainage and release of excess metals including Al, Fe, Mn, Cu have caused enormous damage to plant biodiversity in this area (Sarma, 2005). Due to mining-induced changes in land use pattern and soil pollution the area of fallow land has steadily increased. Between 1975 and 2007, there has been decrease in forest area by 12.5%, while area under mining has increased three-fold (Sarma et.al, 2010). Thirty one percent of the land Jaintia district has been made barren due to coal mine contamination, the highest of all districts in Meghalaya (Mukhopadhyay 2013). The entire Jaintia hills area has become infested with coal mine pits and caves. These open, unfilled pits allow surface water percolation into the groundwater. As a result, smaller streams and rivers of the area are either completely disappearing or becoming seasonal. Consequently, the area is facing acute shortage of clean drinking and irrigation water. Besides, a vast area has become physically disfigured due to haphazard dumping of overburden and mined coal, and caving in of the ground and subsistence of land (Swer and O.P. Singh, 2003).

Numeric minimum, maximum and average dimensions of salient mine area features needed to design a conceptual mitigation plan are included in Table A-2. Note that all mine discharge areas but one had acidic pH. Discharges for winter, rainy and dry seasons are included as well to incorporate monsoon discharge remediation design into the overall mitigation strategy.

Discharge water samples were collected from six locations and results of analysis are included in Table A-3.

Table A-2: Mine Site Inventory Summary

		Min	Max	Average
Pit Dimensions (meters)	Pit Radius	1.5	8	6.2
	Pit Depth	4	52	30.3
Coal Seam (meters)	Coal Seam	3	50	28
	Pit Depth	0.25	1.2	0.71
Coal Storage (m3)		300	10,000	5998
Overburden	Height	2	4	2.7
	Area (meters)	10	100	66.7
Water Discharge (l/day)	Winter	1120	20,150	5544
	Summer	0	13,700	3796
	Rain	0	5,400	1541
Discharge Quality	pH	2.4	6.8	3.2

Table A-3: Jaintia Hills Coal Mine Discharge Analytical Results August 2107

Sampling location	#1 Sohkymphor	#2 Sohkymphor	#3 Moopala	#4 Moopala	#5 Tulh	#6 Tulh
Sampling date	7/30/2017	7/30/2017	7/30/2017	7/30/2017	7/30/2017	7/30/2017
Lab pH	3.3	3.7	2.4	2.6	2.2	2.5
Lab EC	80	180	270	280	630	400
Total Solids (mg/L)	55	142	190	196	494	279
Total Suspended Solids TSS (mg/L)	62	83	112	110	144	121
Acidity (as $CaCO_3$)	32	44	46	48	52	44
Total Alkalinity as $CaCO_3$ (mg/L)	55	96	130	136	320	222
Chloride (mg/L)	16	28	42.5	44.2	180	110

Sampling location	#1 Sohkymphor	#2 Sohkymphor	#3 Moopala	#4 Moopala	#5 Tulh	#6 Tulh
Sulfide (mg/L)	0.2	0.45	0.28	0.72	0.75	0.39
Sulfates (SO_4) (mg/L)	18	34	36	32.2	68.8	52.7
Total Al (mg/L)	0.08	0.09	0.11	0.13	0.15	0.11
Total Mn (mg/L)	0.12	0.21	0.22	0.28	0.26	0.24
Total Fe (mg/L)	1.23	1.91	2.14	2.67	6.2	5.12
Ferric Iron -Fe^{3+} (mg/L)	0.623	1.22	1.1	1.48	4.21	3.1
Ferrous Fe (Fe2+) (mg/L)	**0.607**	**0.69**	**1.04**	**1.19**	**1.99**	**2.02**
Ca as CaCO3 (mg/L)	**12.8**	**22.4**	**28.8**	**29.6**	**67.2**	**48.8**
Mg (as CaCO3) (mg/L)	**6.3**	**12**	**15.6**	**18**	**36**	**26**
Organic Content (mg/L)	**2.8**	**3.1**	**3.4**	**3.3**	**6.8**	**5.2**
Inorganic content (mg/L)	**12.8**	**15.2**	**16.2**	**12.8**	**70.4**	**54.7**

AMD Formation and Transport- Coal mining can result in drainages that have a low pH and are contaminated with elevated concentrations of iron, manganese, aluminum, sulfate, and acidity. The rate and direction of water movement through abandoned mines can be influenced by factors that include precipitation, the structure of the mined coal beds, overburden structure, mine tunnels, air shafts, boreholes, and local collapses. When an underground or open pit mine is abandoned, water levels rise until the water eventually overflows to another mine or at the land surface creating an abandoned mine discharge.

Mine drainage from abandoned mines and coal refuse piles is the major source of water-quality degradation in the Kharkar River, which in turn degrades water quality in the Kopili River to which it drains. It can be assumed, based on the preponderance and geographic spread of open pits in the Kharkar Basin, that at least the lower half the river and many of its tributaries are currently affected by mine drainage. Note that the Kharkar River is the northeastern-most river draining into Assam District. The confluence of the Kharkar River with Kopili River is just where the Kharkar River crosses the Meghalaya border.

Natural processes commonly ameliorate mine discharges and the toxic characteristics of the discharges can decrease because of chemical and biological reactions and by dilution with uncontaminated water. Many of these processes occur as the mine discharge flows on the land surface and is exposed to the air. Comparison of analytical results for sulfates, sulfide, Fe and other parameters for samples taken in January 2017 from the Kharkar River and the Kopili River up and downstream, are shown below in Figure A-1. The sample results are arranged from most upstream (Kopili at confluence) to most downstream (LKHEP dam axis) to evaluate the effects of the Kharkar River input and water chemistry change with distance from the confluence.

Figure A-1: Bar Chart for comparison of water samples taken in January 2017

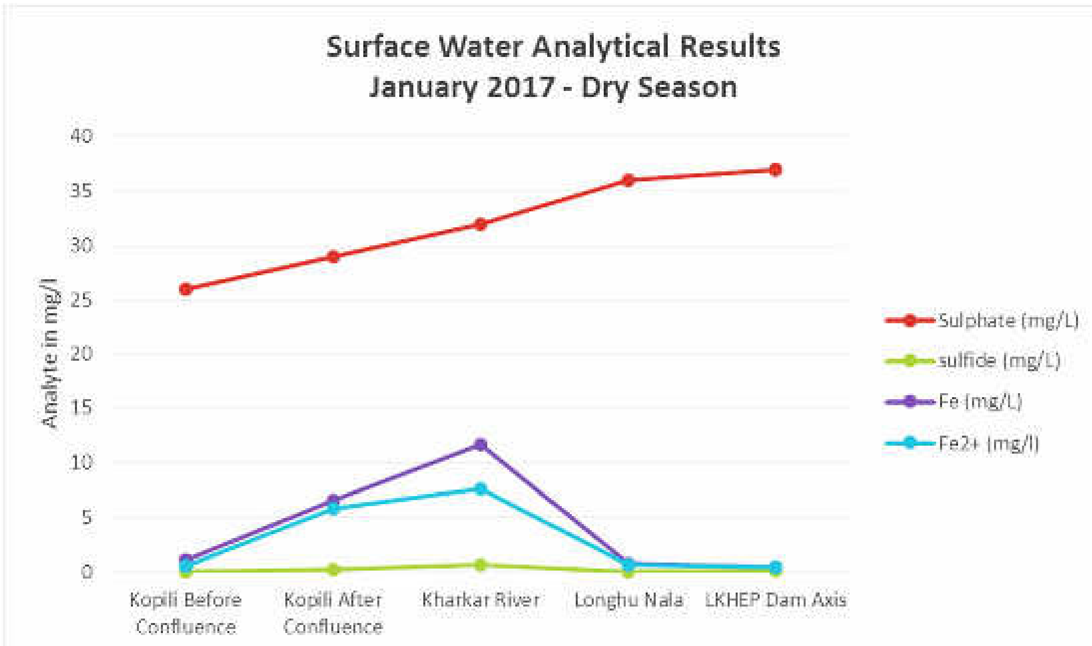
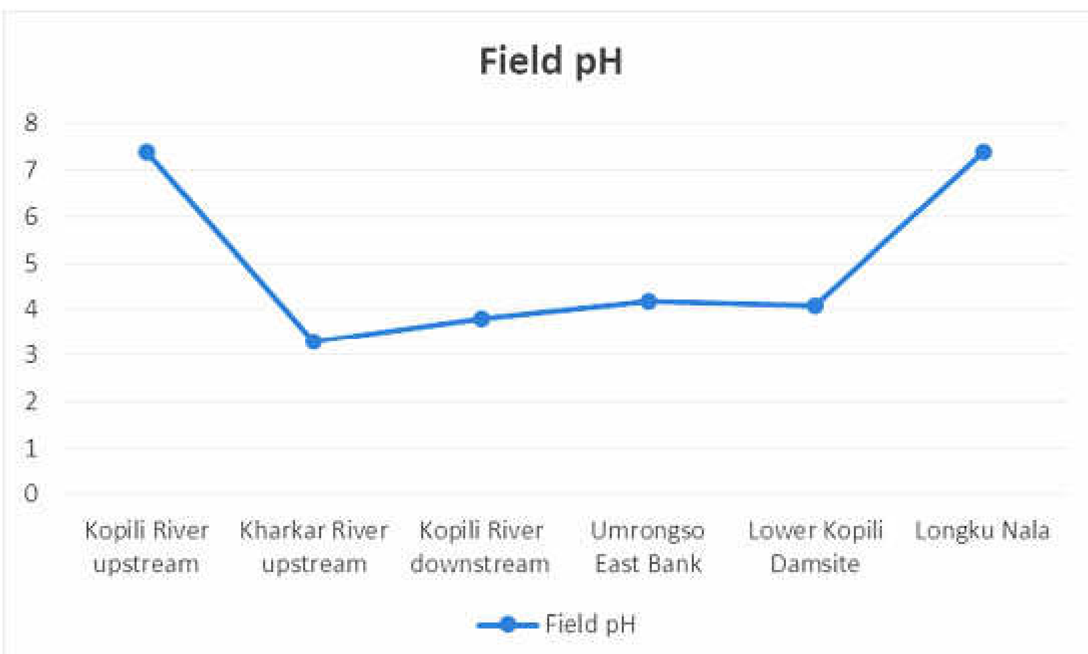


Figure A-2: Bar chart presenting field pH values



It is readily apparent that degraded surface water from Kharkar River impacts water quality in the Kopili River. Sulfate values increase downstream from the confluence, as do metals values. Figure A-2 provides a graph of pH values from the field. pH in the Upper Kopili River is 7.4 then drops to 3.8 after mixing with Kharkar River water, which has a pH of 3.3. Longku Nala is a tributary to the Kopili River below the damsite and is not affected by mining activities as indicated by a normal pH of 7.4. The Kharkar River transports moderate amounts of iron in solution. As discussed in the Interim Report (April 2017) the mixing zone at the confluence of the Kharkar and Kopili Rivers causes iron to oxidize and flocculate causing the yellowish sediment which then collects along the river banks and settles to the river bottoms in low-flow season.

ATTACHMENT 2: Proposed Work Plan - Mine Site Inventory and Characterization

The key tasks involved in completing Deliverable 4 – the WATER QUALITY RESTORATION PLAN FOR KOPILI RIVER, have been updated in response to evaluation of data and information collected during the Interim Phase of the SEA. The updated Work Plan will include data and information requirements for completing the three Options for AMD on-site minimization and remediation listed above.

Task 1: Site Characterization - Data Collection and Analysis in the Kharkar River Area

The main objective of this task is to identify the extent of acid mine drainage affecting the Kharkar River. This site characterization work, including identifying and location sources of acid mine drainage will be conducted in the Kharkar River Catchment area. Assessment will include identification of rathole mining areas, including pits and waste rock dumps, and tributaries into the Kharkar River which may be affected by AMD. The key methodological steps involved:

- Conduct field reconnaissance to identify AMD source areas and determine distance from acid drainage source to drainages and ultimately into the Kharkar River. Fill out a Site Survey Inventory Form for each site as shown in Table A-1.
- Identify drainages and data collection and discharge sampling points for conducting sampling during both dry and monsoon seasons, if possible.
- Finalize the Field Sampling Plan to include: sample locations, analytical parameters, surface water sampling procedures, sample labelling, shipping and packaging, and field documentation.
- Water quality sampling and analysis– pH, conductivity, metals (Fe, Mn, Mg, Al), sulfur (sulfide, sulfate), total dissolved solids, acidity, alkalinity and dissolved oxygen (DO).
- Drainage basin dimensions (catchment area) for the Kharkar River and its tributaries which have been identified as carrying AMD-laden water.
- Topography and drainage gradients within each basing for use in ALD/OLD design passive wetlands and holding ponds.
- Surface geology for the Kharkar Catchment for use in determining suitable passive and active AMD treatment structures.
- Precipitation data and flow rates (minimum, maximum) from Meghalaya State, if available.
- Acid Mine Drainage Source Area – Identify and characterize the most severe AMD source areas including acid rock dump locations, size and volumes, and mine water discharge quantities.
- Identify local sources of limestone, waste rock pile cover material, organic matter, piping, labor and equipment.

- Characterize geochemical properties of limestone sources to determine adequacy for alkalinity generation and optimal rock size in drain placement as needed.

Task 2: Field Sampling Plan:

The field sampling plan consists of the following components:

1) Water sampling: sample collection methods, QA/QC, record-keeping, shipping and laboratory analysis
   Field parameters: pH, EC, DO, temperature
   Laboratory analytes: Fe, Ca, Ni, Al, Mg, Mn, Cu, Zn. Cations, anions
   Waste Rock sampling: chemical composition (whole rock and elemental analysis), mineralogical analysis
   acid base accounting (ABA)
   net acid generation (NAG)
   water extraction (batch extraction) tests - with solution assay
2) Meteorological data collection – set up precipitation collection station if necessary
3) Flow rate collection methods – set up weirs or alternatives
4) Waste rock collection methods and analysis for pH and metals content

152.Optimization of ALD/OLDs depends on careful consideration of certain water quality and quantity factors. Parameters that are important are:

- Flow rate (maximum and minimum) in liters/second
- Dissolved oxygen (DO) content, mg/l
- Acidity and alkalinity, mg/l
- Ferric and ferrous iron concentrations, mg/l
- Aluminum concentrations, mg/l

These parameters will be included in the Kharkar drainage site characterization as discussed above. Flow rates of about 6-7 liters/second are generally considered optimal for ALD operation, therefore ALD application will be limited to tributaries of the Kharkar River, or along the Kharkar River itself during dry season when flows are less than 10 liters/second. If DO is greater than 2 mg/l, ferric iron may be present in quantities that will precipitate and armor over the limestone, thereby reducing alkaline generation. Aluminum precipitates at a minimum pH of 5, so if it is present in quantities above 25 mg/l then its precipitation into the ALD system could clog the system drainage and reduce effectiveness.

Flows from upstream contaminated water sources will be directed into ALDs prior to being discharged into an aerobic wetland, which will be constructed at the perimeter of the reservoir. The number of ALDs and design parameters will be based on overall flow, gradient and existing water quality. ALD design may be altered to address high metals (iron, copper, manganese, aluminum, at a minimum) which may be present in the raw water that will be entrained into the drains at the source. Clay barriers will be placed within the drains to help keep more of the drain flooded. Drains will have air seals at the outlet and remain flooded to ensure that no air is present in the drains. The drains may be constructed with sampling ports to monitor raw water quality. Water quality at the drain outlet as well as at the discharge from the polishing wetlands should be periodically monitored to ensure optimal operation.

Design of the drains and the wetlands areas is dependent on contaminated water flows, distance between the water source and the reservoir, the gradient or elevation change between the source and the reservoir and the chemical nature of the contaminated water.

Data needs for ALD design, as discussed above:

- Water quality – pH, conductivity, metals, sulfur (sulfide, sulfate), total dissolved solids
- Distance from acid drainage source to reservoir
- Drainage basin dimensions (catchment area)
- Gradient
- Precipitation data and flow rates (minimum, maximum) from acid source area
- Local sources of limestone, organic matter, piping, labor and equipment.

Design criteria will include:

- Design and engineering aspects, including costs
- Labor and supervision
- Earthworks equipment
- Materials: limestone, clay, plastic, filter fabric, pipes and valves
- Seed, mulch and fertilizer

Task 3: Prepare a Site-Wide Remedial Action Plan

The objective of this task is to prepare Remedial Action Plans (RAP) for each inspected mine site, including proposed discharge controls at each mining area, if possible. It will include preparing a designs and costs for the short and long-term mitigation and restoration plans for each site.

The RAPs will be developed based on the following site data:

- Characterization of discharge flow and chemistry.
- Calculation of contaminant loadings.
- Classification of discharge as acidic.
- Determine whether a primary treatment system (ALD) is required.
- Determine dimensions of secondary treatment systems (e.g., settling pond, aerobic wetland).
- The mechanism for ALD design and operation are further discussed in Section A.4.

Approach: Acid drainage from the uncontrolled mining areas must be managed by 1) controlling leachate from existing mine waste using active isolating methods, and 2) treating surface water already affected by low-pH leachate ingress. Tasks include:

1) **Catchment area investigation: Identify drainages and data collection and discharge sampling points. Conduct bi-weekly sampling for 2 months (assume 20 sampling points).**

- Complete mine site inventory and dimensions analysis as shown in Table A-1.
- Water quality sampling and analysis– pH, conductivity, metals, sulfur (sulfide,

sulfate), total dissolved solids

- Conduct field reconnaissance to identify AMD source areas and determine distance from acid drainage source to drainages and reservoir.
- Drainage basin dimensions (catchment area)
- Gradients
- Precipitation data and flow rates (minimum, maximum) from acid source area
- Acid Mine Drainage Source Area - Characterize source area including acid rock dump locations, size and volumes, geochemistry (acidity and metals content). Assume 10 samples for analysis of acid production potential and metals leaching.
- Design and construct a bench-scale pilot study of
- Local sources of limestone, waste rock pile cover material, organic matter, piping, labor and equipment

2) Evaluation of treatment technology to include discharge controls at mining area and inflow control upstream of diversion structure and reservoir.

- Design waste rock cover based on waste rock characterization and
- Calculate discharge flow and daily load of key contaminants, using the highest concentrations in the mine discharge (or lowest concentration in the case of total alkalinity). Adjust pH to 4.0 – 4.5 or higher using engineered alkaline anoxic limestone drains;
- Construct an ALD bench-scale pilot system based on information collected during execution of Task 1 above.
- Using data collected from pilot system (estimated to operate for 2 months or less) design ALD systems in targeted drainage areas.
- design parameters include distance from source, gradient, flow rate, etc., with details based on pH and transport modeling.
- Secondary passive treatment at reservoir area using constructed wetlands is anticipated.

3) Evaluation of Treatment Technology

Approach: The objective of this task is to evaluate treatment technologies and options to bring the pH level within limits. It includes evaluation of treatment technology to include AMD prevention and isolation using active treatment and passive treatment discharge controls at mining areas. It is anticipated that the extremes of wet and dry season and corresponding surface water flow will necessitate designing a unique combination of treatment technologies as a “two-phased” system.

The methodology steps will include:

- Designing waste rock cover based on waste rock characterization and
- Calculating discharge flow and daily load of key contaminants, using the highest concentrations in the mine discharge (or lowest concentration in the case of total alkalinity). Adjust pH to 4.0 – 4.5 or higher using engineered alkaline anoxic limestone drains.
- Using data collected from pilot system to design ALD/OLD systems in targeted

drainage areas as identified above.

- Design parameters include distance from source, gradient, flow rate, etc., with details based on pH and transport modeling.
- Secondary passive treatment at reservoir area using constructed wetlands is anticipated.

Task 4: Prepare a RAP for the short and long-term mitigation at each site.

Table A-1: Survey Questionnaire- Coal Mine Site Inventory

Questionnaire No: | | | | | | | | |

Date: | | | / | | | / | | |

Investigator Name …………………………………

A. Location

1. Village (Area Name): …………………………………
   District…………………………………
   Block: …………………………………
2. Coordinates:
   Latitude………………………………Longitude………………………
   …………

B. Respondent/Owner

1. Name of Respondent…………………………………Age……………Gender Male Female
   Father's Name…………………………………
2. Relation with Pit Owner…………………………………
3. Ownership of the Mining Pit
   1. Private 2. Government 3.Community 4. Others
4. Type of Private Ownership
   1. Individual/Single 2. Joint/Shareholders 3. Other (specify): …………
5. Status of Ownership/License
   1. License 2. Customary Right 3. Permission from Local Authority 4. Other (specify): …………………………………

C. Mining Pit

1. Size of the Pit (in meters): Radius………………......Depth...............
2. Years of operations ....

9. Depth to coal seam………….. Height of coal seam………

10. Coal mining method
    1. Manual 2. Mechanical 3. Both 4. Others

11. Total Production from Pit (in tons/day): Winter ………...Summer...…….......Rain.......……

12. Coal Storage Area size (sq.m.) …………………Location………………………

13. Total Capacity of storage (ton) ……………………… Duration (days) ……………………

14. Overburden storage and dimensions………………………………………

15. Production water source…………..

16. Liters/day used………………………

17. Volume of seepage water from pit (lit/day):

Winter ……………….Summer.......………….......Rain.......………………

18. Quality of water discharge, if known……. pH readings and dates……………

19. Discharge water measurements: pH…….. EC……..DO……… Temp……………

20. Pit water measurements: pH…….. EC……..DO……… Temp……………

21. Water Samples taken for laboratory analysis – date, time and location………………………………

22. Seepage water management:
1. Drain to nala/Stream 2. Temporary Drain 3.Retention pit 4. Others ☐

23. Nala flows to river/Major nala …………………

24. If Others; please describe
…………………………………………………………………………………………………
……
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………

25. Supplied to:
1. Government 2. Private 3. Self use 4. Others ☐

26. Expenditure on production per ton (Rs.) …………………

27. Income per ton (Rs.) …………………

D. Health & Safety

1. Number of workers involved…………………
2. Source of drinking water …………………
3. Common health issues /diseases in workers…………………
4. Healthcare facility in area
   1. Yes 2. No
5. Nos. of accident/injury in year during mining…………………
6. Nos. of fatal accident in last 5 years…………………

E. Safe and sustainable operation

1. Requirement of improvement in operations
   1. Yes 2. No
2. Improvement options
   1. Technology 2. Financial 3.Both 4. Others
3. If Others; describe……………………………………………………………………………
   …
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   …………
4. Any schemes from Govt.; describe…………………………………………………………
   …
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   …………

F. Remarks of the Interviewer, if any

………………………………………………………………………………………………
………………………………………………………………………………………………
…………
………………………………………………………………………………………………
……

(Signature of the investigator)

DRAWING/SKETCH OF MINE SITE AREA – Include: approximate dimensions and distances from pit to overburden, coal storage area, drainage area, closest stream (if possible), outbuildings and process water source, roads and other salient structures.

ATTACHMENT 3: Stakeholder Engagement Outline for Coal Mine Best Environmental Management

LKHEP Stakeholders Workshop

Water Quality Restoration and Rathole Coal Mining Areas - Mitigation Planning Commencement

MEETING AGENDA

The goal of the Water Quality Restoration Plan and Mitigation Plan is to restore mined land areas to pre-mining conditions in order to promote original land use activities including: agriculture, horticulture, forestry, ranching, fisheries, etc. Stakeholder participation is mandatory in order to ensure this goal is attained.

Scope:

A - Environmental Awareness for Coal Mine Best Environmental Management

1) Acid Mine Drainage: What is it? How does it form? Environmental And Human Health Hazards
   - What pH is and how it is generated by pyritic material in coal and overburden
   - How low-pH water discharge affects surface water quality and degrades the environment
   - General procedures for containing mine water using constructed containment structures, channels and other isolation techniques
   - Mine water and surface water management during monsoon season
   - Isolating stored overburden using soil covers to prevent low-pH generation by precipitation contact with pyritic material and leaching into surface water
   - Abandoned mine closure methods including pit backfilling to protect groundwater and restore surface contours
   - Storage and management of fuels and other chemicals.
2) Present current knowledge of Kharkar River Basin and rathole mining areas
3) Discuss how AMD impacts downstream quality and water use in Kharkar and Kopili Watersheds

B – Mitigation Measures and AMD Treatment Options

1) Passive treatment for existing AMD – ALDs and OLDs, stormwater diversion, capping and how they work
2) Groundwater protection – how groundwater is impacted and mitigation measures
3) Land Surface Restoration – overburden AMD generation, isolation methods, coal storage methods
4) General Mine Waste Best Management Practices (BMPs)
5) GOAL – to restore mined land areas to pre-mining conditions in order to promote original land use activities including: agriculture, horticulture, forestry, ranching, fisheries, etc.

C – Pilot Study

1) Design and Location, costs
2) Site Set-up and Management
3) Operations and Data Collection
4) Data Evaluation and Planning for Site-wide Integration of AMD Treatment
5) Cost Analysis for Kharkar Basin Remediation Implementation of passive treatment and mitigation

D- Community Environmental Training

Discuss Potential Environmental Training to ensure environmental awareness and promote the institution of best practices for mining environmental management in the coal mining regions in Assam and Meghalaya States.

1) Objectives

- instill knowledge of how to best operate and manage coal mine operations to achieve minimal degradation to surface water
- promote worker health and safety
- promote greater coal extraction efficiency and economic mining methods
- promote cooperation between State Agencies and regional coal producers, land owners and mine operators to facilitate cleaner, more efficient coal production.
- Promote ALTERNATIVE income-generating activity in rathole mining areas. Goal is to RESTORE agriculture, horticulture, forestry and other pre-mining land use.

2) Responsibilities
3) Program Procedures
4) Induction Procedures
5) Environmental Monitoring

E -Costs and Budget

Costs associated with development and implementation of the Environmental Awareness and Mining Management Program will be calculated as part of Stakeholder discussions. Costs will include staff, earthmoving equipment, laboratory and field monitoring, record-keeping and reporting.

F - Environmental Remediation and Mitigation Discussion for Future Mitigation and BMPs

Mitigation measures: A list of measures to either modify, remedy, control or stop any actions, activities or processes leading to or cause of pollution or degradation cross- referenced to the list of the identified impacts of each of the aforesaid main mining activities and verify the completeness thereof.

Mitigation measures are aimed at lessening negative consequences of the rathole mining activities in Assam and Meghalaya States. The mitigation measures include designs and management practices that will be embarked on to prevent the further degradation of Kharkar and Kopili River systems. Several mitigation measures are able to be implemented depending on the results of the mine site investigations and characterization.

1) Surface water

Construction of simple and inexpensive mine and runoff water management facilities and isolation of mine rock will depend on the nature of each mine site. General mitigation measures for surface water can include:

- Minimizing the areas of disturbance
- Divert clean runoff water around mining areas, coal stockpiles and overburden stockpiles
- Ensure that proper measures are in place to contain any fuel spills
- Ensure that mine equipment is properly maintained
- Install pit water storage facilities (ponds, tanks etc) to ensure that low-pH water does not develop and migrate into surface water
- Contain all low-pH water and treat with lime to bring pH to neutral before discharging
- Monitor water quality up and downstream in nearest tributary(s).
- Plan for monsoon flows and increased water management and storage requirements
- Construct buffer berms between mining operations and runoff areas
- Construction of ALD or OLD treatment channels for mine waste water downstream of each mine site
- Construction of simple wetlands areas downstream of mining areas to channel and passively treat mine waste water.

2) Mining Operations

The following activities which may impact water quality and health and safety should be implemented at each ACTIVE mine site:

- Systematic removal of the coal seam by methods which minimize water use and waste rock removal
- Re-use waste water rather than using fresh water whenever possible
- Stockpiling waste rock so as to minimize contact with precipitation and surface water flow. Stockpiles should be covered with clay or rock mixed with lime to prevent AMD generation.
- Immediate piping and disposal of groundwater entering the mine pit to prevent AMD generation
- Proper loading and transport of coal, using trucks with tarpaulin covers to prevent coal spills
- Backfilling of overburden into the pit at cessation of mine operations to prevent further groundwater contamination and AMD generation and minimize dangerous conditions at the surface
- Maintain topsoil stockpiles for use in remediating closed pits and surrounding areas.
- Utilize erosion control measures to prevent surface water contamination
- Revegetate rehabilitated areas as soon as possible using native grasses and other quick-growing vegetation

- Remediation of oil and diesel spills

3) AMD

Currently best practice environmental management of sulfidic mine wastes involves integration of acid drainage prevention, minimization and control into the mining process. It can be summarized as the early characterization and classification of the acid generation potential of the mine materials, development of strategies to minimize the oxidation of sulfides, and where acid drainage formation is unavoidable, the implementation of suitable long-term control and treatment technologies. The primary goal of AMD prevention is to stop contaminated drainage from leaving the mine site at its source by minimizing reaction rates, leaching, and the subsequent migration of weathering products from mine waste to the environment.

Prevention of AMD can be achieved through a risk-based planning and design approach that is applied throughout the mine life cycle. However, prevention is primarily accomplished in the assessment and design phases. The prevention process aims to quantify the long-term impacts of alternatives and to use this knowledge to select the option that has the least impact. Mitigation measures implemented as part of an effective control strategy should require minimal active intervention and management.

The primary approach to the prevention and mitigation of AMD is to apply methods that minimize the supply of the primary reactants for sulphide oxidation, and/or maximize the amount and availability of acid neutralizing reactants. These methods may involve one or more of the following:

- Minimizing oxygen supply because of diffusion or advection
- Minimizing water infiltration and leaching (water acts as both a reactant and a transport mechanism)
- Minimizing, removing, or isolating sulphide minerals
- Controlling pore water solution pH
- Maximizing availability of acid neutralizing minerals and pore water alkalinity
- Controlling bacteria and biogeochemical processes

Factors influencing selection of the above methods include the following:

- Geochemistry (i.e., sulphide/carbonate content and reactivity) of source materials and the potential of source materials to produce ARD
- Type and physical characteristics of the source, including water flow and oxygen transport
- Mine development stage – (More options are available at early stages.)
- Phase of oxidation – (More options are available at early stages when pH may be near neutral and oxidation products have not significantly accumulated.)
- Time period for which the control measure is required to be effective
- Site conditions – location, topography, and available mining voids, climate, geology, hydrology and hydrogeology, availability of materials, and vegetation
- Criteria for discharge
- Risk acceptance by mine owner and stakeholders

ATTACHMENT 4: Environmental Awareness – Stakeholder Training Plan for Environmental Best Management Practices and Implementation

A-4.1 Background and Objectives

The issue of small rathole coal mining in Meghalaya State has reached a critical juncture. Environmental groups are pressuring the state to enforce a National Green Tribunal (NGT) decision that all coal mining be ceased in the state, but claim that the state allows the mining to go on. In Meghalaya, the community owns the natural resources, not the state, so the state believes it cannot enforce the NGT's decision. In addition, the National Coal Company that would presumably operate in a more environmentally sound manner, cannot mine coal in Meghalaya because their charter allows it to contract only with state government, not with the community. Although this situation is complex, and not easily resolved, it is recommended that APCGL and ADB look for ways to engage appropriate parties toward a resolution that will allow the LKHEP AMD problem to be remediated.

APGCL should partner with Meghalaya State, NEC/Coal India and State environmental regulatory agencies to discuss the potential impacts of continued rathole coal mining. The environmental implications associated with the chemical/physical properties of the coal – high sulfur, and high-ash when inefficiently mined to include dirt bands (which is certain to be the case with rathole-produced coal) – should be a topic of stakeholder discussion. Promoting discontinuation of rathole mining in favor of technically-controlled modern extraction methods would increase production and efficiency, radically improve worker safety and environmental best management and pollution controls, both in the mining area and in coal-fired operations.

- Working with the state governments and the national coal and power companies to create a market for private coal development in Meghalaya and Assam that would involve auctioning off coal mining tracts and permits to legitimate and capable coal mining companies with eligibility and selection criteria that include willingness and capacity to: (1) remediate past artisanal coal mining sites on their respective tracts using local community labor resources; and (2) follow best international practice in ongoing environmental management.
- Planning a conference on AMD site remediation and water quality restoration in the IWRM planning context. Promote the conference to the respective states' representatives to the Brahmaputra Board, inviting the Meghalaya Electricity Board, the national coal company and NEEPCO, as well as APCGL and ADB, to participate. Include the conference, or a series of related meetings, in the Kopili River Basin IWRM Plan component of the SEA. Dr. O.P. Singh to know his research work on acid drain from coal fields to Kharkar River in Meghalaya State.
- Engage Dr. O. P. Singh of North Eastern Hill University (NEHU) to conduct the pilot plant study for AMD remediation; he has stated that his department or NEHU is ready to provide advisory and technical support for pilot plant implementation as approved by the affected local communities and state government.
- ADB should continue and increase its support to alternative sources of energy for residents in lieu of coal, for example:
  - Broadening and accelerating the GOI's distribution of gas cylinder stoves
  - Installing pico-solar equipment in homes to power lights and mobile phones
  - Installing photovoltaic solar energy in both on-grid and off-grid village

configurations

- Ensuring access to hydropower via distribution from KHP and LKHEP projects

Stakeholder engagement will include education on AMD formation and prevention methods as described in Attachment 3. Stakeholders will begin the Regional Environmental Training process by soliciting participation of landowners and the local community to create a “community conservation corps” of Kharkar Basin residents, in both Assam and Meghalaya, who would be paid by the GoA to implement AMD mitigation measures in the shorter term and in the longer-term help realize the ecological and economic benefits that improved water quality in the Kopili River and LKHEP reservoir will offer. These activities include:

- Constructing the active treatment and ALD/OLD passive treatment facilities for AMD reduction in the upper reaches of the Kharkar River Basin, beginning with backfilling the rathole coal mining pits, both in Assam and Meghalaya, to reduce AMD generation.
- Helping to implement and/ or monitor the implementation and effectiveness of the LKHEP water quality mitigation measures recommended in the WAPCOS EIA.
- Creating and maintaining fishery, drinking water, irrigation, agricultural, recreational and tourist facilities and businesses that will be able to take advantage of the improved water quality in just 1-2 years.
- Activating an Environmental Awareness Program to integrate the above activities throughout the Kharkar-Kopili Basins.

The Environmental Awareness Training and Implementation Plan and way forward is discussed below.

A-4.2 Scope

This Environmental Training standard procedure sets out the training objectives to ensure environmental awareness and promote the institution of best practices for mine site environmental management, remediation and restoration practices in the coal mining regions in Assam and Meghalaya States.

A-4.3 Responsibilities

Training will be developed and managed by representatives from Stakeholders including APGCL, NEEPCO and Assam and Meghalaya government agencies, to be decided at the onset of Stakeholder discussions. The mining areas of concern will be divided into districts, or by ownership and/or management, each with its own representatives designated to conduct on-site training and monitor progress toward implementation of best practices at each mine site. Environmental monitoring, including low-pH discharge is to be monitored, as designated during Stakeholder discussions. A Coal Mine Management Committee will be formed to include representatives from regional coal producers, Meghalaya and Assam State Regulatory Agencies, with periodic input and cooperation with ADB, NEEPCO and APGCL.

A-4.4 Program Procedures

An induction program, which will include an environmental awareness program, will be established for the mining districts of Assam and Meghalaya that are shown to be affecting surface water quality in the Kharkar and Kopili River Catchments. During the training sessions, various topics will be discussed such as, but not limited to, water pollution prevention, good environmental housekeeping, etc. Through the Induction Program, the responsible appointed person will ensure that all workers at each mine site receives training in:

- What pH is and how it is generated by pyritic material in coal and overburden
- How low-pH water discharge affects surface water quality and degrades the environment
- General procedures for containing mine water using constructed containment structures, channels and other isolation techniques
- Mine water and surface water management during monsoon season
- Isolating stored overburden using soil covers to prevent low-pH generation by precipitation contact with pyritic material and leaching into surface water.
- And abandoned mine closure methods including pit backfilling to protect groundwater and restore surface contours.
- Storage and management of fuels and other chemicals.

A-4.4.1 Monitoring

Monitoring of each mine district will consist of periodic field inspections of surface water drainages for pH and visual inspections of mine activities and management practices. A general monitoring plan will be developed in coordination with Stakeholder planning meetings.

A-4.4.2 Costs and Budget

Costs associated with development and implementation of the Environmental Awareness and Mining Management Program will be calculated as part of Stakeholder discussions. Costs will include staff, earthmoving equipment, laboratory and field monitoring, record-keeping and reporting.

A-4.4.3 Environmental Remediation and Mitigation

Mitigation measures: A list of measures to either modify, remedy, control or stop any actions, activities or processes leading to or cause of pollution or degradation cross-referenced to the list of the identified impacts of each of the aforesaid main mining activities will be produced for each landowner as included in the Remedial Action Plan (RAP) for each mine site characterized (as discussed in Attachment 3).

Mitigation measures are aimed at lessening negative consequences of the rathole mining activities by preventing and/or reducing AMD formation by instituting environmental best practices. The mitigation measures include designs and management practices that will be embarked on to prevent the further degradation of Kharkar and Kopili River systems. Several mitigation measures can be implemented depending on the results of the mine site investigations and characterization.

A-4.4.4 Surface water

Construction of simple and inexpensive mine and runoff water management facilities and isolation of mine rock will depend on the nature of each mine site. General mitigation measures for surface water can include:

- Minimizing the areas of disturbance
- Divert clean runoff water around mining areas, coal stockpiles and overburden stockpiles
- Ensure that proper measures are in place to contain any fuel spills
- Ensure that mine equipment is properly maintained
- Install pit water storage facilities (ponds, tanks etc) to ensure that low-pH water does not develop and migrate into surface water
- Contain all low-pH water and treat with lime to bring pH to neutral before discharging
- Monitor water quality up and downstream in nearest tributary(s).
- Plan for monsoon flows and increased water management and storage requirements
- Construct buffer berms between mining operations and runoff areas
- Construction of ALD or OLD treatment channels for mine waste water downstream of each mine site
- Construction of simple wetlands areas downstream of mining areas to channel and passively treat mine waste water.

A-4.4.5 Mining Operations

The following activities which may impact water quality and health and safety should be implemented at each mine site:

- Systematic removal of the coal seam by methods which minimize water use and waste rock removal
- Re-use waste water rather than using fresh water whenever possible
- Stockpiling waste rock so as to minimize contact with precipitation and surface water flow. Stockpiles should be covered with clay or rock mixed with lime to prevent AMD generation.
- Immediate piping and disposal of groundwater entering the mine pit to prevent AMD generation
- Proper loading and transport of coal, using trucks with tarpaulin covers to prevent coal spills
- Backfilling of overburden into the pit at cessation of mine operations to prevent further groundwater contamination and AMD generation and minimize dangerous conditions at the surface
- Maintain topsoil stockpiles for use in remediating closed pits and surrounding areas.
- Utilize erosion control measures to prevent surface water contamination
- Revegetate rehabilitated areas as soon as possible using native grasses and other quick-growing vegetation
- Remediation of oil and diesel spills

A-4.4.6 AMD

Currently best practice environmental management of sulfidic mine wastes involves integration of acid drainage prevention, minimization and control into the mining process. It can be summarized as the early characterization and classification of the acid generation potential of the mine materials, development of strategies to minimize the oxidation of sulfides, and where acid drainage formation is unavoidable, the implementation of suitable long-term control and treatment technologies. In almost all circumstances, resources spent on prevention and minimization of AMD is returned many- fold through lower control and treatment costs.

Currently best practice environmental management of sulfidic mine wastes involves integration of acid drainage prevention, minimization, minimization and control into the mining process. It can be summarized as the early characterization and classification of the acid generation potential of these materials, development of strategies to minimize the oxidation of sulfides, and where acid drainage formation is unavoidable, the implementation of suitable long-term control and treatment technologies.

Monitoring is a critical component of best practice management of AMD. Identifying AMD or the likelihood of AMD at an early stage may provide advance warning of more significant problems. This will enable proactive control and possibly treatment strategies to be adopted.

Key features of the monitoring program include:

- Monitoring of surface water upstream and downstream of each mine site including pH, conductivity and dissolved oxygen.
- Monitoring of seeps and water and waste water storage areas on the mine site for pH.
- Water flux or ingress through waste dumps

A-4.4.7 Mine site Mitigation, Monitoring and Maintenance Recordkeeping

A robust recordkeeping program will be implemented during the Environmental Awareness and Management Program. Environmental factors to be monitored include, but may not be limited to: surface water pH, precipitation and runoff management, soil and land disturbance, waste rock and overburden management, and coal management. The table below lists environmental factors to be monitored along with considered mitigation measures. Each mine area under environmental management will be required to monitor these environmental factors and periodically report progress to the Coal Mine Management Committee.

Table A-4.1 Environmental Monitoring Parameters

Environmental Factors		Mitigation
Surface water	Runoff control	Berms to prevent inflow of clean water into mine areas. Drains inside berms to direct low pH mine water into storage ponds. Backfill mine pits upon abandonment. ALD/OLD channels and wetlands to treat low-pH discharge.
	Coal and fuel spills	Prompt cleanup and disposal to prevent surface water contamination.
	AMD Treatment	Evaporation ponds to evaporate low-pH water periodically cleaned to remove sludge build-up. Sludge to be backfilled into abandoned pits. ALD and/or OLD channels to be constructed to treat AMD discharge with wetlands “polishing” prior to discharge into tributary.
Land and soil	Soil Erosion	Maintain topsoil stockpile Erosion control measures
	Coal spillage	Prompt cleanup and disposal of affected land to prevent water contamination.
Mine Pit and Area	Pit Management	Removal and storage of topsoil prior to digging pit. Removal of overburden to a designated storage area which is bermed to divert precipitation and runoff to ALD/OLD channels and/or evaporation pond. Prompt pumping of groundwater to avoid contact with sulfidic rock. Pumped water should be tested for pH and if low, removed to evaporation ponds and/or ALD/OLD channels for passive treatment. Proper coal removal and storage methods to minimize land and water contamination. Utilize safe pit ingress-egress methods to protect worker safety. Backfill pit upon mine completion using stored overburden capped with stored topsoil.

APPENDIX 1: SITE CHARACTERIZATION REPORT

Ensuring Safeguards Compliance

LOAN 3327 IND
ASSAM POWER SECTOR INVESTMENT PROGRAM – TRANCHE 2

Consulting Services for Supplemental Environmental Assessment for Lower Kopili Hydropower Project

Final Report
(Volume 4, Appendix-1: Site Characterization Report)

Submitted to:
Assam Power Generation Corporation Limited
INDIA

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1. INTRODUCTION

1.1 Project Background

1. On July 03, 2014 ADB Board approved a Multi-tranche Financing Facility (MFF) to the Government of Assam (through Government of India) for the Assam Power Sector Investment Program (APSIP). The APSIP aimed to finance a portion of the power sector investment plan for generation and distribution of the Government of Assam (GOA). The APSIP objectives are to increase capacity and efficiency of power generation and distribution systems in the State of Assam and to reduce load shedding while meeting growing demand for power in the region. The investment program"s impact will be to increase availability of electricity in Assam. The outcome will be increased capacity and efficiency of energy generation and distribution systems in Assam.

2. The investment program is estimated to cost $430 million. On Government request, ADB provided MFF in an amount up to $300 million from ADB"s ordinary capital resources to help finance a part of the investment program. The MFF comprise three tranches. Tranche 1 for US$ 50 million (Loan 3140-IND) was approved on 11 July 2014 and became effective on 12 May 2015; it includes replacement of an aging, inefficient gas plant, and project implementation support and capacity development support to Assam Power Generation Company Limited (APGCL). Tranche 2 for US$ 48 million (Loan 3327- IND) was approved on 23 November 2015 and the loan was signed on 07 November 2016; it includes expansion and upgrading of the power distribution system in the state of Assam, and strengthening institutional capacity of Assam Power Distribution Company Limited (APDCL). The Government is planning to submit PFR 3 for Tranche 3; it includes financing for the 120 megawatt (MW) Lower Kopili Hydroelectric Project (HEP).

3. The detailed project report (DPR) for the Lower Kopili HEP has been prepared by APGCL including an EIA as per Government of India requirements. The draft EIA report has been reviewed by ADB and existing issues were identified which require action by APGCL before the project can be funded under the Investment Program. These issues include:

- Low pH in Kopili River, Khandong and Umrong Reservoirs is contributing to degradation of the existing Kopili HEP. Source of low pH is presumed to be from illegal coal mining waste discharging acid mine drainage into tributaries to the Kopili River. Some of these illegal coal mine sites have been preliminarily identified but additional investigation and site characterization is needed to design a remedial strategy.
- Draft EIA prepared by WAPCOS (October 2016) requires three additional components in order to be finalized: a Cumulative Impacts Assessment (CIA), an Integrative Water Resources Management Plan (IWRMP) and a Water Quality Restoration Plan including a mitigation strategy.
- Cumulative Impacts Assessment - Need to update Lower Kopili (LK) site characterization including surface drainages, volumes and existing wetlands.
- Further identification of illegal mine sites and pyritic rock exposures contributing to low-pH drainage.
- Further identification of surface drainages and impacts and preparation of this Site Characterization Report.

- Mitigation and remediation plan needed, including pilot study for anoxic limestone drains as a treatment option.
- Comprehensive surface water treatment system needs to be designed and implemented based on above investigations and impact assessment.

4. An additional Terms of Reference (TOR) issued by the Ministry of Environment, Forests and Climate Change (MoEFCC) of India for the EIA, which included cumulative impact of operation of the LKHEP and existing HEP development. The EIA is also required to fulfil ADB requirements for sustainable hydropower. Following review of WAPCOS EIA, ADB and APDCL/APGCL identified additional studies required to complete the EIA to meet GOI and ADB‟s requirements. APDCL invited consulting services proposals for Supplemental Environmental Assessment (SEA). Subsequently, ES Safeguards Compliance Services Private Limited, India was retained by APDCL/APGCL as Consultant to undertake „Consulting Services for Supplemental Environmental Assessment for Lower Kopili Hydropower Project‟. The consultant will work with APGCL and other assisting consultants to conduct the SEA as detailed in the consultant‟s TOR. The supplemental environmental assessment consulting services is being financed under Tranche 2 of the MFF. Lower Kopili Hydropower Project is proposed for financing under Tranche 3 of the Assam Power Sector Investment Program.

5. The scope of work to complete the SEA includes effort to identify the extent of acid mine drainage affecting the Kopili River, and contribute to the Catchment Area Treatment Plan for the LKHEP to include discharge controls at mining areas if possible and inflow controls upstream of the diversion structure and reservoir.

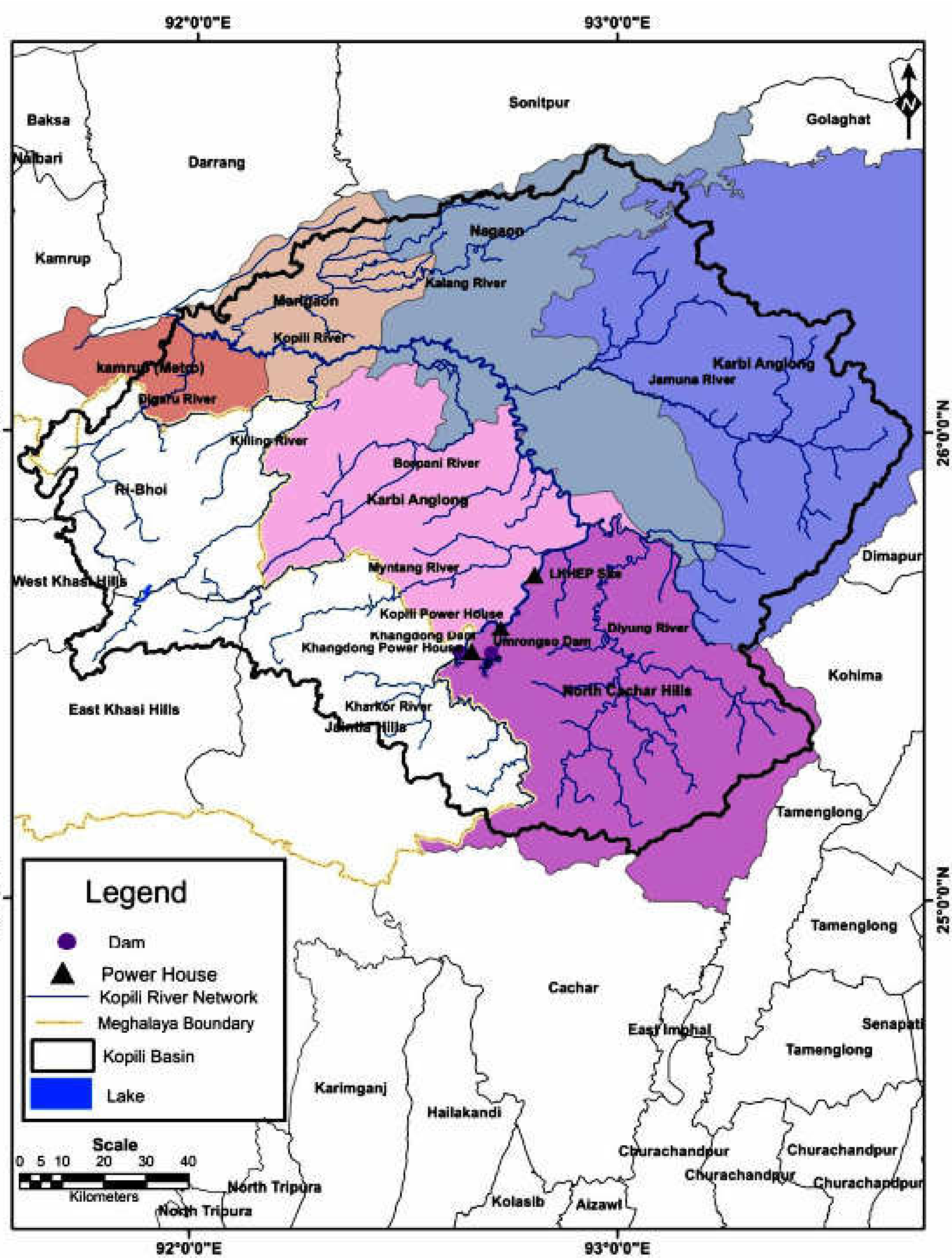
6. The scope includes identifying regulatory requirements and technical options for water quality control and management, including controls on discharge from mining operations and engineered water treatment systems for maintaining water quality in the areas of the LKHEP and Kopili HEP. It also identifies the best engineering design for acid mine drainage, requiring minimal maintenance, and operates well with variations in acid mine drainage flows and varying acidity. The key tasks include:

- Site Characterization - Data Collection and Analysis
- Evaluation of Treatment Technology
- Preparing a Conceptual Engineering Design Report
- Preparing a Preliminary Conceptual Mitigation Plan

1.2 Objectives and Scope

7. The upper reaches of the Kopili River in Assam have been adversely affected by acid drainage from illegal mining in upstream areas. As part of a broader effort to ensure sustainable water resources development in Assam, this Site Characterization Report aims to describe and characterize environmental conditions using all data and information collected to-date upstream of existing Kopili Hydro Electric Plant (HEP) operations and the proposed Lower Kopili Hydro Electric Plant (LKHEP). Figure 1-1 depicts the Kopili River Basin and the location of the existing HEP and proposed LKHEP.

Figure 1-1: Kopili River Basin



8. Since 2006, increased acidity of Kopili River water has disrupted operations of the Kopili HEP. A decision in 2014 by the National Green Tribunal to ban rathole mining, has reportedly resulted in curtailment of illegal mining upstream with concomitant improvements in water

quality. In addition to these regulatory controls, a systematic approach is needed to ensure continued water quality restoration and to protect the integrity of hydropower and other water infrastructure assets. This document will provide the background information meant to assist in coordination with parallel assignments for cumulative impacts assessment, integrated water resource management planning, water quality restoration planning and mitigation management for the LKHEP project.

9. The main objective of this assignment is to characterize to the extent possible the LKHEP site and upstream source areas and transport mechanisms of acid mine drainage affecting the Kopili River. This Site Characterization Report will then be used in developing AMD prevention, treatment and mitigation strategies to include discharge controls at mining areas if possible, and to develop the best engineering conceptual design for AMD mitigation, as part of the WQRP to be completed at the end of 2017 as per the TOR..

10. This document presents the outcome of technical research and data collection processes (both existing data and field data collection) to characterize surface water quality and hydrology in the Kapili and Kharkar Catchments. Current hydrogeochemical conditions will be used as baseline to monitor and assess the success of both the proposed AMD remediation Pilot Study and longer-term AMD mitigation efforts in the Kharkar drainage basin.

11. The work was conducted as below:

1) Existing Data Collection
2) On-Site Data collection and analysis
3) Review Regulatory Framework for Surface Water Quality
4) Prepare Kopili and Kharkar River Catchment
5) Catchment Basin Characterization

12. The site characterization work, including identifying and locating sources of AMD, was conducted in both the Kopili and Kharkar River Catchment areas, as outlined on Figure 1-1. We have preliminarily identified rathole mining areas, including pits and waste rock dumps, and tributaries into the Kharkar River which may be affected by AMD. Until permission is granted to expand field investigations into the Kharkar River Basin and illegal mining areas, this Report must rely existing data and information and the limited field data collected in January 2017 as well as a limited mine site inventory in the Jaintia Hills area of Meghalaya in July 2017, as discussed in Section 5.

1.3 Project Methodology

13. This Report was prepared after conduct and completion of the tasks detailed below.

14. Task 1: Existing Data Collection and Analysis

15. The main objectives of this task are to identify and collect all available existing data and information for the Kopili and Kharkar River Basins, including the preliminarily- identified illegal mining areas in the Assam and Meghalaya States that could be impacting drainage into the Kopili River. The objectives are: to create a database of existing surface water quality data, hydrology, meteorologic data and geologic data from which to build an understanding of how and where AMD is formed, how it impacts the Kharkar and Kopili Rivers and ultimately, how to plan remedial efforts. The compilation of existing data includes the key methodological steps below:

- Identifying and compiling existing discharge sampling points and surface water quality data from Kopili River, Kharkar River and tributaries.
- Water quality sampling and analysis– pH, conductivity, metals, sulfur (sulfide, sulfate), total dissolved solids.
- Conducting field reconnaissance to identify AMD source areas and determine distance from acid drainage source to drainages and reservoir.
- Drainage basin dimensions (catchment area).
- Hydrogeologic data for Kopili and Kharkar Rivers including gradients, seasonal flow rates, and basin dimensions.
- Seasonal precipitation data.
- Acid Mine Drainage Source Area – Define geographic limits of source area using available topographic, geologic and Google Earth maps.

16. Task 2: Review Regulatory Framework for Surface Water Quality

17. **Task 3: Prepare Kopili and Kharkar River Catchment Maps** – Identify and locate tributaries to the Upper Kopili River, including the Kharkar River, which has been identified as the source of AMD-affected discharge. Detailed maps, including surface geology, mine locations and local drainages are needed to design proposed remedial actions as part of the WQRP and Mitigation Plan.

18. **Task 4: Catchment Basin Characterization** – This characterization is to be used to develop treatment options for the Mitigation Plan. Catchment basin Characterization includes:

- Collect and analyze water quality data from AMD-impacted water including pH, conductivity, major ions, metals, sulfur (sulfide, sulfate), total dissolved solids;
- Identify the distance from acid drainage sources to the LKHEP and Kopili HEP reservoirs;
- Identify drainage basin dimensions (catchment area and drainages) and flow gradients;
- Collect precipitation data and flow rates (minimum, median, and maximum) from affected catchment areas

19. Task 5: Prepare Site Characterization Report

20. This report was prepared based on the information available due to limited access to conduct field reconnaissance within the Upper Kopili and Kharkar River Basins. We therefore state that the data contained in this Report is sufficient to produce a Conceptual Mitigation Plan for the purposes of completing the SEA only. Additional data will be needed to prepare and execute a detailed mitigation engineering design for the entire Kharkar Basin coal mining area.

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2. REGULATORY FRAMEWORK FOR SURFACE WATER QUALITY IN MINING AREAS

21. In India, the Ministry of Environment and Forests (MoEF) plays a key role in regulating the environmental impacts of mining and in providing clearances for mining in forest lands. Some environmental protection measures include: pollution prevention; dispatching notices of violation and fine levies; protection of heavily polluted areas and river stretches; encouragement of development and application of best available technological solutions; and involving the public in decision making (Mehta 2002).

22. The 1960 Mineral Concession Rules requires: an assessment of impact by mining activity on forest, land and environment, a forest restoration plan, and adoption of pollution control devices. According to Article 23 of the Mineral Conservation and Development Rules (1988), conditions for mine closure must be determined by the mining company along with an environmental mitigation plan to protect and control pollution during the mining and post-mining operations. The law provides guidelines to restore or protect the flora of the area under the mining lease and nearby areas. The main environmental acts that impact the mining industry in India are: The Wildlife (Protection) Act, 1972 (amended in 1991); The Water (Prevention and Control of Pollution) Act, 1974 (amended in 1988); The Forest (Conservation) Act, 1980 (amended in 1988); The Air (Prevention and Control of Pollution) Act, 1981 (amended in 1988); and The Environment (Protection) Act, 1986 (with rules 1986 and 1987). Separate pollution standards for air quality and coal-mine effluents are promulgated by Central Pollution Control Board for coal mining in India as listed in Table 2-1 (M. Chabukdhara, O. P. Singh, 2016).

Table 2-1: Pollution standards for coal-mine effluent

Parameter	Unit	Value
pH		5.5–9.0
TSS	mg/L	100
Oil & Grease	mg/L	10
COD	mg/L	250
BOD	mg/L	30
Phenolics	mg/L	1.0

23. In order to achieve sustainable utilization of coal resources while minimizing impacts to the environment, an integrated and inter-State approach to prevent and mitigate environmental impacts from coal mining, both permitted and illegal, is necessary. Proper implementation of regulatory rules and policies utilizing Stakeholder engagement and training is proposed as one impact management strategy for long-term AMD management and mitigation. This is discussed further in Section 6.

3. EXISTING DATA REVIEW AND COMPILATION

24. This section summarizes the compilation of existing data for the Project Area of Influence, including the Kopili and Kharkar watersheds, groundwater, AMD source areas.

3.1 Summary of Cumulative Impacts Assessment

25. The purpose of the CIA is to assess the reasonably foreseeable cumulative impacts, including both direct and indirect (or induced) impacts, attributable to the ADB-funded LKHEP investment and its associated facilities. More specifically, as per the TOR, the CIA aims:

- To determine if the combined impacts of LKHEP, the operations of Kopili HEP, and the activities further upstream such as coal mining operations will impair the valued ecosystem components (VECs), broadly defined here to include water resources, biodiversity, agricultural and forest lands, and social infrastructure and welfare
- To identify management measures needed to avoid or minimize any unacceptable condition of the VECs
- WAPCOS EIA. The scope of the CIA prepared as part of the WAPCOS EIA is more limited than the scope of the present CIA in that it calls for collective assessment of the operation of the three Kopili River Basin reservoirs: Khandong dam, Longku dam and Lower Kopili HEP.
- ADB Preliminary CIA. ADB prepared the Assam Lower Kopili Hydroelectric Power Project Preliminary Cumulative and Induced Impacts Assessment (v0 December 2015, an unpublished report funded under TA-8351 IND: Advanced Project Preparedness for Poverty Reduction - Preparing the Second Power Sector Investment Project for Assam). The scope of the ADB Preliminary CIA is broader than the scope of this CIA in that it addresses induced impacts and associated facilities impacts, in addition to cumulative impacts. Induced impacts and associated facilities impacts are addressed in the ADB LKHEP EIA and not in this CIA. These additional types of impacts are defined by ADB‟s Environment Safeguards: A Good Practice Sourcebook Draft Working Document (December 2012), as follows:
  - Induced impacts are diverse and/or beneficial impacts on areas and communities from unintended but predictable developments caused by a project, which may occur later or at a different location.
  - Associated facilities impacts are impacts of facilities that are not funded as part of a project but whose viability and existence depend exclusively on the project, or whose goods or services are essential for successful operation of the project.

26. The cumulative environmental and social impacts of the proposed LKHEP project have been evaluated in the context of four Valuable Ecosystem Components – water quality, water quantity, air quality, and land quality – using IFC‟s guidance for cumulative effects analysis. Some of the major benefits of a proposed hydropower project that would accrue to local affected parties is the provision of clean water to use for drinking, irrigation, and recreation,

as well as water quality and environmental flow that will support healthy lotic and lentic aquatic ecosystems and associated fisheries and community livelihoods. However, due to AMD resulting from rat-hole coal mining in the Kopili River Basin, and the possibility of multiple hydropower projects on the Kopili River, achieving these usual benefits in the case of the LKHEP project will involve the implementation of significant mitigation measures. In addition, there are cumulative impacts on the air quality and land quality VECs that, while less significant than those impinging on the water quality and water quantity VECs, still need to be addressed.

27. Recommendations are presented below in three categories: General Recommendations, combined Water Quality and Water Quality VECs (higher significance) and combined Air Quality and Land Quality VECs (lower significance).

3.1.1 General Recommendations

- The recommendations of this CIA should be integrated into the LKHEP ESMP mitigation and monitoring programs.
- The LKHEP ESMP mitigation and monitoring programs should be closely linked to the many relevant plans of the two autonomous districts relating to environmental and natural resources protection, e.g. those for forestry, wildlife, fisheries, agriculture, municipal infrastructure, energy and planning.
- APCGL"s implementation and oversight of the LKHEP ESMP should be done in close coordination with the two autonomous districts for their technical contributions and from a stakeholder participation perspective.
- The River Basin Organization (RBO) outlined in the Kopili River Basin IWRMP should include representatives of APCGL and the two autonomous districts, as well as other stakeholders such as relevant departments of Assam and Meghalaya State, NEEPCO and Coal India Limited who can address the coal mining AMD issue.
- The RBO should take the lead in implementing the more regional or basin-wide recommendations of this CIA and play a continuing coordination role relative to identifying, evaluating, mitigating and monitoring cumulative impacts from future major projects, energy related or otherwise, in the Kopili River Basin.

3.2 Mitigation Measures Addressing Combined Water Quality and Water Quantity VECs

28. VECs for water quality and water quantity have been defined separately, because independently they pose significant and challenging cumulative impacts to mitigate and will thus benefit from individual management and monitoring. Ultimately, though, they are both intended to restore and sustain the same valued ecosystem, i.e. Kopili River aquatic ecology and its associated fishery and ecosystem services which will in turn provide a significant LKHEP environmental and social benefit to local affected parties. Such a benefit would normally accrue to the affected parties in a typical proposed hydropower project and would very much improve the benefits to risks ratio of the LKHEP project.

29. Summarizing the mitigation measures presented in Sections 5.1 and 5.2 of the CIA Report prepared by ES Safeguards in April 2017, the key actions toward this goal, short-term and long-term, are:

3.2.1 Short-Term

- Engage Dr. O. P. Singh of NEHU or other qualified local university team to collect Kharkar River data for evaluation of passive treatment technology, and possibly implement a pilot project, to be recommended in the WQRP, and as approved by the affected local communities and state government, to evaluate, select and design AMD control measures. Select the most robust and cost-effective control measures and proceed to implement the selected measures. An at-source treatment plan is proposed as the only feasible and cost-effective approach to minimizing existing AMD and to prevent future AMD generation by introducing mining best management practices.
- Plan a Stakeholder conference on AMD site remediation and water quality restoration in the IWRM planning context. Invite representatives to the Brahmaputra Board, APCGL and Meghalaya Electricity Control Board, relevant departments of Assam and Meghalaya States, Dima Hasao and Karbi Anglong Autonomous Districts, CIL and NEEPCO, and Dr. O.P. Singh/ NEHU. This group could then form the nucleus of a permanent Kopili RBO which would be the most functional organization.
- Implement the environmental flow requirements and reservoir bottom drainage design, monitor their implementation and effectiveness during project startup and operation, and adjust the flow requirements as needed to achieve aquatic ecology goals.

3.2.2 Long-Term

- Implement the Water Quality Restoration Plan (WQRP) included in the Supplemental EIA to address rat-hole coal mining in Meghalaya and Assam states that is generating AMD and lowering the pH of the Kopili River. The Water Quality Restoration Plan in the Supplemental EIA will identify and evaluate several mitigation options addressing the AMD issue. Since submittal of the ES Safeguards Interim Report in April 2017, it has been determined that only “at-source” mitigation measures will be developed further due to cost constraints, site availability limitations and mitigation effectiveness. These include but are not limited to: oxic and anoxic alkaline limestone drains, stormwater diversion measures, pit backfilling, waste rock capping, and pit wall shotcreting. In addition to the AMD mitigation measures, the direct LKHEP water quality mitigation measures, as presented in the WAPCOS EIA, (recommended by MoEFCC and as detailed in the technical design report), should be implemented.
- Implement the Integrated Water Resources Management Plan (IWRMP) included in the Supplemental EIA to provide a comprehensive, multi-sectoral plan and adaptive management system for coordinating all water and land uses in the Kopili River Basin.
- Design and implement a comprehensive fisheries reintroduction plan, including specifications of lotic and lentic species, and timing and locations of reintroduction, as well as implementation budget and responsibilities. The plan should provide for long-term regular monitoring and evaluation of plan implementation and effectiveness with contingencies for restocking to maintain population levels and to achieve a balanced gene pool through transfers from other stream stretches, as necessary. In addition, the implementation and effectiveness of the environmental flow rates should be monitored and evaluated on a regular basis during project start-up and operation as part of implementing the ESMP.

3.3 Mitigation Measures for Air Quality and Land Quality VECs (Lower Significance)

30. The VECs for air quality and land quality have been defined separately in Sections 5.3 and 5.4 of the Cumulative Impacts Report, respectively. However, the two VECs can be addressed by many of the same mitigation measures, since many of the measures that control air emissions of PM also help control surface water runoff and consequent soil erosion and land degradation.

31. The following mitigation measures should be considered to address the cumulative impacts of the LKHEP project on the Land Quality VEC:

- Municipal – Utilize rational land use planning, enforce zoning requirements, manage traffic, pave the roads, and expand water, sanitation, and solid waste management services to reduce the long-term, growth-induced air pollution and land degradation in all sectors.
- Agriculture – Work with the two autonomous district agriculture departments to broaden and accelerate their programs to eliminate jhoom (slash and burn) agriculture to reduce surface water runoff and soil erosion, as well as air emissions of PM from dust generation.
- Forestry – Work with the two autonomous forest departments to intensify their afforestation and reforestation programs, including afforestation at a ratio of 2:1 in areas such as the reservoir that will be deforested. Clear the reservoir bottom in a way that minimizes surface water runoff and soil erosion and find ways to utilize the wood cleared with a minimum of burning.
- Energy – Reduce the use of coal, charcoal and wood for fuel, e.g. through intensified support to alternative energy sources for local residents, for example:
  - Broaden and accelerate the GOI"s distribution of gas cylinder stoves
  - Install pico-solar equipment in homes to power lights and mobile phones
  - Install photovoltaic solar energy in both on-grid and off-grid village configurations
  - Employ distributed generation systems for power supply (which could have compensatory effects if natural gas or renewable energy technologies are employed).

32. This will not only reduce air emissions directly from their combustion, but also reduce soil erosion and associated dust generation from the extraction, production or collection of these fuels from the landscape.

- Industry – Upgrade to cleaner production technology, install air pollution control and monitoring technology applicable to the respective industrial sectors, conduct rational land use planning in industrial estates, and enforce existing EIA and environmental management regulations.

3.4 Project Area of Concern

33. For the draft EIA and DPR, the project area of influence defined. However, the SEA and CIA may need to cover broader areas, thus, as a first step in defining and refining the project areas of concerns (AoC), for CIA purposes, it was necessary for us to obtain more precise geographic information for features important to the CIA and to prepare maps

displaying those features. Such maps can be used not only for presenting findings and recommendations in the CIA report, but also for communicating with project stakeholders. For the CIA, the temporal and spatial boundaries, respectively, set for the CIA are described below.

34. **Temporal Boundaries**. Taking into account recent trends and the existing condition of the basin, the potential impacts of LKHEP construction, including construction of related infrastructure, will be evaluated for the 4-year construction period of 2018-2022. The startup and operation phase impacts will be evaluated for the 20-year horizon of 2022-2042. A 20-year period corresponds well with the planning horizons of most government sectoral and regional plans and studies. Longer-term, qualitative projections based on anticipated trends may be possible depending on data availability and uncertainty.

35. **Spatial Boundaries.** The spatial boundaries of the CIA are defined to facilitate evaluation of different types of potential cumulative impacts. External influences that create significant direct impacts in the basin are accounted for in the assessment (e.g., inter-basin water transfer, acid mine drainage), while any external areas identified as having a significant impact on basin values are also addressed. To address the project's potential influences on river water quality and quantity, the main basin values that will be affected by the project, the AoC should cover the catchment of the upper and local Kopili basin, including the Kharkar-Kopili confluence. In addition, to address the facility itself as well as associated facilities and infrastructure, the AoC should encompass the areas within a 25 km radius of the proposed LKHEP, 5 km radius along the alignments of proposed associated facilities/infrastructure, including 60 km along the road from Land to Garampani, and 40 km along the 220 kV transmission line from LKHEP to Lanka (Sankerdevnagar substation). From the social perspective, the AoC should embrace the geopolitical boundaries encompassing the two autonomous districts, Dima Hasao and Karbi Aglong, in which the Kopili River Basin resides and in which social, economic, resettlement and development impacts, both positive and negative, will focus. Moreover, the portion of Assam and Meghalaya States which illegal coal mining is occurring that creates acid drainage which flows via the KharKar River into the Kopili River is considered as a part of the AoC or the purpose of CIA.[1]

[1] The illegal coal mining has been undertaken independently of the project, and the related impacts (i.e high acidity of the river) have occurred due to the mining. Though the impacts have existed regardless of the project, it was considered as a part of the AOC for the purpose of the watershed management study.

4. WATERSHED CHARACTERIZATION

36. Upstream illegal coal mining areas are generating acid mine drainage (AMD) which has significantly deteriorated water quality and aquatic ecology in the Kopili River. The AMD pollution from upstream illegal coal mining should be considered a cumulative impact when considered in conjunction with the water quality impacts anticipated to be generated directly by the proposed LKHEP. The LKHEP water quality impacts are described in detail in the WAPCOS EIA and the ADB EIA for the LKHEP project.

37. In the Draft CIA, a VEC addressing water quality has been designated. This "Water Quality VEC" covers the entire Kopili River Basin, but within that broad area there are two sets of areas critical to improving water quality, called Resource Impact Zones:

- The areas where water quality impacts on aquatic ecosystems and ecosystem services are of greatest significance and concern, namely the stretches of the Kopili River upstream and downstream of the Upper Kopili Hydropower (KHP) project and LKHEP project, as well as their respective reservoirs.
- The areas which offer opportunities for directly preventing or reducing the acid mine drainage, including the upstream illegal coal mining areas extending into Meghalaya State where there are source control (mine closure and AMD-impacted surface water treatment) opportunities, the area immediately upstream of the KHP project, including the Kharkhar River, where passive treatment using limestone drainage systems would be feasible and effective, and the area immediately upstream of the LKHEP project where more active wastewater treatment could be attempted, at a considerably higher cost.

4.1 Existing Conditions and AMD Pollution Sources

38. Illegal coal mining upstream of the KHP project in Assam and especially Meghalaya State does not appear to be abating and, while there is a legal battle ongoing over the cessation of illegal coal mining in the state, no remedial efforts are currently underway or planned to manage and mitigate illegal mining in Meghalaya. Therefore, the safe assumption is that AMD pollution will continue to occur and possibly increase, with the only relief possibly coming in the form of dilution during the annual monsoon season, although this has not been the case in the Umrong and Khandong Reservoirs, where pH remains consistently low through monsoon season.

39. The following summary of Kopili River Basin surface water quality addresses existing AMD/pH and general water quality (conventional water pollutants) in the Kopili River Basin. Aside from the impacts of the proposed LKHEP Project, which are discussed under Cumulative Impacts Assessment below, there are no trends or other factors suggesting that the existing water quality conditions in the basin will change significantly in the next 10 years.

40. Water quality data in the lower Kopili River has been assembled and evaluated using two sources: The WAPCOS EIA (2016) and the APGCL Design Project Report (2015). Additionally pH data was obtained from NEEPCO for the Khandong and Umrong Reservoirs.

41. Acid Mine Drainage Contamination - Water quality in the lower Kopili River is influenced predominately by low-pH surface water draining from illegal mining areas in southwest

Assam and Meghalaya. The acid mine drainage (AMD) flows into the Kharkar River which then discharges into the Upper Kopili River. The mineral pyrite (FeS_2) contained in the coal deposits produces sulfuric acid upon exposure to air and water. A study conducted by the Central Soil and Materials Research Station (CSMRS), New Delhi (2010) reported pH levels at 2.8 to 3.3 in the Kharkar River. This was confirmed during a site visit in January 2017, where pH in the Kharkar was measured at 3.3 and 3.8 below the confluence with the Kharkar River, as shown in Table 4-1.

Table 4-1: Water Quality Sample Locations and Field Parameters, January 2017

Tributary	pH Value	EC (µs/cm)
Kopili River upstream	7.4	40
Kharkar River upstream	3.3	480
Kopili River downstream	3.8	440
Umrongso East Bank	4.2	120
Lower Kopili Damsite	4.1	140
Longku Nala	7.4	60

42. The pH measurements obtained from NEEPCO for the Khandong and Umrong Reservoirs for the period 2007-2015 indicate that pH ranges between 3 and 5 with little to no seasonal variation. Water quality in the lower Kopili does vary seasonally, due to influx of precipitation during monsoon rains. The pH in the Lower Kopili Project Area varies between from 3.2 to 5.2 (WAPCOS EIA). There inadequate data to evaluate seasonal variations in Upper Kopili and Kharkar Rivers, or whether pH levels are trending down due to increasing illegal mining activity.

43. General Water Quality – Other than low pH, there are no major sources of pollution loading in the basin. The catchment has low population density and little agricultural activity. Other than illegal mining there are no other industrial sources of contaminant discharge into the Kopili drainage other than total suspended solids.

4.2 Kopili Watershed Geography

44. The Kopili River is one of the major river systems of the Brahmaputra. About three fourth of the basin area lies in the hills and balance is in the plains. The hill catchment is mostly covered by dense forest. The plains catchment is a fertile agricultural land with elevation ranging from 150 m to 50 to the confluence of the Brahmaputra.

45. Kopili is a south bank tributary of Brahmaputra which originates in the Borail Range in Meghalaya at an altitude of about 1600 m and has a total length of 290 km up to its confluence with Brahmaputra. Its basin is bound by the Jaintia Hills in the west and the South Cachar and Mikir Hills in the east. Kharkor, Myntriang, Dinar, Longsom, Amring, Umrong, Longku and Langkri are its major tributaries in its upper reaches.

46. After entering Assam, the Kopili forms the boundary between the Karbi-Anglong district and Dima Hasao (North Cachar Hills) district up to its confluence with Diyung River, on its right at 135 km. After the confluence with Diyung, Kopili flows into the Nagaon district in a north- westerly direction. The Jamuna River, with a catchment of 3946 km^2 flows to the Kopili at Jamunamukh. The river then flows in western direction, and further downstream, the

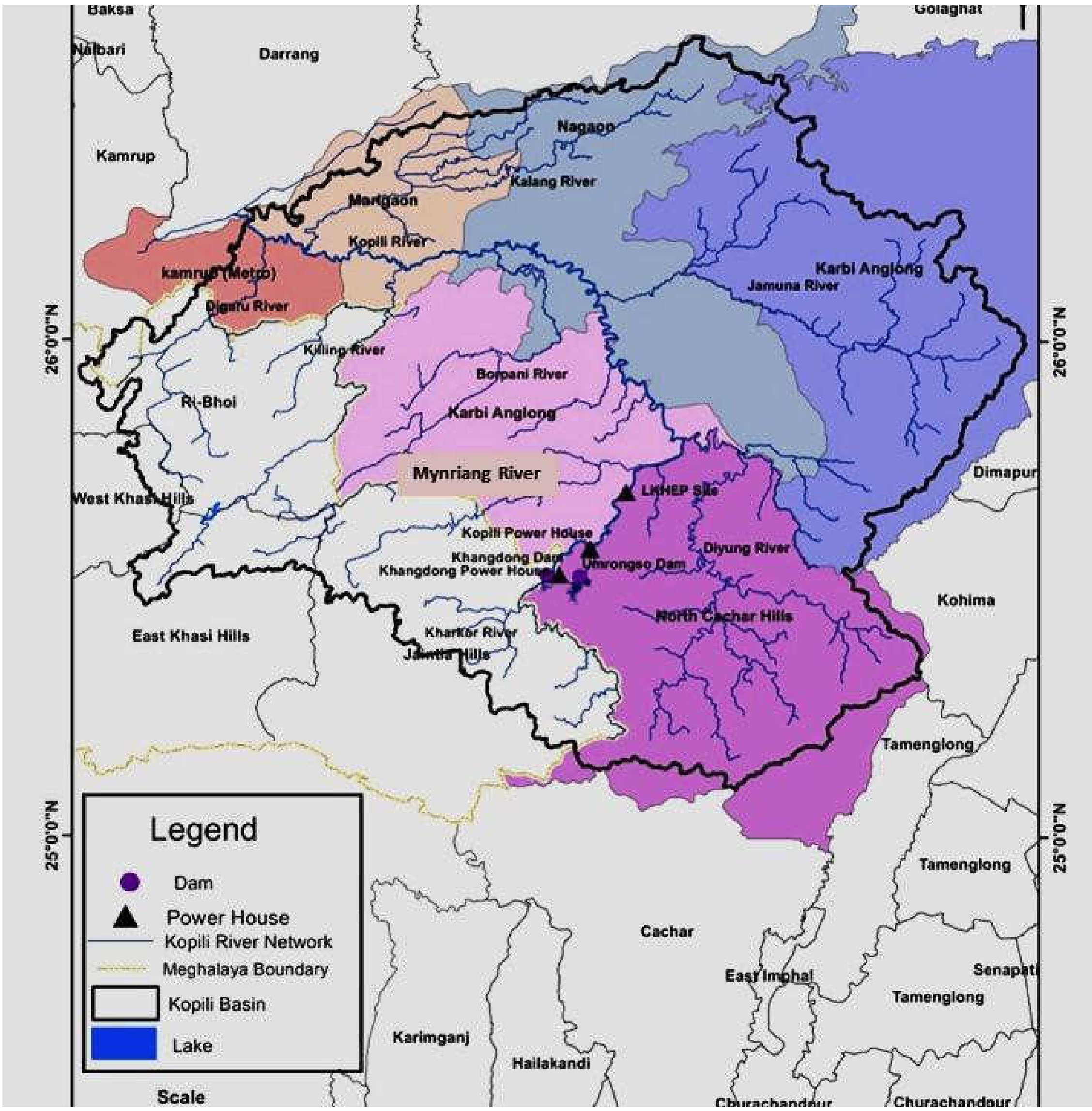
Umkhen- Borapani River which rises in the Shillong plateau and drains an area of 1821 km^2 joins Kopili at a distance of 220 km from the left. The Killing River, known as Umiam in its upper reaches draining an area of about 1355 km^2, flows into Kopili from the left at about 234 km. The Kopili River finally flows to Kalang, a spill channel of Brahmaputra, near Hatimukh after traversing a distance of 290 km^2. The total catchment of Kopili River is about 20,997 km^2.

47. The major tributaries of the Kopili River are, as shown in Figure 4-1: Diyung, Jamuna, Myntang, Borpani, Killing and Kallang. The basin covers four districts of Assam, namely Dima Hasao (North Cachar hills), Krabi Anglong, Nagaon and Morigaon. The river originates form Jayantia hills and its tributaries drain the West Khasi hills of Meghalaya. The total basin area as calculated using recent GIS analysis is 20,997 sq.km. This includes the area occupied by the Kopili river channel, Kallang River and the lower flood plains of the Kopili-Kalang river system (Table 4-2).

Table 4-2: Catchment area of the Kopili River basin (tributaries and key locations)

Sub-catchment / tributary	Distance from origin (km)	Area (sq.km)	Cumulative Area (sq.km)
Head water catchment	0	403	403
Kharkar River	70	509	912
local nalas and catchment up to Khandong dam	0-80	341	1253
LKHEP dam site	90	757	2010
Mynriang River	125	898	2908
Diyung River	135	3887	6795
Jamuna River	165	3946	10741
Borpani River	220	1821	12562
Killing River	234	1355	13917
Kallang River	243	1891	15808
Digaru, Titamari channel & lower floodplain	243-287	1709	17517
Kopili River channel	290	3480	20997
TOTAL	**290**	**20,997 km^2**	**20,997 km^2**

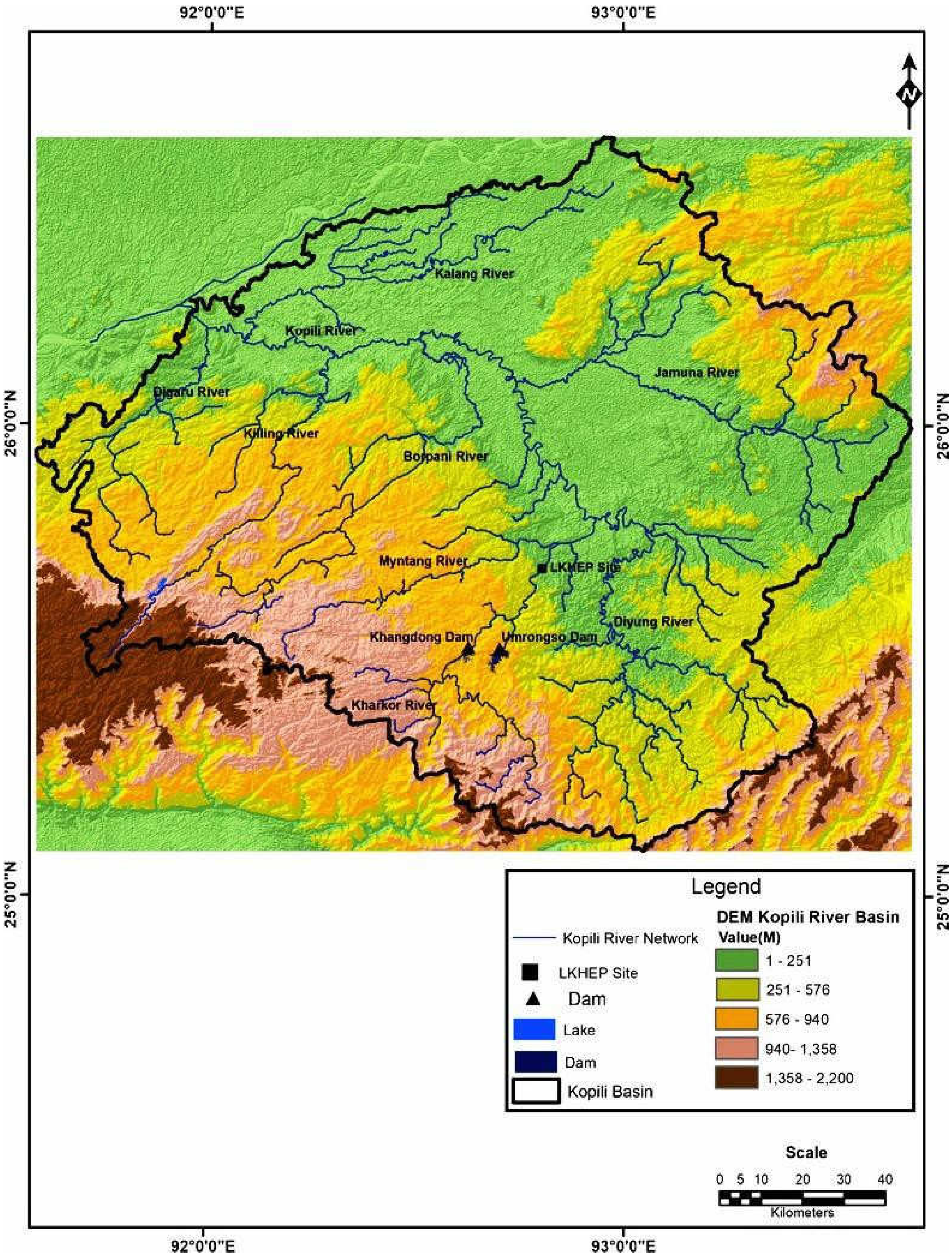
Figure 4-1: Koplili River basin showing major tributaries and districts of Assam



48. Figure 4-2 shows the topographic map of the Kopili River basin based on the downloaded Digital Elevation Model (DEM) provided by at the Suttle Radar Topographic Mission (SRTM) of NASA– https://www2.jpl.nasa.gov/srtm/

49. A detailed analysis of the basin drainage system was carried out using GIS to delineate the sub-catchments and drainage system of the basin as shown in Figures 4-3 and 4-4.

Figure 4-2: The Koplili River Basin Digital Elevation Model



(Source: https://www2.jpl.nasa.gov/srtm/)

Figure 4-3: Sub-watersheds of the Kopili River basin

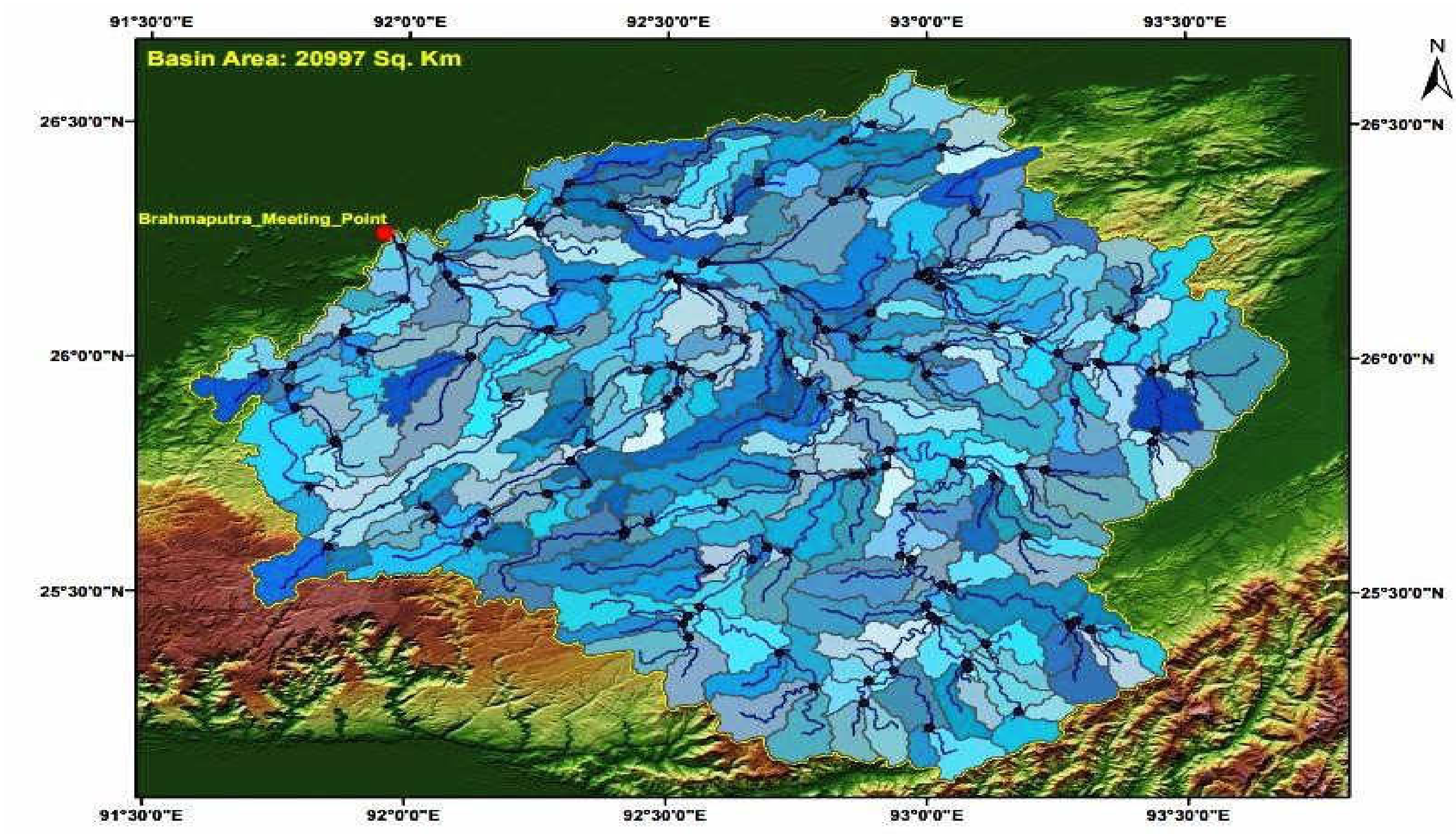
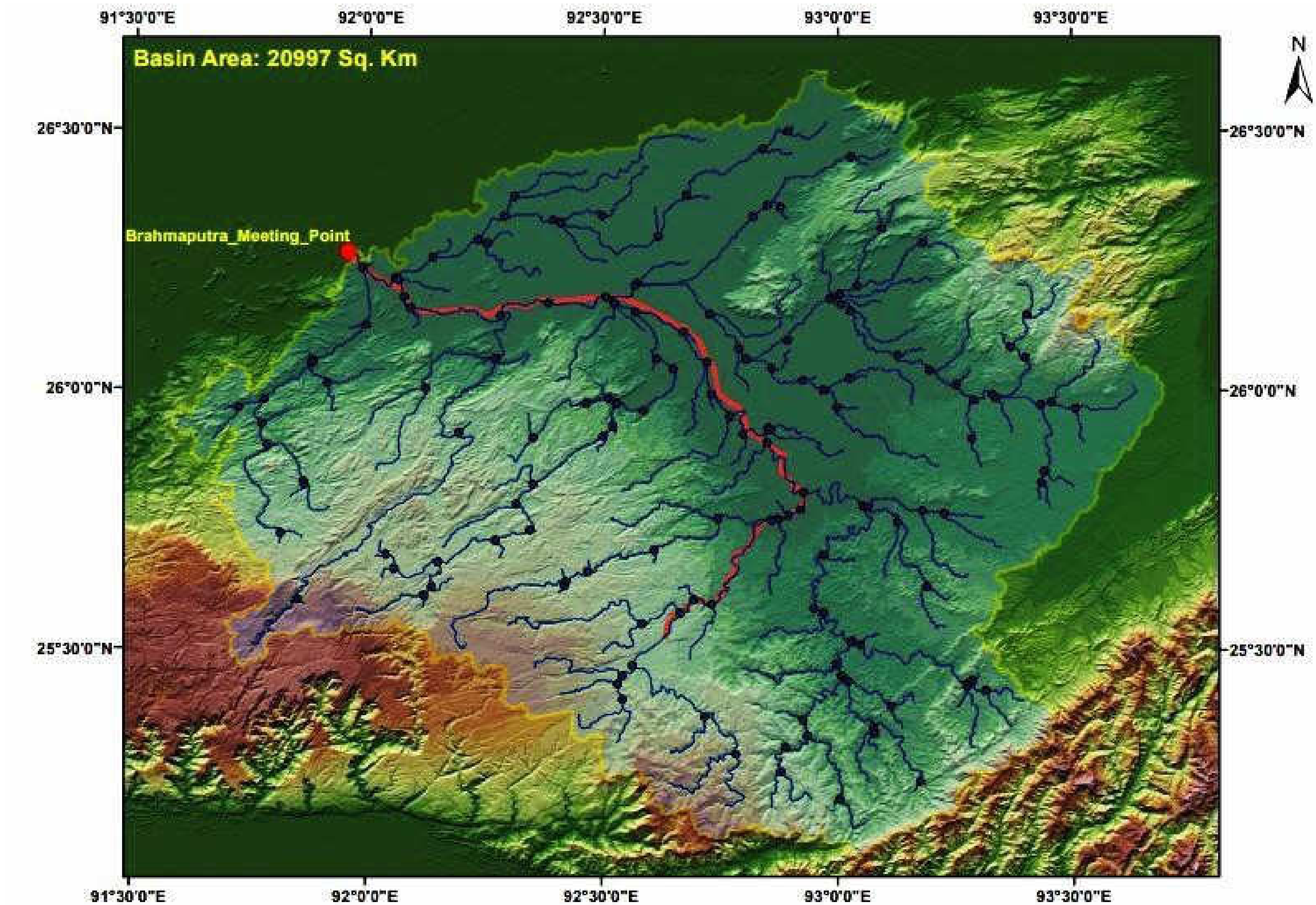
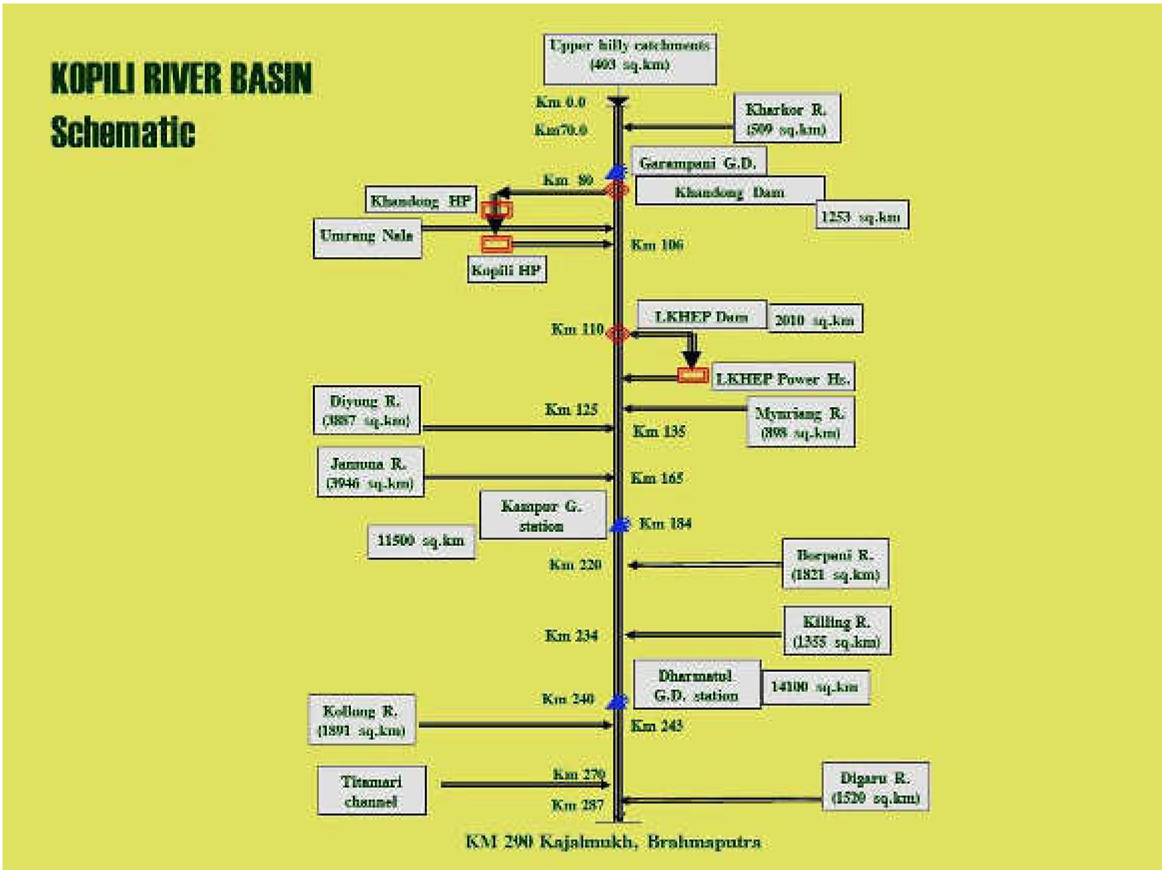


Figure 4-4: Drainage system of the Kopili River Basin



50. Based on GIS analysis, a schematic of the Kopili river system has been developed as shown in Figure 4-5.

Figure 4-5: Kopili River Basin Schematic



4.3 Flow Volumes and Gradients

51. **Assessment of Kopili Basin Water Quantities and Flows.** The following summary of existing water flows in the Kopili River Basin, provided by the Consultant team preparing the IWRMP, addresses existing quantity, timing, and quality of water flows in the Kopili River Basin as evaluated from existing data.

52. Daily discharge records of Kopili River at Garampani Ferry Ghat are available from Years 1955 to 1969. This station is located upstream of the proposed dam site. Discharge data at Longku Dam site is available from 1979-1992 and from 1999 to 2016.

53. The existing/ongoing water flow trends and future years" projections were established by recent discharge data from 1999-2016 to evaluate the continuity of the data sets. To assess the potential impact of dam on Kopili River flow and to establish before and after dam flow scenario, the period from 1959 to 1992 was considered as pre- dam era while period

from 1999 to 2016 was considered post-dam era.

54. The LKHEP project is a “run-of-river” HPP, as defined by the GOI. As such, during the dry season, it will store water – on a daily basis only – and discharge it at the base of the dam as “environmental flow”. According to the WAPCOS EIA, to mitigate the of the LKHEP dam and reservoir on Kopili River water quality and aquatic and riparian ecology, an environmental flow requirement has been set, as follows:

- Monsoon Season - May to September - the cumulative flow releases including spillage during monsoon period should be about 30% of the average flows during the 90% dependable year
- Non-monsoon / Non-lean Season - October and April - 25% of the average flows during the 90% dependable year
- Lean Season - November to March - 20% of the average flows during the 90% dependable year

55. The environmental flow requirements are based on release data provided by the DPR and approved by the Expert Environmental Appraisal Committee of the MoEFCC, as well as the Central Electricity Authority and Central Water Commission of India.

4.4 Seasonal Variations in Flow

56. A summary of the mean monthly flows in during the three period is given in Table 4-3. Tables 4-4 to 4-6 show mean monthly data for the above three periods. The different flow characteristics during the three periods are also depicted Figure 4-3. As expected, the impact of operation of the Kopili hydropower system, by releasing regulated from the Khandong and Umrang reservoirs, is positive on the down steam river flows at the LKHEP site. The mean monthly flows in the lean season are increased while the flows during the monsoon season are reduced. Therefore, further analysis of water resources in the Kopili basin are guided by the above findings. While analysis natural catchment flows will be based the natural flows before 1984, analysis for future planning will be based on the flow data post-LKHEP period after 1994. Kopili Basin hydrology, including seasonal flow modeling is included in the IWRMP Report.

Table 4-3: Summary of Mean Monthly Flows at LKHEP during the three periods

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
1959- 1983 (Prior to Kopili HEP)	8.95	8.33	18.96	26.54	77.60	301.87	194.48	135.29	112.57	83.11	22.27	12.35	83.82
1984 - 1996 (1 unit operating)	20.35	43.59	54.56	49.03	103.13	192.95	177.34	172.73	176.37	169.94	51.84	34.31	103.85
1997-2016 (Post Kopili HEP)	40.14	35.06	32.81	46.73	77.78	148.90	168.84	145.39	135.53	109.39	76.00	52.04	89.05

Table 4-4: Mean Monthly Flows at LKHEP (period-i: Pre-KHEP)

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual Mean
1959	7.03	6.51	9.39	8.15	139.83	553.27	117.77	72.39	97.74	176.13	38.23	11.81	103.19
1960	7.34	6.23	5.54	4.75	38.83	235.35	214.60	93.20	209.97	40.08	18.50	9.47	73.66
1961	7.16	5.94	126.71	37.49	163.53	219.57	144.87	62.48	122.58	49.55	17.56	9.13	80.55
1962	6.71	7.44	5.34	15.70	26.88	299.84	119.65	272.54	40.86	24.53	12.76	8.05	70.03
1963	6.07	4.88	5.54	9.69	44.75	492.78	172.85	83.31	57.02	69.40	18.84	12.17	81.44
1964	9.24	9.18	9.06	60.14	216.17	190.26	310.98	175.98	223.09	151.18	24.99	13.51	116.15
1965	8.92	13.10	8.27	14.23	94.11	296.11	181.55	238.30	104.31	67.34	22.36	13.29	88.49
1966	9.41	5.59	4.87	10.63	34.97	848.03	274.48	125.70	87.25	124.99	20.81	13.81	130.04
1967	9.61	11.40	13.06	21.63	80.65	111.65	250.24	44.99	60.85	59.38	8.57	8.92	56.75
1968	7.05	5.26	8.12	20.95	45.97	142.68	235.80	116.33	66.52	42.70	15.45	11.13	64.26
1969	5.75	4.07	5.63	31.98	28.42	328.85	124.40	116.27	107.02	80.53	19.81	11.13	71.99
1980	11.21	10.61	19.37	48.41	86.48	161.30	153.61	125.27	123.72	151.35	37.18	19.62	79.01
1981	16.13	12.45	25.58	39.90	55.87	103.18	181.90	107.15	123.15	34.88	14.30	16.09	60.88
1982	8.87	6.79	6.73	39.18	36.69	351.95	200.65	181.39	114.19	40.54	25.37	16.69	85.75
1983	13.69	15.52	31.16	35.31	70.84	193.16	233.90	213.98	150.35	133.99	39.28	10.49	95.14
Mean	**8.95**	**8.33**	**18.96**	**26.54**	**77.60**	**301.87**	**194.48**	**135.29**	**112.57**	**83.11**	**22.27**	**12.35**	**83.82**

Table 4-5: Mean Monthly Flows at LKHEP (period-ii: transition)

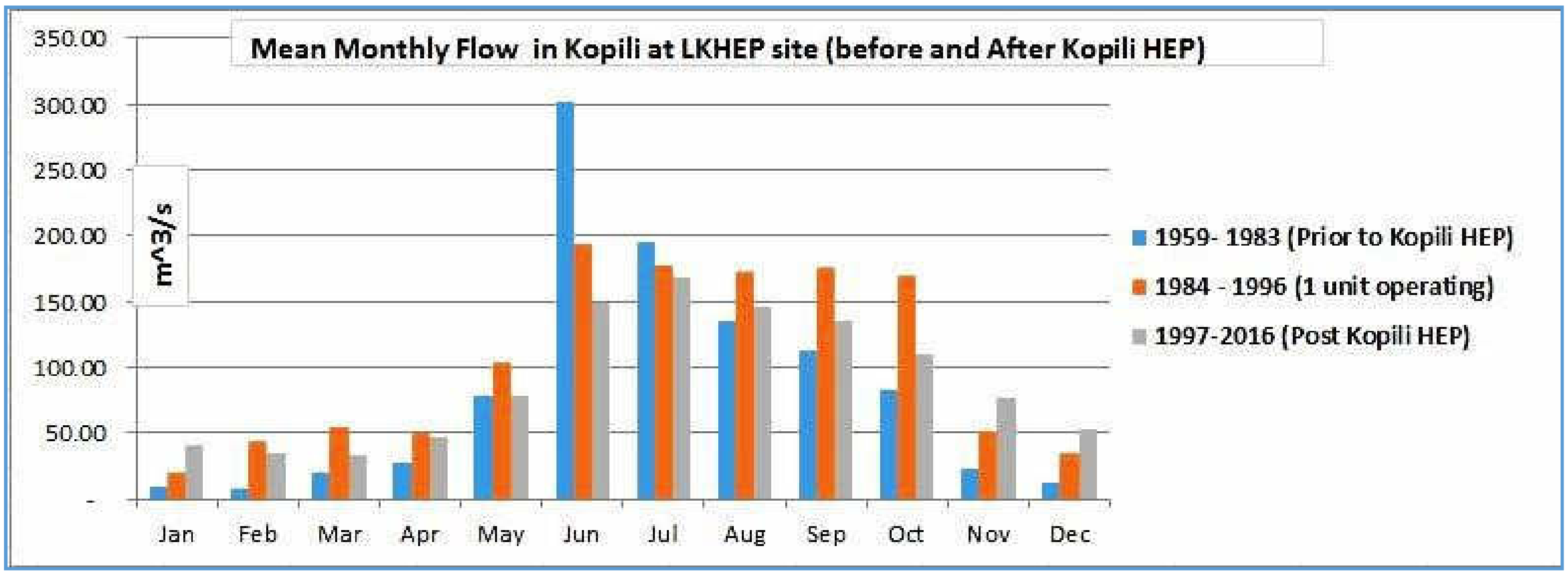
Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual Mean
	No data during 1970-1979												
	First Unit of the Kolili HEP commissioned in 1984												
1984	11.66	12.39	7.93	50.24	221.15	167.98	275.04	129.44	224.84	102.92	36.30	32.79	106.06
1985	17.91	16.87	32.12	65.13	113.02	319.05	220.42	124.72	130.48	78.11	36.62	14.65	97.42
1986	7.18	5.04	20.50	26.59	33.57	30.74	86.63	84.73	157.90	237.76	80.16	45.83	68.05
1987	15.69	11.50	22.47	76.68	66.51	243.23	255.30	300.09	273.78	229.38	52.76	21.14	130.71
1988	8.69	7.07	10.46	21.18	138.72	234.54	214.90	251.31	209.28	200.22	75.26	52.51	118.68
1989	32.91	257.00	305.64	33.22	30.08	291.68	190.63	255.33	246.77	312.57	43.88	32.30	169.34
1990	29.17	28.33	36.35	114.24	160.86	138.60	158.08	124.91	113.42	221.15	43.88	32.30	100.11
1991	30.81	28.41	28.28	29.85	115.98	231.60	91.02	119.39	167.81	86.95	49.44	29.69	84.10
1992	29.13	25.70	27.33	24.16	48.30	79.17	104.00	164.62	63.04	60.43	48.25	47.56	60.14
Mean	**20.35**	**43.59**	**54.56**	**49.03**	**103.13**	**192.95**	**177.34**	**172.73**	**176.37**	**169.94**	**51.84**	**34.31**	**103.85**

Table 4-6: Mean Monthly Flows at LKHEP (period-iii: Post-KHEP)

	No data during 1993-1998												
	Second Unit of Kopili HEP commissioned in 1994												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Mean**
1999	31.46	19.37	27.27	13.90	15.45	159.51	294.24	148.59	104.51	131.01	71.32	42.27	88.24
2000	18.19	16.28	14.85	17.15	82.17	360.32	360.32	248.79	190.66	131.53	69.74	35.28	128.77
2001	37.35	19.38	17.74	20.85	36.34	143.40	180.44	136.07	149.46	112.19	51.17	32.14	78.04
2002	47.25	39.80	27.30	40.41	130.50	207.76	287.60	217.07	75.36	77.93	75.97	49.41	106.36
2003	38.73	41.46	58.77	48.78	29.72	199.32	193.95	74.52	82.02	95.54	68.67	36.95	80.70
2004	32.22	23.29	17.36	37.17	66.61	87.00	122.65	131.72	168.56	106.92	53.55	31.65	73.23
2005	29.79	30.15	30.06	33.63	112.06	156.98	122.12	136.92	223.85	149.09	57.90	32.71	92.94
2006	42.93	33.61	29.74	34.96	33.08	132.86	150.55	163.69	177.96	137.13	52.53	31.83	85.07
2007	34.40	28.61	29.17	37.26	49.86	134.52	173.15	140.92	189.11	141.37	105.60	77.56	95.13

	No data during 1993-1998												
	Second Unit of Kopili HEP commissioned in 1994												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Mean**
2008	54.55	49.81	39.39	40.93	65.11	141.66	172.48	153.77	230.78	149.74	114.80	87.51	108.38
2009	55.83	55.31	39.90	40.42	49.18	78.35	116.86	175.79	116.69	149.56	79.71	66.04	85.30
2010	20.50	24.09	23.56	142.37	219.91	291.44	168.77	138.24	32.12	31.73	81.87	34.03	100.72
2011	29.47	29.63	33.97	70.14	108.72	134.33	183.49	172.83	128.89	59.70	51.80	29.60	86.05
2012	20.73	31.60	33.47	70.42	109.17	51.86	46.00	41.71	37.04	59.97	51.73	55.63	50.78
2013	25.56	25.73	30.36	44.03	65.74	111.12	109.21	114.70	112.56	91.33	78.32	58.11	72.23
2014	53.72	37.71	39.21	58.06	91.19	98.63	125.23	124.96	116.38	108.05	112.06	100.71	88.83
2015	82.72	67.08	57.74	61.91	89.58	113.45	125.44	169.98	189.21	144.20	113.43	83.18	108.16
2016	67.12	58.16	40.77	28.83	45.68	77.77	106.71	126.78	114.40	92.04	77.88	52.04	74.01
Mean	40.14	35.06	32.81	46.73	77.78	148.90	168.84	145.39	135.53	109.39	76.00	52.04	89.05

Figure 4-6: Flow Characteristics during the three periods



4.5 Surface Water Chemistry

4.5.1 Monsoon dilution

56. Water quality sampling in the Lower Kopili is reported in the EIA and was divided into three seasons: winter, summer and monsoon, as listed in Table 4-7. The pH level in the project area of Lower Kopili hydroelectric project ranged from 3.2 to 5.2, and does not meet the permissible limit for drinking water standards. The TDS level in monsoon season ranged from 40 to 47 mg/l. The TDS level ranged from 59 to 66 mg/l in winter season and 61 to 66 mg/l in winter season. The TDS levels were well below the drinking water limit of 500 mg/l. The hardness levels are below the permissible limit of 200 mg/l specified for drinking water. Hardness is caused by divalent metallic cations. The principal hardness causing cations are calcium, magnesium, strontium and ferrous and iron. The low levels of calcium and magnesium are mainly responsible for the soft nature of water. Chlorides and sulfates are also below the permissible drinking water limit of 200 mg/l. The concentration of cations, including sodium, potassium, calcium and magnesium observed to be quite low which is also reflected by the low TDS level. Iron and other metals are also well below the permissible drinking water limits. Concentration of phenolic compounds and oil and grease are also low.

57. The BOD values are well within the permissible limits, indicating the absence of organic contaminants. This is mainly due to the low population density and absence of industries in the area. The low COD values also indicate the absence of chemical pollution loading in the area. Dissolved oxygen ranged from 4.2 to 4.9 mg/l at various sampling locations monitored for three seasons as a part of the study. Due to low pH, water quality of river Kopili is unfit for domestic, irrigation, bathing or industrial use.

Table 4-7: EIA Kopili River Analytical Results

			Monsoon					Winter					Summer				
Sl.No.	Parameter	Unit	W1	W2	W3	W4	W5	W1	W2	W3	W4	W5	W1	W2	W3	W4	W5
1	pH	-	5.2	5	5.2	4.6	4.8	4	4	4.2	3.6	3.8	4	4	3.5	3.2	3.4
2	EC	µs/cm	70	72	70	62	65	84	81	85	90	85	90	92	90	90	94
3	TDS	mg/l	45	47	44	40	41	62	59	62	66	63	62	65	61	62	66
4	Nitrate as NO_3	mg/l	3.1	3.5	3.4	3.2	3.8	3	3.1	2.7	2.8	3	3.1	3.5	3.4	3.2	3.6
5	Phosphate as PO_4	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6	Fluoride as F	mg/l	0.8	0.8	1	1	1	0.8	0.9	1.1	1	1	0.8	0.8	1	1	1
7	Sulphate as SO_4	mg/l	4	5	4	4	4	4	3.5	4	4	4	4	5	4	4	4
8	Chloride as Cl	mg/l	16	18	16	20	18	10	11	10	11	11	16	18	16	20	18
9	Sodium as Na	mg/l	12	16	14	14	17	11	13	13	14	15	12	16	14	14	17
10	Potassium as K	mg/l	3.2	3.9	3.7	3.8	4.2	2.7	2.9	2.7	2.8	3	3.2	3.9	3.7	3.8	4.2
11	Calcium as Ca	mg/l	15.2	16	15.1	16	15.5	12.6	13.2	14.1	12.7	13	15.2	16	15.1	16	15.5
12	Magnesium as Mg	mg/l	3.3	3.2	3.3	3.3	3.3	3.1	3.2	3	3	3.2	3.3	3.2	3.3	3.3	3.3
13	Iron as Fe	mg/l	0.7	0.6	0.6	0.4	0.4	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.4	0.4
14	Copper as Cu	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
15	Zinc as Zn	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
16	Arsenic as As	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
17	Cadmium as Cd	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
18	Chromium as Cr	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
19	Cyanide as Cn	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
20	Lead as Pb	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
21	Selenium as Se	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
22	Mercury as Hg	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
23	COD	mg/l	3.8	3.7	3.6	4.1	3.7	3.5	3.7	3.6	4	3.5	3.8	3.7	3.6	4.1	3.7
24	BOD 3 days at 27°C	mg/l	1.9	1.9	1.8	2.1	1.9	1.7	1.8	1.8	2	1.8	1.9	1.9	1.8	2.1	1.9
25	DO	mg/l	4.8	4.5	4.6	4.7	4.7	4.2	4.4	4.5	4.5	4.4	4.9	4.6	4.9	4.7	4.7
26	Phenolic compound	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Oil & Grease	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
28	Total Coliform	MPN/ 100 ml	3	3	4	4	3	9	9	8	8	8	3	3	4	4	3
29	Total Hardness	mg/l	51.8	53.2	51.3	53.6	52.3	44.2	46.5	47.6	44.1	44.9	51.8	52.2	51.3	53.6	52.3
30	Nitrates	mg/l	1.2	1.4	1.4	1.3	1.3	1.1	1	1	1	1	1.2	1.4	1.4	1.3	1.3

Table 4-8: Details of water samples collected for analysis

Sample Code	Details
W1	Upstream of Dam Site
W2	Dam Site
W3	Downstream of Dam Site
W4	Power House site
W5	Downstream of Power House Site
Season	**Months**
Monsoon	August-14
Winter	December 2014-January 2015
Summer	April 2015

58. January 2017 Surface Water Sampling - Six (five surface and one ground water) samples for laboratory analysis were collected at the sites listed in Table 4-8. Samples were sent for analysis to the Civil Engineering Department laboratory, Assam Engineering College, Guwahati.. The team also took field readings of pH and conductivity, included in Table 4-9.

Table 4-9: Analytical Results (Water Samples Collected in January 2017)

Parameter	Specifications	Sampling locations					
		Kopili river before confluence	Kopili river after confluence	Kharkar River	Longku Nala	LKHEP Dam axis	Well
Field pH	-	7.4	3.8	3.3	7.4	4.1	-
Lab pH	-	7.1	2.7	2.5	5.1	3.2	6.7
Field EC	-	40	440	480	60	140	-
Lab EC	-	30	42	920	150	150	120
Acidity (as CaCo3)	-	20	37.5	77.5	20	15	40
Total Alkalinity (as CaCO3) (mg/L)	600	30	10	10	70	40	30
Sulfide (mg/L)	0.02	0.01	0.26	0.7	BDL	0.09	0.002
Total Al (mg/L)	0.02	BDL	0.006	1.107	BDL	BDL	0.002
Total Mn (mg/L)	0.5	0.146	0.563	0.826	0.112	0.133	0.114
Total Fe (mg/L)	1	1.145	6.592	11.625	0.834	0.437	0.752
Ferric Iron-Fe3+ (mg/L)	-	0.595	0.781	3.974	0.142	0.014	0.084
Ferrous Fe [Fe2+] (mg/L)	-	0.55	5.811	7.651	0.692	0.423	0.668
Ca as CaCO3 (mg/L)	200	28	31	36	33	29	37
Mg as CaCO3 (mg/L)	150	39	44	42	46	48	43
Total Solids mg/L)	2000	180	340	214	230	280	290
Chloride mg/L)	500	44.02	46.86	51.12	41.18	48.28	45.44
Suspende d Matter mg/L)	2000	40.0	100	54	50	90	80

Parameter	Specifications	Sampling locations					
		Kopili river before confluence	**Kopili river after confluence**	**Kharkar River**	**Longku Nala**	**LKHEP Dam axis**	**Well**
Amount of 0.1N NaOH to neutralize 200 ml (Phenolphthalein Indicator)	Not more than 2 ml	0.8	1.5	3.1	0.8	0.6	1.6
Amount of 0.1N HCl to neutralize 200 ml (Methyl Orange Indicator)	Not more than 10 ml	1.2	0.4	0.4	2.8	1.6	1.2
Organic Content (mg/L)	200	0.07	0.16	1.52	0.15	0.64	BDL
Inorganic Content (mg/L)	3000	59.5	116.3	187.5	55	41.5	66

59. Preliminary evaluation of this data set indicates that water quality in the Kopili River is affected by low-pH water from the Kharkar River. Sulfide levels are highest in the Kharkar River and in the Upper Kopili. Aluminum levels are highest in the Kharkar River (1.1 mg/L) but are lower than the maximum amount recommended for successful ALD and other passive treatment technologies (less than 25 mg/L). Total iron in all samples is also less than recommended maximum for passive treatment (10 mg/L). These initial results of all the river samples indicate that water quality is suitable for passive treatment design with some oxide flocculation collection and management necessary to maintain low turbidity and sedimentation accumulation.

4.6 Kharkar River

60. The Kharkar River drains the Jaintia Hills District of east Meghalaya State. The topography of the district is composed of undulating hilly landscapes dissected by numerous rivers and streams, many draining to the Kharkar River. On the northern and western borders, these hills take the form of north- south trending hilly ranges, and ranging two to three thousand feet in height.

61. The drainage system of the district is controlled by topography. Broadly, there are

mainly two watershed in the district, one river flowing in the northern direction toward the Brahmaputra and the other in the south, towards the Surma valley in Bangladesh. The drainage pattern is sub parallel to parallel and is controlled by joints and faults as indicated by the straight courses of the rivers and streams with deep gorges.

62. The Kharkar River is the main contributor of low-pH surface water into the Upper Kopili River. Previous investigations, including a brief trip to the confluence of the Kharkar River and Kopili River in January 2017 (ES Safeguards Interim Report, February 2017) confirmed the low-pH conditions. Extremely limited access to the Kharkar Valley precluded collection of any additional data from the site. The data and information available for the Kharkar River has been evaluated in this section to give a preliminary assessment of Kharkar River flows and quality.

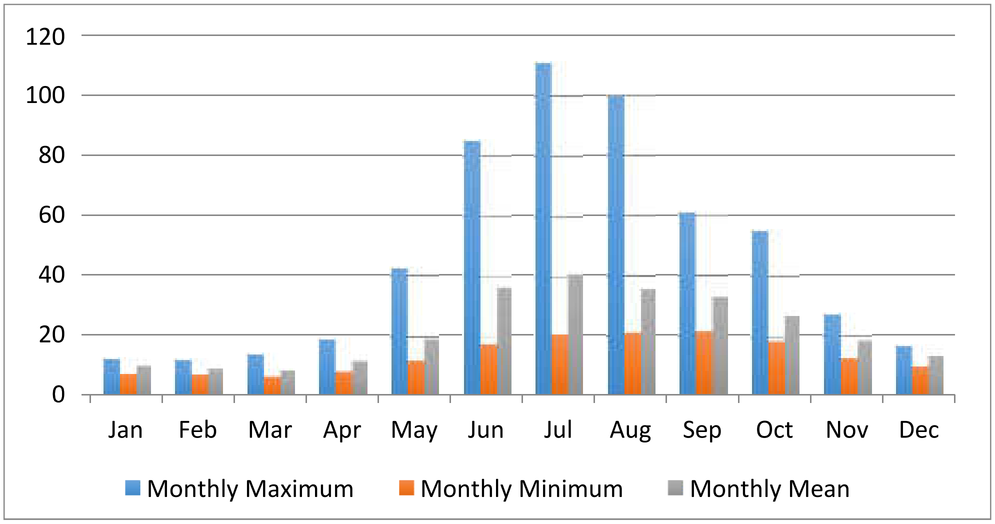
4.6.1 Kharkar River Flow and Gradients

63. Kharkar River discharge has been estimated by extrapolating Kopili River discharge data, catchment area of LKHP dam site and Kharkar River catchment areas. Based on last 18 years‟ discharge data (from Year 1999-2016), the annual mean Kharkar River discharge is estimated at 21.49 Cumecs. Variation in estimated monthly maximum, minimum and average discharge for the Kharkar River is summarized in Table 4-10 and Figure 4-7 below.

Table 4-10: Estimated Discharge Data of Kharkar River

Months	Monthly Maximum	Monthly Minimum	Monthly Mean
Jan	12.19	7.39	9.69
Feb	11.72	6.38	8.51
Mar	13.78	6.33	7.92
Apr	18.67	7.67	11.28
May	42.44	11.82	18.77
Jun	84.90	17.20	35.93
Jul	111.14	20.71	40.74
Aug	99.86	20.85	35.08
Sep	61.09	21.33	32.70
Oct	55.05	18.23	26.40
Nov	27.08	12.58	18.34
Dec	16.40	9.70	12.56
Annual Mean (Cumecs) Cubic Meter/Sec.			**21.49**

Figure 4-7: Kharkhar river Discharge data



4.7 Regional Hydrogeology

64. **General Geology:** The Jaintia District area falls mainly within the Shillong or Meghalaya Plateau consists mainly of Precambrian rocks of gneissic composition in which granites, schists, amphibolites, calc-silicate rocks occur as inclusions of various dimensions. The gneisses form the basement complex for the overlying Shillong Group of rocks and is separated by an unconformity indicated in places, by the occurrence of a conglomerate bed. The presence of primary structures like current bedding, ripple marks etc. indicated that quartzites of the Shillong Group are of sedimentary derivative later metamorphosed to quartzites. These occur mostly as thick layers. Grainite plutons occur as isolated patches in the district, intruding the Basement gneissic complex and Shillong Group of rocks. The granites occur as intrusive body in the basement Gneissic complex. Both porphyritic and fine-grained pink granite occur in the area. The Shella Formation of Jaintia Group consists of alteration of sandstone and limestone occurs in the south-central and south-western part of the district. The shelf facies of Barail Group consists of fairly coarse grained sandstone, shale, carbonaceous shale with minor seams (streaks) of coal and occupy the south-eastern part of the district. The Quaternary fluvial sediments occur as valley-fill deposits and in the extreme southern plain of the district bordering Bangladesh (Groundwater Information Booklet, Jaintia Hills District, Meghalaya. http://cgwb.gov.in/NEW/District_Profile/Meghalaya/Jaintia.pdf)

65. **Hydrogeology:** The GROUND WATER INFORMATION BOOKLET,JAINTIA HILLS DISTRICT, MEGHALAYA reports the following information on groundwater:

- Hydrogeologically, the district can be divided into three units, namely consolidated, semi consolidated and unconsolidated formations.
- The major water bearing formation in the Jaintia Hills District occurs in Tertiary sedimentary rocks, including sandstones and shales and alluvium valley fill deposits.
- Depth To Water Level: Pre-monsoon depth to water level during 2011 - 0.77 to 2.86m below ground level (bgl); Post-monsoon during 2011 - 0.57 to 1.40 m bgl; long term water level trend in 10 years (2001 – 2010) in m/yr - 0.186 to 0.26 m rise in post-monsoon
- Ground water occurs under both unconfined and semi confined conditions in the hard rocks controlled mostly by topography and secondary porosities of weathered

residuum and in joints and fractures.

- Groundwater quality - Higher concentration of Fe is observed in few pockets in deeper aquifer of the district (higher than permissible limit prescribed by Bureau of Indian Standards (BIS), World Health Organization).
- Management and utilization of Groundwater. Coal mining, limestone quarries and cement factories affecting the water quality and the environment particularly the water bodies.

66. The entire coal mining area of the Jaintia hills has become full of mine pits and caves. These open, unfilled pits allow surface water percolation into the aquifer systems. As a result, not only is surface water disappearing, groundwater quality is most likely being degraded also. Groundwater impacts are twofold: degradation due to infiltration of contaminated surface water, and contact of groundwater with air and exposed pit wall rock containing sulfidic minerals, causing sulfuric acid to form and percolate into the aquifer. Ground caving and subsistence of land due to underground mining is also impacting surface and groundwater quality and availability, the extent to which is not yet known.

67. As a result of disappearing and/or contaminated surface water, and degradation of groundwater resources, the area is facing an acute shortage of clean drinking and irrigation water.

68. Singh and Sinha (1992) reported variation of pH in northeastern coalfields, pH 2.8–4.1 in Churcha, pH 4.2–5.0 in West Chirimir, pH 5.2–5.6, pH 5.3–6.0 in Rakhikhol and pH 4.0–4.6 in Gorbi coalfields. Highly acidic mine water with high sulphate (up to 1500 mg/L) and Fe (40 mg/L) were reported in Margherita group of mines in Assam (Rawat and Singh 1982). Bhole (1994) reported pH of 3.9, 3.10 and 4.3 in Ledo, Tirap and Bargolia mines of Assam. Based on a similar study carried out in Makum coalfields in Assam by Equeenuddin et al. (2010), it was found that the mine discharges were highly acidic (up to pH 2.3) to alkaline (up to pH 7.6) in nature with high concentration of SO4 2- and mine water was highly enriched with Fe, Al, Mn, Ni, Pb and Cd. In addition, ground water close to the mines and AMD-affected creeks were highly contaminated by Mn, Fe and Pb but major rivers were not much impacted by AMD due to their large volume of water. Different physico-chemical parameters of surface and groundwater near coalfields in northeast and other parts of India. Chabukdhara and Singh report the maximum concentrations of metals detected in groundwater near Makum coalfield, Assam, India was (mg/L): 0.018 for Cr, 0.2 for Ni, 0.108 for Zn, 2.18 for Mn, 3.9 for Fe, 1.1 for Al, 0.061 for Pb, and 0.009 for Cu. In a study by Abhishek et al. (2006), water quality parameters in groundwater in Jharia coalfield ranged: pH (6.72–7.94), TDS (213–530 mg/L), SO_4 (8.8–41.2 mg/L), Cl- (19.8–96 mg/L), NO_3 - (3–77.7 mg/L), Fe (0.13–2.18 mg/L), Zn (0.02–0.04 mg/L), Pb (0.01–0.04 mg/L). The maximum TDS, NO_3 and Fe concentrations exceeded the Bureau of Indian Standards (BIS) limit for drinking water quality.

69. Limited groundwater quality data are available for Jaintia Hills groundwater as of preparation of this report, so the above groundwater quality results from nearby coal mine fields can be considered as possibly representative of expected mine pit and groundwater in the vicinity of rathole mining.

70. The following is an excerpt from the Groundwater Information Booklet:

- *Jaintia Hills District The district is a major coal producing area of the state with an estimated coal reserve of about 40 million tonnes. The areas where coal mining is prominent are Sutnga, Lakadong, Musiang-Lamare, Lumshnong, Ioksi, Ladrymbai, Bapung, Jarain, Shkentalang, Sakynphor Khilehriat and Rymbai. The thickness of* *coal seams vary from 30 to 212 cm and is found to occur imbedded in sedimentary rocks (sandstones and shale) of the Eocene age (The main characteristics of the coal found in the district are its low ash content, high volatile matter, high calorific value and comparatively high sulphur content. The coal is mostly sub-bituminous in character. The physical properties characterize the coal as hard, lumpy bright and jointed except for the coal in Jarain which is both soft and hard in nature. Coal extraction is done by adopting obsolete and primitive surface mining method which is commonly known as „rat-hole‟ mining. In this method the land is first cleared by cutting and removing the ground vegetation and then pits ranging from 5 to 100 m2 are dug into the ground till the coal seam is reached. Thereafter, tunnels are made into the seam sideways to extract coal which is dumped on the ground surface nearby till carried away by trucks. Coal mining in the district undoubtedly has brought wealth and employment opportunities but leads to large scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural land.*

- *The chemical quality of surface water is worst affected as a result of coal mining in the district. Most of the rivers and streams in the mining areas are polluted. The main source of this pollution in the mining area is "Acid Mines Drainage" originating from mines and spoils, leaching of metals from soil and rocks, organic enrichment, silting etc. The waters of the mining areas have been found containing sulphate concentration between 16 to 161 mg/L. The high concentration of sulphates is mainly due to presence of iron sulphide in coal and rocks and its reaction with water and oxygen. On the other hand, water of the non*

mining areas very low concentration of sulphates. Water pollution is exhibited by the colour of the water in mining areas which varies from brownish to reddish colour. Other parameters which characterized the degradation of water quality are low pH, high conductivity, high concentration iron and toxic metals, low dissolved oxygen and high BOD.

5. ACID MINE DRAINAGE SOURCES AND CHARACTERIZATION

71. Mitigation efforts must concentrate on remediating existing and abandoned coal mines in the Kharkar Basin as discussed previously. The following sections provide a basic understanding of the general physical locations, dimensions and geochemical characteristics of rathole mining in the Kharkar River basin, with a focus on Jaintia Hills District of Meghalaya State. This preliminary characterization is based both on collection and evaluation of salient existing data and information, and data collected during a brief field excursion into the Jaintia Hills conducted in July 2017, discussed in Section 5.1.1.

5.1 Illegal Mining – Location and Extent

72. Over 10,000 illegal rathole mines, active and abandoned, have been identified in Meghalaya State as shown in Figure 5-1. These open-pit, mostly hand-dug mines using pressure wash and hydraulic hoisting methods to extract coal, are the source of acidity in the Kharkar River. The mining activities in Jaintia hills district are small scale ventures controlled by individuals who own the land. Coal extraction is done by primitive surface mining methods, or rathole mining where the land is first cleared by removing ground vegetation and then digging pits ranging from 5 to 100 m^2 to reach the coal seam. Tunnels are then excavated into the seam to extract coal which is removed from the pit in a conical basket or a wheel barrow and then taken out and dumped on nearby storage area. The coal is carried by trucks to the larger storage areas near highways for export. Entire road sides in and around mining areas are used for coal stockpiling, which is major source of air, water and soil pollution. Off road movement of trucks and other vehicles in the area causes further damage to the ecology of the area. Thus, a large area of the land is spoiled and denuded of vegetal cover not only by mining but also by dumping and storage of coal and associated vehicular movement.

73. The majority of rathole mining occurs in the Jaintia hills, districts of Meghalaya, lies between latitude 25^{o}5"N to25^{o}4"N and longitude 91^{o}51"E to 92^{o}45"E. The districts are bound by the state of Assam on the north and east, the East Khasi Hills on the west and Bangladesh in the south. The district covers an area of 3819 km^2 constituting 17.03% of the total area of the state. The topography of the district is composed of undulating hilly landscapes dissected by numerous rivers and streams. Jaintia hills is a part of the Meghalaya plateau which composed of rocks belonging to the age group of Archean and tertiary period represented by granites, phyllite, gnessis, sandstone and limestone (Swer and Singh, 2003).

74. Due to narrow nature of the coal seam in this area, large-scale mining is not economically profitable. Land owner"s property rights give them the freedom to extract the coal from their property without using environmental or safety best management practices. As a result, tribal community land has been gradually privatized to reap the immediate benefit from mining without no concern for the long-term environmental consequences. Economically, landowners compete to extract their coal as rapidly and as completely as possible in order to gain market value. Rathole mining was declared illegal in 2012, however mining is still occurring and it is reported that the government collects revenue in the form of royalty and transport tax from mine owners (Mukhopadhyay 2013).

75. The Jaintial hills district of Meghalaya is a major coal producing area with an estimated

coal reserve of about 40 million tonnes. Sutnga, Lakadong, Musiang-Lamare, Khilehriat, loksi, Ladrymbai, Rymbai, Byrwai, Chyrmang, Bapung, Jarain, Shkentalang, Lumshnong, Sakynphor etc. are the main coal bearing areas of the district. Areas under coal mining in Jaintia hills district are shown in Figure 5-2. The coal seams varying from 30 to 212 cm in thickness occur imbedded in sedimentary rocks, sandstones and shale of the Eocene age (Chabukdhara and Singh, 2016). The main characteristics of the coal found in Jaintia hills are its low ash content, high volatile matter, high calorific value and comparatively high sulphur content. The coal is mostly sub-bituminous in character. The physical properties characterize the coal of Jaintia hills district as hard, lumpy bright and jointed except for the coal in Jarain which is both soft and hard in nature. Composition of the coal revealed by chemical analysis indicates moisture content between 0.4% to 9.2%, ash content between 1.3% to 24.7%, and Sulphur content between 2.7% to 5.0%. The calorific value ranges from 5,694 to 8230 kilo calories/Kilogram (Directorate of Mineral Resources, 1985).

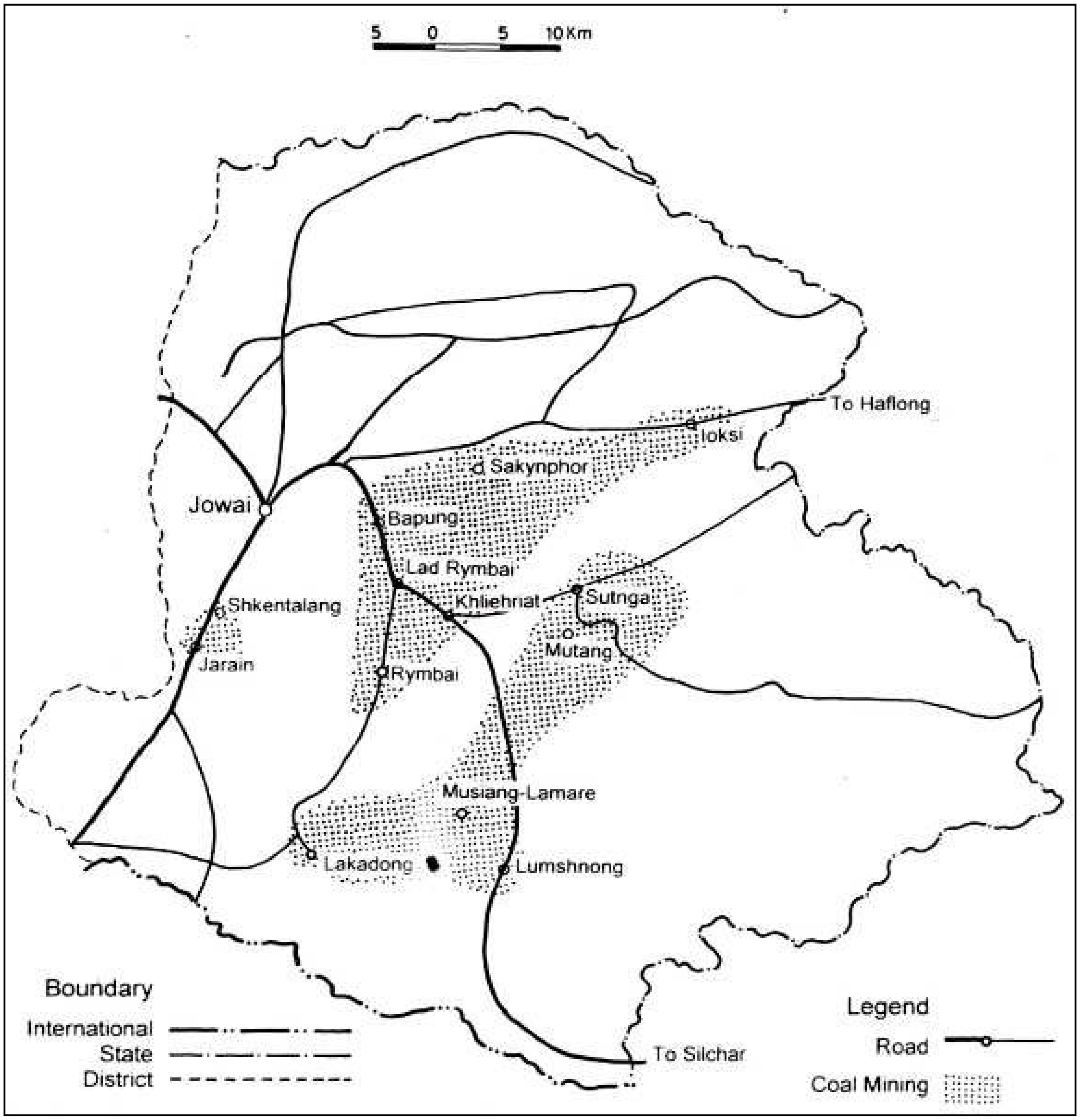
76. During recent years, illegal coal mining in the area has resulted in soil erosion, scarcity of water, pollution of air, water and soil, reduced soil fertility and loss of biodiversity (Das Gupta et. al., 2002). Continued soil acidification due to acid mine drainage and release of excess metals including Al, Fe, Mn, Cu have caused enormous damage to plant biodiversity in this area (Sarma,2005). Due to mining induced changes in land use pattern and soil pollution the area of fallow land has steadily increased. Between 1975 and 2007, there has been decrease in forest area by 12.5%, while area under mining has increased three fold (Sarma et.al, 2010). Thirty one percent of the land Jaintia district has been made barren due to coal mine contamination, the highest of all districts in Meghalaya (Mukhopadhyay 2013).

Figure 5-1: Google Earth Image of Rathole Mines in the Kharkar River Valley, Meghalaya State

77. As noted on Figure 5-1, the entire Jaintia hills area has become infested with coal mine pits and caves. These open, unfilled pits allow surface water percolation into the groundwater.

As a result, smaller streams and rivers of the area are either completely disappearing or becoming seasonal. Consequently, the area is facing acute shortage of clean drinking and irrigation water. Besides, a vast area has become physically disfigured due to haphazard dumping of overburden and mined coal, and caving in of the ground and subsistence of land (Swer and O.P. Singh, 2003).

Figure 5-2: Coal Mining areas of Jaintia Hills, Meghalaya



5.1.1 Kharkar Basin - Jaintia Hills Coal mining

78. No data exists on the extent of active illegal mining in the Kharkar catchment, but several illegal rathole mines were inspected on the Assam side of the Kharkar-Kopili confluence to capture a sense of the scope of mining activities, including pit depth, process water use and overburden storage, among other features. To this extent, ES Safeguards developed an on-site data gathering scheme was developed to collect information on the nature and extent of mining activities at some accessible minesites in the Jaintia Hills. This

information was used to create a schematic of representative mine site dimensions and discharge water quality and quantity. A mine site inspection checklist was developed as contained in Attachment 1. The Mine Site Inventory Field Trip Report is contained in Attachment 2.

79. Data collected during this field effort is categorized in Table A-1 and will be used to develop a conceptual design for general site remediation strategies including costs and schedule. It is obvious, given the relative inaccessibility of the Meghalaya coal mining areas, that only a very small number of the actual active and closed mines were able to be assessed. Therefore the results of our preliminary mine site assessments will be considered as representative of the general conditions of the over 10,000 mine sites located in the Kharkar River basin.

80. For each mine site visited the following data was collected:

- GIS Coordinates
- Landowner identification
- lawful occupier on the property other than the Landowner
- Tribal authority or host community that may be affected
- Number of workers at the site
- Power, water and other infrastructure
- public roads
- Pit active or inactive
- Pit dimensions – depth, width and length
- Coal seam depth and width
- Groundwater present
- Pit pumping and pit water disposal
- Volume of coal produced per day
- Closest tributary and distance to Kharkar River
- Volume of water used and released per day
- Field measurement of mine water acidity
- Volume estimate of waste rock displaced

81. Results of the rathole mine survey are included in Attachment A. The full survey is included in Table A-2 of Appendix-B. The physical extent of the survey is shown on Figure 5-3 below. Numeric minimum, maximum and average dimensions of salient mine area features needed to design a conceptual mitigation plan are included in Table 5-1. Note that all mine discharge areas but one had acidic pH. Discharges for winter, rainy and dry seasons are included as well to incorporate monsoon discharge remediation design into the overall mitigation strategy.

82. Discharge water samples were collected from six locations as shown on Figure 5-3, and results of analysis are included in Table 5-2. Results will be used to model input parameters for design of passive oxic/anoxic limestone drains as a pilot study and will be reported in the Water Quality Restoration Report.

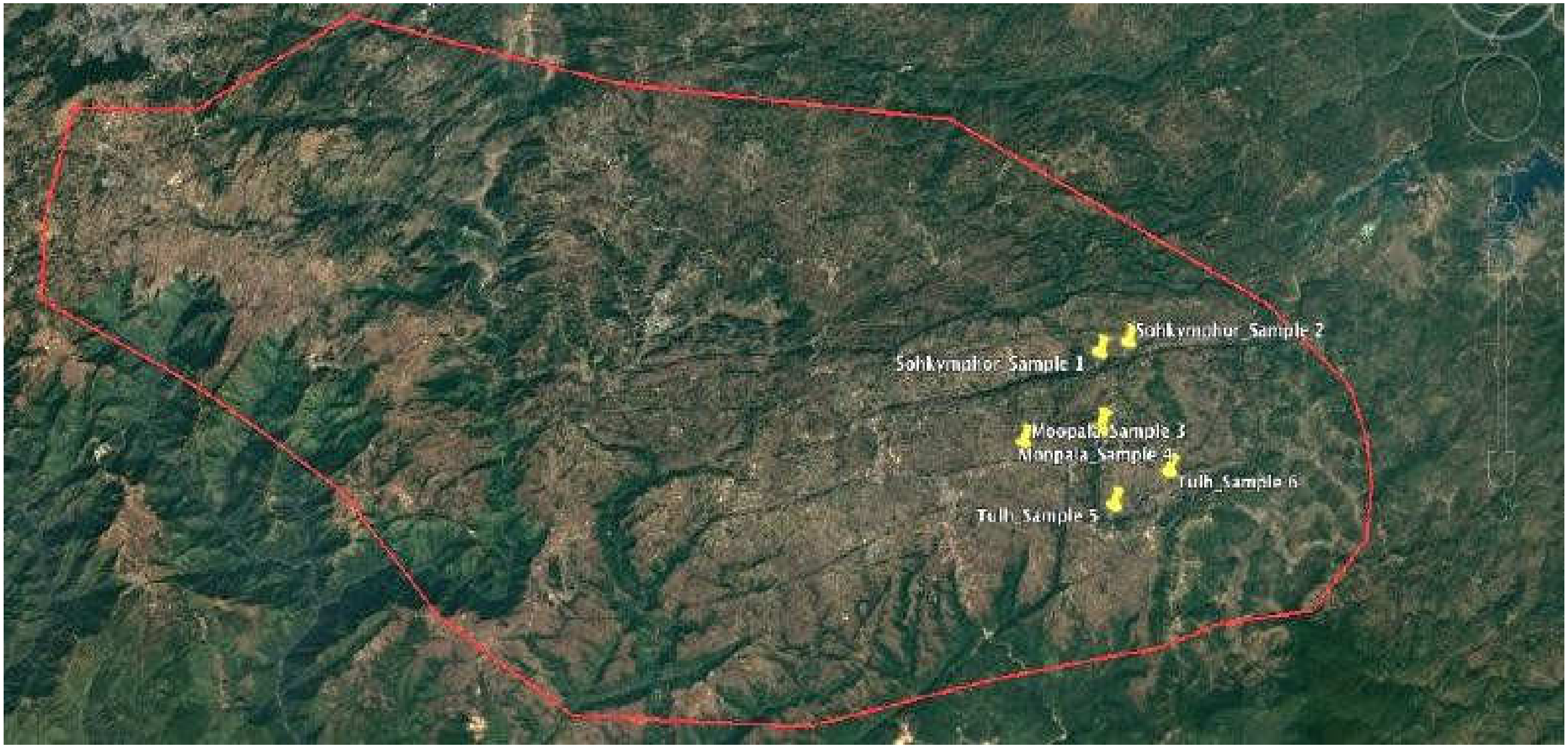
Table 5-1: Mine Site Inventory Summary

		Min	Max	Average
Pit Dimensions (meters)	Pit Radius	1.5	8	6.2
	Pit Depth	4	52	30.3
Coal Seam (meters)	Coal Seam	3	50	28
	Pit Depth	0.25	1.2	0.71
Coal Storage (m3)		300	10,000	5998
Overburden	Height	2	4	2.7
	Area (meters)	10	100	66.7
Water Discharge (l/day)	Winter	1120	20,150	5544
	Summer	0	13,700	3796
	Rain	0	5,400	1541
Discharge Quality	pH	2.4	6.8	3.2
	EC	1	63	22.7

Table 5-2: Jaintia Hills Coal Mine Discharge Analytical Results August 2107

Sampling location	#1 Sohkymphor	#2 Sohkymphor	#3 Moopala	#4 Moopala	#5 Tulh	#6 Tulh
Sampling date	7/30/2017	7/30/2017	7/30/2017	7/30/2017	7/30/2017	7/30/2017
Lab pH	3.3	3.7	2.4	2.6	2.2	2.5
Lab EC	80	180	270	280	630	400
Total Solids (mg/L)	55	142	190	196	494	279
Total Suspended Solids TSS (mg/L)	62	83	112	110	144	121
Acidity (as CaCO3)	32	44	46	48	52	44
Total Alkalinity as CaCO3 (mg/L)	55	96	130	136	320	222
Chloride (mg/L)	16	28	42.5	44.2	180	110
Sulfide (mg/L)	0.2	0.45	0.28	0.72	0.75	0.39
Sulfates (SO4) (mg/L)	18	34	36	32.2	68.8	52.7
Total Al (mg/L)	0.08	0.09	0.11	0.13	0.15	0.11
Total Mn (mg/L)	0.12	0.21	0.22	0.28	0.26	0.24
Total Fe (mg/L)	1.23	1.91	2.14	2.67	6.2	5.12
Ferric Iron -Fe3+ (mg/L)	0.623	1.22	1.1	1.48	4.21	3.1
Ferrous Fe (Fe2+) (mg/L)	0.607	0.69	1.04	1.19	1.99	2.02
Ca as CaCO3 (mg/L)	12.8	22.4	28.8	29.6	67.2	48.8
Mg (as CaCO3) (mg/L)	6.3	12	15.6	18	36	26
Orgnanic Content (mg/L)	2.8	3.1	3.4	3.3	6.8	5.2
Inorganic content (mg/L)	12.8	15.2	16.2	12.8	70.4	54.7

Figure 5-3: Jaintia Hills coal mine inventory area along with six water samples location



5.1.2 Jaintia General Surface Water Quality

83. Review of existing reporting indicates that surface water quality in Jaintia is generally affected by coal mining including, contamination by AMD originating from mines and spoils, leaching of heavy metals, organic enrichment and silting by coal and sand particles. Pollution of the water is evidenced by the color of the water which in most of the rivers and streams in the mining area varies from brownish to reddish orange. Low pH (between 2-3), high conductivity, high concentration of sulfates, iron and toxic heavy metals, low dissolved oxygen (DO) and high BOD are some of the physico-chemical and biological parameters which characterize the degradation of water quality. The water in coal mining areas has been found highly acidic. The pH of streams and rivers varies between 2.31 to 4.01. However, pH of the Myntdu river was found to be 6.67. Table 5-3 lists water quality from Jaintia Rivers as reported in Swer and O.P. Singh, (2003).

Table 5-3: Physico-chemical properties of the water of some rivers of Jaintia Hills, Meghalaya

Rivers/ Streams & Location	Land Use	Water color	pH	DO (mg/L)	Sulphate content (mg/L)	Conductivity (mMHOS)	Remarks
Waikhyrwi, Sutnga	Coal mining area	Brownish	3.96	5.94	78.69	Not analysed	Polluted
Rawaka, Rymbai	Coal mining area	Reddish brown	2.31	4.24	166.5	1.35	Highly polluted
Kmai-um, Rymbai	Coal mining area	Reddish brown	2.66	5.84	144.0	0.74	Highly polluted
Metyngka, Rymbai	Coal mining area	Reddish brown	2.42	4.24	168.0	2.70	Highly polluted
Um-Mynkseh, Ladrymbai	Coal mining area	Brownish orange	3.52	5.04	118.7	0.67	Polluted
Thwai-Kungor, Bapung	Coal mining area	Brownish	4.01	5.68	82.87	0.18	Polluted
Umkyrpon, Khliehriat	Coal mining area	Light Orange	3.67	4.4	161.3	0.37	Polluted
Myntdu, Jowai	Away from Coal mining area	Bluish	6.67	10.2	3.66	0.10	Clean

Source: Swer and O.P. Singh, 2003

84. The low pH, low DO and high sulfates are indicative of AMD generation, and is most obvious when compared with non-impacted water from the Myntdu River in Jowai, which has normal pH and high DO and is described as clean.

85. Average metals concentrations in mine pit water in Indian coal mining areas shown in Table 5-4. Fe, Cu, Mn, Zn, Ni and Pb in mine water of northeast India (Jaintia and Makum) showed higher concentrations as compared to other mining sites in India. Zn and Pb showed the maximum concentrations in Jaintia coalfield of Meghalaya, northeast India and Ni showed the maximum level in Makum coalfield of Assam. Such high concentrations of metals in these sites can be attributed to higher leaching under acidic conditions in these coalfields. However, elemental contents in leachate water are controlled by three factors:

the oxidation rate of pyrite, the acidity of the leachate water and the mineralogy of the rejects (From Chabukdhara and Singh, 2016).

Table 5-4: Metal Contents in Mine Water (Ig/L) in Three Coal Mines in India

Parameter (Ig/L)	Fe	Cu	Mn	As	Zn	Ni	Pb	Cr	Cd	References
Jaintia coalfield (Meghalaya, India)	118,400	320	470	-	4220	1080	430	60	30	Sahoo et al. (2012)
Jharia coalfield (Jharkhand, India)	423	32.3	136	3.4	106.1	17.6	14.9	8.1	-	Singh et al. (2009)
Raniganj (West Bengal, India)	329	18.8	39.4	10.06	60	45.6	22.6	44.6	-	Singh et al. (2009)

86. These regional surface water and pit water quality data sets illustrate the impact of AMD in the streams and groundwater in the vicinity of coal mining areas in northeast India. The Meghalaya State Pollution Control Board, Shillong (MSPCB 2007) reported a case of massive fish death in Lukha River on the eastern border of JaintiaHills district, which was attributed to AMD contaminating the stream water and sediments. Swer and Singh (2003, 2004) have reported the lack of commonly found aquatic life forms such as fish, frogs and benthic macroinvertebrate such as Plecoptera, Ephemeroptera and Tricoptera in water bodies of coal mining areas in Jaintia Hills, Meghalaya (Chabukdhara and Singh, 2016).

87. The above regional and on-site water quality data indicates that coal mining in the Kharkar Basin is contributing to degradation of surface water quality downstream, into the Kopili River Basin and that this degradation is due to AMD emanating from rathole mining in the Kharkar Basin. AMD formation and transport processes are discussed in detail below.

5.2 AMD Formation and Transport

88. Coal mining can result in drainages that have a low pH and are contaminated with elevated concentrations of iron, manganese, aluminum, sulfate, and acidity. The rate and direction of water movement through abandoned mines can be influenced by factors that include precipitation, the structure of the mined coal beds, overburden structure, mine tunnels, air shafts, boreholes, and local collapses. When an underground or open pit mine is abandoned, water levels rise until the water eventually overflows to another mine or at the land surface creating an abandoned mine discharge.

89. Mine drainage from abandoned mines and coal refuse piles is the major source of water-quality degradation in the Kharkar River, which in turn degrades water quality in the

Kopili River to which it drains. It can be assumed, based on the preponderance and geographic spread of open pits in the Kharkar Basin, that at least the lower half the river and many of its tributaries are currently affected by mine drainage. Figure 5-4 shows the river systems that drain the coal mining areas in the Jaintia Hills District. Note that the Kharkar River is the northeastern-most river draining into Assam District. The confluence of the Kharkar River with Kopili River is just where the Kharkar River crosses the Meghalaya border.

Figure 5-4: Map Showing Rivers/Streams of coal mining areas of Jaintia Hill District, Meghalaya

5.3 Impacts to Kharkar River and Downstream

90. When mine spoils containing sulfides are exposed to air and water, the sulfide minerals are oxidized by a series of microbial and chemical processes. The products of these reactions are carried into surface waters where they degrade water quality via acidification, metal

contamination, and sedimentation. AMD waters are characterized by high metal and sulfate concentrations, high conductivity, and low pH.

91. Previous hydrogeochemical studies by Sahoo et al (2011) indicate that AMD-influenced surface water draining from Jaintia Hills carries heavy metals as well as rare- earth elements (REEs) due to corrosion of metals from exposed rock surfaces and that this process is dependent on the geochemical composition of the host rock. They found that Jaintia Hills mine drainage is characterized by low pH with high concentrations of Fe, Al, Mn, Ni, Pb and SO_4^{2-} and rare earth elements with an average concentration in AMD of 714.7 µg/L (Sahoo et al, 2011). They also found that surface water was more contaminated by AMD than groundwater. They also observed that total REE concentrations increase with decreasing pH. In acidic water, REEs behave as conservatives, and dominate as free ion facies or as complexes with SO_4^{2-}. Of note for future mitigation planning is the substantial Al concentration, which, if present in significant quantities in AMD affected water within the mitigation area, implies the potential for limestone drainage treatment failure due to the potential for Al oxides to precipitate and clog the treatment system. Results of the surface water sampling summarized in Table 5-
2 will be used to determine whether Al concentrations will be detrimental to passive treatment design and operation.

92. Natural processes commonly ameliorate mine discharges and the toxic characteristics of the discharges can decrease because of chemical and biological reactions and by dilution with uncontaminated water. Many of these processes occur as the mine discharge flows on the land surface and is exposed to the air. Comparison of analytical results for sulfates, sulfide, Fe and other parameters for samples taken in January 2017 from the Kharkar River and the Kopili River up and downstream, are shown below in Figure 5-5. The sample results are arranged from most upstream (Kopili at confluence) to most downstream (LKHEP dam axis) to evaluate the effects of the Kharkar River input and water chemistry change with distance from the confluence.

Figure 5-5: Bar Chart for comparison of water samples taken in January 2017

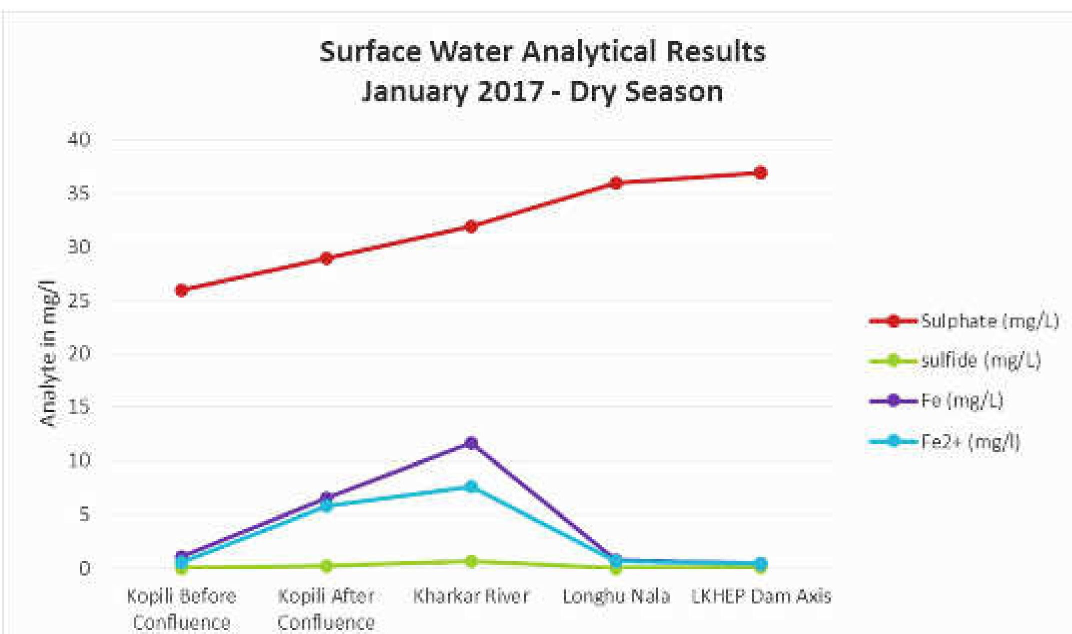


Figure 5-6: Surface water analytical results of samples from Kopili and Karkhar Rivers

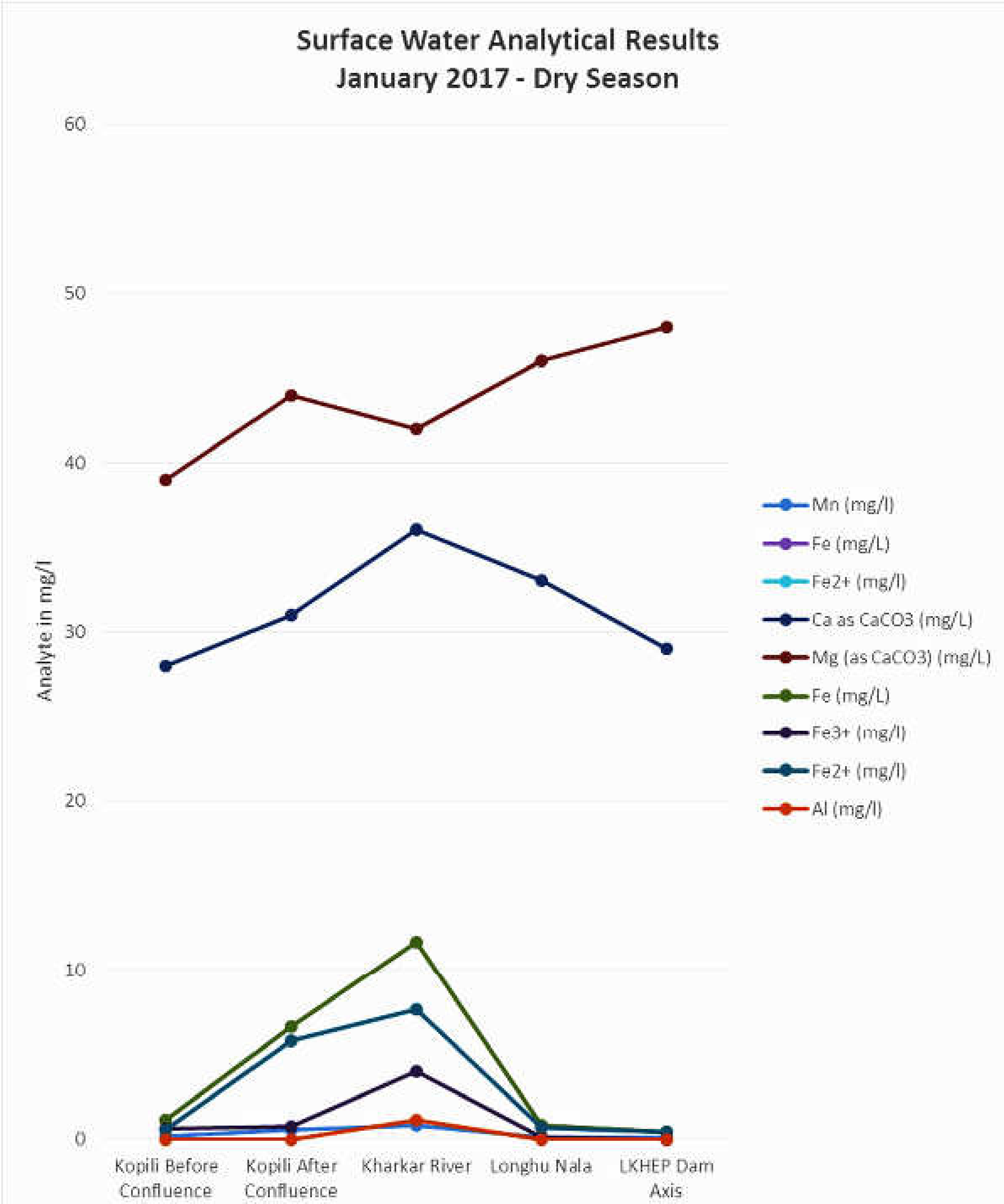
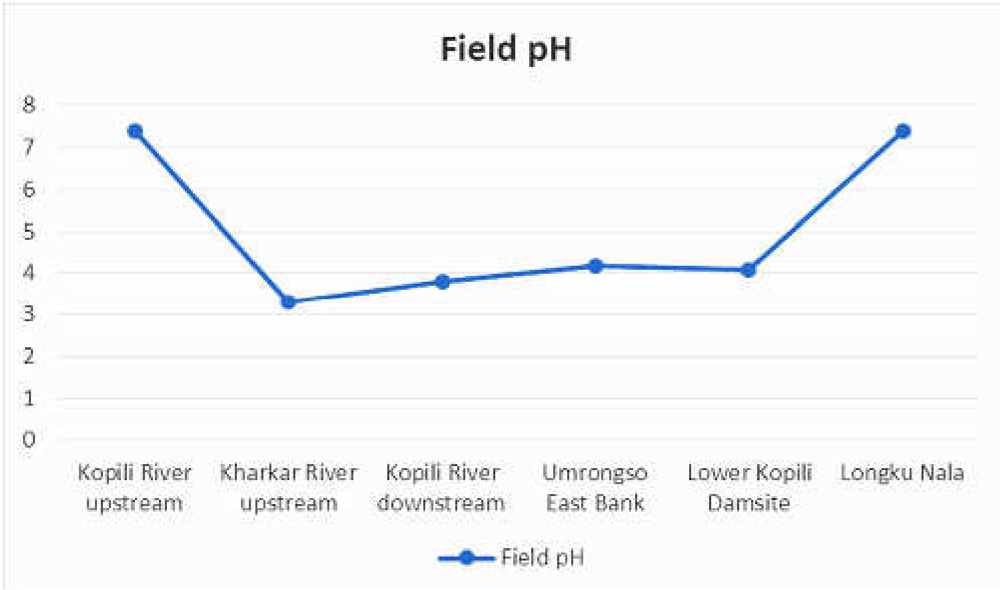


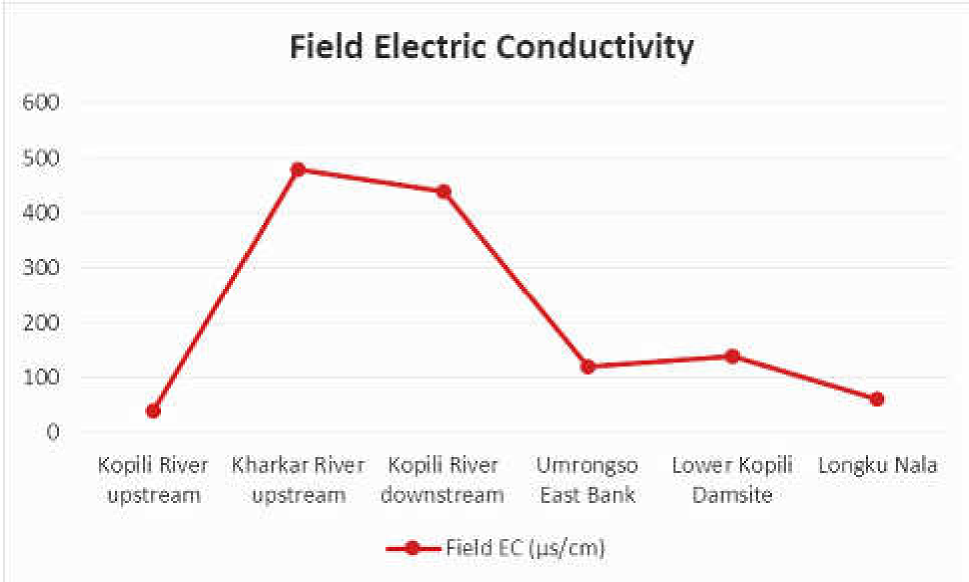
Figure 5-7: Bar chart presenting field pH values



93. It is readily apparent that degraded surface water from Kharkar River impacts water quality in the Kopili River. Observation of Figures 5-5 and 5-6 show that sulfate values increase downstream from the confluence, as do metals values. Figure 5-7 provides a graph of pH values from the field investigation as listed in Table 4-1. pH in the Upper Kopili River is 7.4 then drops to 3.8 after mixing with Kharkar River water, which has a pH of 3.3. Longhu Nala is a tributary to the Kopili River below the damsite and is not affected by mining activities as indicated by a normal pH of 7.4. The Kharkar River transports moderate amounts of iron in solution. As discussed in the Interim Report (April 2017) the mixing zone at the confluence of the Kharkar and Kopili Rivers causes iron to oxidize and flocculate causing the yellowish sediment which then collects along the river banks and settles to the river bottoms in low-flow season.

94. Field EC measurements are shown in Figure 5-8 below. EC levels rise dramatically as Kharkar River water discharges into the Kopili River then decline with distance from the confluence.

Figure 5-8: Bar chart presenting field EC values



6. AN OVERVIEW OF AMD MITIGATION AND WATER QUALITY RESTORATION STRATEGIES

95. Site characteristics as detailed in this report will be used to develop a conceptual design for AMD remediation, with the objective of restoring normal pH water in the Kopili Drainage Basin. At present, we propose to remediate the preliminarily-identified active and abandoned coal mine AMD discharges using a combination of AMD isolating and passive treatment systems which are targeted at AMD source areas. Possible scenarios are briefly described below. Data and information discussed in detail in this report which will be utilized in the mitigation methodology conceptual design process include:

- Average of coal mine dimensions
- Average local and regional geographic features
- Average discharge water quality
- Average monsoon and dry season surface water flows
- Minimum and maximum AMD generation modeling from source areas

96. Isolating methods include: backfilling pits with overburden to prevent surface water ingress and groundwater contamination, capping overburden with neutral material, and constructing AMD discharge lined holding ponds that can allow evaporation rather than discharge into surface water systems as a temporary preventative measure. It is assumed that each minesite will have an open pit and at least one overburden dump. If the mine site utilizes water for mining and coal transport then process water piping, storage and disposal apparatus will be in place. The amount of water present and disposed as well as its pH will determine whether a holding pond can and should be constructed. If the mine is active, and overburden contains acid-generating material, then a stormwater diversion trench would be constructed and possibly lined with lime as a neutralization material. Overburden piles can be capped with material including soil, neutral rock, clay, limestone, or a combination thereof and left as is until the mine is abandoned, at which stage the overburden can be bulldozed back into the abandoned pit.

97. Passive treatments to restore water quality include aerobic wetlands, compost wetlands, and anoxic or oxic limestone drains (ALDs/OLDs). Each of the three passive technologies is most appropriate for a particular type of mine water, and discharge volume but commonly, they are most effectively used in combination with each other. For mine discharges that are extremely acidic (acidity concentration greater than 300 mg/L as CaCO3) with high concentrations of ferric iron (concentrations greater than 1.0 mg/L), the use of a successive alkalinity producing system (SAPS) would be most effective in treating the AMD. A SAPS combines ALD technology with the sulfate reduction mechanism of the compost wetland. A series of SAPS is commonly necessary until the AMD either meets effluent criteria or the limit of the area available for treatment is reached.

98. The overall objectives of mitigation planning are to:

i. Reduce and eventually eliminate AMD and consequent surface water contamination, up and downstream in the Kharkar and Kopili Rivers
ii. Remediate abandoned mine areas to isolate AMD-producing geologic material
iii. Restore coal mine-affected land to eventually support pre-mine land

ecosystems including flora and fauna

iv. Restore pre-mining land use including agriculture, horticulture and grazing

v. Restore riverine systems to pre-AMD quality to support fisheries.

vi. Guide eventual land use and local economy away from coal mining, to one that promotes sustainable development.

99. The Water Quality Restoration component will consider possible passive remedial options to be implemented to the extent possible at the rathole mine sites, in order to maximize mined land and water quality restoration at the lowest cost. At-source remediation and reclamation also proffers the most reduction in AMD production and proliferation. Local workers will be utilized to construct, operate, monitor and maintain these systems, with the eventual goal of transferring the local economy and workforce away from coal mining, and back to an agricultural-based livelihood.

7. REFERENCES

- Chabukdhara, Mayuri and O. P. Singh. 2016. “Coal Mining in Northeast India: An Overview of Environmental Issues and Treatment Approaches”. International Journal Coal Science and Technology 3(2):87–96
- Groundwater Information Booklet, Jaintia Hills District, Meghalaya, Government of India, Ministry of Water Resources, Central Groundwater Board, Technical Report Series: No: 49/2011-12 Dhttp://cgwb.gov.in/NEW/District_Profile/Meghalaya/Jaintia.pdf
- Mehta PS (2002) “The Indian mining sector: effect on the environment and FDI inflows”. Conference on foreign direct investment and the environment, 7–8 February, Paris, France
- Mukhopadhyay, Lekha (2013). “Sustainable Development - A Path Dependent Analysis to the Rat hole Coal Mining in Jaintia Hills District, India”. Indian Society for Ecological Economics (INSEE) Global Change, Ecosystems, Sustainability. Seventh Biennial Conference
- Sahoo, P. K., S. Tripathy, Sk. Md. Equeenuddin, M. K. Panigrahi. 2011. “Geochemical Characteristics of Coal Mine Discharge Vis-à-vis Behavior of Rare Earth Elements at Jaintia Hills Coalfield, Northeastern India”. Journal of Geochemical Exploration 112 (2012) 235–243.
- Sarma, K (2005). “Impact of coal mining on vegetation: a case study in Jaintia district of Meghalaya, India” Thesis submitted to the International Institute for Geo- Information Science and Earth Science (ITC).
- Sarma, K., Tripathi, R.S. and S.P.S. Kushwaha, (2010). “Land use/land cover change analysis in coal mine affected areas in Jaintia Hills district of Meghalaya, northeast India using remote sensing and GIS technique.” Indian Journal of Tropical Biodiversity, 16(1), 43-50.
- Singh G, Sinha DK (1992). “The problem of acid mine drainage its occurrence and effects”. Proceedings of Environment Management of Mining Operations, Department of Environment and Forest Government of India, pp 156–167
- Swer, Sumarlin and O.P. Singh 2003 “Coal Mining Impacting Water Quality and Aquatic Biodiversity in Jaintia Hills District of Meghalaya” ENVIS Bulletin Vol 11(2) : Himalayan Ecology
- Pankaj Sharma, P, Sameer Vyas, Sharma S., Mahure N., Anil Rustagi, Sivakumar , Murari Ratnam. (2011). “Acid mine discharge – Challenges met in a hydro power project”. International Journal of Environmental Sciences Volume 1, No 6, 2011

APPENDICES

Appendix- A: SURVEY QUESTIONNAIRE- Coal Mine Site Assessment

Questionnaire No: | | | | | | | | | **Date:** | | | / | | | / | | |

Investigator Name …………………………………

A. Location

1. Village (Area Name): …………………………………
   District…………………………………

   Block: …………………………………

2. Coordinates:
   Latitude………………………………Longitude………………………
   …………

B. Respondent/Owner

1. Name of Respondent…………………………………Age……………Gender Male Female
   | | | Father"s Name…………………………………
2. Relation with Pit Owner…………………………………
3. Ownership of the Mining Pit
   1. Private 2. Government 3.Community 4. Others
4. Type of Private Ownership
   1. Individual/Single 2. Joint/Shareholders 3. Other (specify): …………
5. Status of Ownership/License
   1. License 2. Customary Right 3. Permission from Local Authority 4. Other (specify):
   …………………………………

C. Mining Pit

1. Size of the Pit (in meters): Radius………………......Depth................

2. Years of operations ....

3. Depth to coal seam………….. Height of coal seam……….

4. Coal mining method

   1. Manual 2. Mechanical 3. Both 4. Others

5. Total Production from Pit (in tons/day): Winter ………...Summer...………......Rain.......……

6. Coal Storage Area size (sq.m.) …………………Location………………………

7. Total Capacity of storage (ton) ……………………… Duration (days) ……………………

8. Overburden storage and dimensions………………………………………

9. Production water source…………..

10. Liters/day used………………………

11. Volume of seepage water from pit (lit/day):

    Winter ……………….Summer.......……………......Rain.......………………

12. Quality of water discharge, if known……. pH readings and dates……………

13. Discharge water measurements: pH…….. EC……..DO……… Temp……………

14. Pit water measurements: pH…….. EC……..DO……… Temp……………

15. Water Samples taken for laboratory analysis – date, time and location………………………………

16. Seepage water management:

    1. Drain to nala/Stream 2. Temporary Drain 3.Retention pit 4. Others

17. Nala flows to river/Major nala …………………

18. If Others; please describe
……
…
……
……
……

19. Supplied to:

1. Government 2. Private 3. Self use 4. Others ☐

20. Expenditure on production per ton (Rs.) …………………

21. Income per ton (Rs.) …………………

D. Health & Safety

1. Number of workers involved…………………
2. Source of drinking water …………………
3. Common health issues /diseases in workers…………………
4. Healthcare facility in area
   1. Yes 2. No ☐
5. Nos. of accident/injury in year during mining…………………
6. Nos. of fatal accident in last 5 years…………………

E. Safe and sustainable operation

1. Requirement of improvement in operations
   1. Yes 2. No ☐
2. Improvement options
   1. Technology 2. Financial 3.Both 4. Others ☐
3. If Others; describe……………………………………………………………………………
   ……
   ……
   ……
4. Any schemes from Govt.; describe…………………………………………………………
   ……
   ……
   ……

F. Remarks of the Interviewer, if any

……
……
……
…

(Signature of the investigator)

DRAWING/SKETCH OF MINE SITE AREA – Include: approximate dimensions and distances from pit to overburden, coal storage area, drainage area, closest stream (if possible), outbuildings and process water source, roads and other salient structures.

Appendix- B: Trip Report on visit to Meghalaya coal mining site

DAY-1:

23rd July, 2017

Team member: (1) Rishi Punia, & (2) Sanatomba

We left Guwahati by 11 AM and reached Jowai by around 4 PM. Stayed at GHM Guest House, Jowai. After checking in the guest house, we went to Jowai market to look for locals, who can accompany us for our field works. Being a Sunday, which is Church day in the region, there were not much people to approach and it was also raining intermittently. We met some locals, however they were reluctant to work with us for they could not understand the work profile properly. Then, it was getting dark and we came to the guest house

DAY-2:

24th July, 2017

It was drizzling. We started the day by 9 AM. We approached some locals on the way to the market. Some were ready to work with us but they turned out to be uneducated. Nearby the market, we approached the Pastor of a Church. He told us that the Village Headman "Mr. L.D. Lakiang" in the region can help us. We went to Headman's office in Ladthadlaboh, Jowai. There, we met him and discussed our requirement. He let us met some of the members of his office. He told us to come the next day for confirmation.

Then, we went to a nearby college called "Kiang Nangbah Govt. College, Jowai. On reaching there, we came to know that it was a general holiday in Jowai. Luckily, we met a student "Mr. Riwat" of the college, who let us talk to one of his friend "Mr. Paul", who happened to be the student leader of the college. We spoke to Mr. Paul but he was out of station. He told us that he would be coming back in the evening and can meet him next day.

DAY-3:

25th July, 2017

Around 10 AM, we went to the village Headman's office of Ladthadlaboh. There we met the Headman by around 11:30 AM. He didn't seem to be taking the things seriously. We called up Mr. Paul & met him near his college. There, we discussed our requirement with him. Being a student leader, he was not ready to spare time for us. He took us to one of his friend Mr. Refil's residence and discussed the things there. Mr. Refil was a bit reluctant to work and he called up one of his friend "Mr. Mutshwa Jhabah". Mr. Mutshwa came to Mr. Refil's residence and we discussed our requirements. He agreed to work with us. He also called up one of his friend Mr. Lakshman Siangshai. Three of them were ready to work with us. We called them to our guest house in the evening.

They turned by around 9 PM and we explained the details of things to be done in the field visit on the mining sites. However, Mr. Mutshwa, due to an urgent work, dropped out. So, finally, it was decided to go ahead for the field survey with four of us only.

Photo-1: Mr. Rishi Punia briefing format to field invigilators for information from site

DAY-4:

26th July, 2017

We picked them up from the college gate around 7:30 AM. Then, on the way we picked up one of Mr. Refil's friend Mr. Amos Dkhar in Narwan village. We started the actual field visit from Narwan village and later on covered Pomra Kmai, Inrim Khliehshnoy, Sohkymphor, Pamrapaithlu, Dkhiah & Khliehriat villages during the day.

Mr. Amos is the secretary of the local community. His no. is 9856256088. He can be contacted for establishment of the pilot plant in their community.

The day's visit was culminated by around 7 PM.

Some of the significant photographs taken during the field visit of 26th July, 2017 are given below;

Photo-2: Collection of seepage water from pit at Narwan village

The pH of the collected water was 4.0. The water is used for drinking purpose by the workers. However, the pH of the water spilled in the coal pit was 3.3.

Photo-3: Horizontal mining at Narwan village

Wood logs are used to support the rock layer above. The worker said the horizontal mining goes upto the length of about 2-3 Kms.

Photo-4: Unscientific Coal Storage nearby the pit in Pomra Kmai village

This kind of unscientific storage is practiced in all the mining areas.

Photo-5: Near an abandoned coal pit in Narwan village.

This area is a low lying area and can be considered for the pilot project.

Photo-5: Discussion with community head in Sohkymphor village.

The community head Mr. Kmen Lapasang was ready for establishment of the pilot plant in the area, if proposed. Mr. Kmen's contact no. is 9612463673.

Photo-5: An abandoned pit in Pamrapaithlu village.

The water from the pit was flowing out at high flowrate.

Photo-6: Unscientific Coal Stockpile area in Pamrapaithlu village

Photo-7: An abandoned coal pit in Dkhiah village

DAY-5:

27th July, 2017

On 2nd day of field visit, we stared with Mootyngkrong village and later on covered Moopala, Tluh, Latyrke, Mylmaliang & Myrsiang villages.

Some of the significant photographs taken during the field visit of 26th July, 2017 are given below;

Photo-8: Discussion with the worker in the mining area in Moopala village.

Photo-9: A drain in Tluh village.

The water in the drain recorded the lowest pH during the whole field visit. It measured pH 2.2.

Photo-10: Kids catching fishes in Latyrke

village. The pH of the water was 5.4.

Photo-11: Kids taking bath in Narwe stream having pH3.5 in Mootyngkrong village

DAY-6:

28th July, 2017

We went to M/s Jaintia Cements Ltd. located at Latyke village. There, we met a staff, Mr. D. Upadhyay, of the company. He told us that they are not longer taking any limestone from the locality. Whatever limestone, they are using now for production of cement in their plant is old stock, which was purchased before the NGT band came effective. The plant was utilizing the limestone mined from Satnga area which is about 10 KM from the plant. The production capacity of the plant is 150MT/day. They were purchasing the lime from the mine owner @Rs 250/ton of limestone.

We requested Mr. Upadhyay to provide us some analysis report of limestone. He said he is not in the position to provide such details. He spoke to the Director of the plant & gave us the plant's Head office address for getting other details. However, he gave us some limestone sample.

After this, we left for Guwahati.

Note: Water Samples & coal samples were also collected for analysis purposes.

Table A-1: Mine Inventory Locations and Ownership

Location			Respondent/Owner							
	Northing	Easting	Name	Age (yrs.)	Gender	Father's Name	Relation with pit Owner	Ownership type	Type of ownership	License Status
Saipung	25° 23.873	92°23.470	Amos Dkhar	31	Male	Blin Phawa	Neighbour	Private	Individual	Customary right
Saipung	25° 24.081	92° 23.302	Tokmen Tamang	55	Male		Labour	Private	Individual	Customary right
Saipung	25° 24.148	92° 23.271	Son Kouse	38	Male	Anjan Kouse	Labour	Private	Individual	Customary right
Bapung	25° 24.373	92° 19.678	Tai Keiwbharym Bai	33	Male	Kritsaingshai	Neighbour/son	Private	Individual	Customary right
Bapung	25° 24.349	92 ° 19.718	Shylla	63	Male		Neghbour	Private	Individual	Customary right
Bapung	25° 25.800	92° 20.507	Ibasumar Lyngdoh	22	Female	Shavas Lapasam	Neghbour	Private	Individual	Customary right
Bapung	25° 25.32	92° 22.122	Kmen Lapsay	60	Male	L) Harbad Suchian	Neghbour	Private	Individual	Customary right
Bapung	25° 25.754	92° 22.785	Kmen Lapasay	60	Male	L) Harbad Suchian	Neghbour	Private	Individual	Customary right
Bapung	25° 26.370	92° 22.722	Kmen Lapasay	60	Male	L) Harbad Suchian	Neighbour	Private	Individual	Customary right
Bapung	25° 24.751	92° 19.170	Lakshmon Siangshai	28	Male	Ladbha Chyrmang	Neighbour	Private	Individual	Customary right
Bapung	25° 25.012	92° 19.654	Lakshmon Siangshai	28	Male	Ladbha Chyrmang	Neighbour	Private	Individual	Customary right
Bapung	25° 24.655	92° 20.117	Lakshmon Siangshai	28	Male	Ladbha Chyrmang	Neighbour	Private	Individual	Customary right
Bapung	25° 25.015	92° 19.885	Lakshmon Siangshai	28	Male	Ladbha Chyrmang	Neighbour	Private	Individual	Customary right
Bapung	25° 22.003	92° 20.171	Lakshmon Siangshai	28	Male	Ladbha Chyrmang	Neighbour	Private	Individual	Customary right
Bapung	25° 21.965	92° 20.148	Furak Khan	27	Male	Shafi Uddin	Neighbour	Private	Individual	Customary right
Bapung	25° 22.156	92° 20.551	Azzauridin Mukhatot	23	Male		Worker	Private	Individual	Customary right
Bapung	25° 20.926	92° 21.488	Pynshai Thoo	22	Male		Neighbour	Private	Individual	Customary right
Bapung	25° 21.275	92° 22.165	Principal Rhmbai	36	Male		Neighbour	Private	Individual	Customary right
Bapung	25° 21.221	92° 22.785	Principal Rhmbai	36	Male		Neighbour	Private	Individual	Customary right
Bapung	25° 20.131	92° 20.112	Pynshai Thoo	22	Female		Neighbour	Private	Individual	Customary right
Saipung	25° 2230.308	92° 2323.683	Anzari	32	Male		Labour	Private	Individual	Customary right
Saipung	25° 22.555	92° 25.353	Wan Langstang	42	Male		Worker	Private	Individual	Customary right
Saipung	25° 23.16	92° 25.384	Manik Hazara	40	Male		Worker	Private	Individual	Customary right
Saipung	25° 23.76	92° 25.88	Jeid Shongplong	35	Male		Worker	Private	Individual	Customary right
Saipung	25° 20.851	92° 26.449	Helen Dkhar	42	Female		Neighbour	Private	Individual	Customary right
Saipung	25° 20.98	92° 26.893	Helen Dkhar	42	Female		Neighbour	Private	Individual	Customary right
Saipung	25° 20.98	92° 26.893	Helen Dkhar	42	Female		Neighbour	Private	Individual	Customary right
Saipung	25° 21.66	92° 26.27	Anzari	32	Male		Worker	Private	Individual	Customary right
Saipung	25° 22.01	92° 26.11	Minul	35	Male		Worker	Private	Individual	Customary right
Saipung	25° 22.01	92° 26.11	Minul	35	Male		Worker	Private	Individual	Customary right
Saipung	25° 22.01	92° 26.11	Minul	35	Male		Worker	Private	Individual	Customary right
Saipung	25° 20.451	92° 27.839	Kwan Pala	48	Male		Neighbour	Private	Individual	Customary right
Saipung	25° 20.781	92° 28.314	Kwan Pala	48	Male		Neighbour	Private	Individual	Customary right
Saipung	25° 20.117	92° 28.675	Kwan Pala	48	Male		Neighbour	Private	Individual	Customary right
Saipung	25° 20.589	92° 28.44	Baburam Kaple	63	Male		Neighbour	Private	Individual	Customary right
Saipung	25° 20.899	92° 29.324	Nangkhreh Nongthu	45	Male		Neighbour	Private	Individual	Customary right
Saipung	25° 21.385	92° 28.015	Nangkhreh Nongthu	45	Male		Neighbour	Private	Individual	Customary right
Saipung	25° 20.312	92° 29.027	Ramkumar Rai	28	Male		Labour	Private	Individual	Customary right
Saipung	25° 20.312	92° 29.027	Ramkumar Rai	28	Male		Worker	Private	Individual	Customary right
Saipung	25° 20.771	92° 30.125	Ramkumar Rai	28	Male		Worker	Private	Individual	Customary right
Saipung	25° 21.181	92° 29.881	Ramkumar Rai	28	Male		Worker	Private	Individual	Customary right
Saipung	25° 20.751	92° 30.187	Ramkumar Rai	28	Male		Worker	Private	Individual	Customary right
Saipung	25° 20.155	92° 28.182	Harman Bamon	37	Male		Neighbour	Private	Individual	Customary right
Saipung	25° 21.665	92° 30.158	Bun Gympod	27	Female		Neighbour	Private	Individual	Customary right
Saipung	25° 21.811	92° 30.321	Arlinda Gympad	30	Female		Neighbour	Private	Individual	Customary right

Table A-2: Jaintia Hills Coal Mine Inventory

Mining pit																												
Size of pit (m)		Years of Operations	Depth of Coal Seam (m)	Ht of coal Seam (m)	Mining Method	Total Production (ton)			Coal Storage area		Storage		Overburden		Production water				Volume of Discharge water (lit per day)			Quality of water		Discharge water Mgt	Discharge to	Coal Supplied	Coal Per Ton (Rs.)	
Radius	Depth					Winter	Summer	Rain	Size (sq.m.)	Location	Volume (tons)	Duration (days)	Hgt. (m)	Area (sq.m.)	Source	Winter	Summer	Rain	Winter	Summer	Rain	pH	EC				Expenditure	Income
1.5	27	Not Operational	24	0.34	Manual	26	13	6	2000	Near to drainor lowlaying area	350	50	2	60	Seepage and drain diverted during winter	13000	7150	2050	9100	4650	2150	4.2	5	Natural Drain	Waikhyr wi	Private	3500	4000
3	5	25	3	0.5	Manual	18	10	3	1000	as above	50	90	3	100	as above	8450	6000	900	5900	3900	950	4	6	Natural Drain	Not Known	Private	3600	6000
2	14	21	12.5	0.6	Manual	17	9	7	800	as above	40	35	3	15	as above	8150	5300	2250	5712	3450	2350	4.1	4	Natural Drain	Myntriang	Private	3600	4500
4	50	7	47	1	Both	40	10	7	5000	as above	1000	90	2	90	as above	18400	5700	2500	12900	3700	2650	6.8	1	Natural Drain	Myntang	Private	3500	4000
5	10	Not Known	8	0.5	Manual	8	6	3	300	as above	150	100	2	80	as above	3450	3100	1000	2400	2000	1050	5	11	Natural Drain	Not Known	Private	4000	5000
6	23	Not Known	22	1.2	Both	20	12	5	7000	as above	400	30	4	70	as above	8200	6400	1550	5750	4150	1600	3.1	12	Temporary Drain	No Major Drain	Private	3500	4000
2	6	20	4.5	0.35	Manual	6	3	1	1700	as above	350	90	3	70	as above	2400	1500	300	1700	1000	300	3.3	8	Natural Drain	Wah lubu	Private	3600	4000
3	4	18	3	0.4	Manual	14	8	1.5	6000	as above	300	70	3	80	as above	5300	3850	600	3700	2500	600	3.7	18	Natural Drain	Wah lubu	Private	4500	5000
2.5	3.4	15	3	0.45	Manual	8	6	2	5000	as above	250	60	2	65	as above	3450	3100	650	2400	2000	700	3.5	15	Natural Drain	Pamswet	Private	3500	4000
7	26	Not Known	25	0.7	Manual	18	14	10	4000	as above	200	60	2	50	as above	7400	7450	3100	5200	4800	3250	2.7	37	Natural Drain	Pamswet	Private	4000	5000
6	23	Not Known	22	0.7	Manual	21	13	5	3000	as above	100	30	3	70	as above	9050	6700	1650	6300	4400	1750	3	15	Natural Drain	Pamswet	Private	3500	4500
5	22	Not Known	21	0.5	Manual	10	7	3	4000	as above	200	60	3	60	as above	4600	3950	1100	3200	2600	1150	2.6	15	Natural Drain	Chynrang	Private	4500	5000
7	23	Not Known	22	0.7	Both	20	15	3	6000	as above	300	60	3	70	as above	9600	8850	1000	6750	5750	1000	2.8	30	Temporary Drain	Not Known	Private	3000	4500
6	20	Not Known	18	0.5	Manual	16	5	1	4000	as above	200	60	3	50	as above	7500	3000	300	5200	1950	300	2.5	30	Temporary Drain	No Major Drain	Private	3500	4500
6	6	Not Known	4	0.75	Manual	17	14	3	5000	as above	300	60	3	80	as above	8500	7700	1000	5950	5000	1100	2.4	53	Natural Drain	Not Known	Private	4000	5000
6	23	Not Know	22	0.5	Manual	6	4	1	5000	as above	200	60	2	60	as above	2200	1950	400	1550	1250	400	2.7	30	Tempora r	No Major Drain	Private	4100	5200

Mining pit

Size of pit (m)		Years of Operations	Depth of Coal Seam (m)	Ht of coal Seam (m)	Mining Method	Total Production (ton)			Coal Storage area		Storage		Overburden		Production water				Volume of Discharge water (lit per day)			Quality of water		Discharge water Mgt	Discharge to	Coal Supplied	Coal Per Ton (Rs.)	
Radius	Depth					Winter	Summer	Rain	Size (sq.m.)	Location	Volume (tons)	Duration (days)	Hgt. (m)	Area (sq.m.)	Source	Winter	Summer	Rain	Winter	Summer	Rain	pH	EC				Expenditure	Income
		n																						y Drain				
6	26	Not Known	24	0.9	Both	27	15	5	5000	as above	300	60	3	100	as above	10800	7500	1500	7500	4900	1600	2.8	12	Other	Not Known	Private	4000	5000
5.6	23	Not Known	22	1	Both	28	15	7	10000	as above	250	60	3	70	as above	11500	7900	2200	8000	5200	2300	3.1	25	Natural Drain	No Major Drain	Private	3000	4500
6	36	Not Known	33	0.85	Both	16	14	8	5000	as above	600	80	3	80	as above	6800	7200	2600	4800	4700	2800	3	14	Temporary Drain	Um Sylli	Private	3500	4000
6	32	Not Known	31	0.25	Mechanical	4	0	0	9000	as above	500	50	3	70	as above	1600	0	0	1120	0	0	3	25	Temporary Drain	Um Sylli	Private	3500	4000
8	37	Not Known	36.5	0.5	Mechanical	50	40	15	10000	as above	500	90	2	50	as above	20500	21000	4650	14350	13700	4850	2.6	27	Natural Drain	Marwe Stream	Private	4000	5000
6	36	Not Known	33	0.45	Mechanical	40	20	10	6000	as above	150	90	3	100	as above	17200	10400	3300	12000	6700	3500	2.4	27	Temporary Drain	Not Known	Private	3000	4000
7	33	Not Known	30	0.75	Mechanical	45	15	10	10000	as above	500	60	2	10	as above	20700	8550	3600	14500	5550	3800	2.6	28	Natural Drain	Not Known	Private	3000	4000
6.5	36	Not Known	33	0.7	Manual	60	35	16	1000	as above	500	70	2	30	as above	28800	20650	5100	20150	13450	5400	2.6	35	Natural Drain	Not Known	Private	4000	5000
8	40	Not Known	33	0.5	Mechanical	40	31	10	5000	as above	500	30	3	30	as above	18800	18600	300	13150	12000	315	2. 4	8	Natural Drain	Not Known	Private	3500	5000
8	36	Not Known	33	0.85	Mechanical	3	0	0	5000	as above	600	40	2	15	as above	1500	0	0	1050	0	0	2.7	31	Temporary Drain	Not Known	Private	4000	5000
8	33	Not Known	30	0.85	Mechanical	6	4	0	10000	as above	450	65	2	80	as above	2300	1950	0	1600	1250	0	2.8	30	Natural Drain	No Major Drain	Private	3000	4000
6	33	Not Known	32	0.85	Manual	5	3	1	800	as above	500	30	3	70	as above	2050	1600	300	1450	1050	300	3.1	15	Natural Drain	No Major Drain	Private	3500	4000
7	33	Not Known	32	0.5	Mechanical	7	5	2	10000	as above	600	70	3	100	as above	3000	2600	650	2100	1700	700	3.2	13	Natural Drain	Not Known	Private	3000	4000
8	36	5	34	0.85	Mechanical	6	3	1	9000	as above	600	60	3	50	as above	2700	1700	350	1900	1100	400	2.2	63	Natural Drain	Not Known	Private	1800	5000
6	37	Not Known	36	0.55	Mechanical	10	6	4	500	as above	60	60	2	50	as above	4800	3550	1300	3350	2300	1350	2.5	40	Natural Drain	Not Known	Private	3000	5000
6	37	5	34	0.85	Mechanical	10	5	2	10000	as above	800	90	2	50	as above	4700	3000	600	3300	1950	650	3.8	37	Temporary Drain	Not Known	Private	3500	8000
8	33	3	32	0.8	Mechanical	5	3	1	9000	as above	600	60	3	80	as above	2500	1650	350	1750	1050	350	3.7	30	Natural Drain	Not Known	Private	3600	5000

Mining pit																												
Size of pit (m)		Years of Operations	Depth of Coal Seam (m)	Ht of coal Seam (m)	Mining Method	Total Production (ton)			Coal Storage area		Storage		Overburden		Production water				Volume of Discharge water (lit per day)			Quality of water		Discharge water Mgt	Discharge to	Coal Supplied	Coal Per Ton (Rs.)	
Radius	Depth					Winter	Summer	Rain	Size (sq.m.)	Location	Volume (tons)	Duration (days)	Hgt. (m)	Area (sq.m.)	Source	Winter	Summer	Rain	Winter	Summer	Rain	pH	EC				Expenditure	Income
6	33	3	30	0.87	Mechanical	6	4	2	10000	as above	800	30	3	70	as above	2450	2100	650	1700	1350	650	3.5	10	Natural Drain	Not Known	Private	4000	5000
6	45	3	43	1	Mechanical	15	9	7	800	as above	500	30	4	70	as above	6450	4700	2300	4500	3050	2400	3.5	10	Natural Drain	Moopun River	Private	3500	4000
8	36	10	33	0.8	Mechanical	16	9	2	10000	as above	600	40	2	80	as above	7350	5150	700	5150	3350	750	3.7	18	Natural Drain	Moopun River	Private	4000	6000
8	37	5	33	0.8	Mechanical	18	9	4	10000	as above	600	40	4	80	as above	8650	5300	1300	6050	3450	1350	3.1	18	Natural Drain	Moopun River	Private	4000	6000
8	50	12	47	0.95	Mechanical	15	10	6	4000	as above	600	60	3	70	as above	7050	6000	1800	4950	3900	1900	2.9	30	Natural Drain	Moopun River	Private	5000	10000
8	46	10	39	1	Mechanical	10	7	4	5000	as above	100	70	3	70	as above	4300	3650	1300	3000	2350	1400	3	35	Natural Drain	Moopun River	Private	4000	8000
8	52	15	50	1	Mechanical	20	15	10	10000	as above	1000	90	2	80	as above	9200	8550	3600	6450	5550	3700	3.3	10	Natural Drain	Moopun River	Private	5000	10000
8	42	10	40	1	Both	10	5	2	10000	as above	100	90	4	70	as above	4800	2950	650	3350	1900	700	3.3	17	Natural Drain	Moopun River	Private	5000	11000
8	40	5	37	0.9	Mechanical	16	8	2	10000	as above	1000	60	3	80	as above	7500	4800	600	5250	3100	650	2.8	31	Natural Drain	Moopun River	Private	6000	8000
8	43	5	40	0.75	Manual	16	14	2	9000	as above	600	60	3	80	as above	6400	7000	600	4500	4550	650	3.1	31	Natural Drain	Moopun River	Private	5000	8000
6	37	5	33	0.5	Mechanical	15	13	0	8000	as above	500	50	3	70	as above	6150	6900	0	4300	4500	0	2.7	31	Natural Drain	Moopun River	Private	3500	4500
8	40	Not Known	38	0.65	Mechanical	15	12	8	8000	as above	200	30	4	80	as above	6450	6250	2650	4500	4050	2750	3.3	31	Natural Drain	Moopun River	Private	4000	9000

Health & Safety						Safe & Sustainable operations		Limestone mining
No. of Workers	Source of drinking water	Common Diseases	Health Facility	Nos. of accidents	Nos. of fatal accident	Improvement Requirement	Improvement options	
3	Stream	Not Known	Yes	0	0	No	4	No
5	Stream	No	No	0	0	Yes	3	Not known
4	Stream	No	No	0	0	No	3	Not known
6	Stream	No	Yes	0	0	Yes	3	No
10	Stream	No	Yes	0	0	Yes	3	Not known
6	Stream	Not Known	Yes	0	0	Yes	3	No
5	Stream	Not Known	Yes	0	0	Yes	3	Not known
6	Stream	No	Yes	0	0	Yes	3	Not known
4	Stream	Not Known	No	0	0	Yes	3	No
3	Stream	No	Yes	0	0	Yes	3	Not known
5	Stream	Not Known	Yes	0	0	Yes	3	No
7	Stream	No	Yes	0	0	Yes	3	Not known
3	Stream	No	Yes	0	0	Yes	3	No
4	Stream	Not Known	Yes	0	0	Yes	3	Not known
6	Stream	No	Yes	0	0	Yes	3	No
3	Stream	Not Known	Yes	0	0	Yes	3	Not known
4	Stream	No	Yes	0	0	Yes	3	No
4	Stream	Not Known	Yes	0	0	Yes	3	No
3	Stream	No	Yes	0	0	Yes	4	Not known
3	Stream	No	Yes	0	0	Yes	4	Not known
3	Stream	No	Yes	0	0	Yes	3	No
3	Stream	No	Yes	0	0	No	4	Not known
4	Stream	No	No	0	0	No	3	No
6	Stream	No	No	0	0	No	4	No
3	Stream	No	No	0	0	No	3	Not known
3	Stream	No	No	0	0	No	4	Not known
3	Stream	No	No	0	0	No	4	Not known
3	Stream	No	Yes	0	0	Yes	3	Not known
3	Stream	No	No	0	0	No	3	Not known

4	Stream	No	No	0	0	No	3	No
4	Stream	No	No	0	0	No	4	Not known
5	Stream	No	No	0	0	No	3	Not known
5	Stream	No	Yes	0	0	Yes	3	Not known
4	Stream	No	Yes	0	0	Yes	2	Not known
5	Stream	No	Yes	0	0	Yes	3	Not known
3	Stream	No	No	0	0	Yes	4	Not known
3	Stream	No	Yes	0	0	Yes	4	Not known
5	Stream	No	Yes	0	0	Yes	3	Not known
5	Stream	No	No	0	0	No	3	Not known
5	Stream	No	No	0	0	Yes	2	No
6	Stream	No	Yes	0	0	Yes	2	No
6	Stream	No	Yes	0	0	No	3	No
4	Stream	No	Yes	0	0	No	4	Not known
3	Stream	No	No	0	0	No	2	Not known
2	Stream	No	Yes	0	0	No	4	Not known