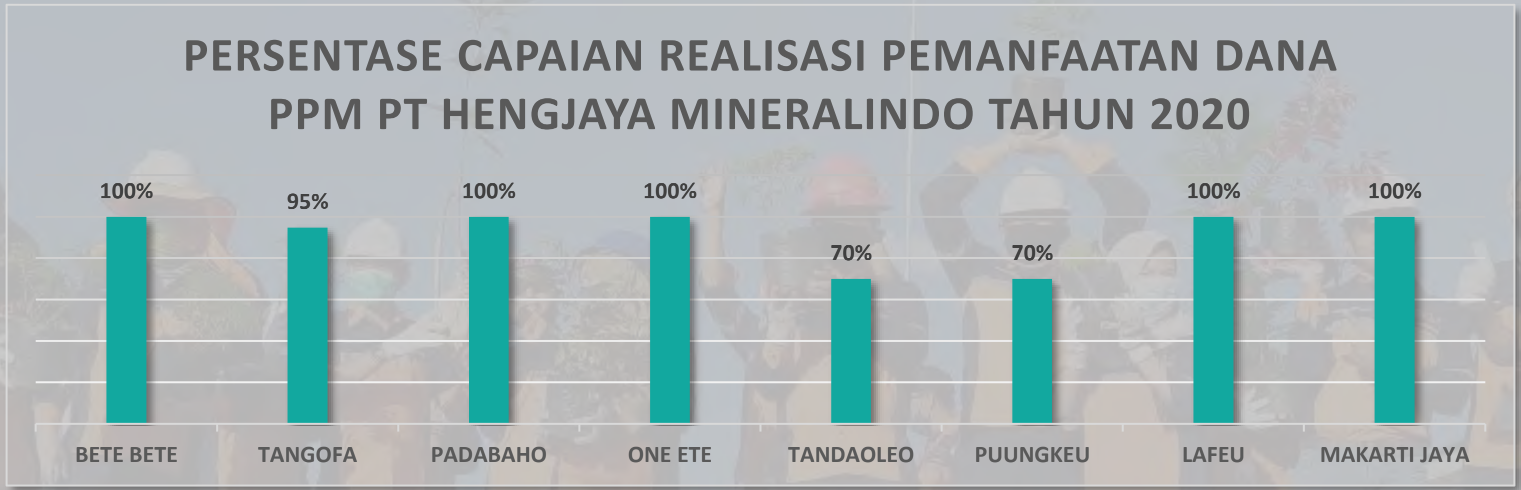
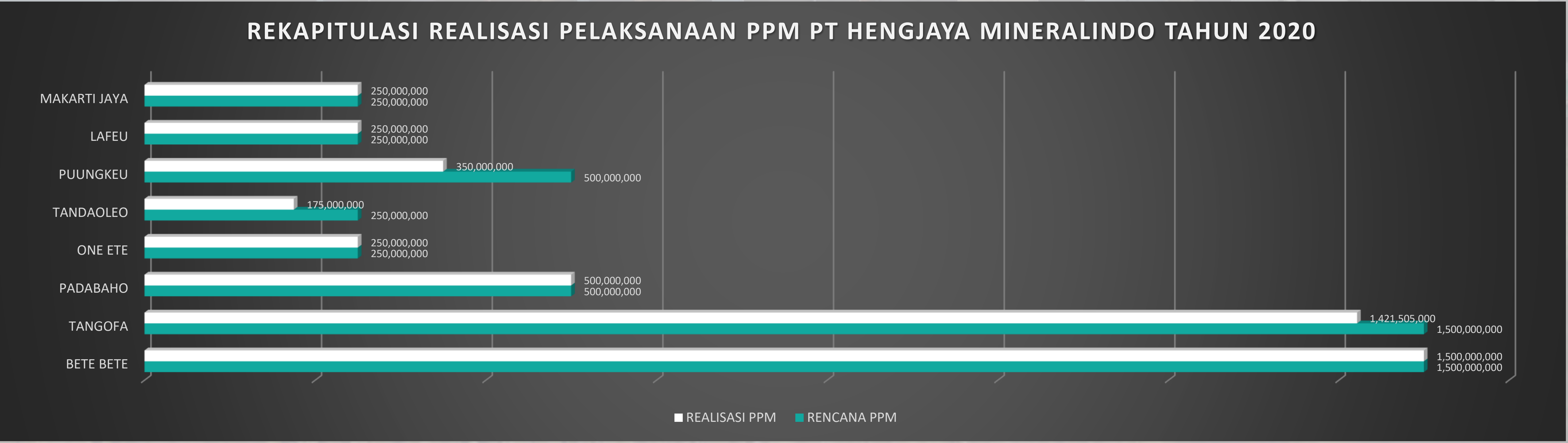
PPM 2021 RECAPITULATION

REKAPITULASI LAPORAN PELAKSANAAN PPM PT HENGJAYA MINERALINDO TAHUN 2020

BETE BETE	5	6	1,500,000,000	[illegible]	4,700,000,000	1,500,000,000	2,014,875,000	3,136,488,000	67%	[illegible]	
TANGOFA	6	6	1,500,000,000	-	1,500,000,000	1,500,000,000	-	1,421,505,000	95%	[illegible]	sisa Termyn
PADABAHO	1	2	500,000,000	-	500,000,000	500,000,000	-	500,000,000	100%	-	
ONE ETE	2	2	250,000,000	-	250,000,000	250,000,000	-	250,000,000	100%	-	
TANDAOLEO	1	2	250,000,000	-	250,000,000	250,000,000	-	175,000,000	70%	75,000,000	sisa Termyn 3
PUUNGKEU	2	2	500,000,000	-	500,000,000	500,000,000	-	350,000,000	70%	150,000,000	sisa Termyn 3
LAFEU	1	1	250,000,000	-	250,000,000	250,000,000	-	250,000,000	100%	-	
MAKARTI JAYA	1	1	250,000,000	-	250,000,000	250,000,000	-	250,000,000	100%	-	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2,014,875,000	[illegible]	[illegible]	[illegible]	

PPM 2021 RECAPITULATION





Terima Kasih

PT. HENGJAYA MINERALINDO

Head Office	:	Noble House Building, 20nd Floor-Unit No.6 Jl. DR Ide Anak Agung Gde Agung Kav.E.4.2 No.2, Mega Kuningan -Jakarta Selatan, 12950
Telp/Fax	:	021-29183191, 29183192 / 021-29183194
Site Tangofa	:	Desa Tangofa, Kec. Bungku Pesisir, Kab. Morowali, Sulawesi Tengah

HSE – SAFETY STATS 2020

Safety Statistics (Last LTI - November 2019)

PT. HENGJAYA MINERALINDO

Nickel Mines Limited
MONTHLY REPORT
Nickel Mine Project - Tangofa
Agu-20

MAN HOURS RECORD 2020

Year 2020

Month	PT. HM	Yr Cum	Proj Cum	Contractor's	Yr Cum	Proj Cum	Total Yr Cum	Total Proj Cum	Start Jan 2020
Jan-20	44,176	44,176	516,860	140,553	140,553	1,542,189	184,729	2,059,049	Jan 01-31
Feb-20	44,176	88,352	561,036	136,375	276,928	1,678,564	365,280	2,239,600	Feb 01-29
Mar-20	43,975	132,327	605,011	164,455	441,383	1,843,019	573,710	2,448,030	Mar 01-31
Apr-20	36,344	168,671	641,355	84,473	525,856	1,927,492	694,527	2,568,847	Apr 01-30
Mei-20	35,300	203,971	676,655	94,157	620,013	2,021,649	823,984	2,698,304	May 01-31
Jun-20	38,276	242,247	714,931	105,978	725,991	2,127,627	968,238	2,842,558	Jun 01-30
Jul-20	36,752	278,999	751,683	73,420	799,411	2,201,047	1,078,410	2,952,730	Jul 01-31
Agu-20	38,248	317,247	789,931	122,015	921,426	2,323,062	1,238,673	3,112,993	Aug 01-31
Sep-20		317,247	789,931		921,426	2,323,062	1,238,673	3,112,993	
Okt-20		317,247	789,931		921,426	2,323,062	1,238,673	3,112,993	
Nov-20		317,247	789,931		921,426	2,323,062	1,238,673	3,112,993	
Des-20		317,247	789,931		921,426	2,323,062	1,238,673	3,112,993	
Hrs Year 2020	**317,247**			**921,426**			**1,238,673**		
Hrs Since LTI	**379,385**			**1,114,258**			**1,493,643**		

Last LTI date: 12-Nov-19 18-Nov-19
First LTI on 2019: 03-Jun-19
Report date: 31-Aug-20
Safe days on 2020: 244
Safe days since last LTI: 287
Start Project: 01-Jan-19
Number of safe days lost before LTI: 161
Number of safe hours lost before LTI: 1,681,091

MAN POWER & MAN HOURS

The total project hours worked, start 2019 to date, reached 3.112.993 hours. Since the last LTI (November 12th, 2019) we have accumulated 1.493.643 safe worked hours with 287 days LTI free.

In 2020, we strive for zero LTI.

PT. HENGJAYA MINERALINDO

Nickel Mines Limited
MONTHLY REPORT
Nickel Mining Project - Tangofa
Agu-20

OHSE PERFORMANCE STATISTIC PROJECT TO DATE

Safety Statistics (Project to Date from 01 Jan 2019)

ACCIDENT / INCIDENT CLASSIFICATION	HM (Project to Date) (Incl. mgmt/Admin/Superv / Direct Labour)		CONTRACTOR (Project to Date) (Incl. mgmt/Admin/Superv / Direct Labour)		PROJECT TOTALS (Project to Date) (Incl. mgmt/Admin/Superv / Direct Labour)	
	This Period	Cumulative	This Period	Cumulative	This Period	Cumulative
Hours Worked	38,248	789,931	122,015	2,323,062	160,263	3,112,993
Average No. of Workers	217		580		797	
Fatalities	0	0	0	1	0	1
Number of Lost Time Injuries (LTI)	0	1	0	2	0	3
Number of safe days lost before LTI	0	154	0	161	0	315
Number of Hours Since Last LTI (12 Nov 2019)	38,248	379,385	122,015	1,114,258	160,263	1,493,643
FATALITIES	0	0	0	1	0	1
LTI	0	1	0	0	0	1
AWI	0	0	0	0	0	0
MTI	0	0	0	1	0	1
FAI	0	0	1	2	1	2
Non Injury Incident Potential Class #1	0	0	0	5	0	5
Non Injury Incident Potential Class #2	0	0	0	0	0	0
Non Injury Incident Potential Class #3	0	0	0	0	0	0
Lost Time Injury Frequency Rate (LTIFR):						
No. of Lost Time Injuries x 1,000,000	0.00	1.27	0.00	1.29	0.00	1.28
No. of Hours Worked						
Total Incident Frequency Rate (TIFR):						
Fatal + LTI + AWI + MTI + FAI + PC1 + PC2 + PC3 x 1,000,000	0.00	1.27	8.20	3.87	6.24	3.21
Hours Worked						
Severity Rate (SR):						
No. of LTD x 1,000,000	0.00	194.95	0.00	69.31	0.00	101.19
Hours Worked						

HSE – SAFETY STATS 2021

Safety Statistics (Last LTI - November 2021)

PT. HENGJAYA MINERALINDO

Nickel Mines Limited
MONTHLY REPORT
Nickel Mine Project - Tangofa
Des-21

MAN HOURS RECORD 2021

Year 2021

Month	PT. HM	Yr Cum	Proj Cum	Contractor's	Yr Cum	Proj Cum	Total Yr Cum	Total Proj Cum	Start Jan 2021
Jan-21	41,458	41,458	997,351	205,031	205,031	3,169,479	246,489	4,166,830	Jan 01 - 31
Feb-21	39,174	80,632	1,036,525	212,869	417,900	3,382,348	498,532	4,418,873	Feb 01 - 28
Mar-21	44,298	124,930	1,080,823	207,076	624,976	3,589,424	749,906	4,670,247	Mar 01 - 31
Apr-21	43,038	167,968	1,123,861	229,719	854,695	3,819,143	1,022,663	4,943,004	Apr 01 - 30
Mei-21	37,514	205,482	1,161,375	224,867	1,079,562	4,044,010	1,285,044	5,205,385	Mei 01 - 31
Jun-21	45,302	250,784	1,206,677	247,514	1,327,075	4,291,523	1,577,859	5,498,200	Juni 01 - 30
Jul-21	43,392	294,176	1,250,069	261,871	1,588,946	4,553,394	1,883,122	5,803,463	Juli 01 - 31
Agu-21	42,282	336,458	1,292,351	261,928	1,850,874	4,815,322	2,187,332	6,107,673	Aug 01 - 31
Sep-21	47,132	383,590	1,339,483	271,210	2,122,084	5,086,532	2,505,674	6,426,015	Sept 01 - 30
Okt-21	48,067	431,657	1,387,550	294,497	2,416,581	5,381,029	2,848,238	6,768,579	Oct 01 - 31
Nov-21	7,712	439,369	1,395,262	47,590	2,464,170	5,428,618	2,903,539	6,823,880	Nov 26 - 30
Des-21	43,036	482,405	1,438,298	265,865	2,730,035	5,694,483	3,212,440	7,132,781	Dec 01 - 31
Hrs Year 2021	**509,495**			**2,899,604**			**3,409,099**		
Hrs Since LTI	**50,748**			**313,455**			**364,203**		

Last LTI date:	19-Nov-21
Report date:	31-Dec-21
Safe days on 2021 since last LTI:	**36**
Safe days since last LTI:	**36**
Start Project:	01-Jan-19
Number of safe days lost before LTI:	**737**
Number of safe hours lost before LTI:	**5,345,888**

PT. HENGJAYA MINERALINDO

Nickel Mines Limited
MONTHLY REPORT
Nickel Mining Project - Tangofa
Des-21

SHEQ PERFORMANCE STATISTIC PROJECT TO DATE

Safety Statistics (Project to Date from 01 Jan 2019)

ACCIDENT / INCIDENT CLASSIFICATION	HM (Project to Date) (Incl. mgmt/Admin/Superv / Direct Labour)		CONTRACTOR (Project to Date) (Incl. mgmt/Admin/Superv / Direct Labour)		PROJECT TOTALS (Project to Date) (Incl. mgmt/Admin/Superv / Direct Labour)	
	This Period	Cumulative	This Period	Cumulative	This Period	Cumulative
Hours Worked	43,036	1,438,298	265,865	5,694,483	308,901	7,132,781
Average No. of Workers	249		1,120		1,369	
Number of safe days lost before LTI	18	737	18	737	18	737
Number of safe days lost cause Fatality			6,000			
Number of Hours Since Last LTI (26 Nov 2021)	43,036	50,748	265,865	313,455	308,901	364,203
FATALITIES	0	0	0	2	0	2
LTI	0	1	0	0	0	1
AWI	0	0	0	0	0	0
MTI	0	1	0	2	0	3
FAI	0	2	0	7	0	9
Non Injury Incident Potential Class #1	0	0	0	5	0	5
Non Injury Incident Potential Class #2	0	0	0	0	0	0
Non Injury Incident Potential Class #3	0	0	0	0	0	0
Lost Time Injury Frequency Rate (LTIFR): No. of Lost Time Injuries x 1,000,000 / No. of Hours Worked	0.00	0.70	0.00	0.35	0.00	0.42
Total Incident Frequency Rate (TIFR): Fatal + LTI + AWI + MTI + FAI + PC1 + PC2 + PC3 x 1,000,000 / Hours Worked	0.00	2.78	0.00	2.81	0.00	2.80
Severity Rate (SR): No. of LTD x 1,000,000 / Hours Worked	139418.16	4171.60	22567.84	1053.65	19423.70	841.19

MAN POWER & MAN HOURS

The total project hours worked, start 2019 to date, reached 7.132.781 hours. Since the last LTI (November 26th, 2021) we have accumulated 364.203 safe worked hours with 36 days LTI free.

In 2021, we strive for zero LTI.

HSE – SAFETY STATS - 2022

Safety Statistics (Last LTI - November 2021)

PT. HENGJAYA MINERALINDO

Nickel Mines Limited
MONTHLY REPORT
Nickel Mine Project - Tangofa
Jun-22

MAN HOURS RECORD 2022

Year 2022

Month	PT. HM	Yr Cum	Proj Cum	Contractor's	Yr Cum	Proj Cum	Total Yr Cum	Total Proj Cum	Start Jan 2022
Jan-22	45,454	45,454	554,949	281,526	281,526	3,181,130	326,980	7,459,761	Jan 01 - 31
Feb-22	40,800	86,254	595,749	253,819	535,345	3,434,949	621,599	7,754,380	Feb 01 - 28
Mar-22	47,610	133,864	643,359	285,003	820,348	3,719,952	954,212	8,086,993	Mar 01 - 31
Apr-22	48,928	182,792	692,287	269,821	1,090,169	3,989,773	1,272,961	8,405,742	Apr 01 - 30
Mei-22	44,670	227,462	736,957	277,152	1,367,321	4,266,925	1,594,783	8,727,564	May 01 - 31
Jun-22	49,060	276,522	786,017	310,323	1,677,644	4,577,248	1,954,166	9,086,947	Jun 01 - 30
Jul-22		276,522	786,017		1,677,644	4,577,248	1,954,166	9,086,947	
Agu-22		276,522	786,017		1,677,644	4,577,248	1,954,166	9,086,947	
Sep-22		276,522	786,017		1,677,644	4,577,248	1,954,166	9,086,947	
Okt-22		276,522	786,017		1,677,644	4,577,248	1,954,166	9,086,947	
Nov-22		276,522	786,017		1,677,644	4,577,248	1,954,166	9,086,947	
Des-22		276,522	786,017		1,677,644	4,577,248	1,954,166	9,086,947	
Hrs Year 2022	**276,522**			**1,677,644**			**1,954,166**		
Hrs Since LTI	**327,270**			**1,991,098**			**2,318,368**		

Last LTI date:	19-Nov-21
Report date:	30-Jun-22
Safe days on 2022:	**181**
Safe days since last LTI:	**217**
Start Project:	01-Jan-19
Number of safe days lost before LTI:	**737**
Number of safe hours lost before LTI:	**5,345,888**

MAN POWER & MAN HOURS

The total project hours worked, start 2019 to date, reached 9.086.947 hours. Since the last LTI (November 26th, 2021) we have accumulated 2.318.368 safe worked hours with 217 days LTI free.

In 2022, we strive for zero LTI.

PT. HENGJAYA MINERALINDO

Nickel Mines Limited
MONTHLY REPORT
Nickel Mining Project - Tangofa
Jun-22

SHQ PERFORMANCE STATISTIC PROJECT TO DATE

Safety Statistics (Project to Date from 01 Jan 2019)

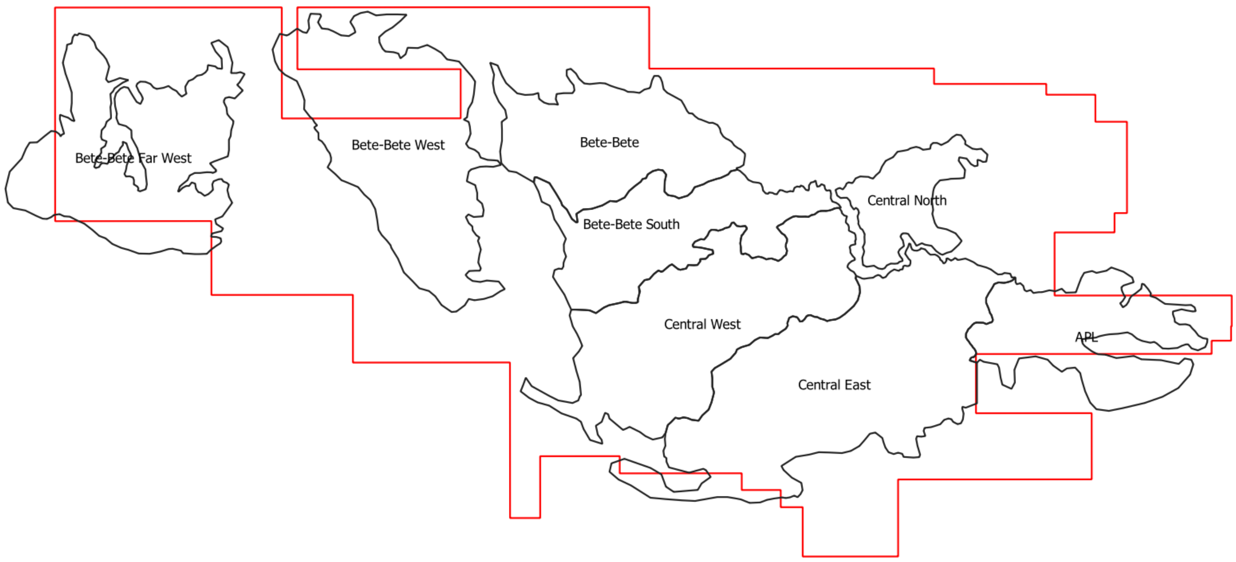
ACCIDENT / INCIDENT CLASSIFICATION	HM (Project to Date) (Incl. mgmt/Admin/Superv/ Direct Labour)		CONTRACTOR (Project to Date) (Incl. mgmt/Admin/Superv/ Direct Labour)		PROJECT TOTALS (Project to Date) (Incl. mgmt/Admin/Superv/ Direct Labour)	
	This Period	Cumulative	This Period	Cumulative	This Period	Cumulative
Hours Worked	49,060	786,017	310,323	4,577,248	359,383	5,363,265
Average No. of Workers	263		1,301		1,564	
Number of safe days lost before LTI		737		737		737
Number of safe days lost cause Fatality			6,000			
Number of Hours Since Last LTI (26 Nov 2021)	49,060	327,270	310,323	1,991,098	359,383	2,318,368
FATALITIES	0	0	0	2	0	2
LTI	0	1	0	0	0	1
AWI	0	0	0	0	0	0
MTI	0	1	0	2	0	3
FAI	0	2	0	8	0	10
Nearmiss	0	0	0	5	0	5
Lost Time Injury Frequency Rate (LTIFR):						
No. of Lost Time Injuries x 1,000,000	0.00	1.27	0.00	0.44	0.00	0.56
No. of Hours Worked						
Total Incident Frequency Rate (TIFR):						
Fatal + LTI + AWI + MTI + FAI + Nearmiss x 1,000,000	0.00	5.09	0.00	3.71	0.00	3.92
Hours Worked						
Severity Rate (SR):						
No. of LTD x 1,000,000	122299.23	7633.42	19334.69	1310.83	16695.28	1118.72
Hours Worked						

Appendix 4
Descriptive Statistics and Swath plots

Hengjaya Mineralindo

Descriptive Statistics

JORC 2022



WEIGHTED AVERAGE BY DOMAIN

Domain	Genlith	Thick	Weighted Average				
			% Ni	% Co	% Fe	% MgO	% SiO2
Bete-Bete	Limonite	6.85	0.95	0.13	46.67	1.96	5.73
	Saprolite	8.39	1.51	0.04	15.23	21.43	36.77
Bete-Bete South	Limonite	11.67	1.06	0.13	43.06	1.62	7.42
	Saprolite	9.18	1.24	0.04	16.96	18.77	34.25
Central West	Limonite	12.23	1.10	0.14	44.80	1.49	7.81
	Saprolite	9.88	1.46	0.04	15.16	21.12	36.25
Central East	Limonite	11.07	1.03	0.12	42.53	1.43	11.37
	Saprolite	11.09	1.36	0.04	15.10	18.50	40.40
Bete-Bete West	Limonite	5.69	0.86	0.11	41.85	1.64	14.47
	Saprolite	5.92	1.31	0.03	15.95	18.81	38.20
Bete-Bete Far West	Limonite	5.31	0.89	0.14	44.12	2.66	10.48
	Saprolite	7.33	1.06	0.03	12.58	23.09	37.20
APL	Limonite	8.78	0.91	0.11	37.99	1.50	17.48
	Saprolite	12.43	1.13	0.04	14.15	17.44	46.61

ALL DOMAIN STATISTICS

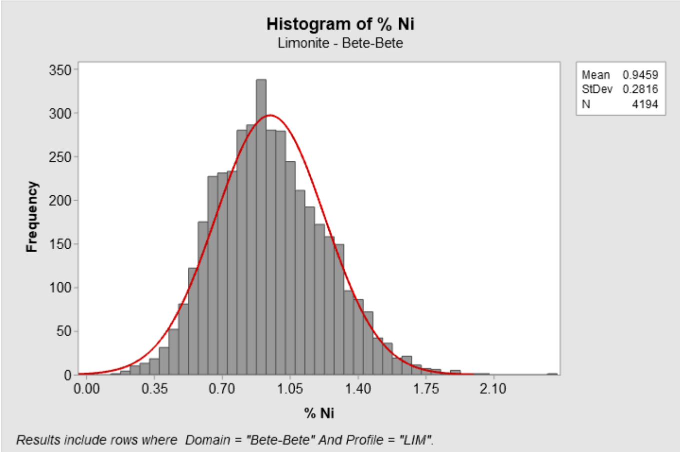
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	270	0.09	0.03	0.13	0.02	141.32	0.01	0.76	2.36	6.59
	LIM	53739	1.05	1.06	0.29	0.09	28.05	0.00	3.38	0.06	0.03
	SAP	52509	1.36	1.30	0.62	0.38	45.61	0.02	6.36	0.65	0.68
	BRK	15108	0.36	0.34	0.13	0.02	34.76	0.03	1.66	1.46	4.58
Co	SED	270	0.01	0.01	0.01	0.00	147.01	0.00	0.20	11.03	156.76
	LIM	53739	0.13	0.12	0.07	0.00	54.02	0.00	1.36	2.40	16.89
	SAP	52509	0.04	0.03	0.05	0.00	113.28	0.00	1.51	6.46	106.08
	BRK	15108	0.01	0.01	0.01	0.00	61.36	0.00	0.13	2.52	21.73
Fe	SED	270	3.02	2.24	2.56	6.56	84.91	0.16	17.74	2.19	8.18
	LIM	53739	43.73	44.68	7.22	52.11	16.51	0.00	69.80	-1.38	3.82
	SAP	52509	14.84	11.87	8.54	72.86	57.51	1.00	64.80	1.53	2.22
	BRK	15108	7.13	6.89	1.78	3.17	24.96	0.34	54.86	6.19	88.69
MgO	SED	270	6.94	2.66	8.37	70.08	120.68	0.10	30.63	1.53	0.94
	LIM	53739	1.54	1.00	2.07	4.28	134.59	0.00	42.06	8.35	108.06
	SAP	52509	20.37	21.80	9.60	92.17	47.14	0.00	46.63	-0.33	-0.85
	BRK	15080	31.69	32.98	7.06	49.81	22.27	0.00	49.11	-2.33	7.03
SiO2	SED	270	25.97	25.03	15.54	241.60	59.85	2.23	68.42	0.32	-0.83
	LIM	53739	9.14	5.30	10.05	101.01	110.01	0.00	99.00	3.10	13.51
	SAP	52509	38.49	39.12	10.40	108.21	27.02	0.00	99.00	0.53	4.10
	BRK	15080	42.03	40.50	7.78	60.57	18.52	0.00	96.17	3.20	14.41

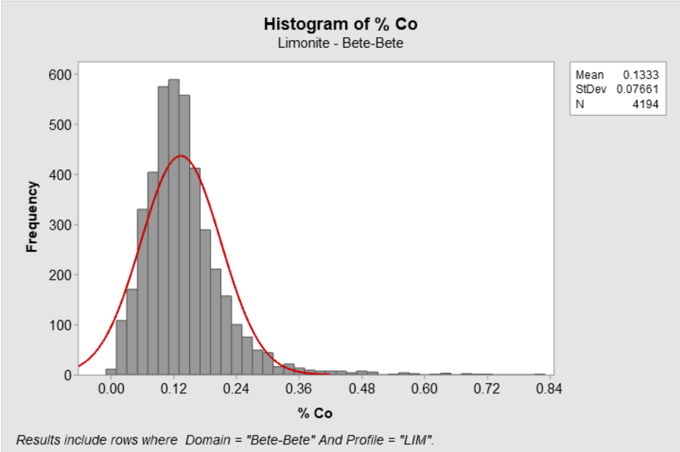
BETE-BETE

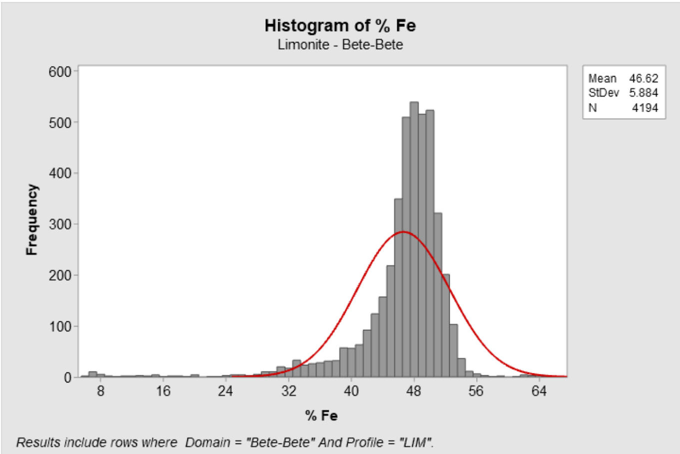
STATISTICS

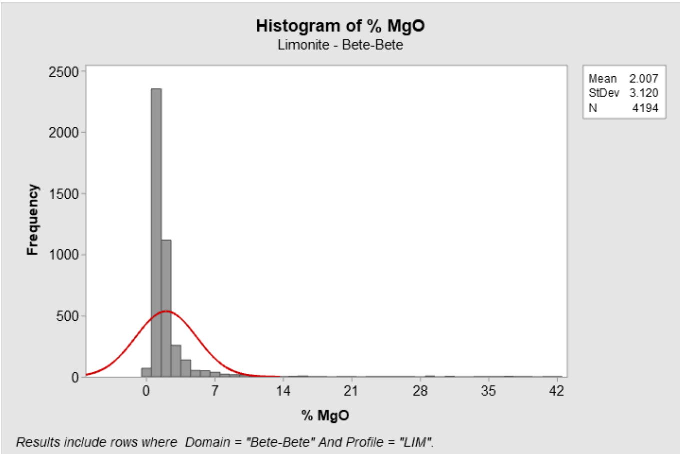
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	28	0.07	0.04	0.05	0.00	67.81	0.02	0.18	0.98	-0.05
	LIM	4194	0.95	0.92	0.28	0.08	29.78	0.01	2.39	0.34	0.12
	SAP	5425	1.48	1.47	0.61	0.37	41.16	0.09	4.23	0.21	-0.38
	BRK	2020	0.37	0.31	0.16	0.02	42.95	0.10	1.29	1.46	2.43
Co	SED	28	0.01	0.01	0.00	0.00	44.92	0.00	0.02	0.27	1.31
	LIM	4194	0.13	0.12	0.08	0.01	57.47	0.00	0.83	2.03	8.91
	SAP	5425	0.04	0.03	0.04	0.00	110.49	0.00	1.12	6.68	109.66
	BRK	2020	0.02	0.01	0.01	0.00	61.26	0.00	0.06	0.09	-1.08
Fe	SED	28	3.69	3.36	2.02	4.07	54.68	0.17	7.38	0.16	-1.05
	LIM	4194	46.62	47.80	5.88	34.62	12.62	6.43	66.30	-2.87	13.56
	SAP	5425	14.69	11.67	8.37	70.08	57.01	4.73	51.40	1.60	2.43
	BRK	2020	7.16	6.89	1.32	1.75	18.48	3.89	21.13	3.02	19.46
MgO	SED	28	5.54	2.57	6.05	36.64	109.27	0.83	24.56	1.64	2.37
	LIM	4194	2.01	1.28	3.12	9.74	155.47	0.20	42.06	7.80	75.33
	SAP	5425	22.21	23.79	9.21	84.72	41.44	0.01	42.27	-0.41	-0.70
	BRK	2020	32.71	33.27	5.09	25.88	15.55	0.60	47.12	-2.53	12.01
SiO2	SED	28	25.69	26.99	19.44	377.87	75.66	2.40	53.49	0.10	-1.74
	LIM	4194	5.79	3.77	5.76	33.20	99.52	0.00	52.46	2.98	11.78
	SAP	5425	37.05	39.10	6.94	48.10	18.72	2.45	52.51	-2.01	4.79
	BRK	2020	39.50	39.75	3.34	11.14	8.45	20.11	61.46	1.27	8.92

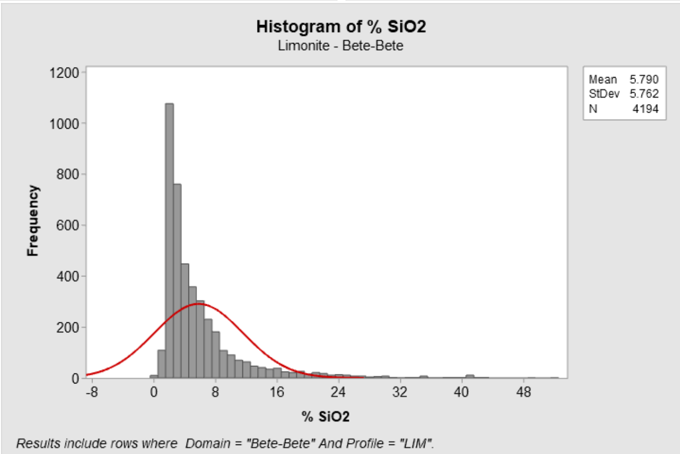
HISTOGRAM: LIM



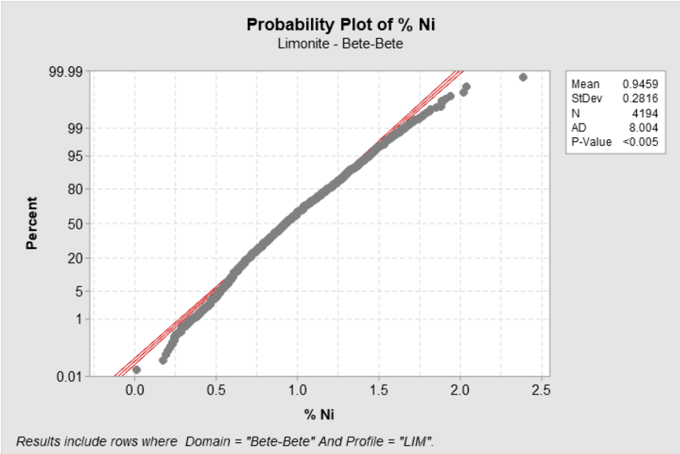


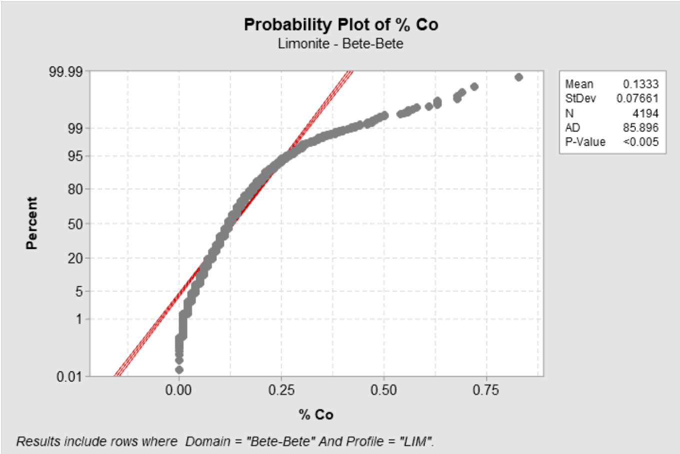


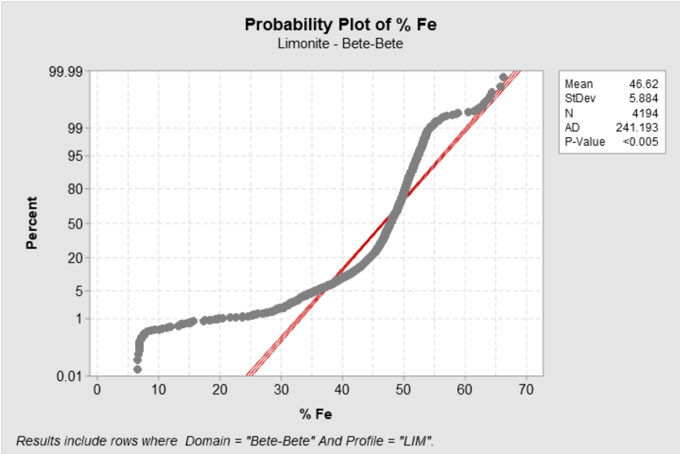


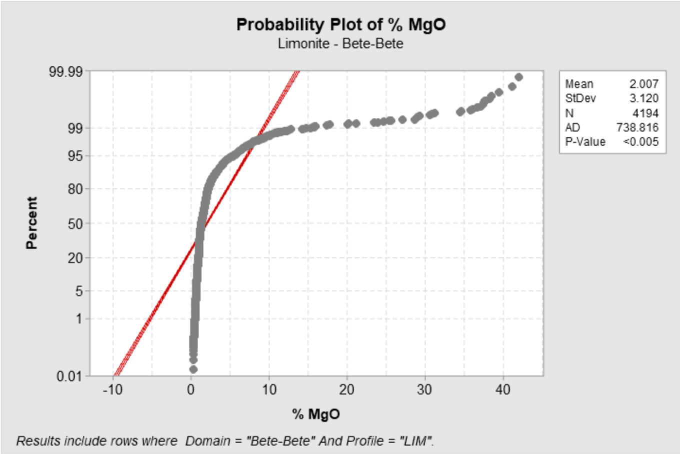


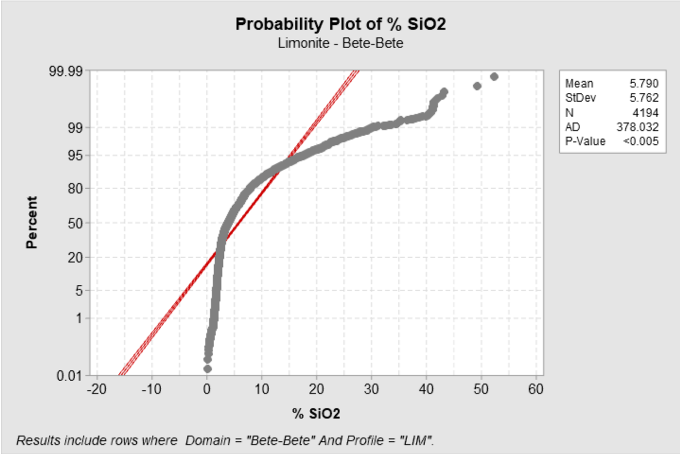
PROBABILITY PLOT: LIM











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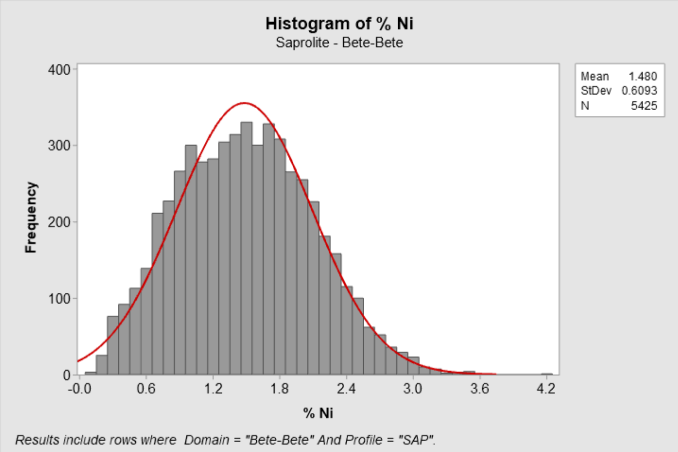

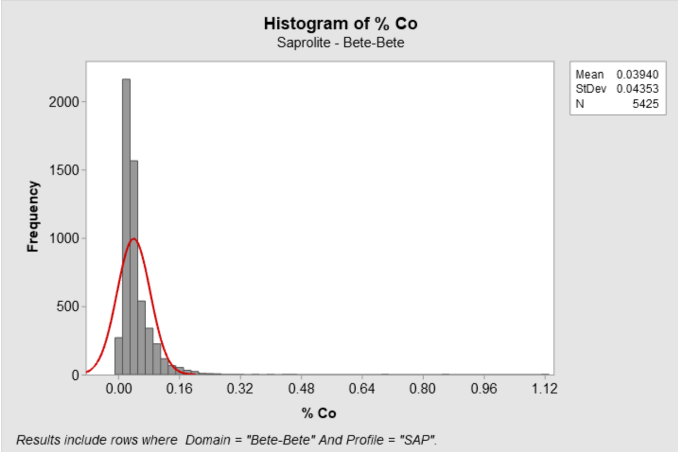

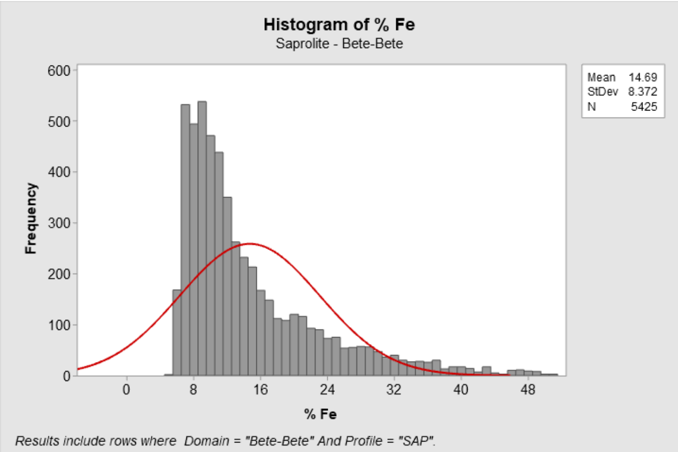

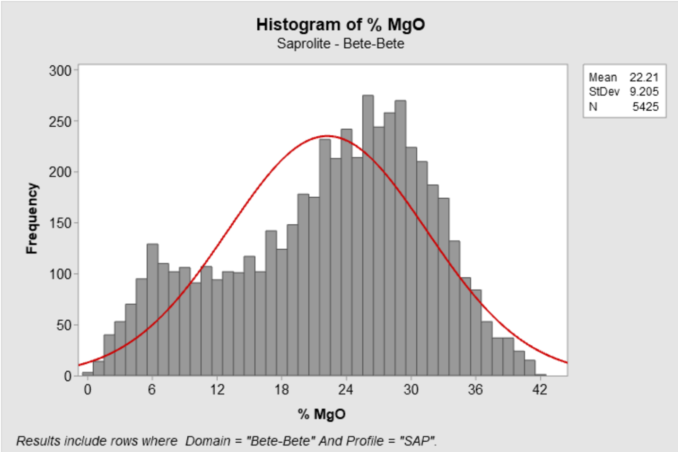

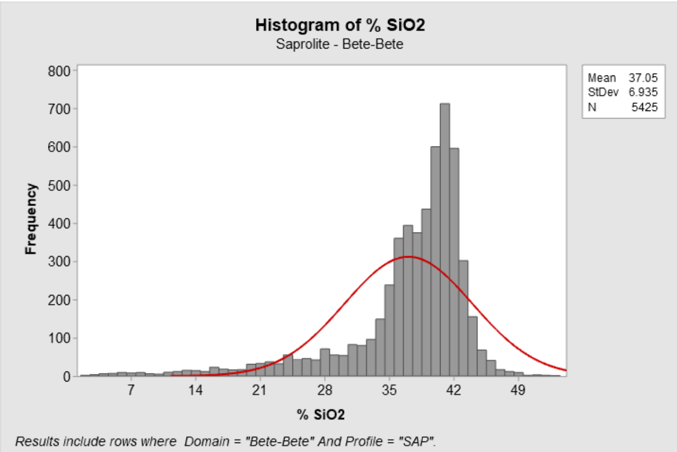

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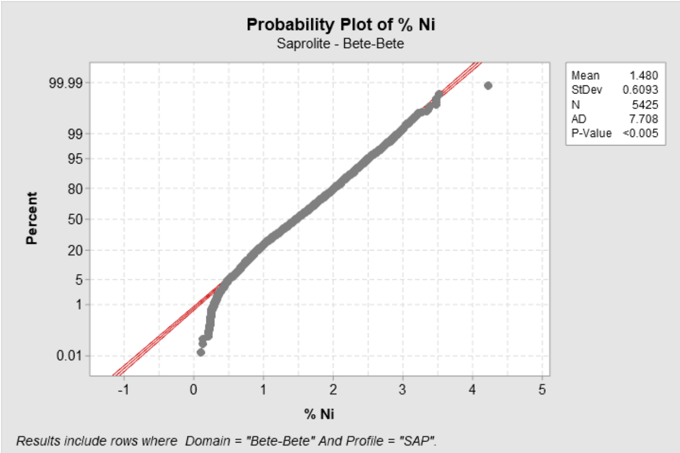
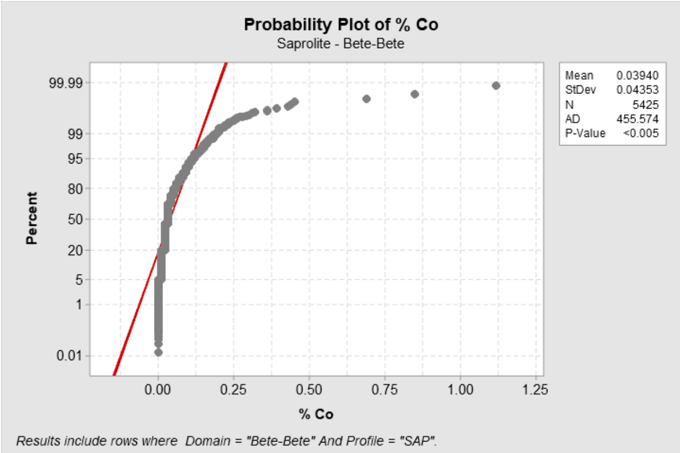
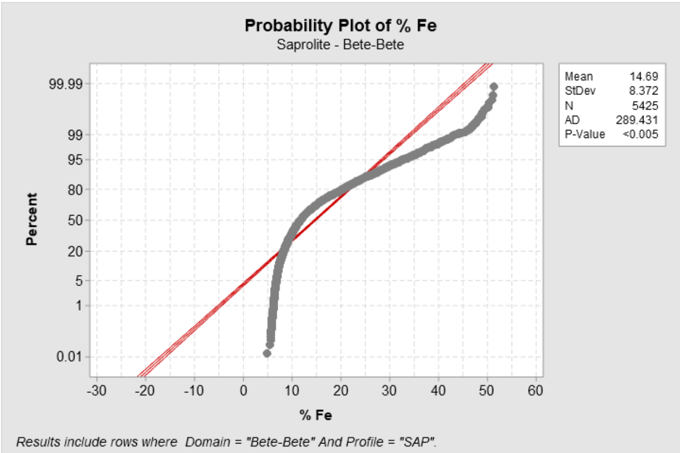
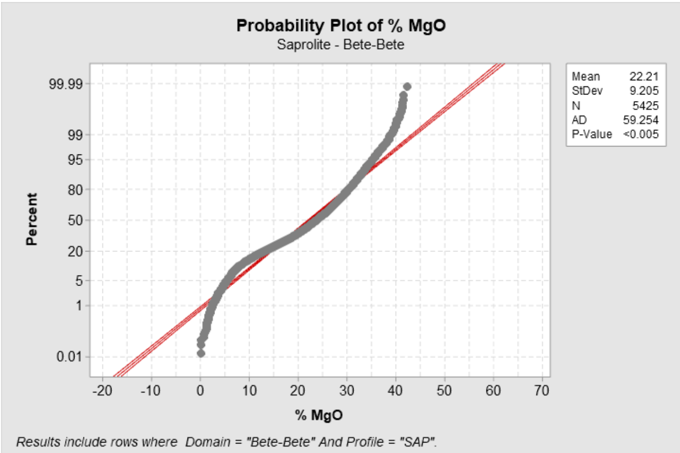
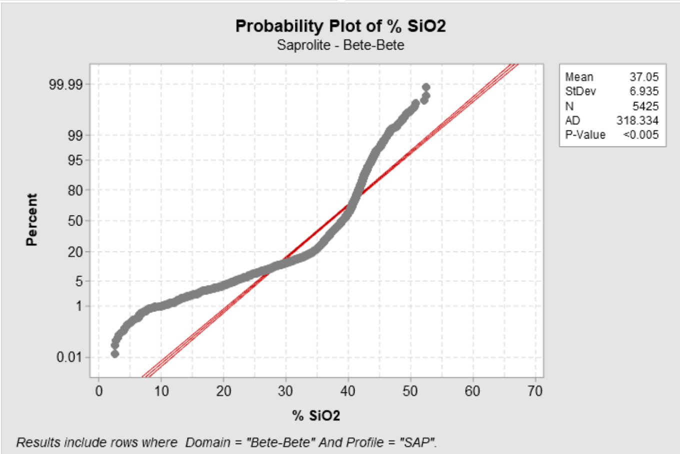


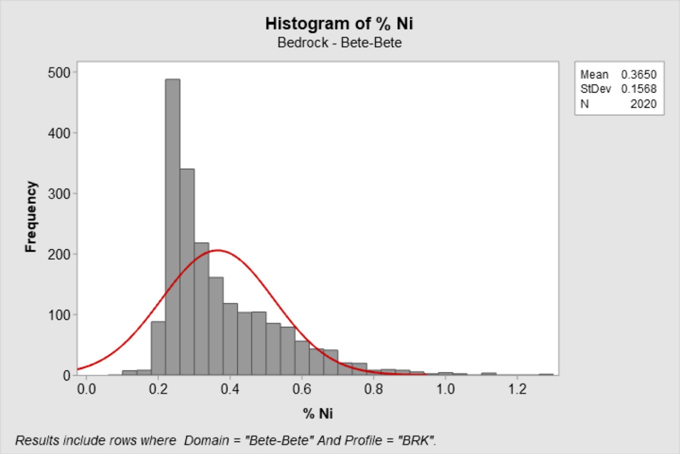


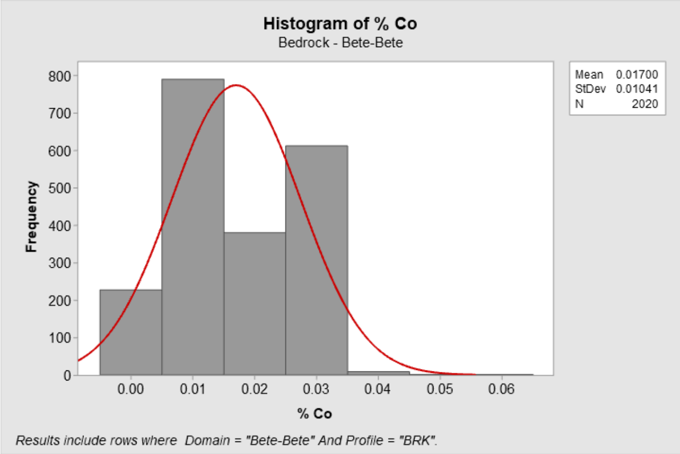


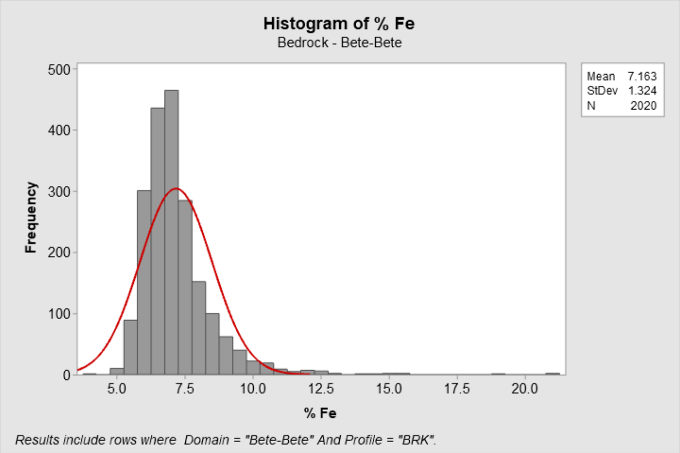


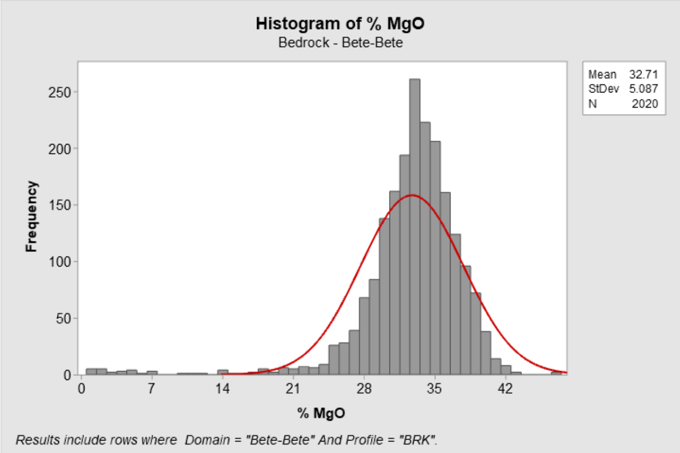


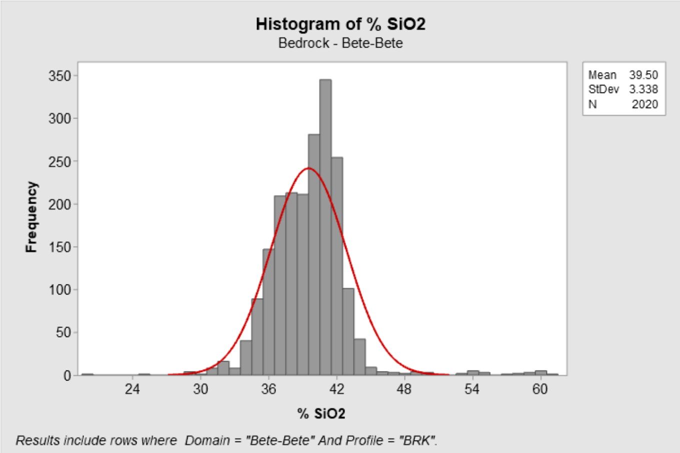
HISTOGRAM: BRK



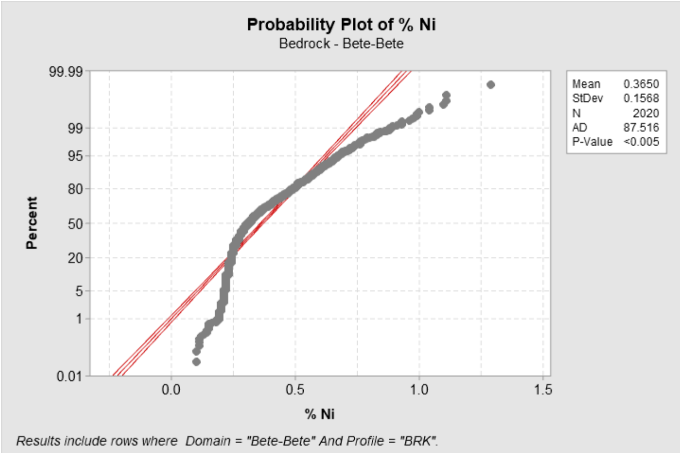


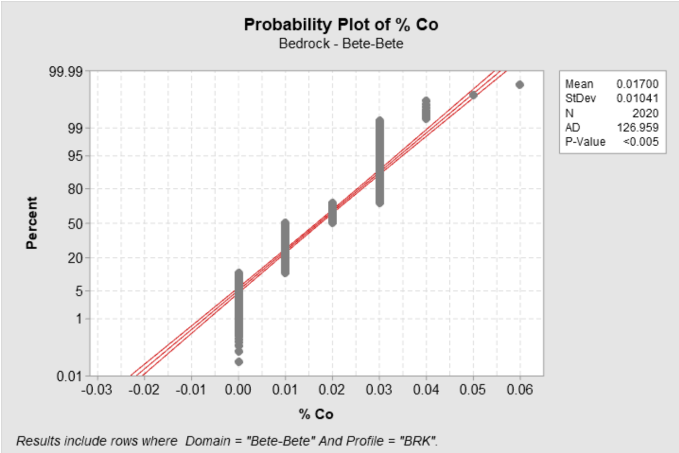


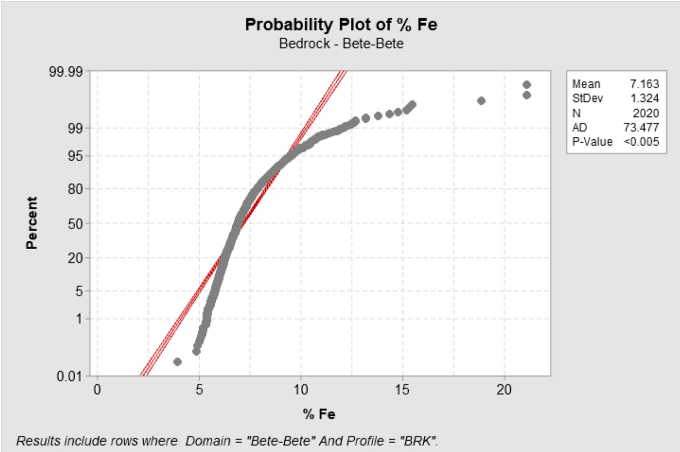


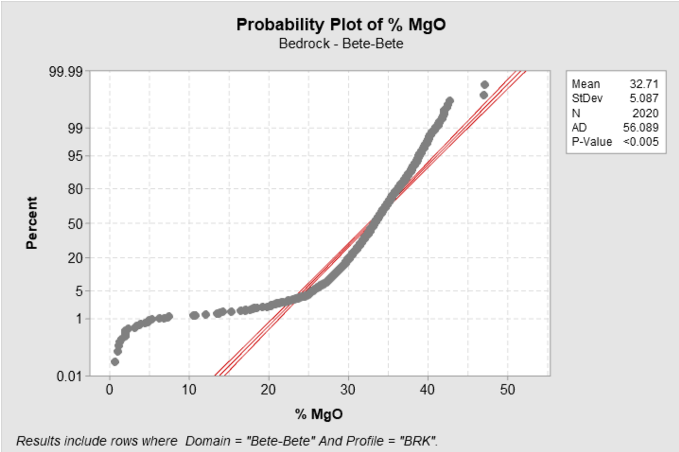


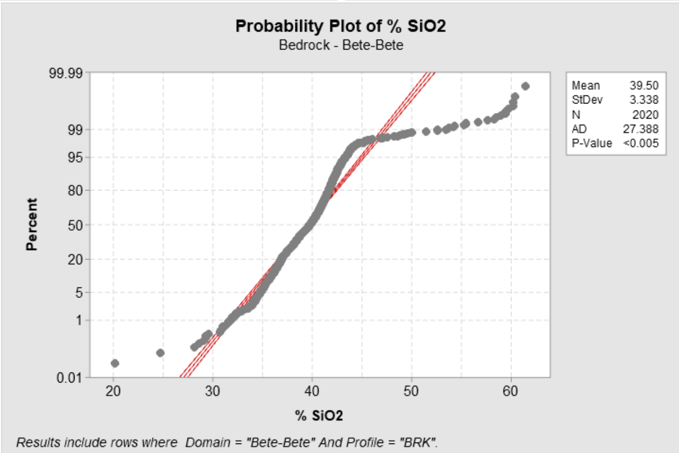
PROBABILITY PLOT: BRK









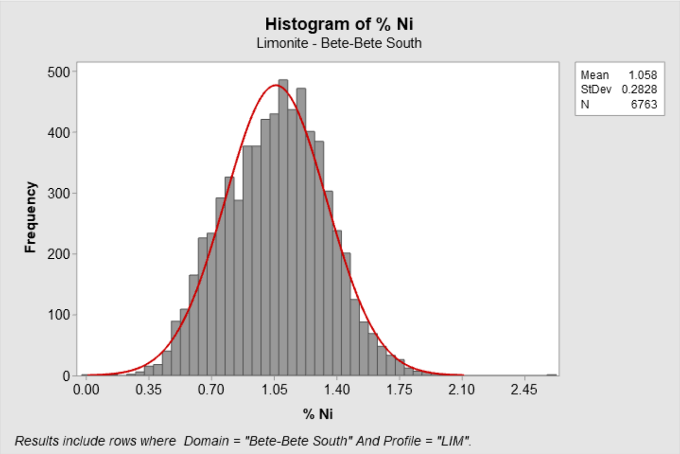


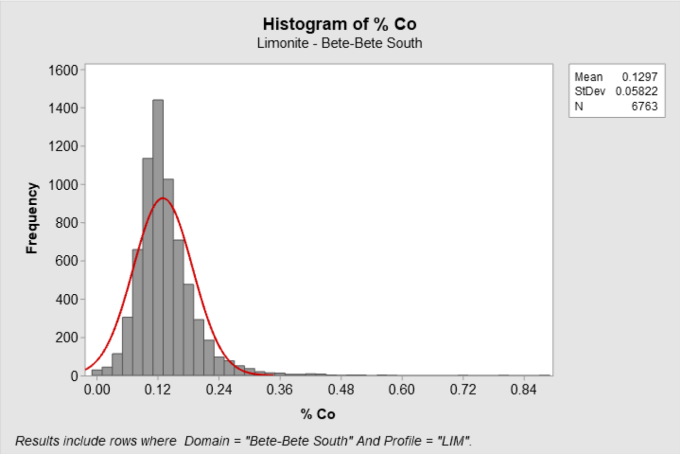
BETE-BETE SOUTH

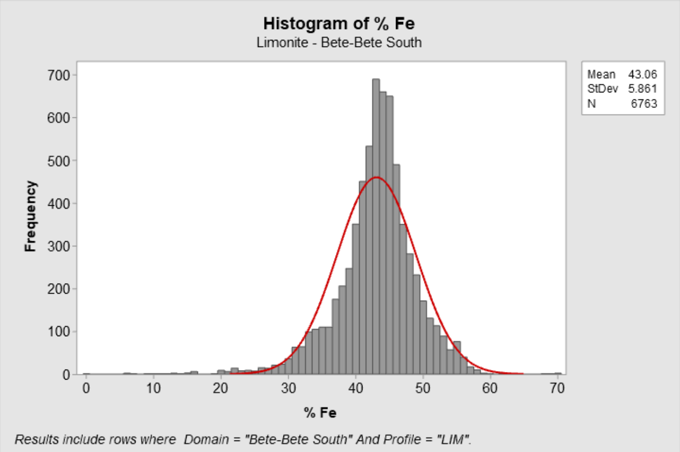
STATISTICS

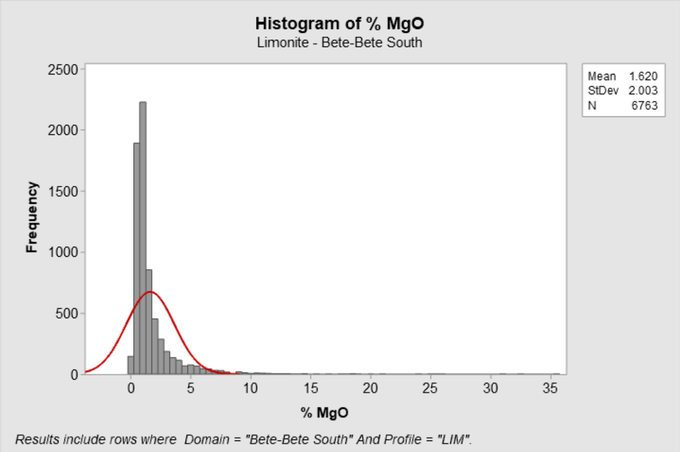
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	3	0.25	0.25	0.10	0.01	38.53	0.15	0.34	-0.16	
	LIM	6763	1.06	1.07	0.28	0.08	26.72	0.00	2.59	0.01	-0.18
	SAP	5524	1.22	1.18	0.47	0.22	38.22	0.16	3.88	0.71	1.16
	BRK	1373	0.38	0.36	0.13	0.02	33.02	0.16	1.17	1.01	1.56
Co	SED	3	0.02	0.02	0.01	0.00	34.64	0.01	0.02	-1.73	
	LIM	6763	0.13	0.12	0.06	0.00	44.90	0.00	0.87	2.21	13.54
	SAP	5524	0.04	0.03	0.04	0.00	91.63	0.00	0.96	5.33	79.18
	BRK	1373	0.02	0.01	0.01	0.00	52.38	0.00	0.12	2.12	18.46
Fe	SED	3	6.66	7.02	1.32	1.74	19.78	5.20	7.76	-1.14	
	LIM	6763	43.06	43.49	5.86	34.35	13.61	0.00	69.80	-0.86	3.49
	SAP	5524	16.51	13.75	8.87	78.64	53.72	3.47	55.26	1.16	0.95
	BRK	1373	7.14	6.98	1.77	3.13	24.78	4.09	54.86	16.31	406.77
MgO	SED	3	22.91	25.94	5.45	29.72	23.79	16.62	26.18	-1.73	
	LIM	6763	1.62	1.02	2.00	4.01	123.59	0.00	35.53	5.42	51.26
	SAP	5524	19.33	19.37	9.07	82.33	46.95	0.27	44.46	-0.05	-0.95
	BRK	1373	33.19	33.54	3.82	14.59	11.51	1.24	46.68	-1.32	6.87
SiO2	SED	3	40.19	39.97	0.88	0.78	2.19	39.44	41.16	1.05	
	LIM	6763	7.42	4.70	6.66	44.30	89.65	0.00	56.03	2.22	6.80
	SAP	5524	34.54	36.65	8.48	71.84	24.54	2.66	78.82	-0.64	0.78
	BRK	1373	39.25	38.96	3.41	11.60	8.68	3.30	61.50	0.06	12.52

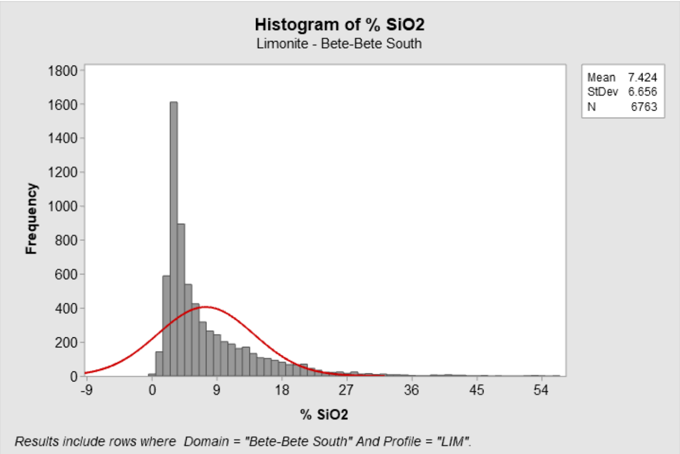
HISTOGRAM: LIM



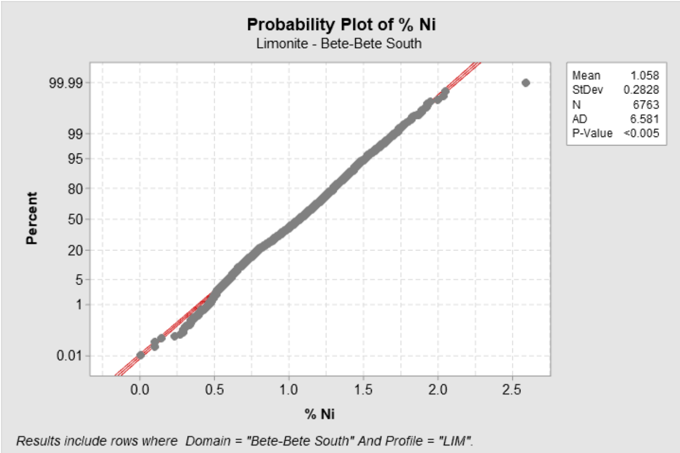


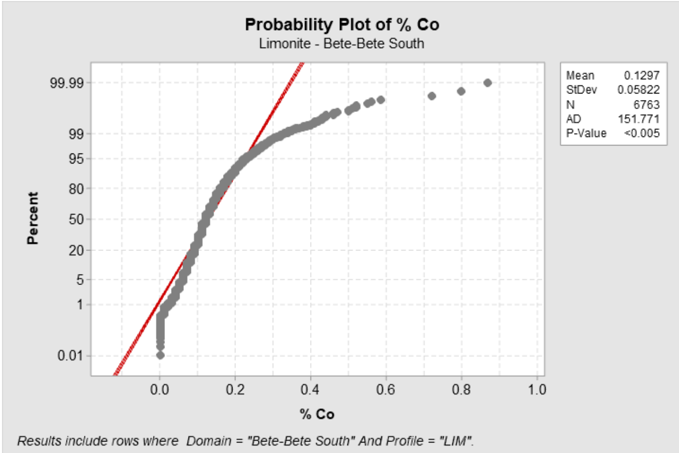


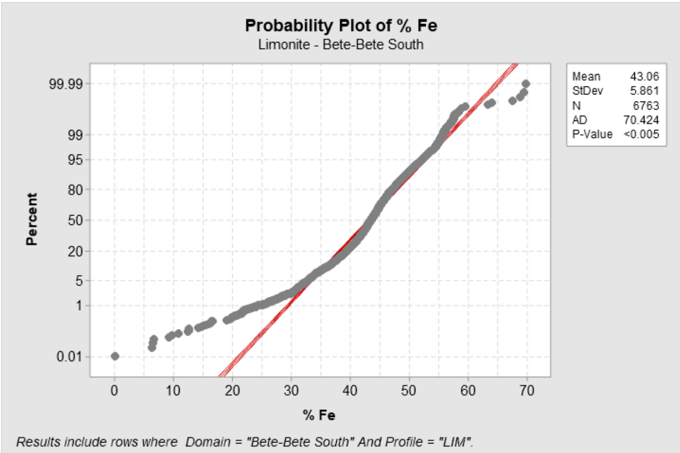


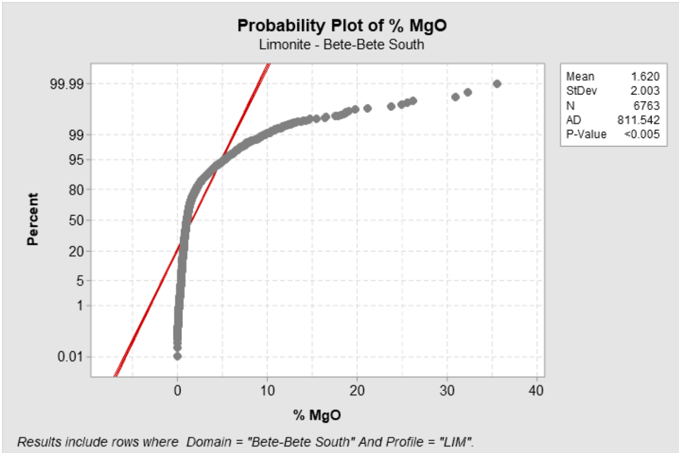


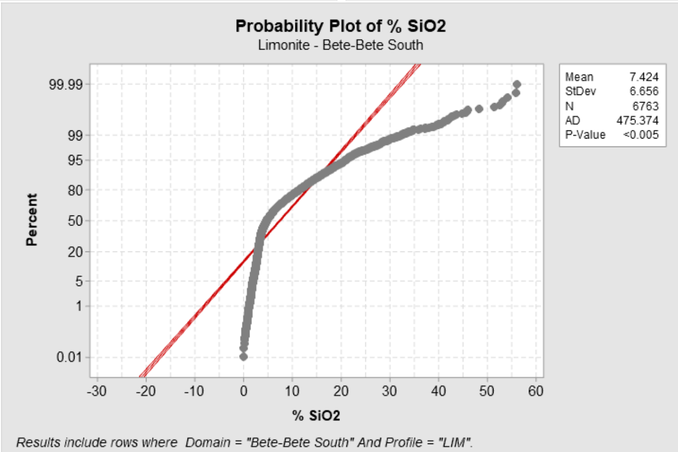
PROBABILITY PLOT: LIM











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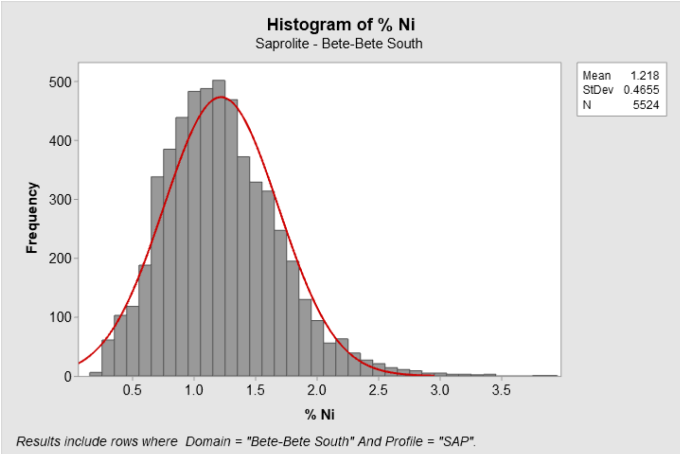
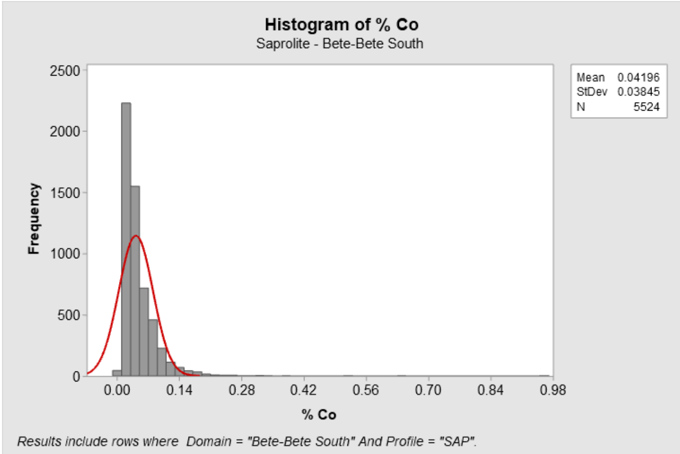
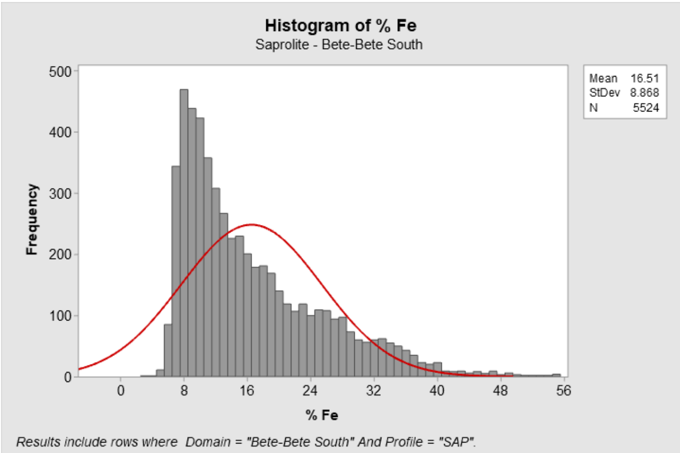
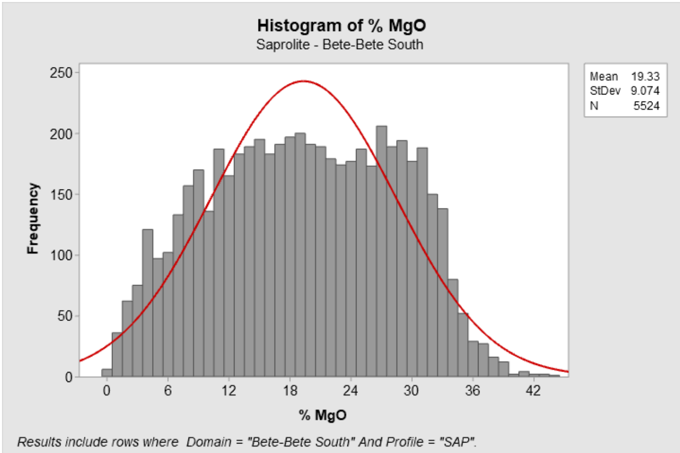
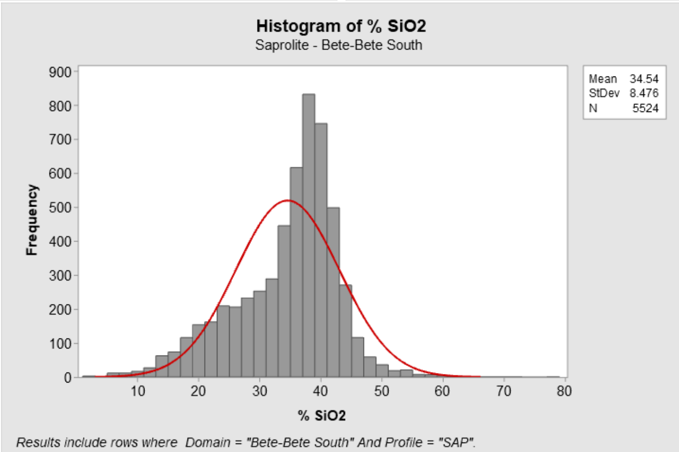


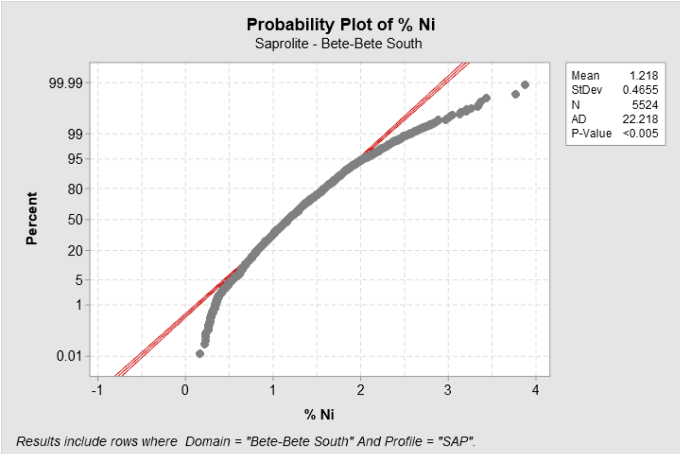


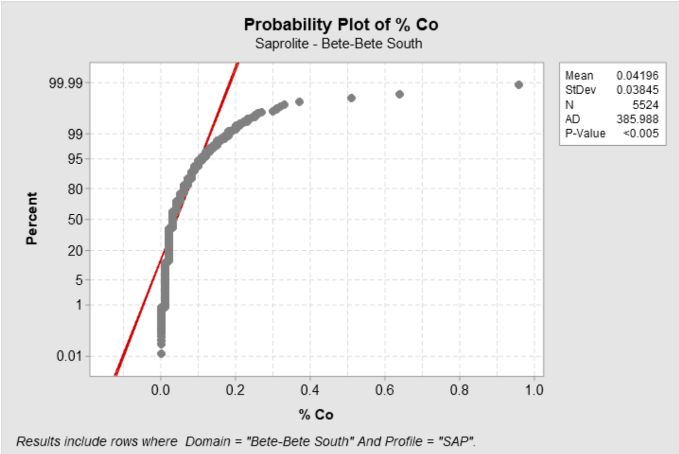


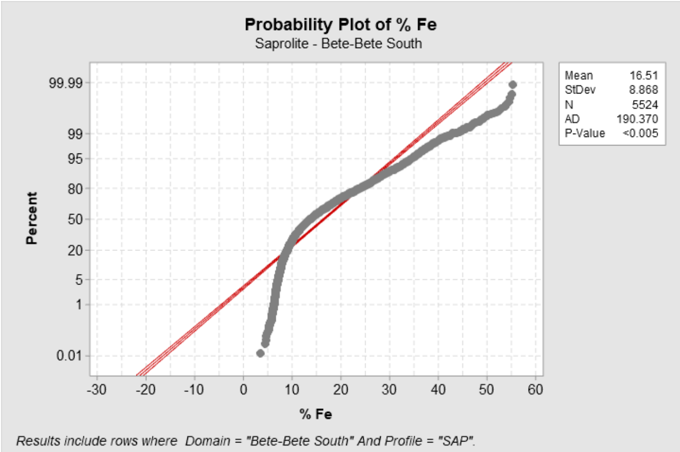


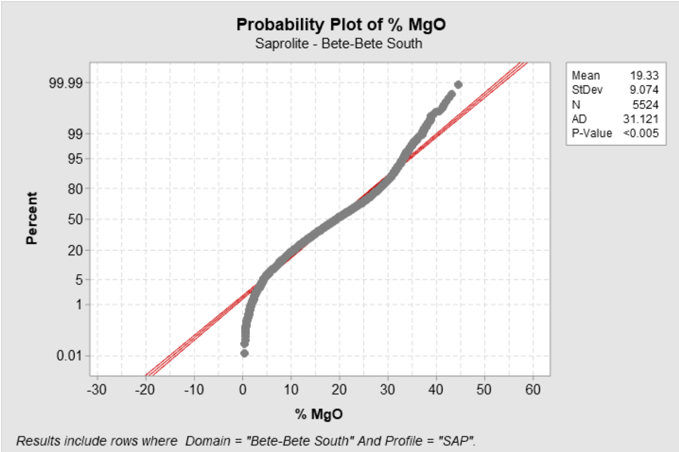


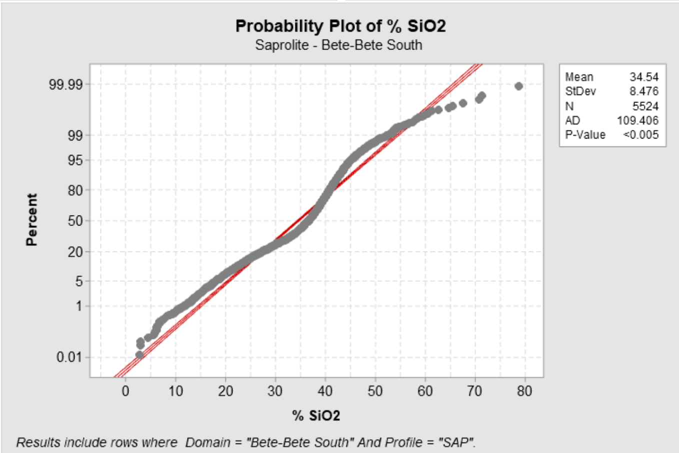
PROBABILITY PLOT: SAP











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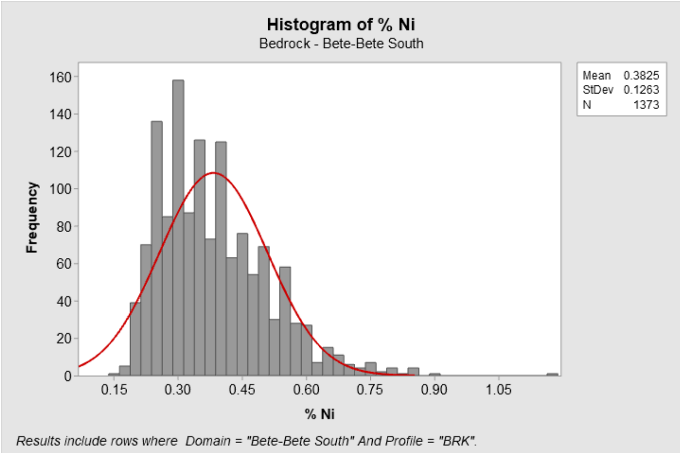
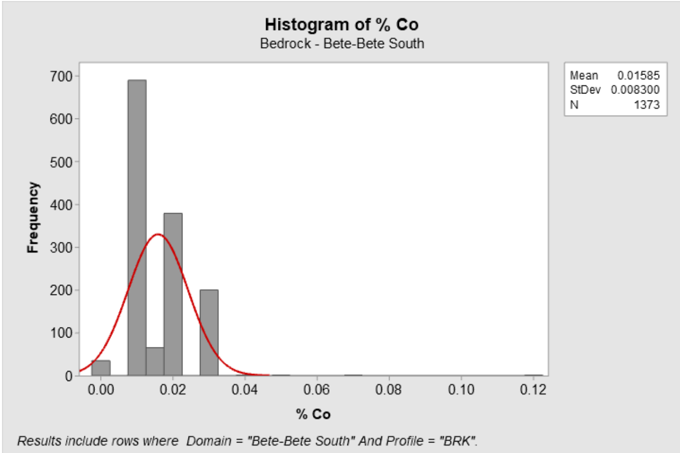
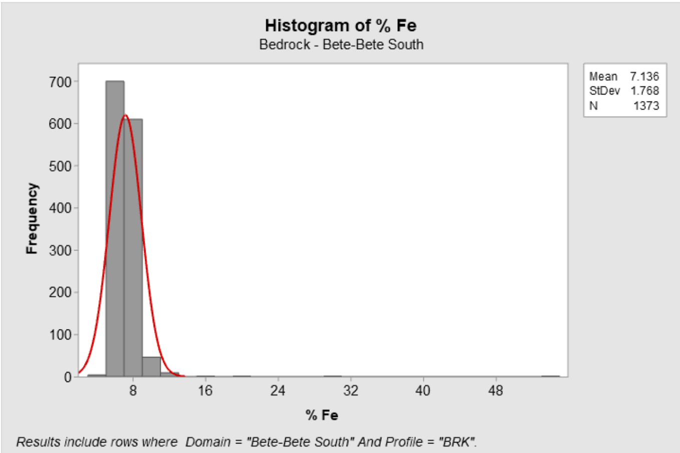
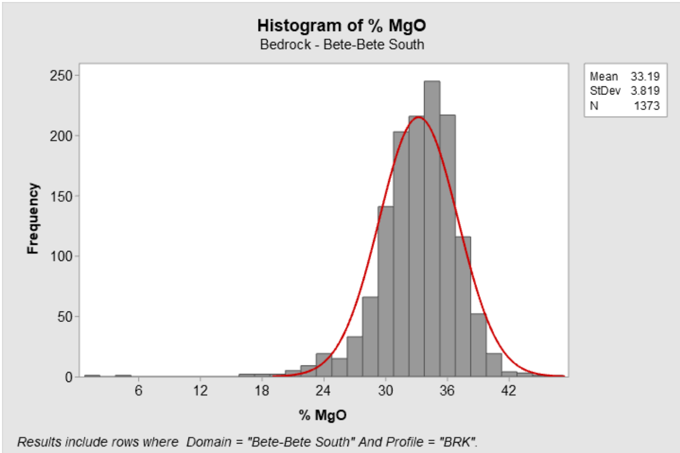
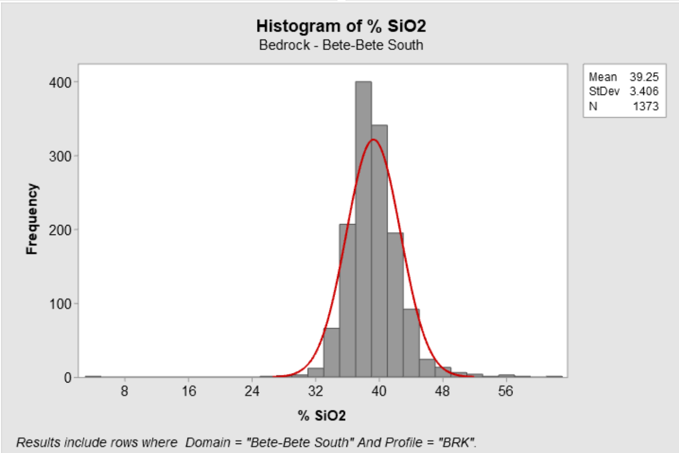


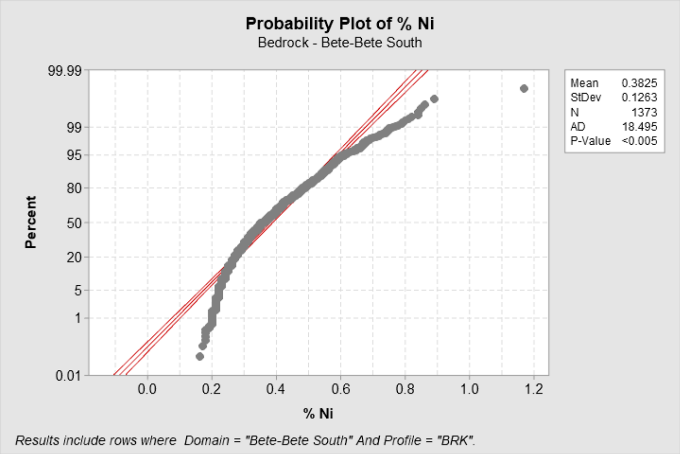


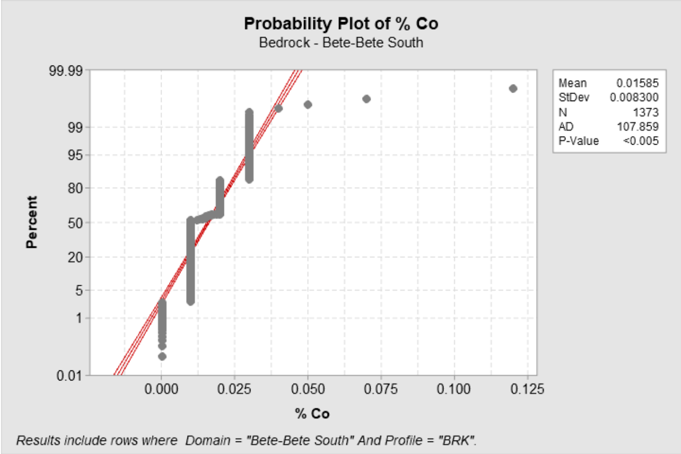


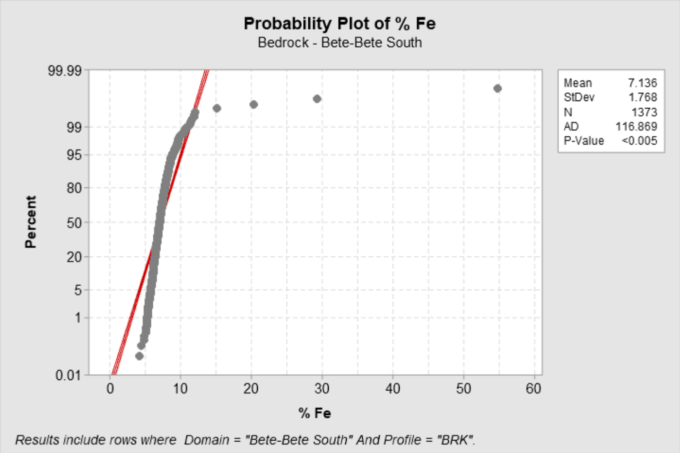


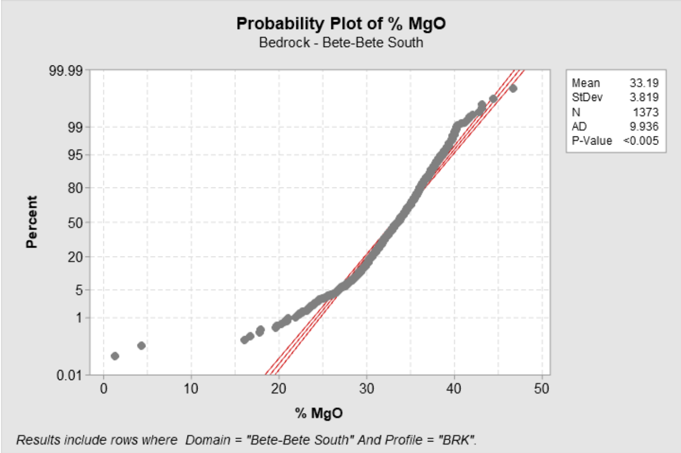


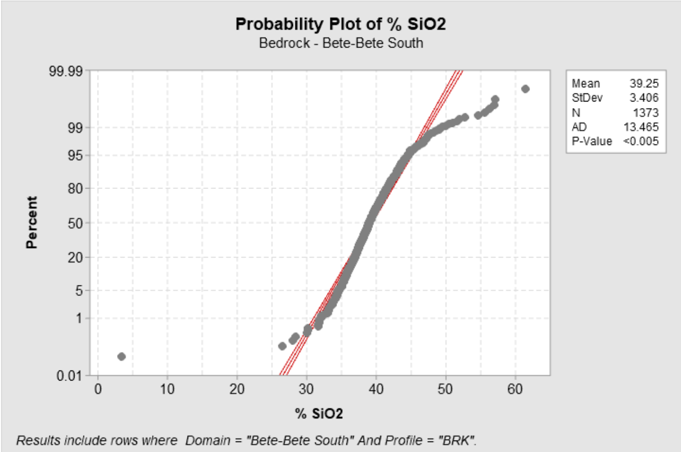
PROBABILITY PLOT: BRK









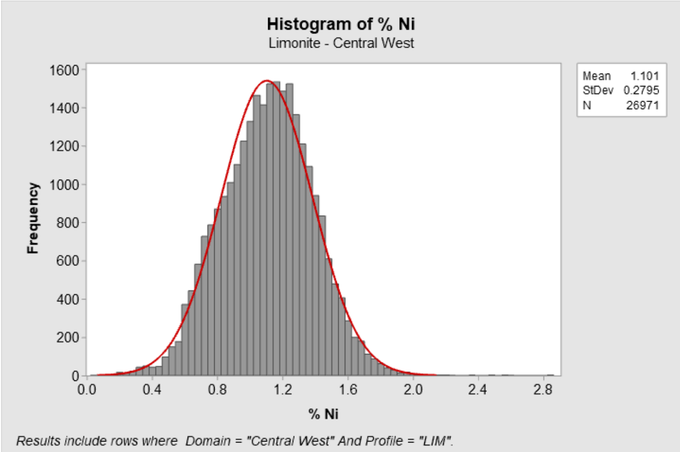


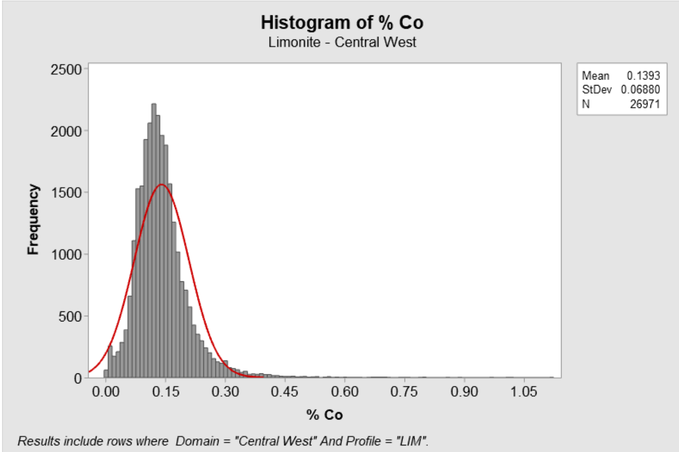
CENTRAL WEST

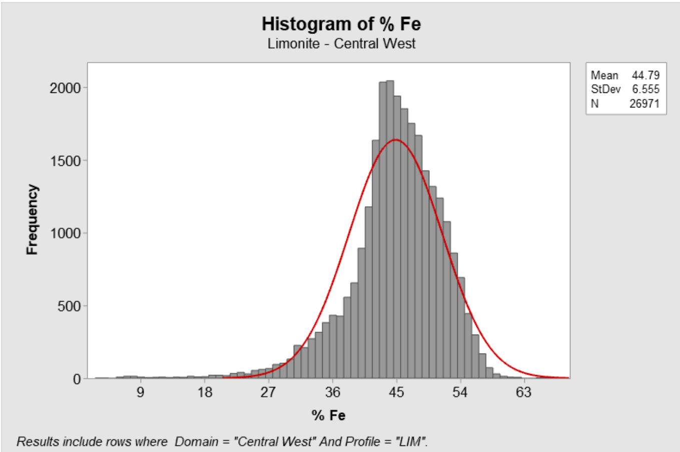
STATISTICS

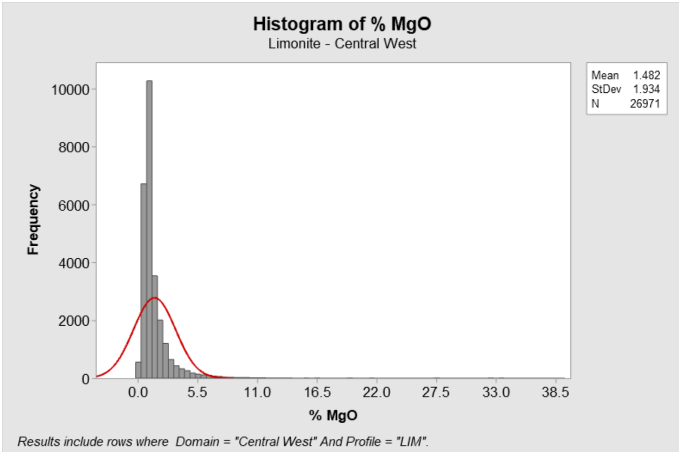
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	7	0.14	0.16	0.07	0.00	48.45	0.03	0.21	-0.69	-0.85
	LIM	26971	1.10	1.11	0.28	0.08	25.39	0.05	2.85	0.01	0.20
	SAP	22704	1.45	1.41	0.64	0.41	44.18	0.16	6.36	0.49	0.23
	BRK	5582	0.37	0.35	0.11	0.01	29.79	0.09	1.66	1.49	7.02
Co	SED	7	0.01	0.01	0.00	0.00	44.10	0.00	0.01	-2.65	7.00
	LIM	26971	0.14	0.13	0.07	0.00	49.38	0.00	1.12	2.23	13.61
	SAP	22704	0.04	0.03	0.05	0.00	116.88	0.00	1.51	5.98	90.33
	BRK	5582	0.01	0.01	0.01	0.00	50.40	0.00	0.12	0.85	13.82
Fe	SED	7	3.92	4.89	1.84	3.38	46.94	0.82	5.42	-1.03	-0.54
	LIM	26971	44.79	45.21	6.56	42.97	14.63	2.82	68.10	-1.10	3.22
	SAP	22704	14.86	11.72	8.80	77.47	59.22	3.12	64.80	1.61	2.46
	BRK	5582	7.03	6.90	1.25	1.56	17.79	2.19	29.16	5.29	74.40
MgO	SED	7	17.94	25.17	12.42	154.26	69.22	0.70	28.13	-0.87	-1.38
	LIM	26971	1.48	0.97	1.93	3.74	130.48	0.00	39.03	8.52	113.79
	SAP	22704	21.49	23.20	9.08	82.41	42.25	0.00	44.01	-0.47	-0.76
	BRK	5582	32.88	33.16	4.10	16.79	12.46	0.00	47.40	-2.36	14.92
SiO2	SED	7	31.08	38.26	15.73	247.31	50.60	6.01	47.26	-1.06	-0.63
	LIM	26971	7.82	4.74	7.59	57.63	97.01	0.00	80.52	2.52	8.57
	SAP	22704	36.37	38.28	8.35	69.68	22.95	1.26	78.51	-0.95	1.88
	BRK	5582	39.72	39.35	3.85	14.86	9.70	0.00	74.66	1.47	11.97

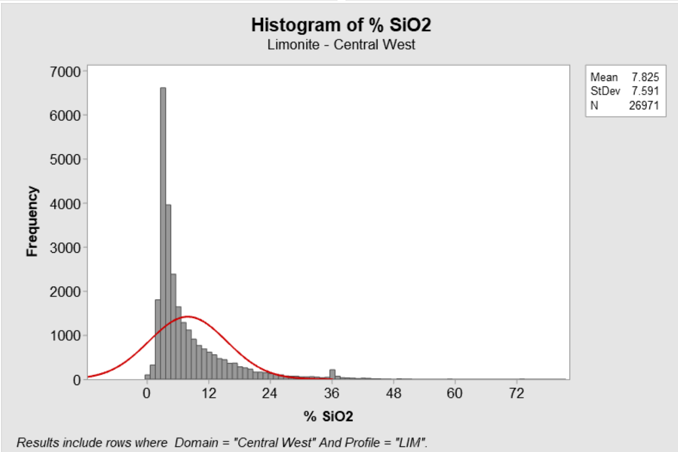
HISTOGRAM: LIM



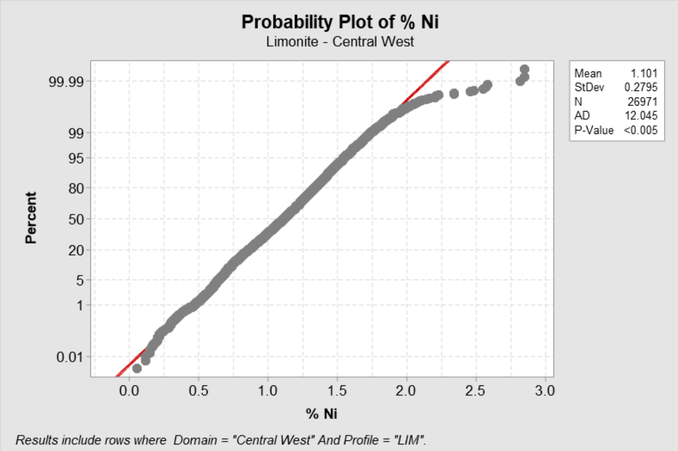


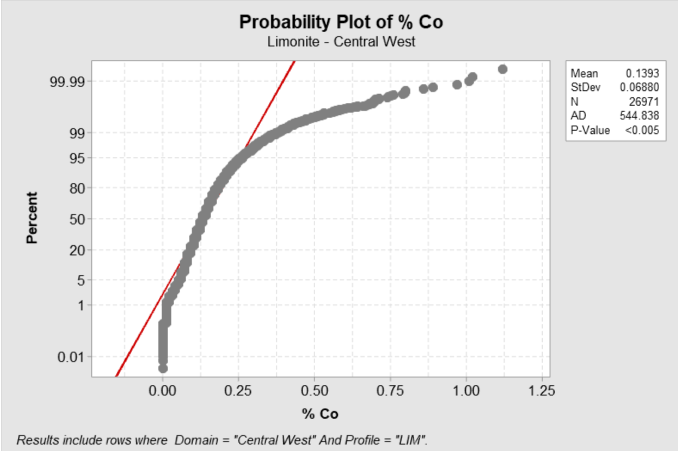


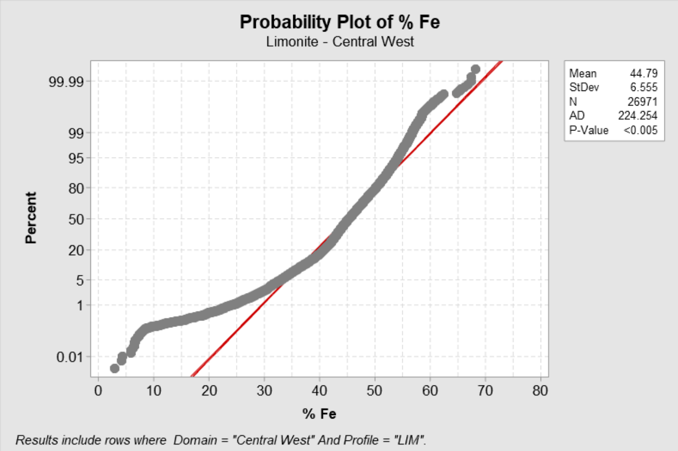


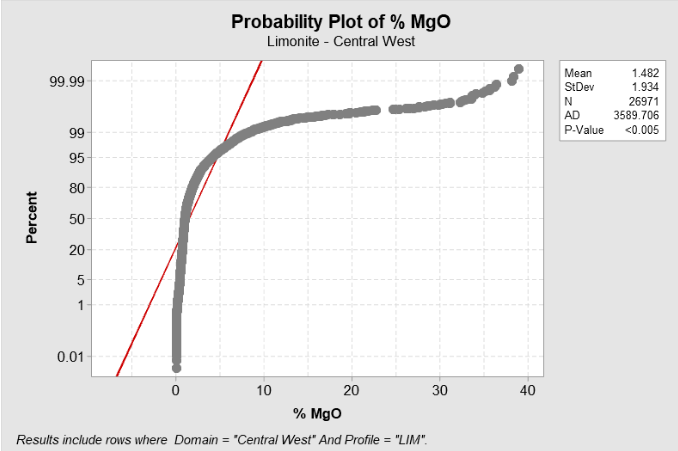


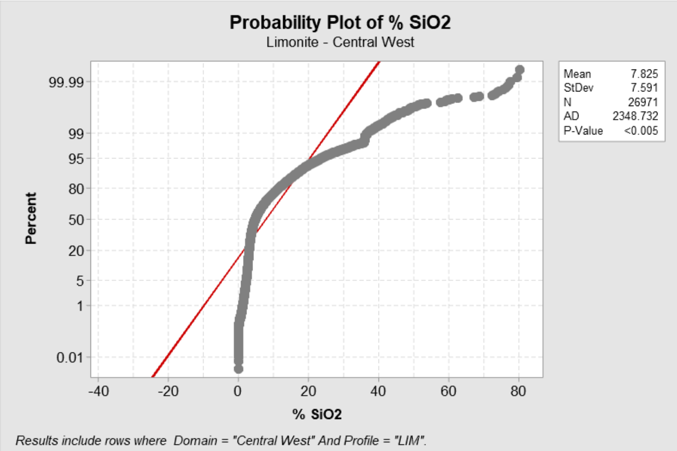
PROBABILITY PLOT: LIM











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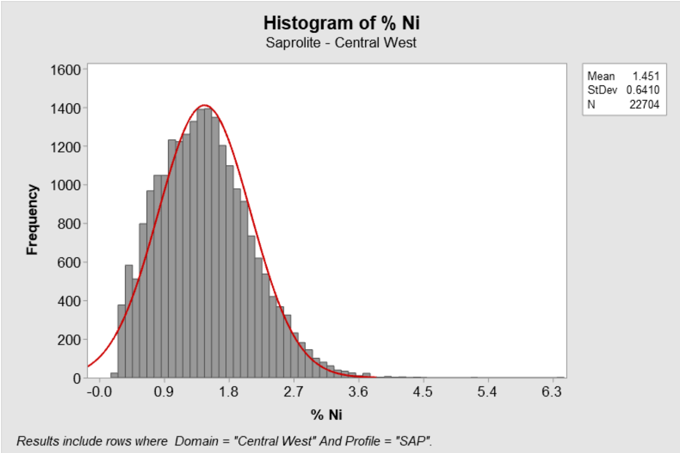
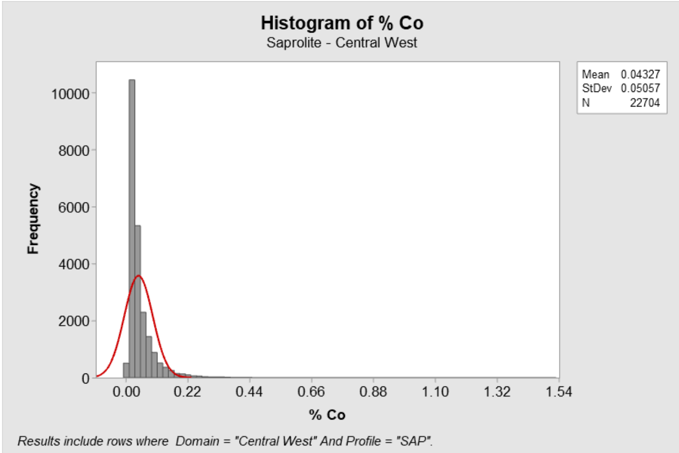
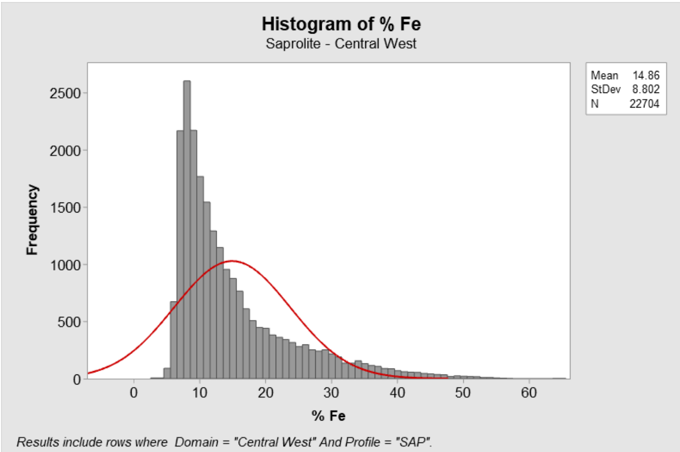
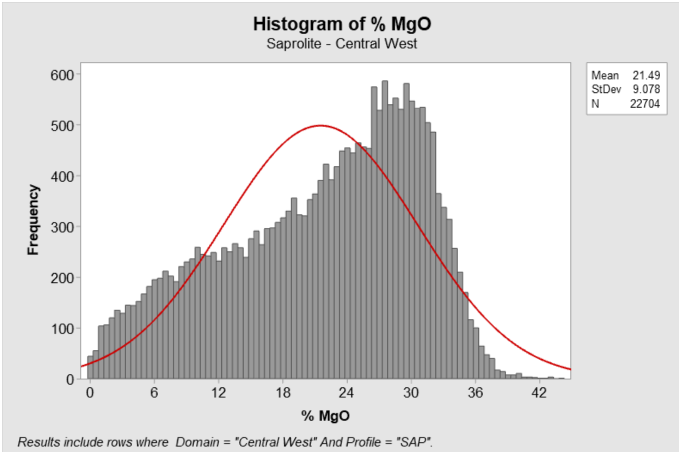
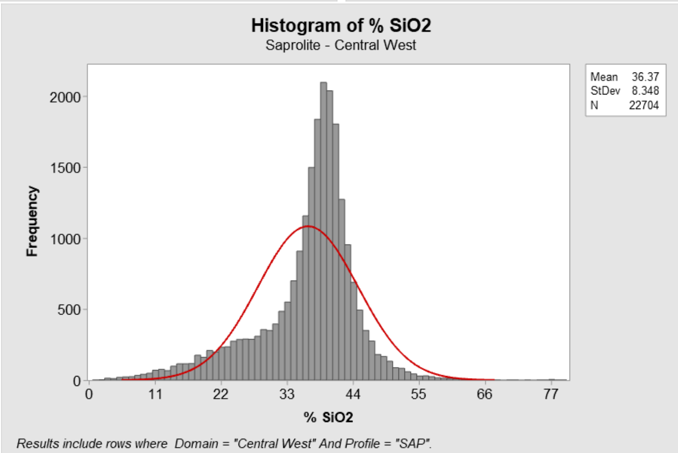


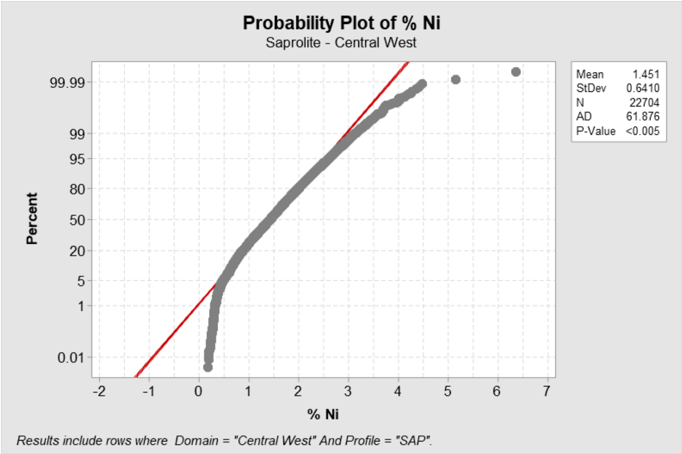


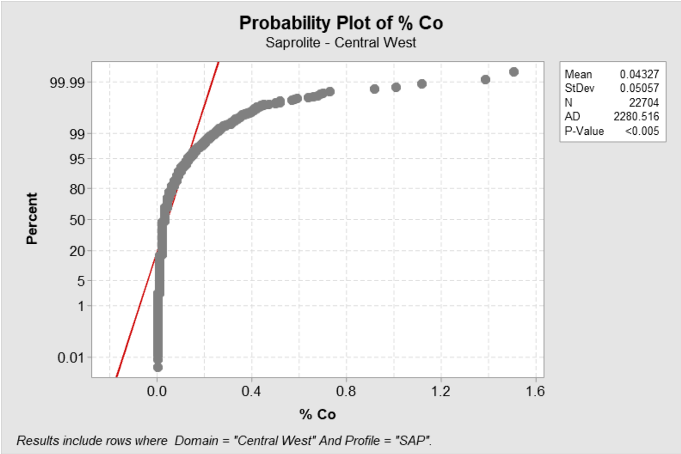


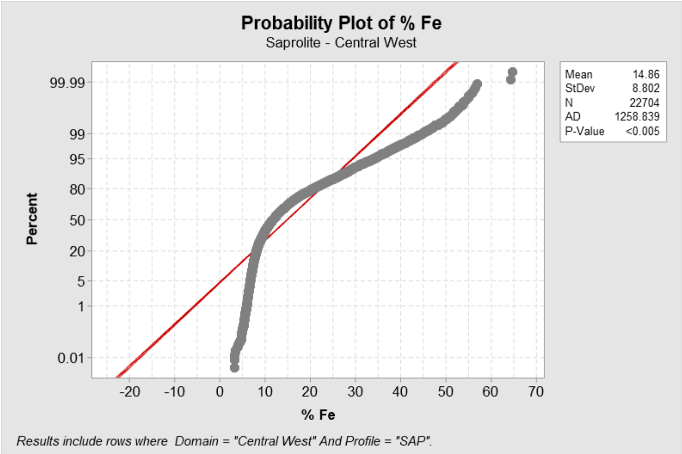


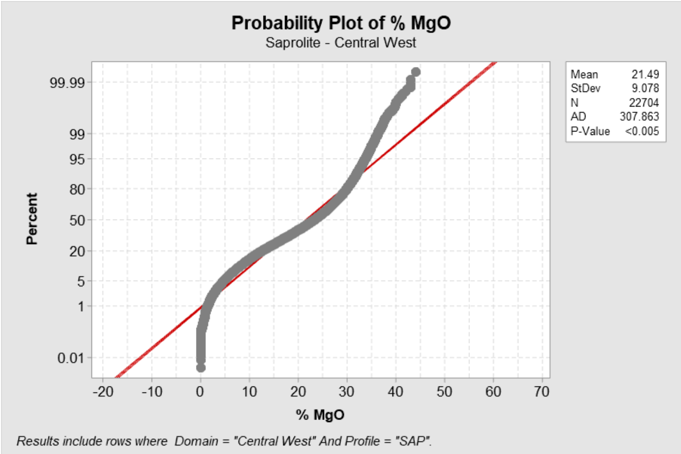


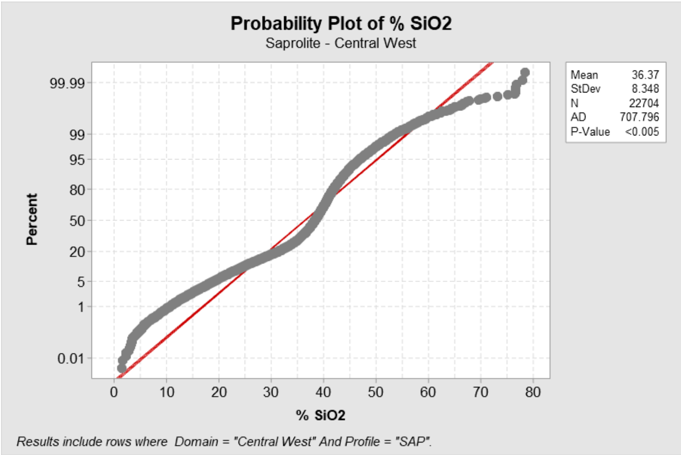
PROBABILITY PLOT: SAP



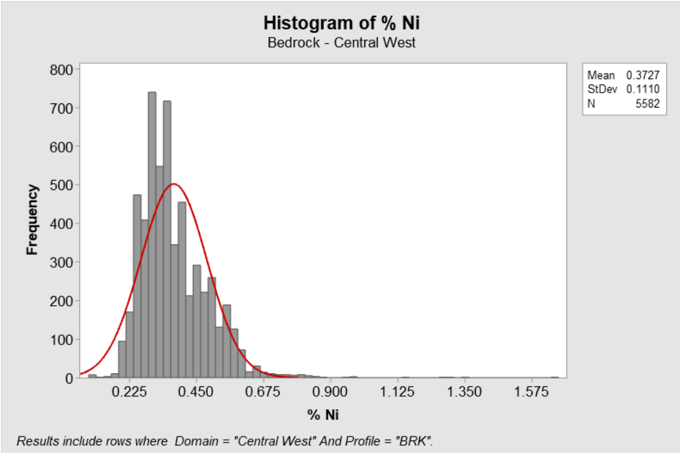


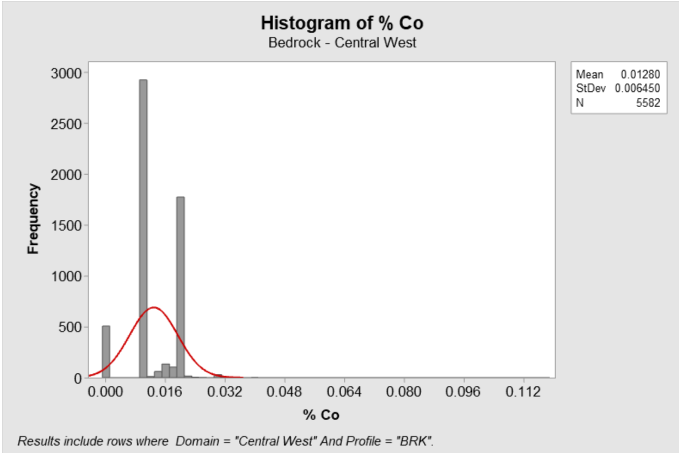


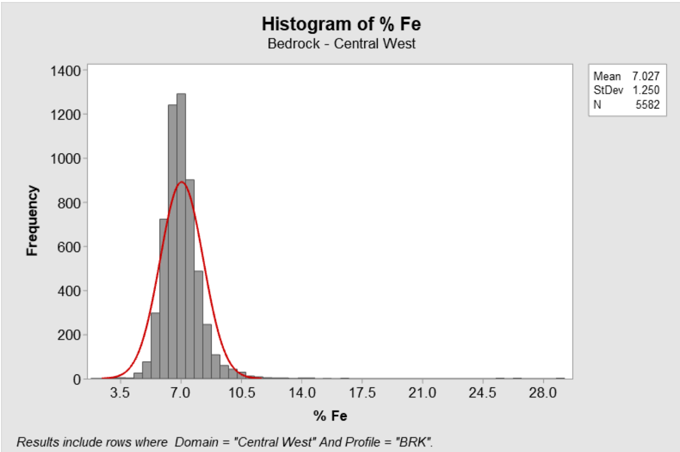


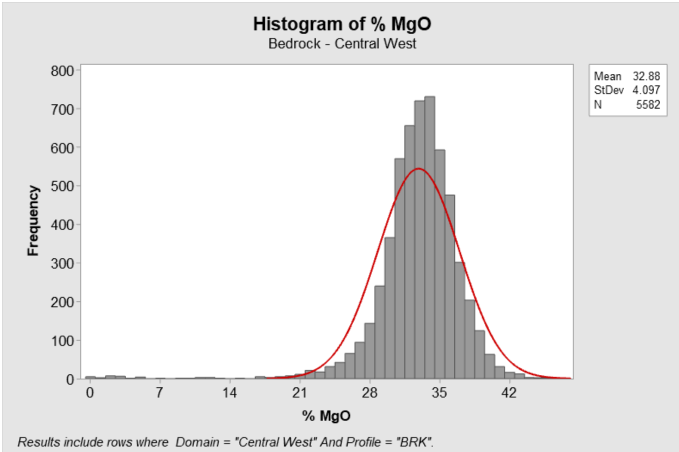


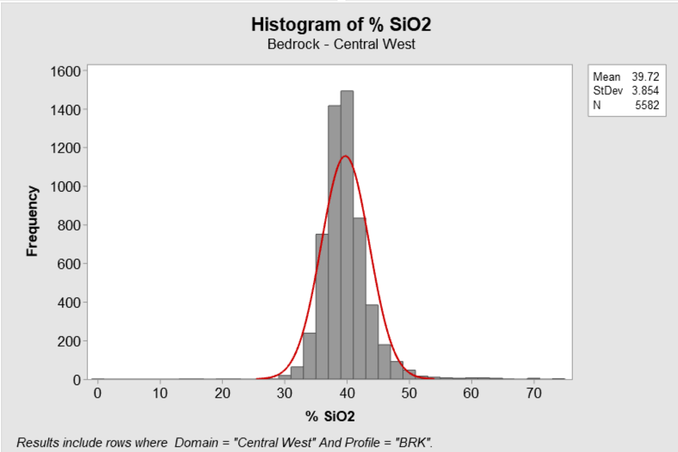
HISTOGRAM: BRK



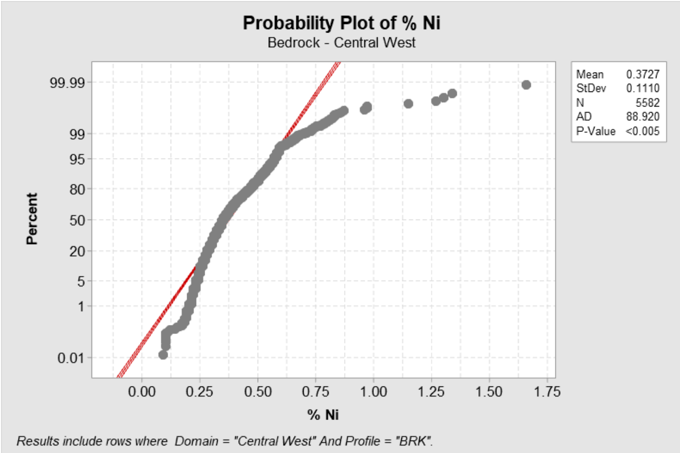


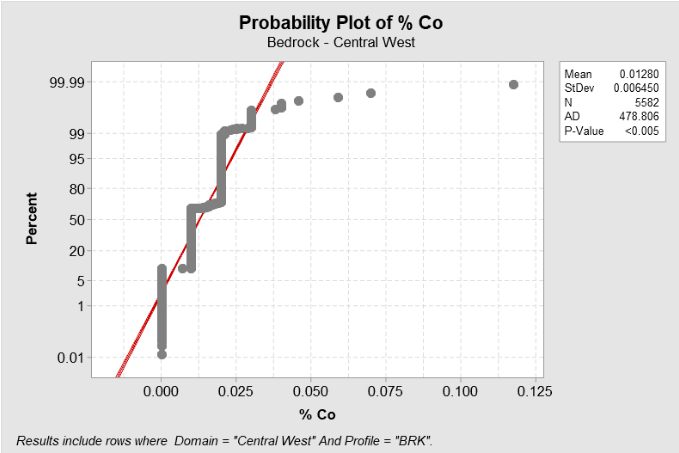


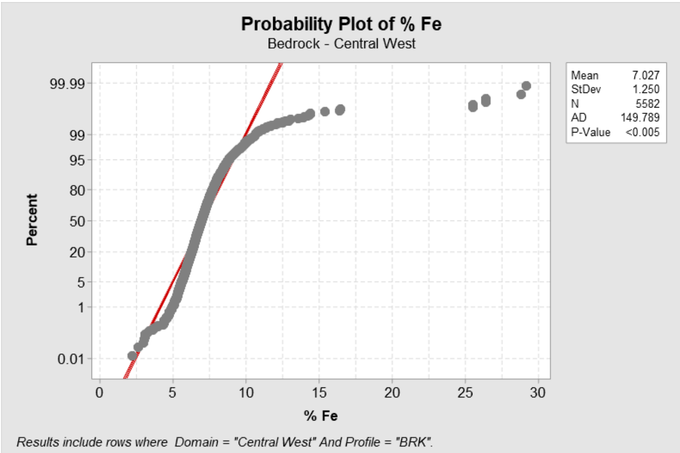


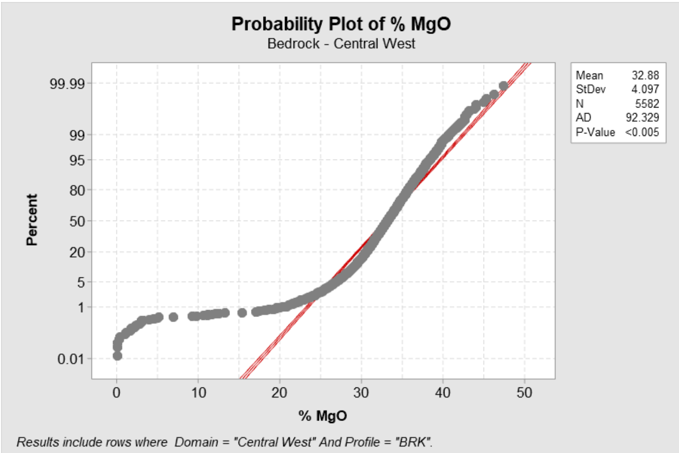


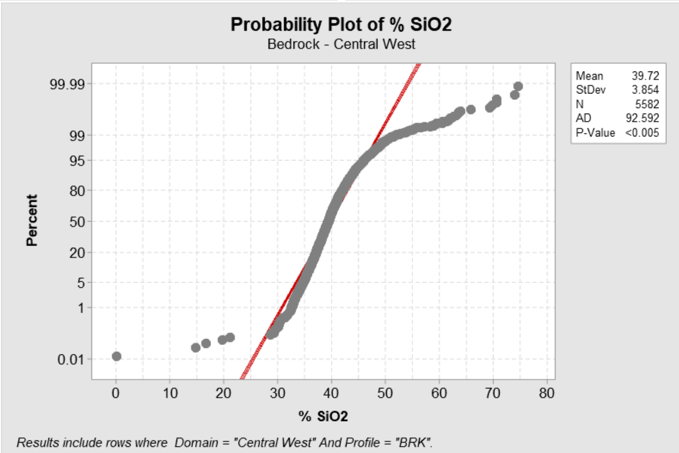
PROBABILITY PLOT: BRK







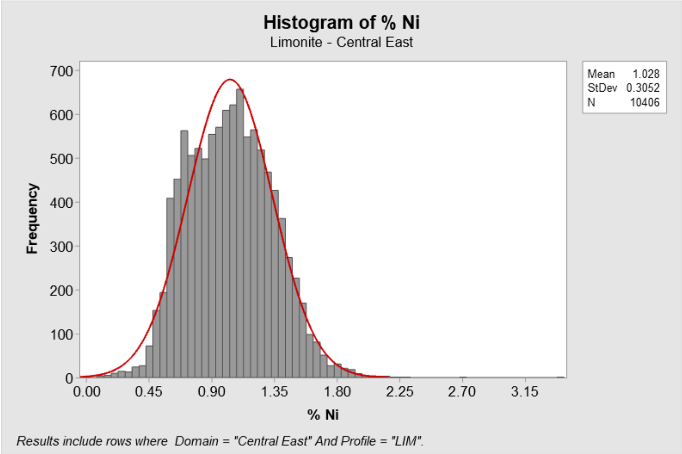


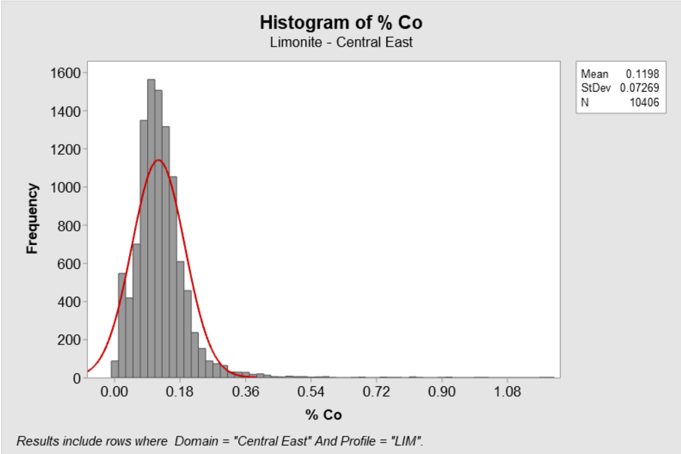


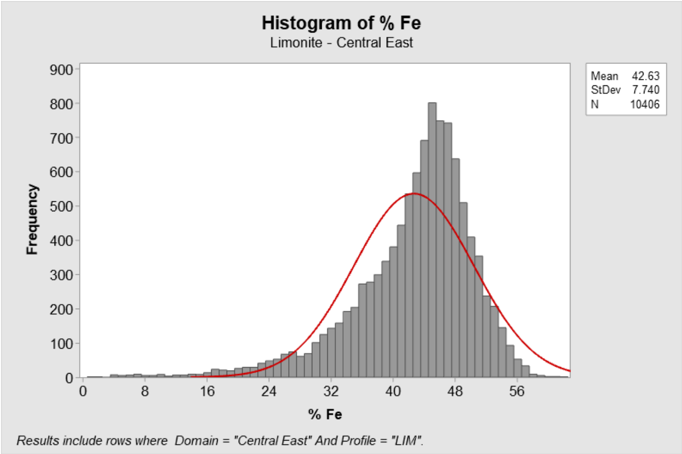
CENTRAL EAST
STATISTICS

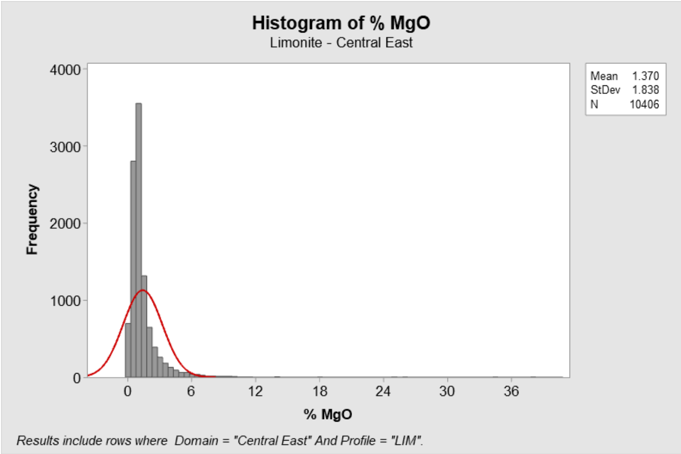
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	1	0.05	0.05				0.05	0.05		
	LIM	10406	1.03	1.02	0.31	0.09	29.69	0.02	3.38	0.25	0.13
	SAP	10688	1.35	1.28	0.62	0.39	46.18	0.02	6.02	0.82	1.46
	BRK	2439	0.38	0.36	0.12	0.02	32.99	0.07	1.37	1.50	5.38
Co	SED	1	0.01	0.01				0.01	0.01		
	LIM	10406	0.12	0.11	0.07	0.01	60.68	0.00	1.20	3.03	26.07
	SAP	10688	0.04	0.03	0.04	0.00	113.20	0.00	1.35	7.64	139.38
	BRK	2439	0.01	0.01	0.01	0.00	56.06	0.00	0.11	3.80	34.00
Fe	SED	1	1.96	1.96				1.96	1.96		
	LIM	10406	42.63	44.19	7.74	59.90	18.16	0.80	61.50	-1.29	2.68
	SAP	10688	14.79	12.08	8.22	67.53	55.56	1.84	54.09	1.51	2.19
	BRK	2439	7.37	7.03	2.06	4.25	27.99	0.94	38.13	4.39	38.24
MgO	SED	1	0.95	0.95				0.95	0.95		
	LIM	10406	1.37	0.91	1.84	3.38	134.12	0.00	40.59	9.12	137.81
	SAP	10688	18.92	20.30	9.91	98.25	52.39	0.00	46.27	-0.23	-0.89
	BRK	2439	30.35	32.20	8.51	72.46	28.05	0.00	49.11	-1.74	3.42
SiO2	SED	1	5.46	5.46				5.46	5.46		
	LIM	10406	11.28	6.67	11.75	138.15	104.25	0.00	94.65	2.38	7.17
	SAP	10688	40.59	40.64	10.81	116.90	26.64	0.00	99.00	0.46	3.20
	BRK	2439	43.86	42.00	8.83	77.94	20.13	17.64	93.00	2.31	6.80

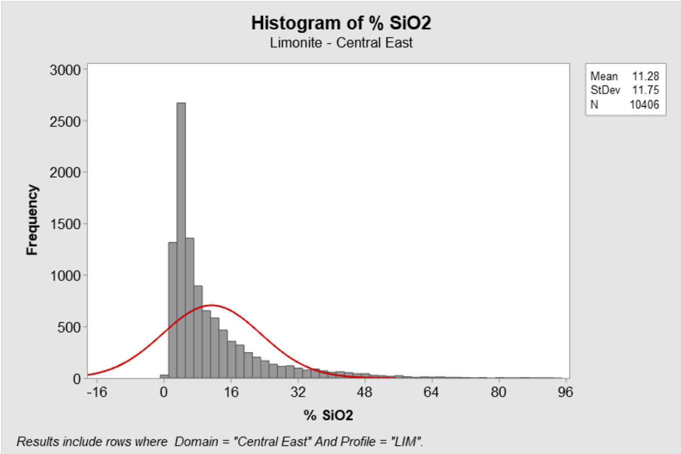
HISTOGRAM: LIM



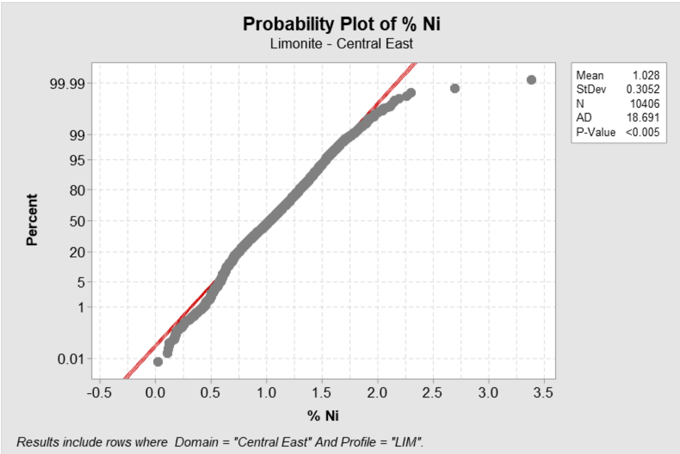


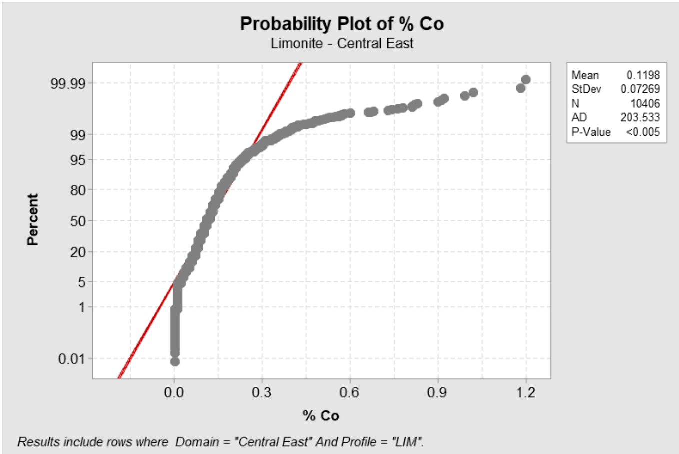


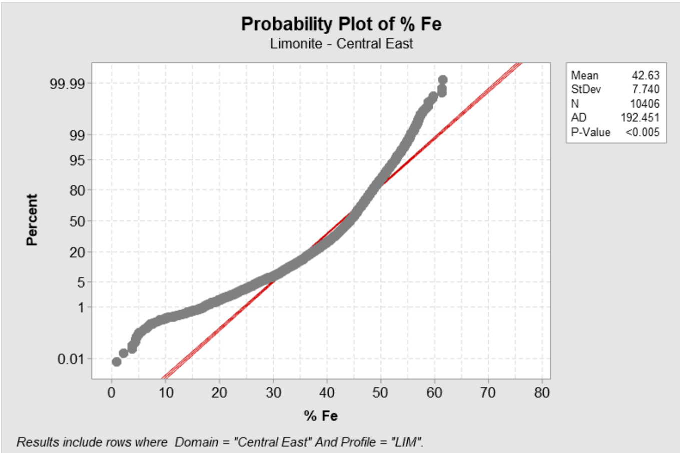


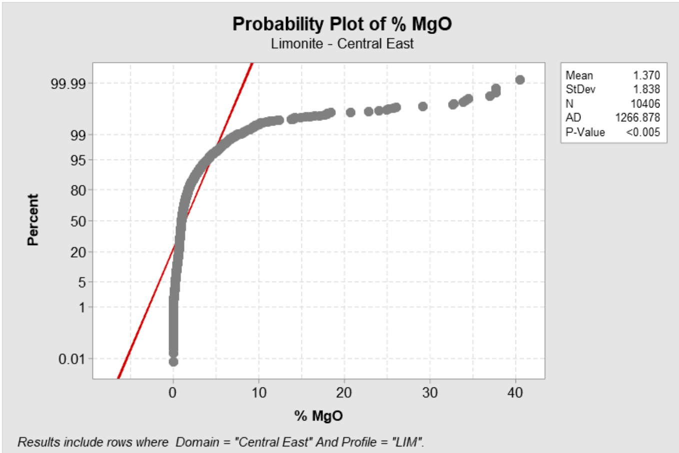


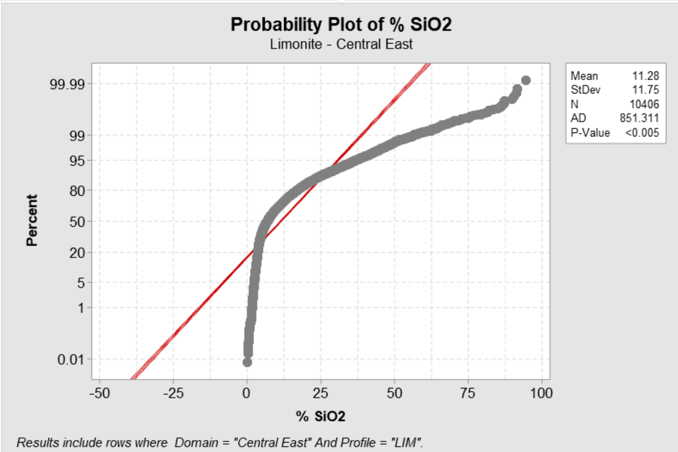
PROBABILITY PLOT: LIM











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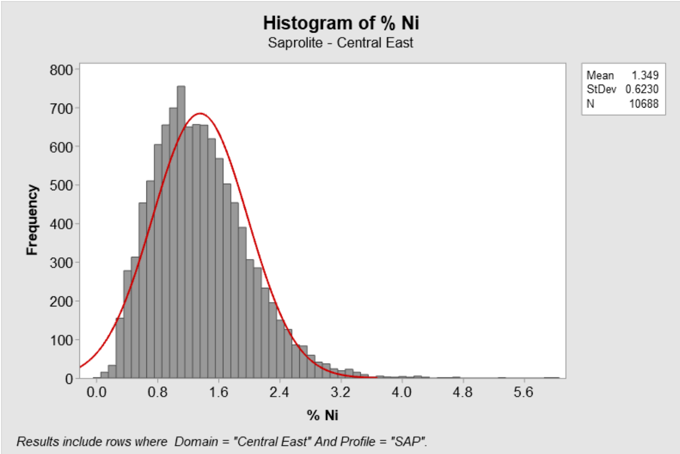
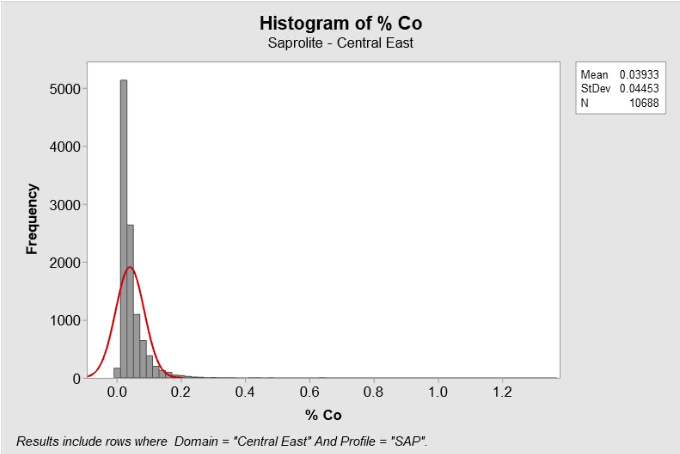
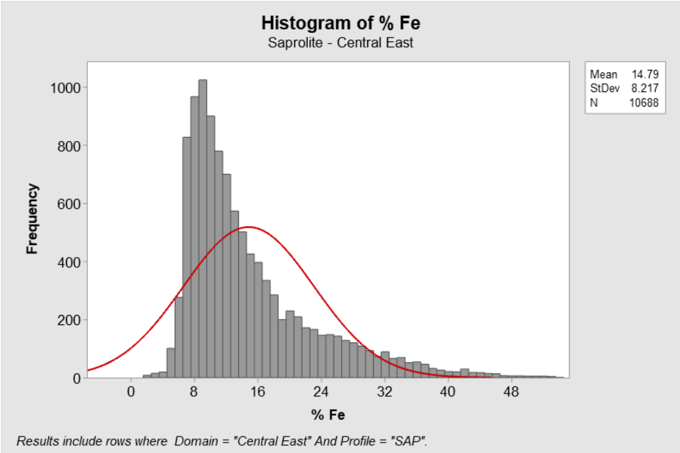
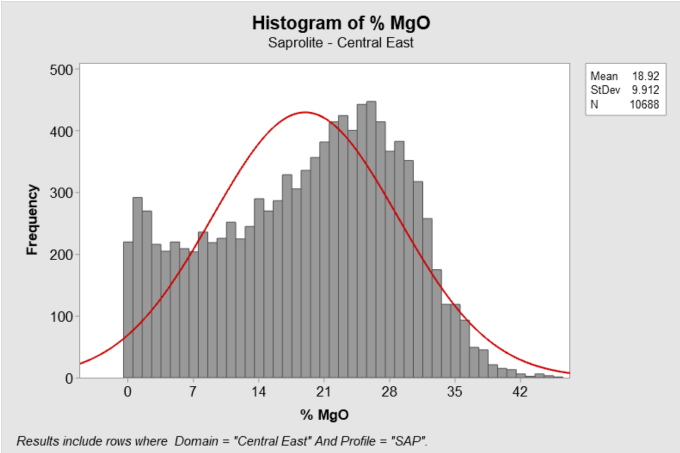
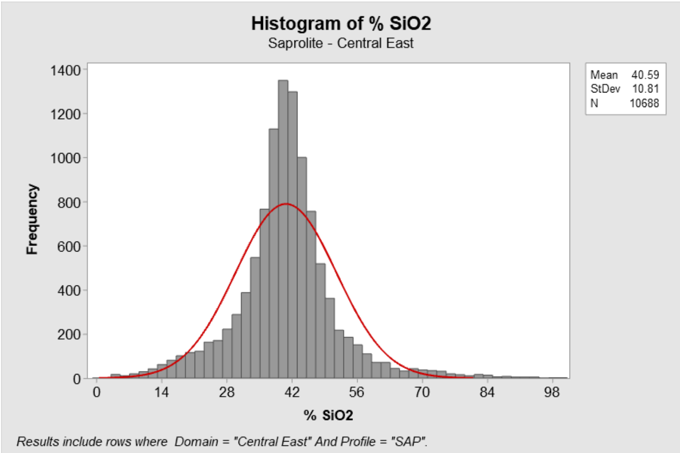


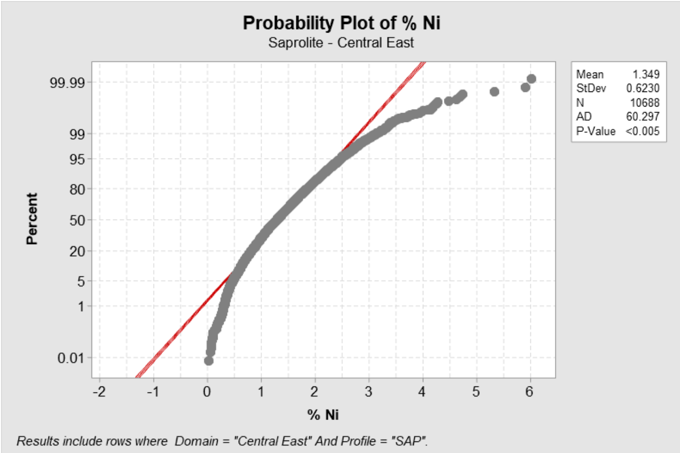


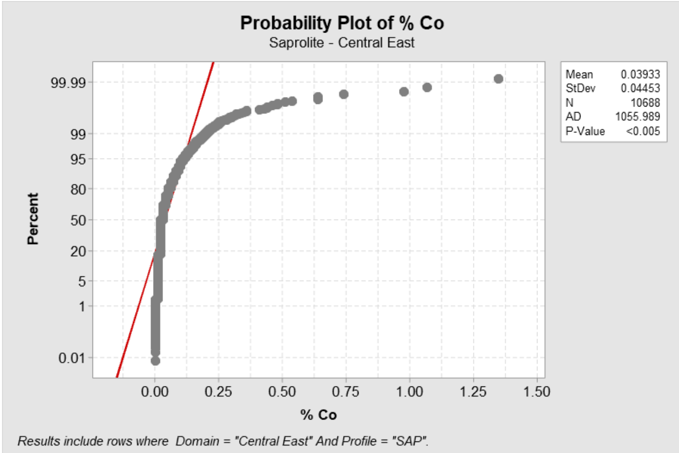


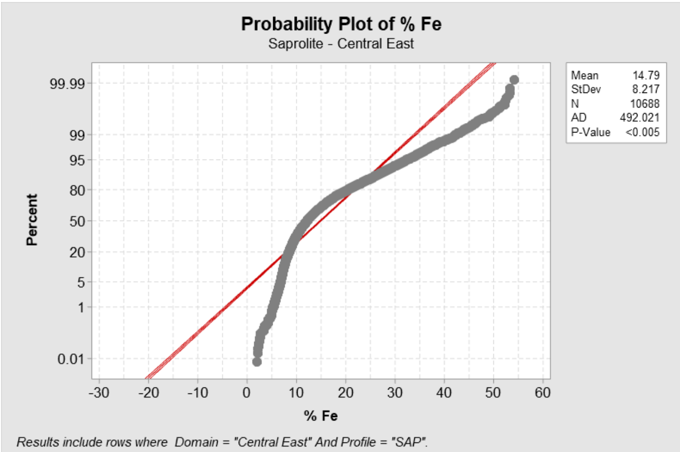


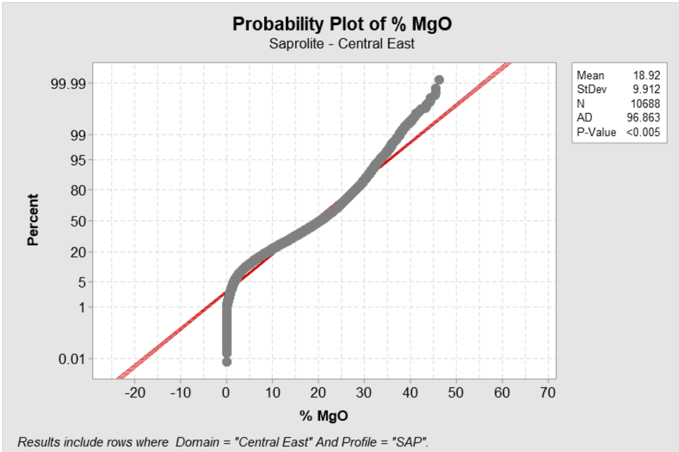


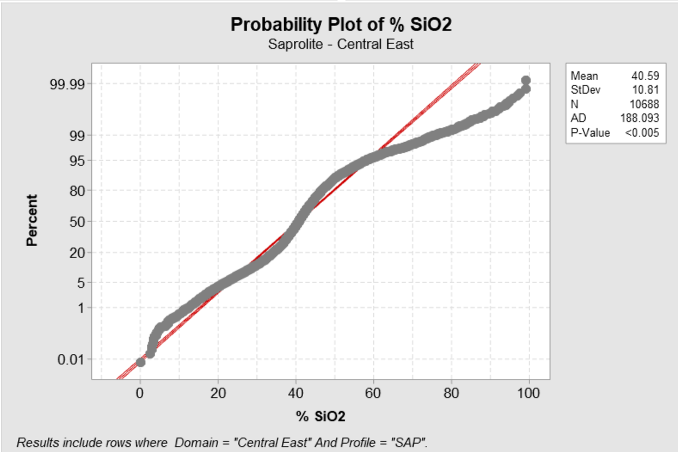
PROBABILITY PLOT: SAP











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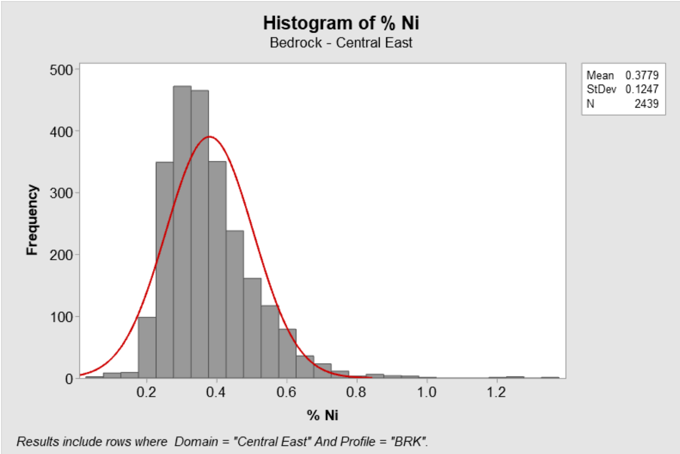
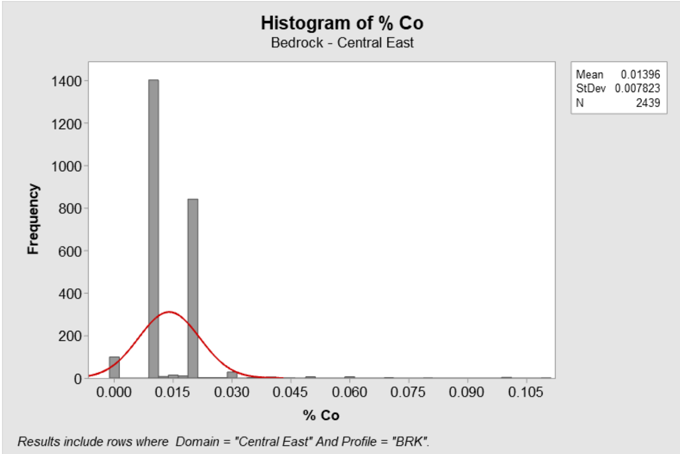
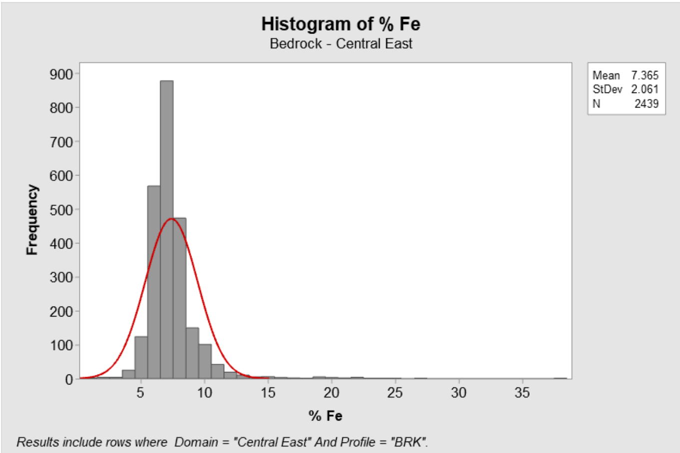
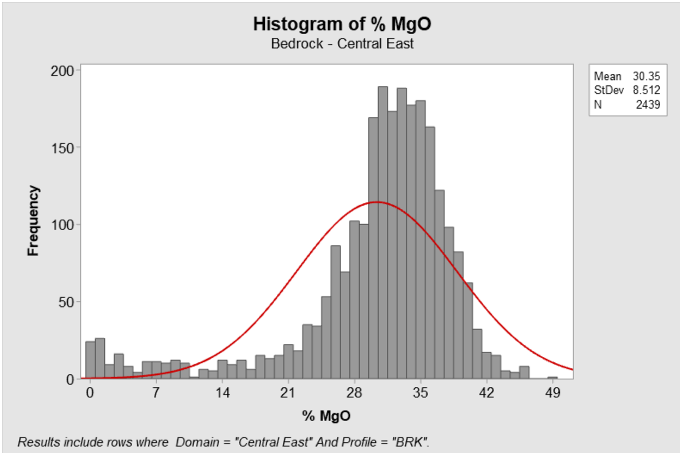
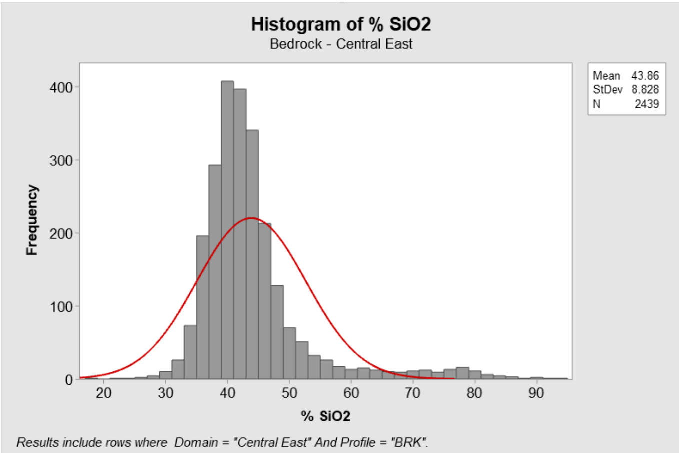


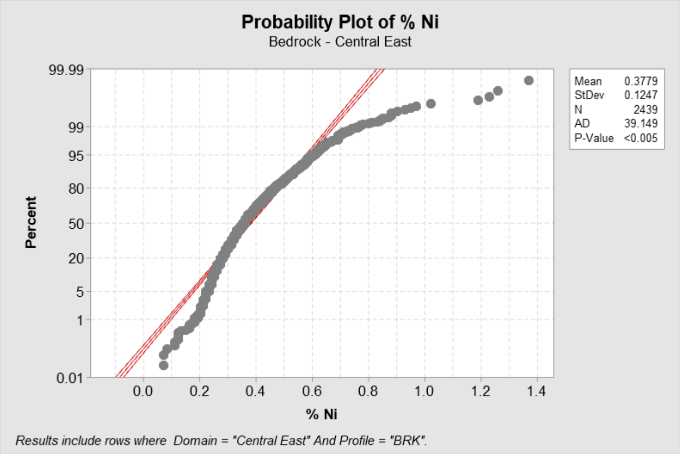


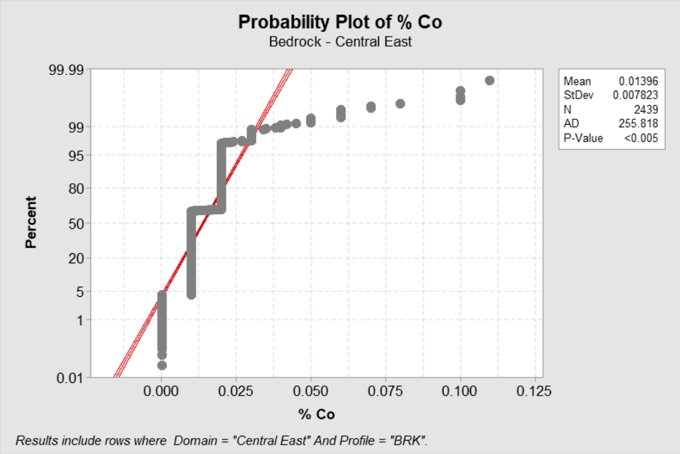


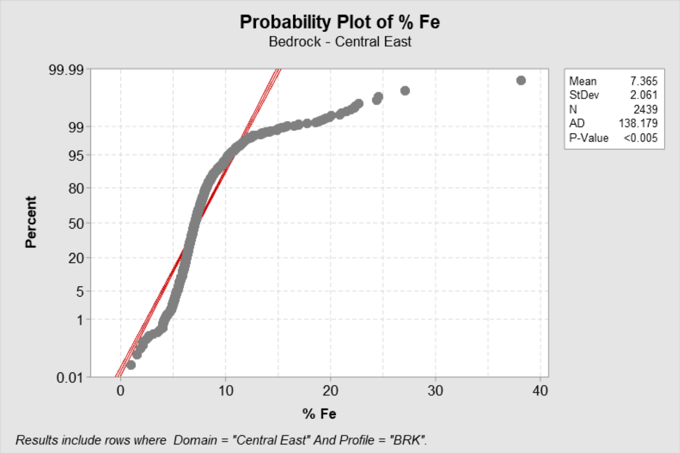


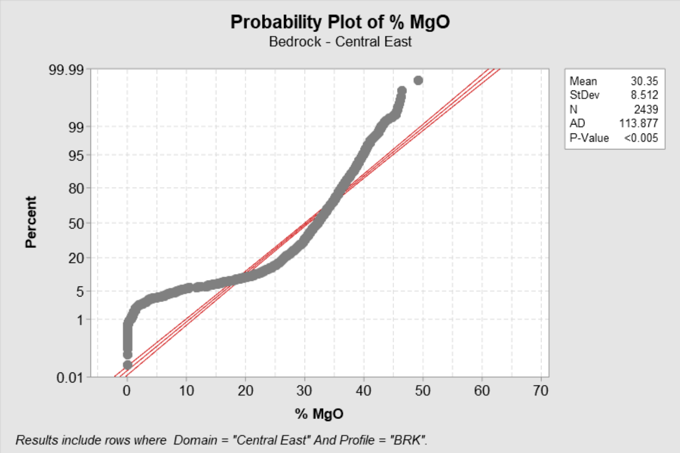


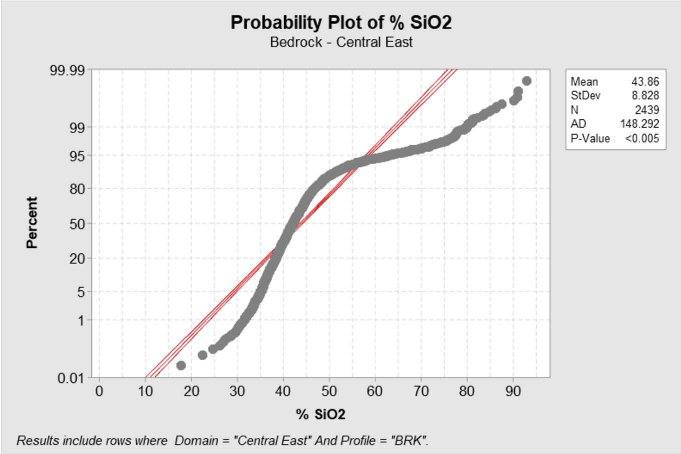
PROBABILITY PLOT: BRK









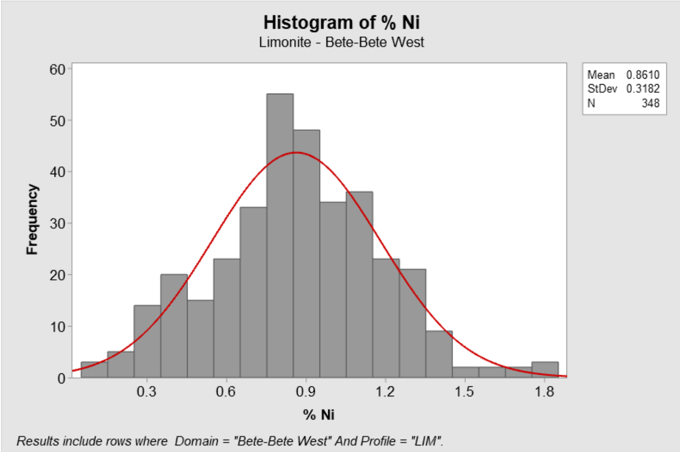


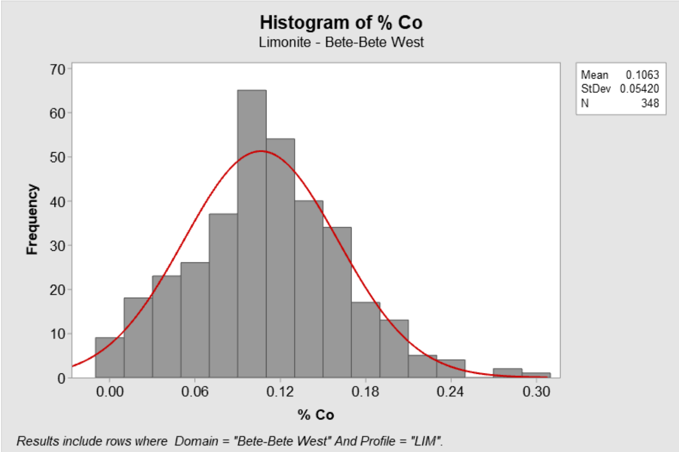
BETE-BETE WEST

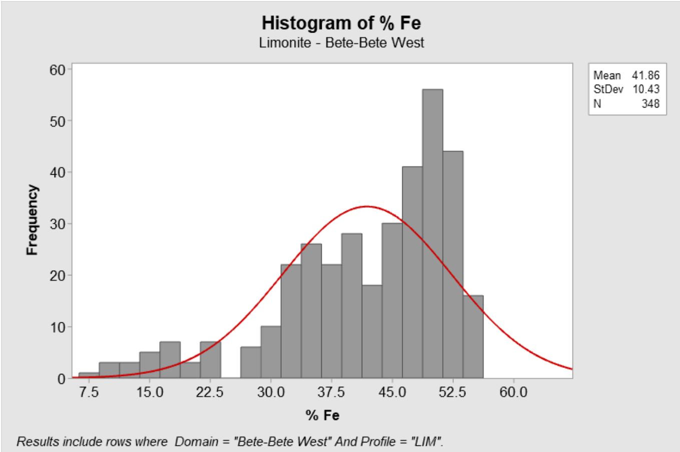
STATISTICS

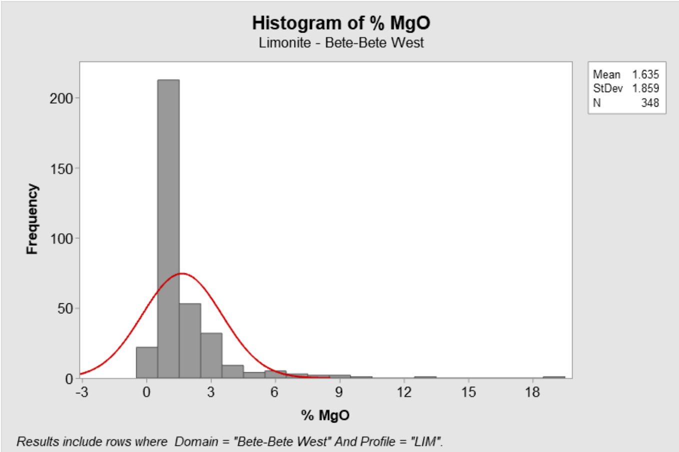
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	27	0.23	0.20	0.09	0.01	41.56	0.09	0.49	1.39	2.58
	LIM	348	0.86	0.85	0.32	0.10	36.95	0.08	1.80	0.07	0.05
	SAP	384	1.33	1.31	0.54	0.29	40.66	0.12	3.75	0.53	1.55
	BRK	226	0.35	0.30	0.16	0.02	44.84	0.07	0.93	1.16	1.11
Co	SED	27	0.01	0.01	0.01	0.00	34.37	0.01	0.02	0.08	-2.16
	LIM	348	0.11	0.10	0.05	0.00	50.99	0.00	0.31	0.30	0.44
	SAP	384	0.03	0.02	0.03	0.00	99.09	0.00	0.19	1.94	4.24
	BRK	226	0.02	0.01	0.01	0.00	67.02	0.00	0.10	3.28	20.98
Fe	SED	27	5.88	5.59	1.64	2.68	27.87	3.38	11.17	1.42	3.49
	LIM	348	41.86	44.90	10.43	108.85	24.92	8.72	55.30	-1.08	0.68
	SAP	384	16.14	13.05	8.90	79.21	55.14	6.30	54.94	1.74	3.27
	BRK	226	8.70	7.45	3.30	10.90	37.93	4.99	18.83	1.28	0.71
MgO	SED	27	20.29	18.64	7.64	58.40	37.66	3.02	30.63	-0.24	-0.85
	LIM	348	1.64	1.00	1.86	3.46	113.70	0.01	19.17	4.36	28.56
	SAP	384	20.03	21.17	10.60	112.37	52.93	0.01	38.76	-0.29	-1.07
	BRK	226	26.16	33.77	14.31	204.77	54.70	0.09	42.51	-0.81	-1.09
SiO2	SED	27	29.91	32.72	6.84	46.76	22.86	16.39	43.25	-0.35	-0.79
	LIM	348	14.46	9.94	12.35	152.43	85.36	2.64	72.52	1.85	3.53
	SAP	384	39.59	41.85	8.43	71.03	21.29	4.09	60.30	-1.57	3.98
	BRK	226	43.53	42.42	4.77	22.72	10.95	34.99	62.27	1.83	3.74

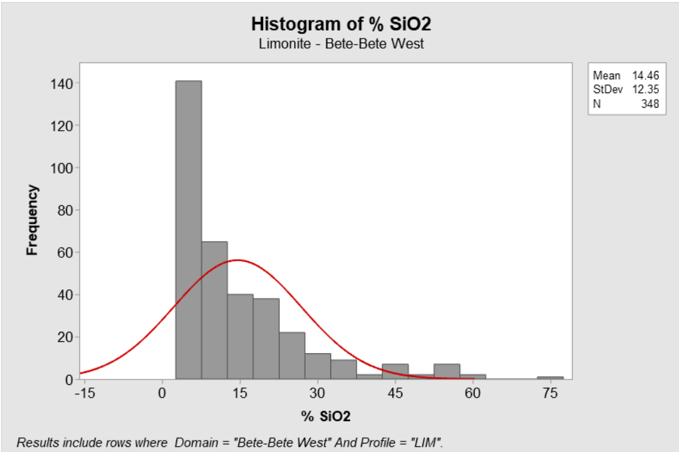
HISTOGRAM: LIM



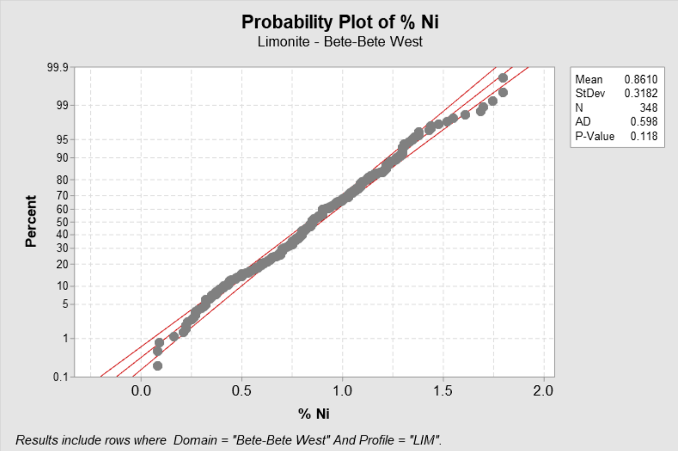


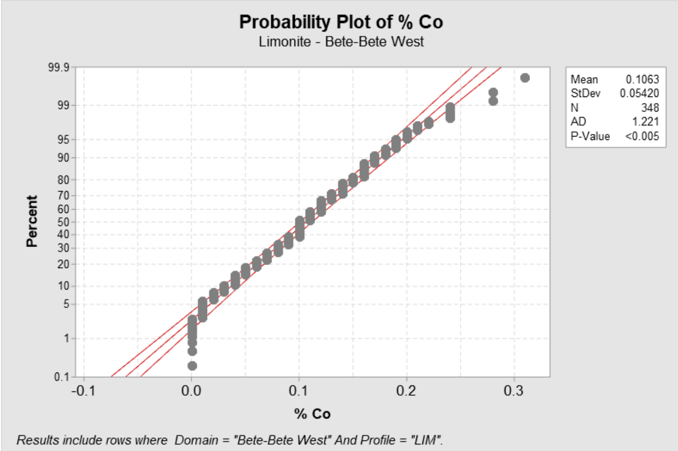


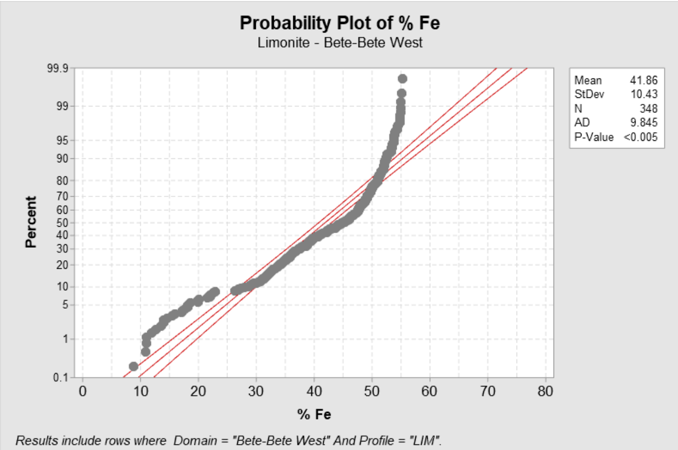


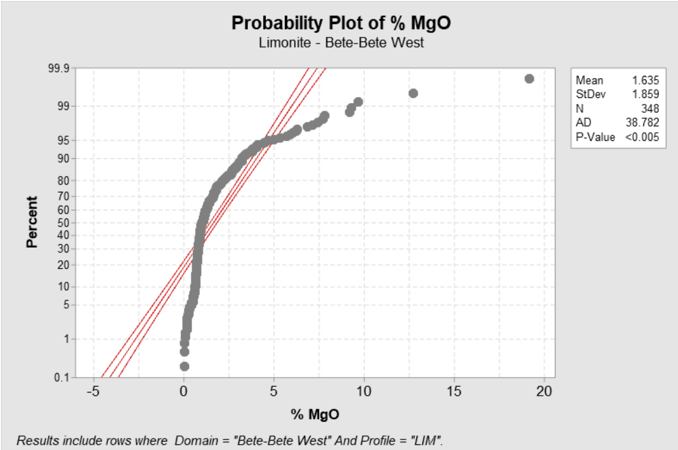


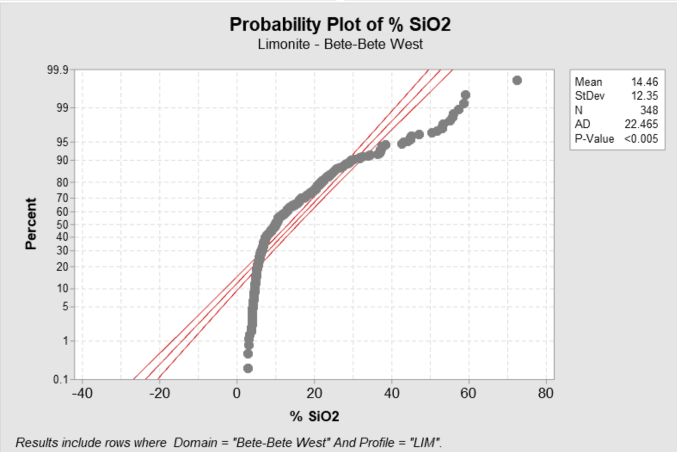
PROBABILITY PLOT: LIM











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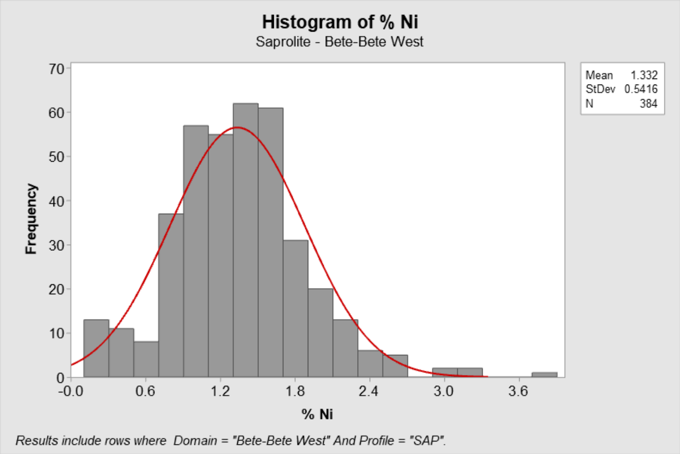

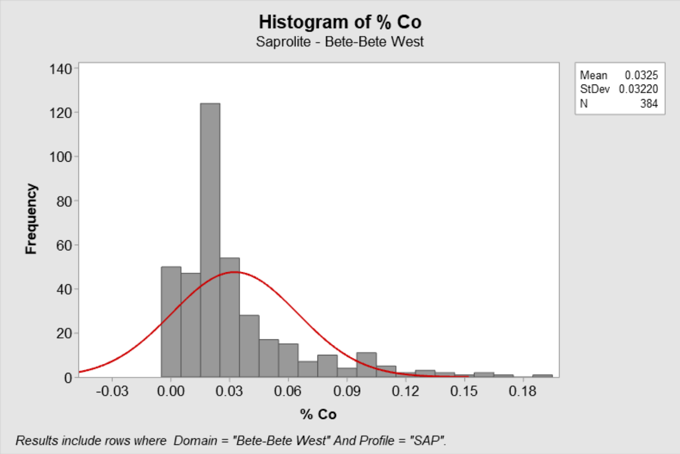

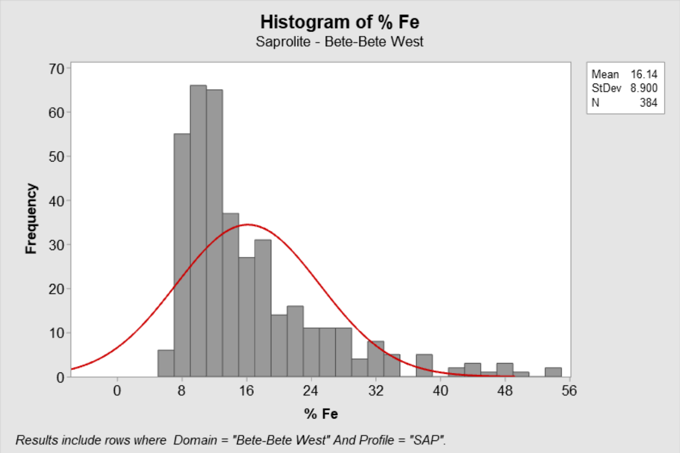

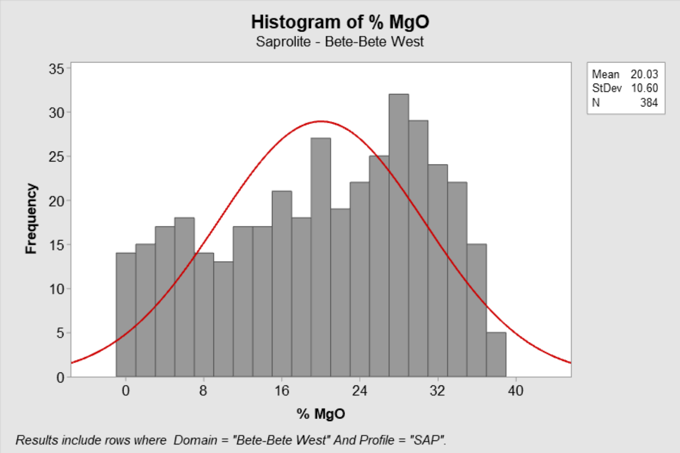

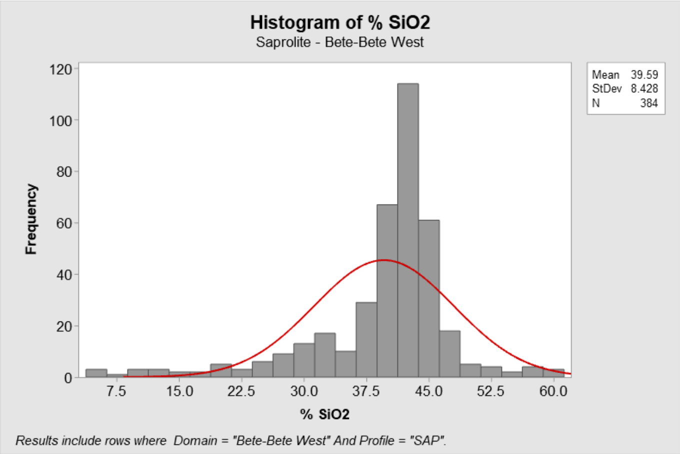

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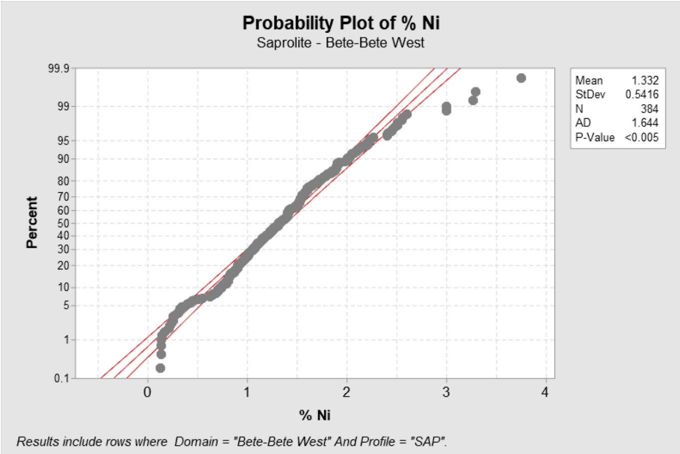

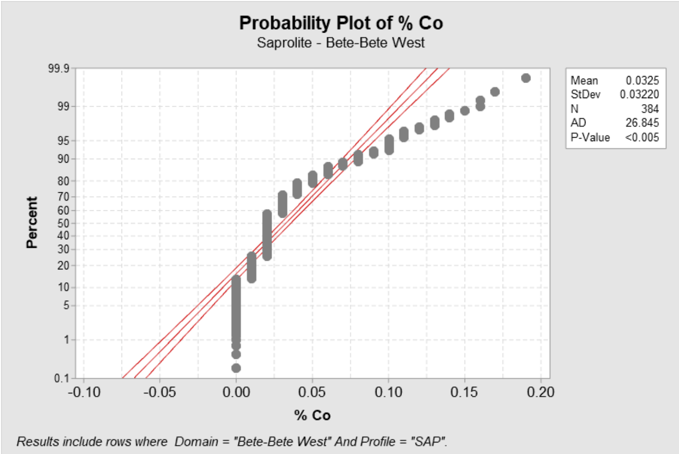

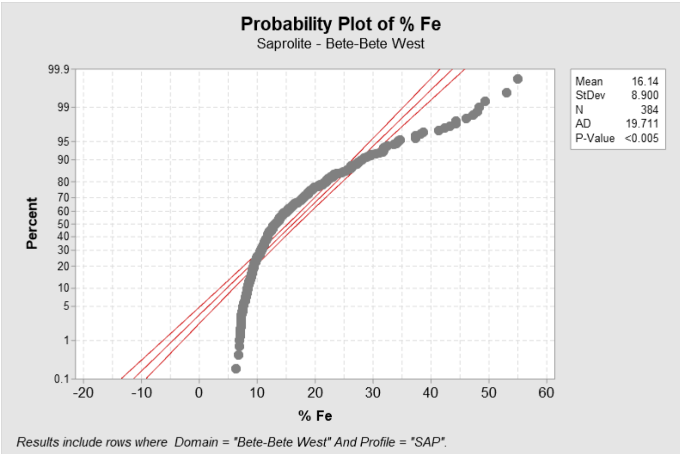

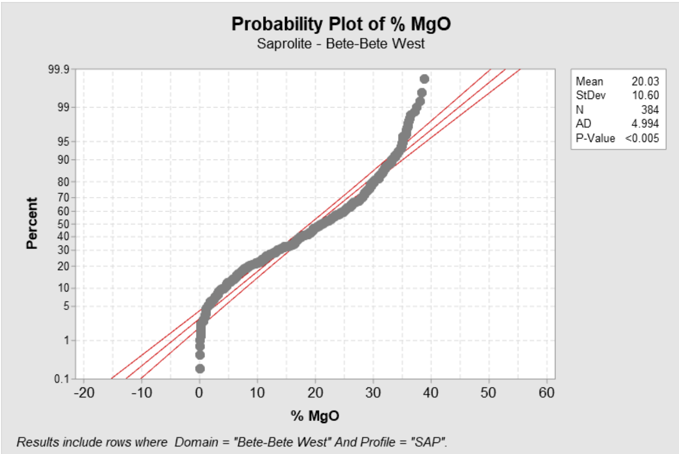

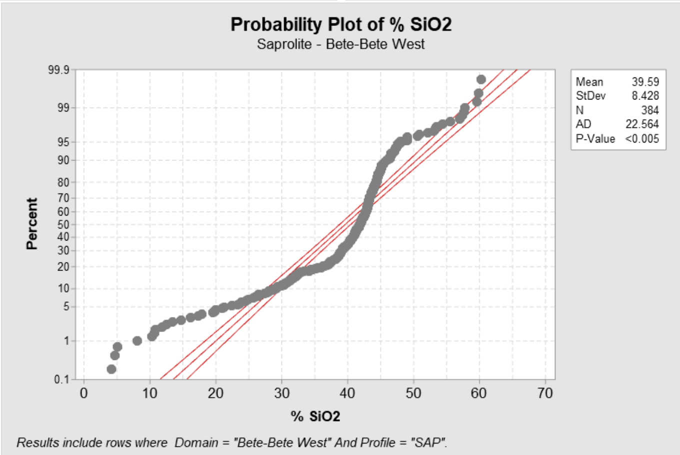

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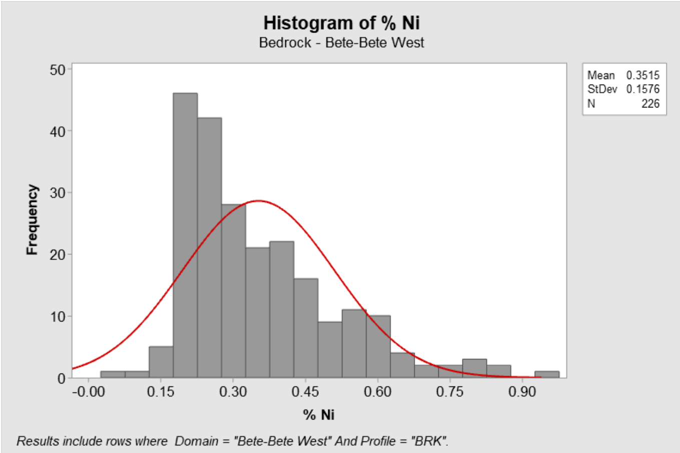
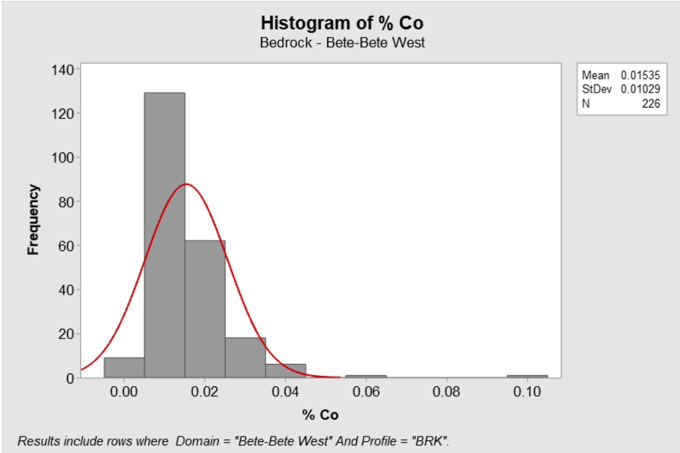
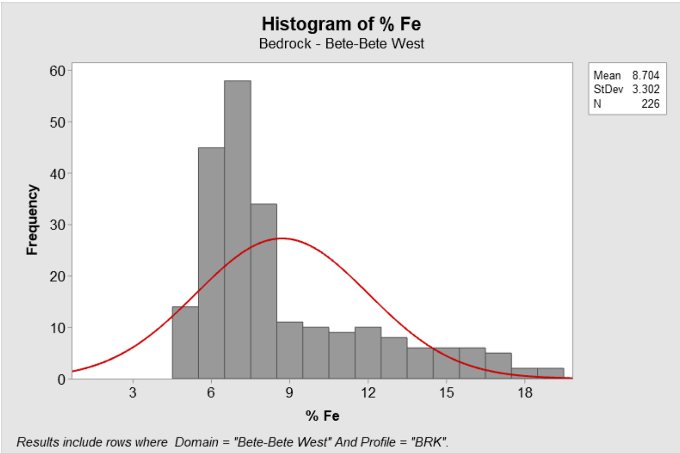
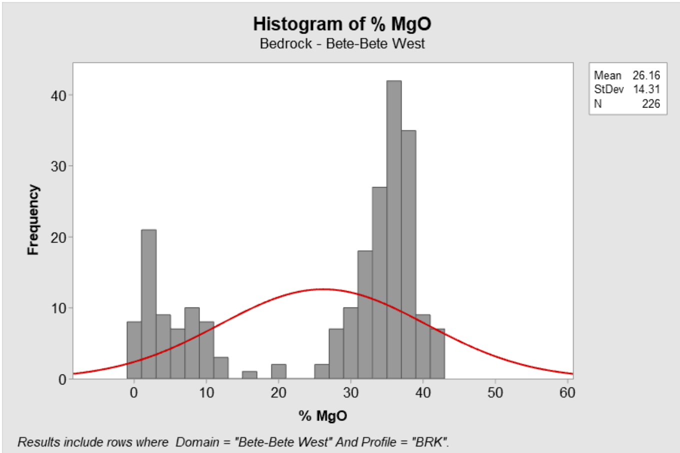
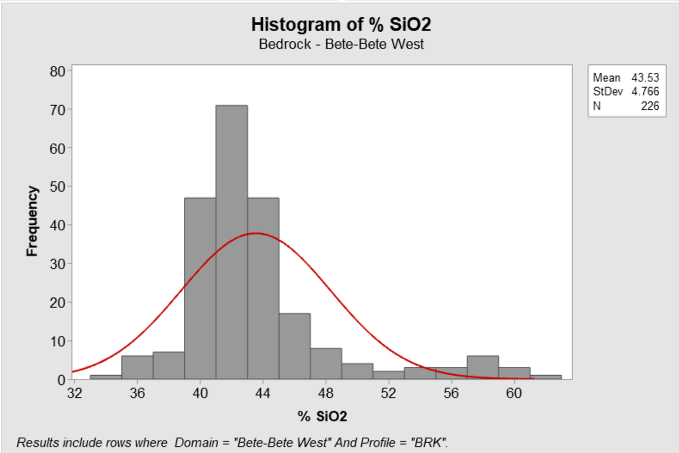


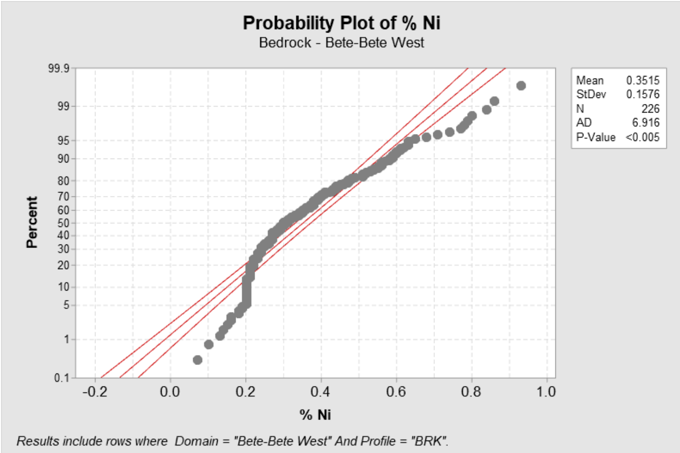


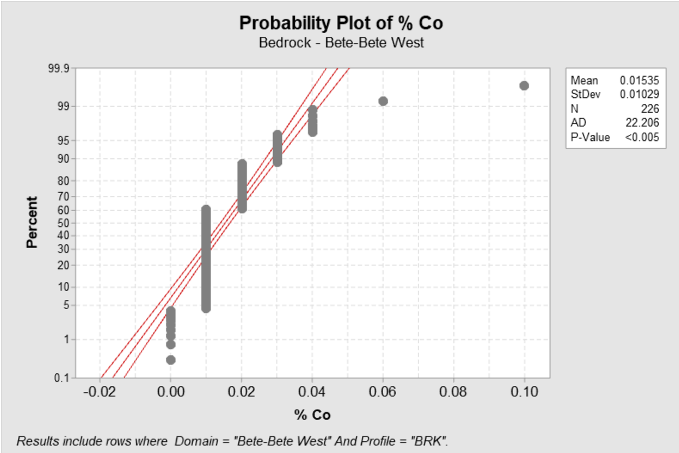


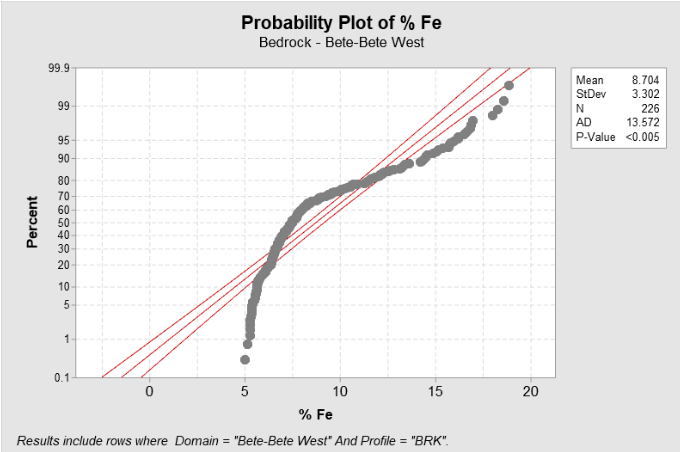


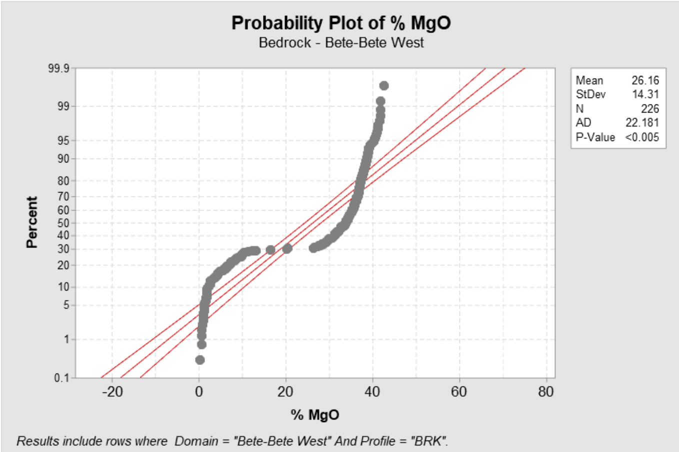


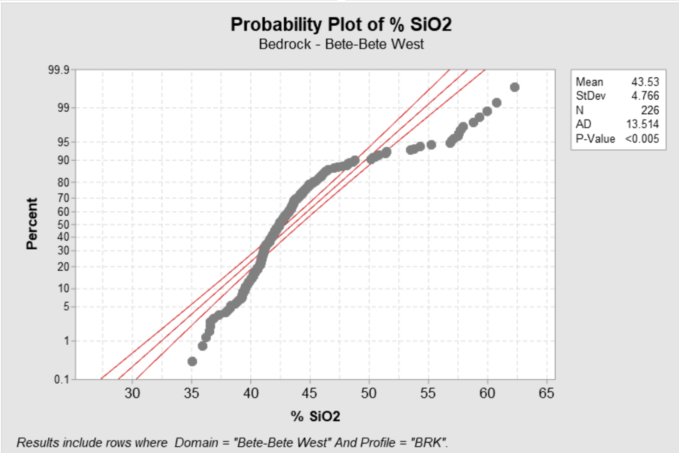
PROBABILITY PLOT: BRK









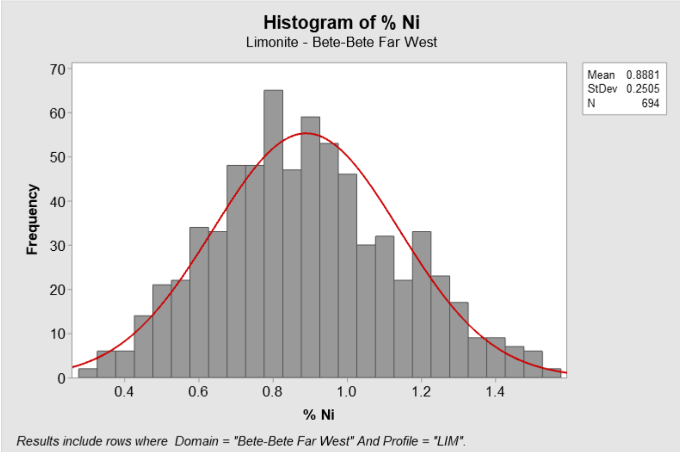


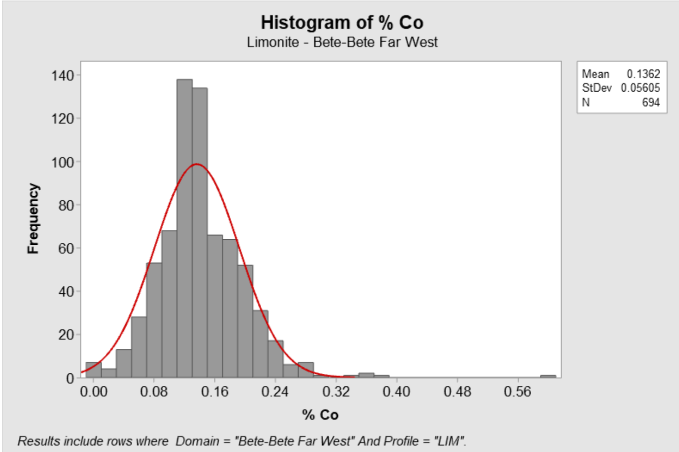
BETE-BETE FAR WEST

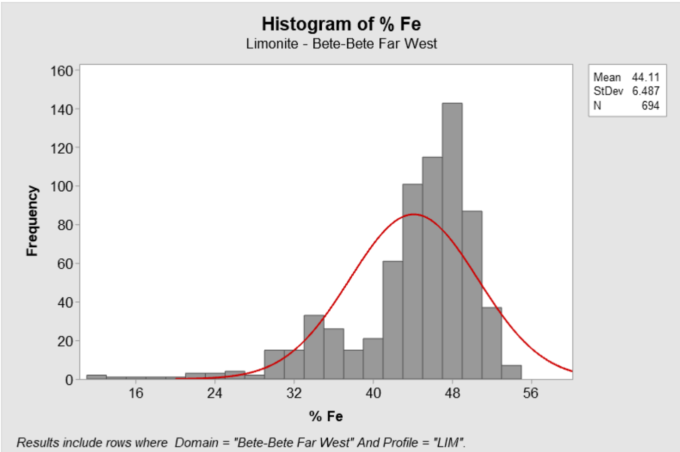
STATISTICS

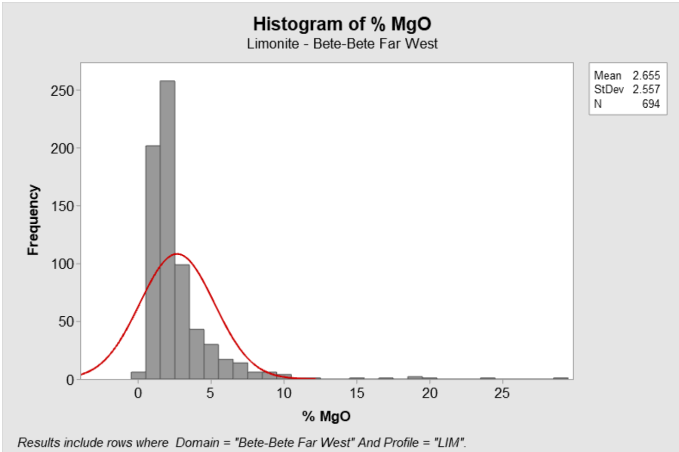
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	23	0.32	0.31	0.17	0.03	52.11	0.01	0.74	0.61	0.67
	LIM	694	0.89	0.88	0.25	0.06	28.21	0.31	1.56	0.22	-0.38
	SAP	995	1.06	0.97	0.49	0.24	46.33	0.22	2.95	0.89	0.93
	BRK	520	0.34	0.32	0.10	0.01	30.64	0.15	0.69	0.84	0.16
Co	SED	23	0.01	0.01	0.01	0.00	74.67	0.00	0.04	1.26	1.78
	LIM	694	0.14	0.13	0.06	0.00	41.16	0.00	0.60	1.25	7.37
	SAP	995	0.03	0.02	0.03	0.00	107.01	0.00	0.33	2.45	10.90
	BRK	520	0.01	0.01	0.01	0.00	133.47	0.00	0.10	4.00	23.09
Fe	SED	23	6.54	5.85	3.70	13.70	56.62	1.53	17.68	1.51	2.92
	LIM	694	44.11	45.88	6.49	42.08	14.71	11.59	54.11	-1.62	3.43
	SAP	995	12.50	9.83	7.03	49.45	56.25	3.82	49.48	1.96	4.17
	BRK	520	7.39	6.90	2.46	6.03	33.22	4.66	25.70	4.84	26.38
MgO	SED	23	15.71	20.51	8.60	73.96	54.73	2.04	25.11	-0.50	-1.56
	LIM	694	2.66	2.03	2.56	6.54	96.30	0.41	28.94	4.64	32.34
	SAP	995	23.32	25.68	7.96	63.29	34.12	1.12	36.03	-0.96	0.03
	BRK	520	30.33	31.67	6.43	41.29	21.19	1.80	38.30	-3.44	12.20
SiO2	SED	23	31.60	32.86	11.06	122.31	35.00	7.88	56.43	-0.57	1.61
	LIM	694	10.50	8.90	7.46	55.66	71.03	2.33	43.13	1.80	3.62
	SAP	995	37.21	37.85	6.80	46.17	18.26	7.83	76.31	0.06	5.89
	BRK	520	38.37	37.77	4.13	17.02	10.75	31.80	64.86	2.23	9.52

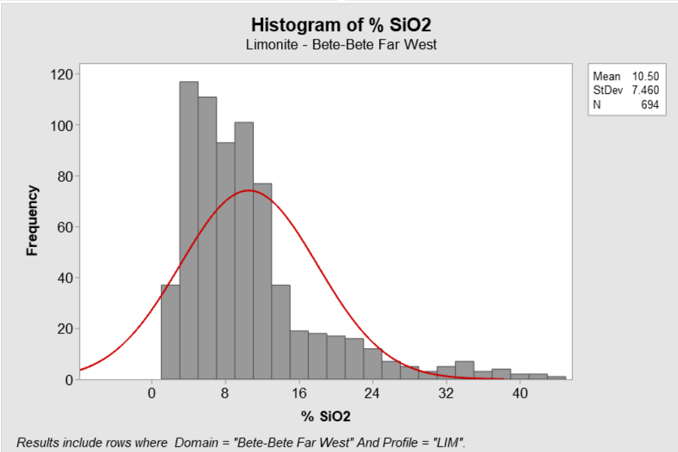
HISTOGRAM: LIM



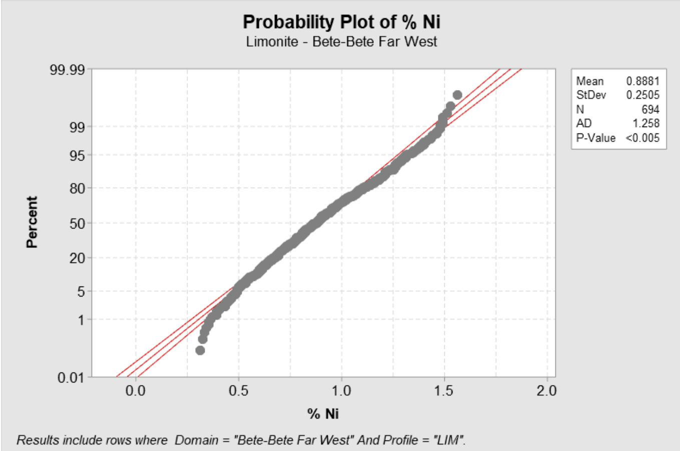


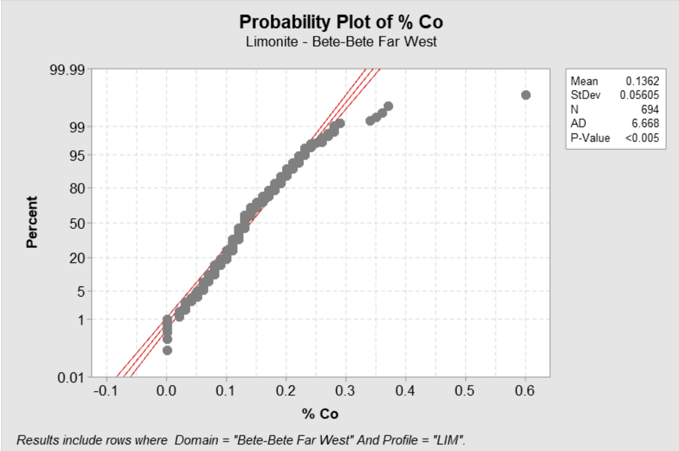


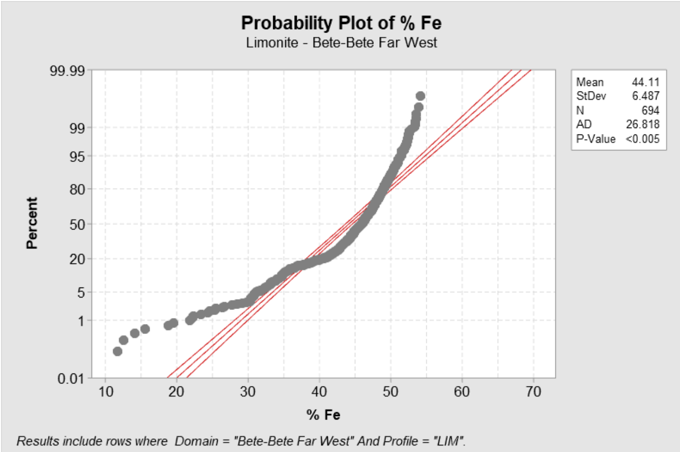


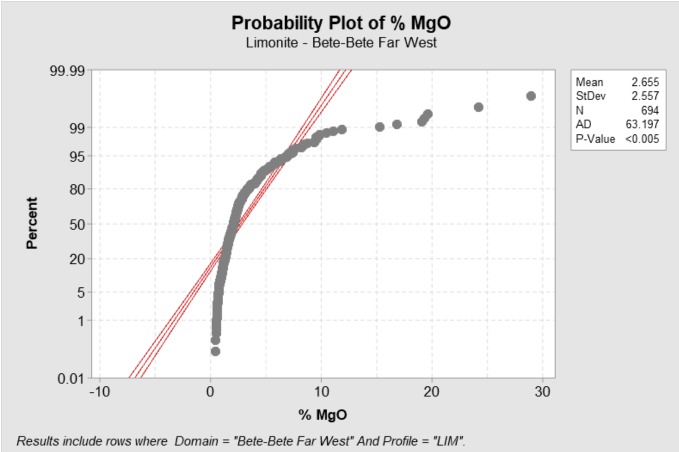


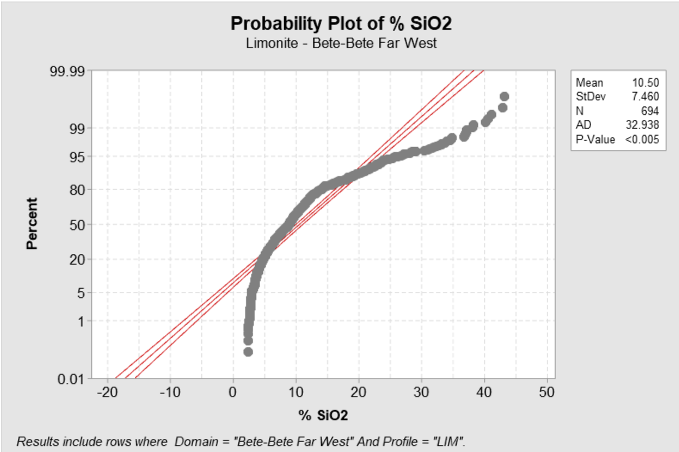
PROBABILITY PLOT: LIM











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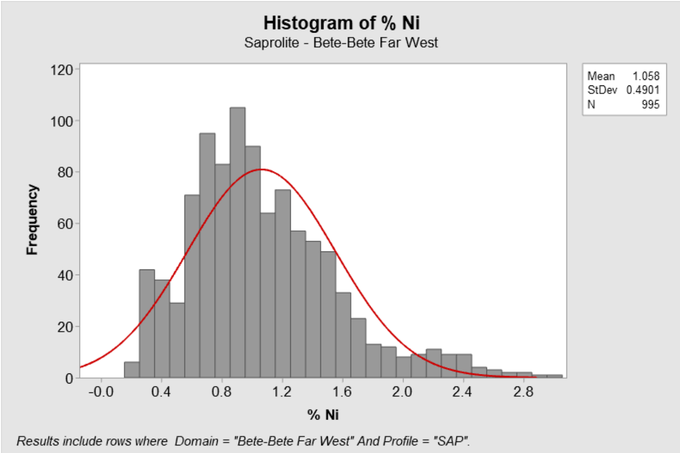
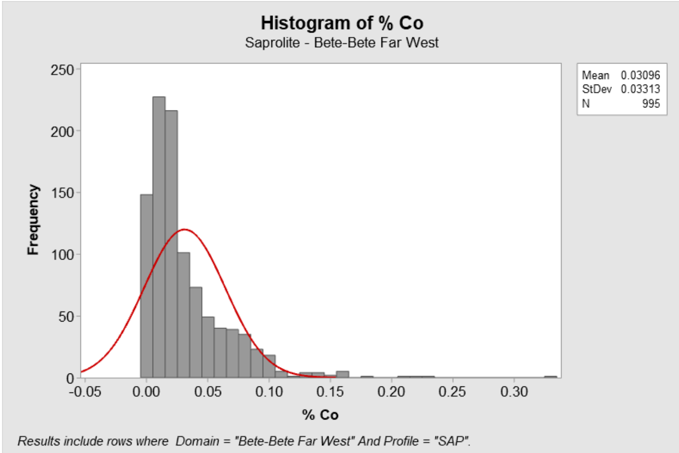
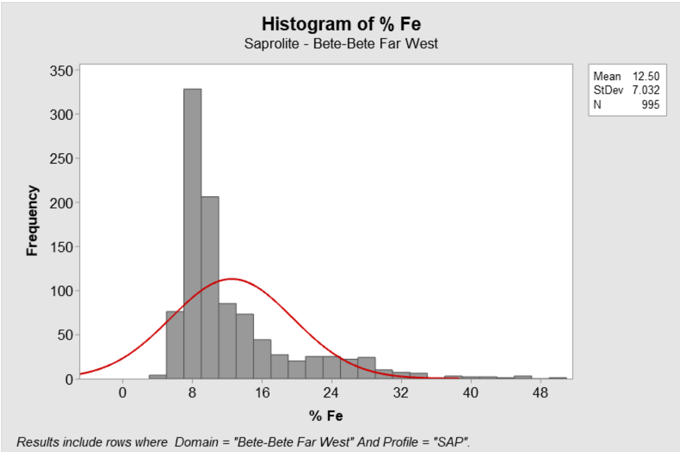
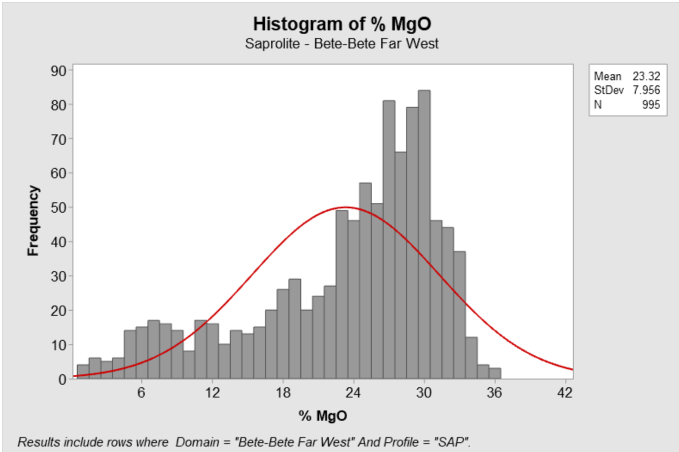
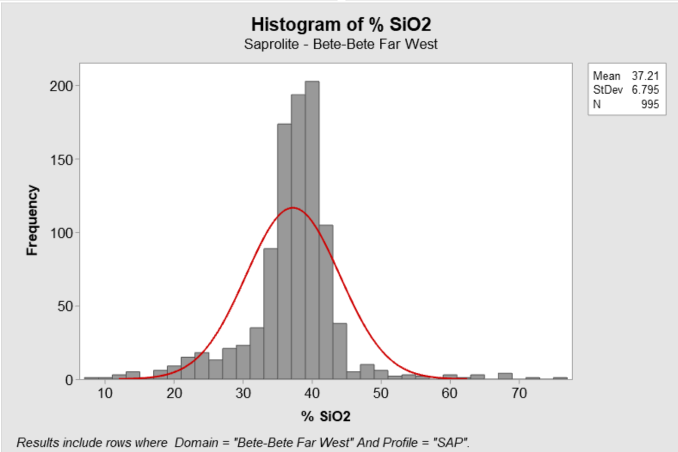


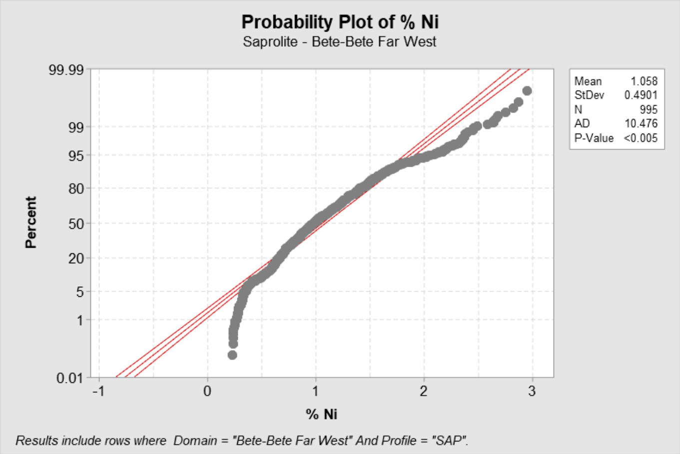


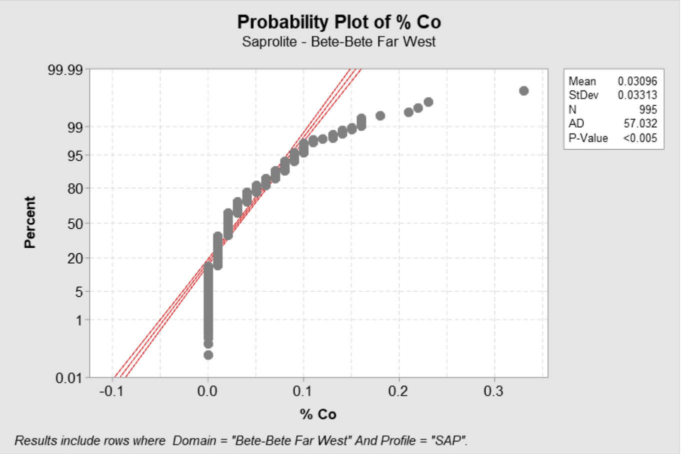


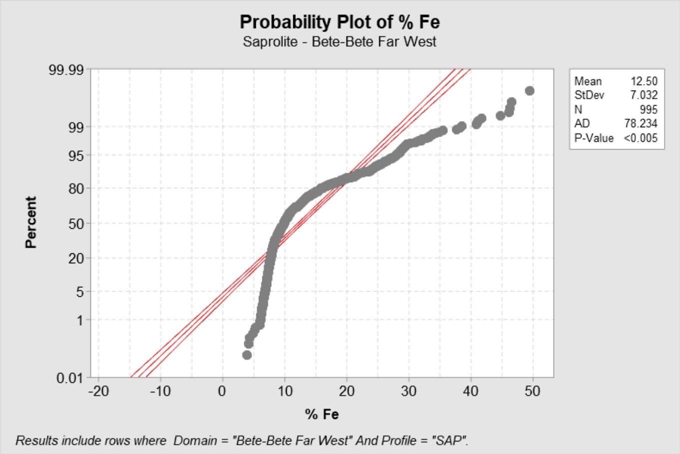


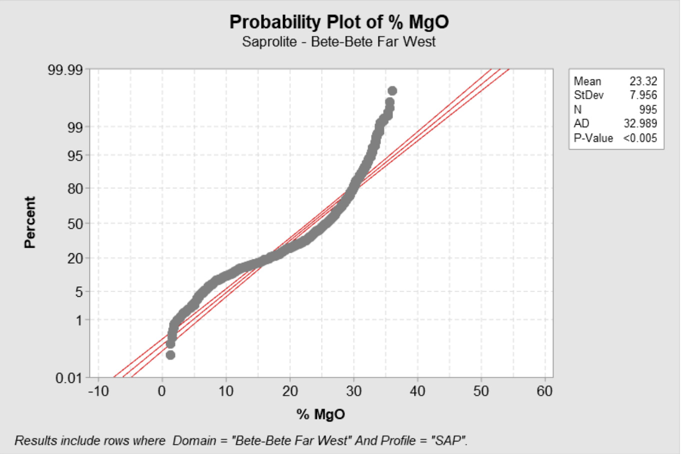


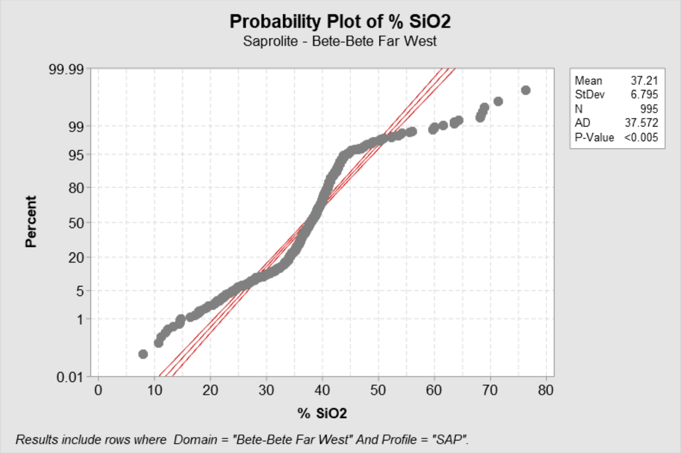
PROBABILITY PLOT: SAP











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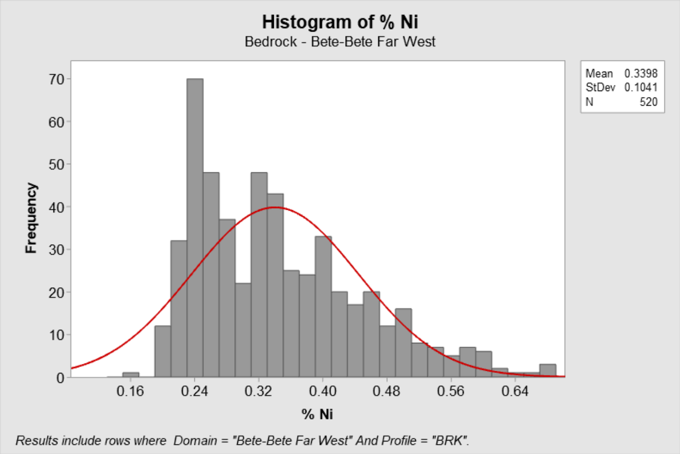
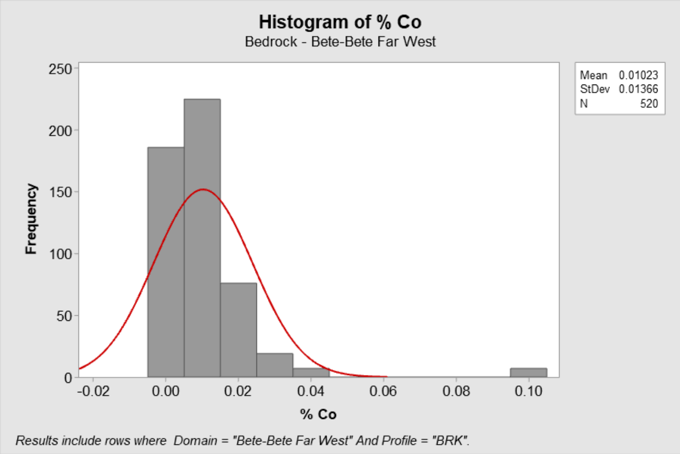
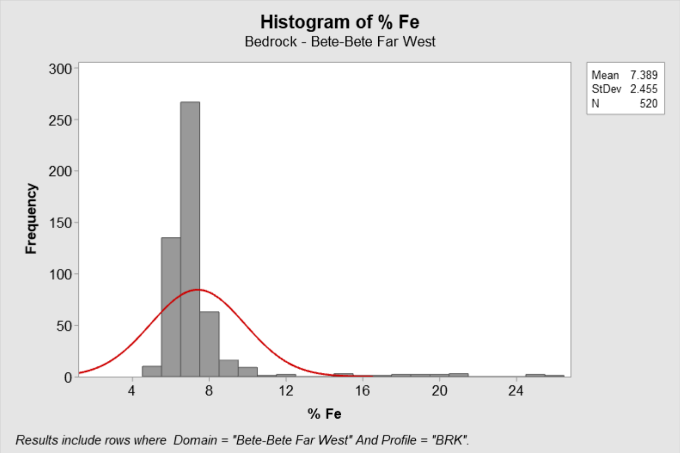
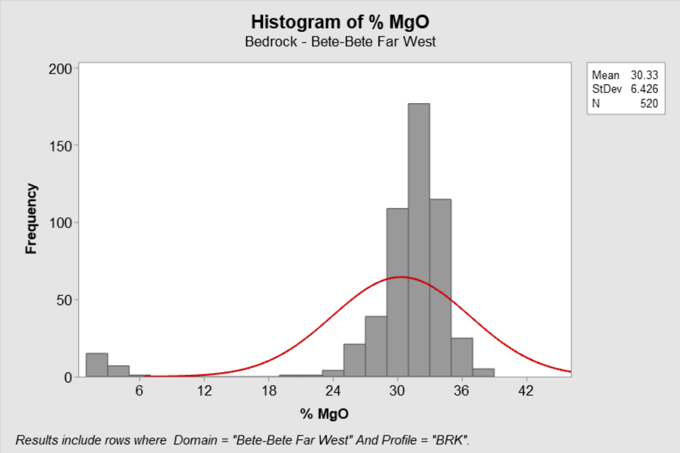
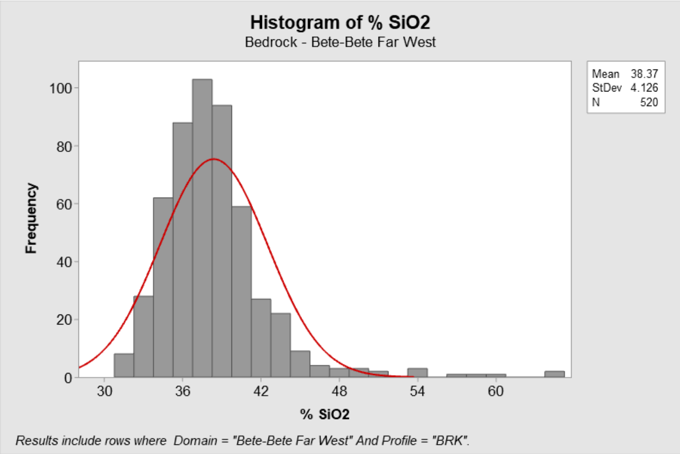


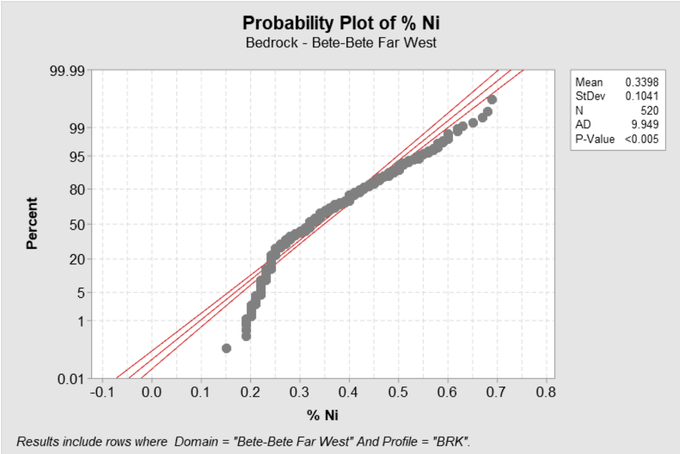


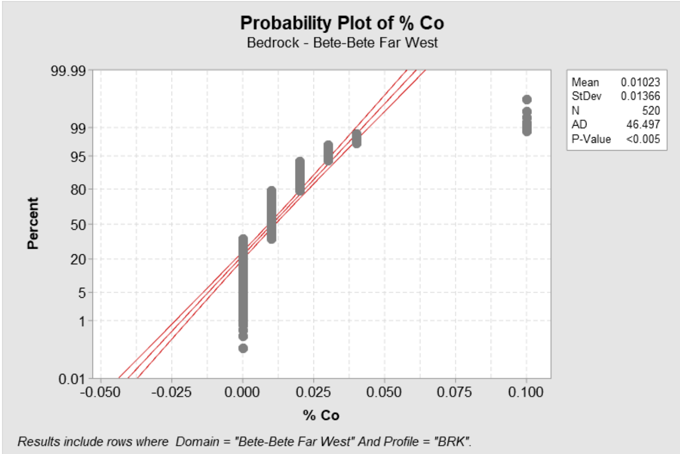


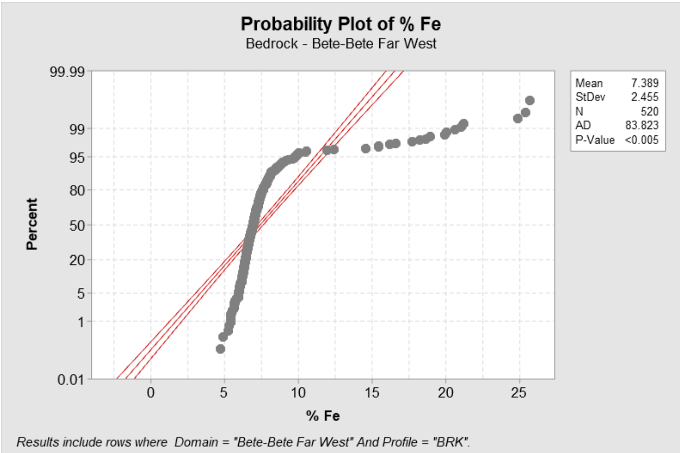


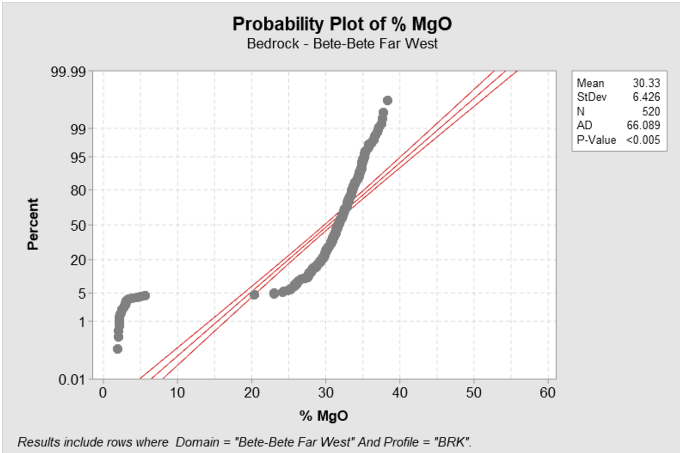


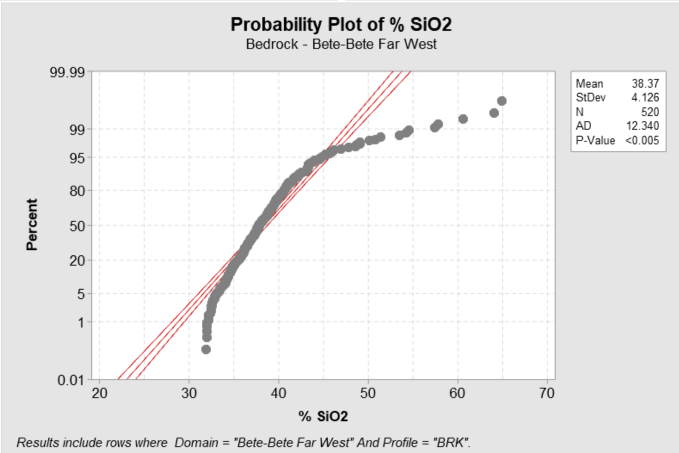
PROBABILITY PLOT: BRK









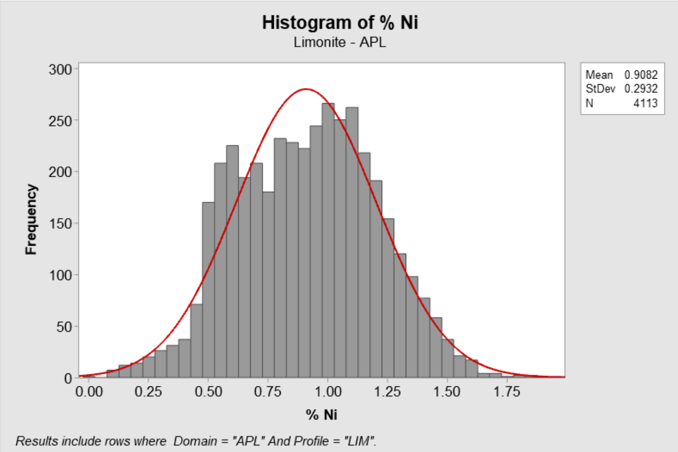


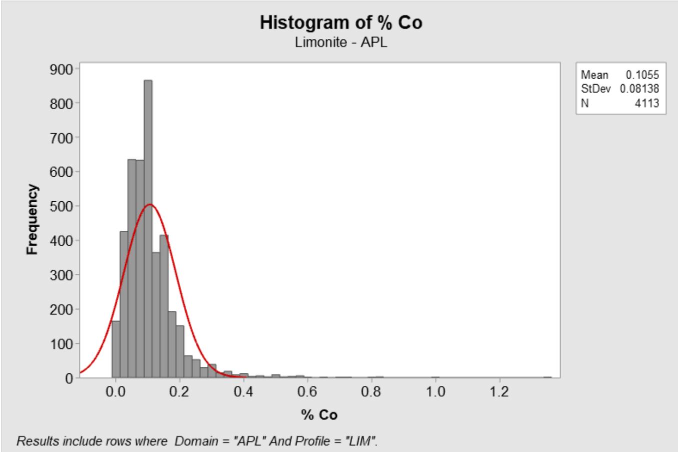
APL

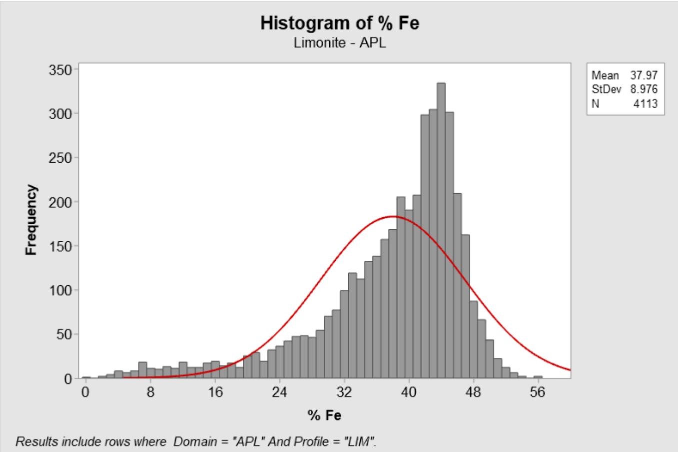
STATISTICS

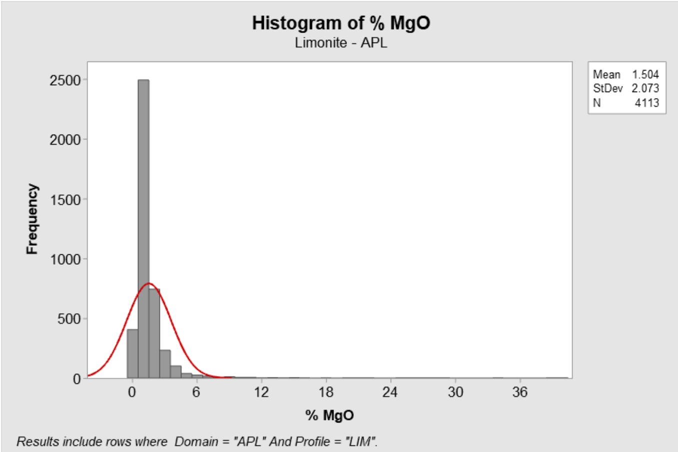
Variable	Profile	Samples	Mean	Median	StDev	Variance	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Ni	SED	173	0.04	0.02	0.08	0.01	201.35	0.01	0.76	6.08	46.27
	LIM	4113	0.91	0.92	0.29	0.09	32.29	0.01	1.93	0.00	-0.43
	SAP	6619	1.13	1.04	0.58	0.34	51.65	0.05	5.20	1.19	2.94
	BRK	2744	0.33	0.30	0.12	0.02	37.28	0.03	1.28	1.93	6.72
Co	SED	173	0.01	0.01	0.02	0.00	218.31	0.00	0.20	10.99	135.86
	LIM	4113	0.11	0.09	0.08	0.01	77.13	0.00	1.36	3.41	27.24
	SAP	6619	0.04	0.02	0.04	0.00	117.41	0.00	1.28	7.13	127.07
	BRK	2744	0.01	0.01	0.01	0.00	62.86	0.00	0.13	5.06	54.20
Fe	SED	173	1.95	1.73	1.65	2.71	84.24	0.16	17.74	5.31	48.49
	LIM	4113	37.97	40.49	8.98	80.56	23.64	0.27	55.80	-1.44	2.20
	SAP	6619	13.86	11.17	7.88	62.06	56.85	1.00	50.40	1.48	2.03
	BRK	2744	6.90	6.64	1.99	3.95	28.81	0.34	43.60	6.02	82.46
MgO	SED	173	3.19	2.34	3.41	11.59	106.85	0.53	28.31	4.43	23.91
	LIM	4113	1.50	1.04	2.07	4.30	137.81	0.00	39.50	9.00	117.12
	SAP	6619	17.82	18.45	10.65	113.38	59.74	0.00	46.63	0.03	-1.00
	BRK	2716	30.51	33.14	9.47	89.62	31.03	0.00	46.17	-1.44	1.82
SiO2	SED	173	23.95	21.88	15.62	243.94	65.22	3.06	61.23	0.61	-0.73
	LIM	4113	17.54	10.86	18.23	332.40	103.93	0.00	99.00	1.94	3.61
	SAP	6619	46.88	44.55	14.41	207.73	30.75	2.84	99.00	0.66	1.44
	BRK	2716	47.94	44.35	10.83	117.24	22.59	6.71	96.17	2.26	5.58

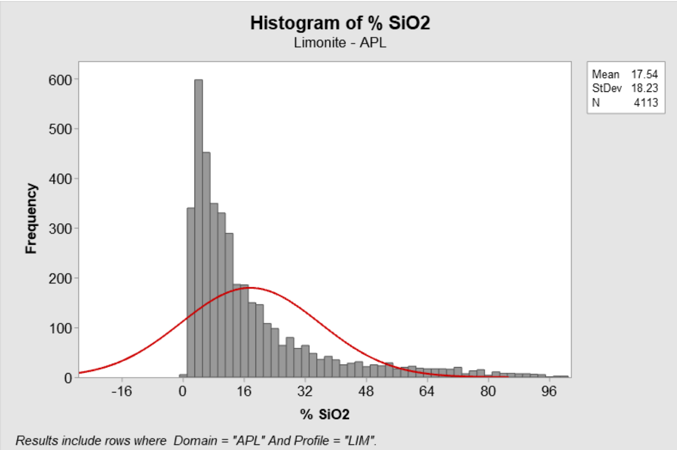
HISTOGRAM: LIM











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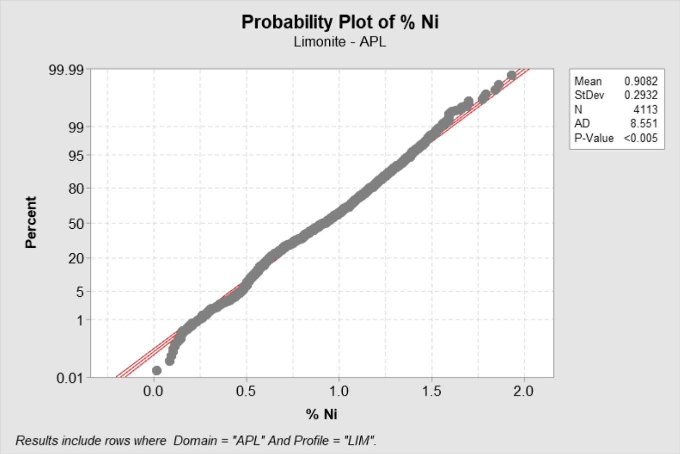

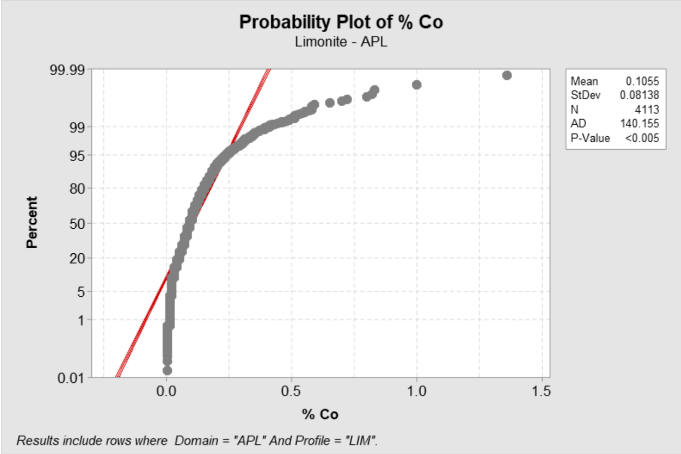

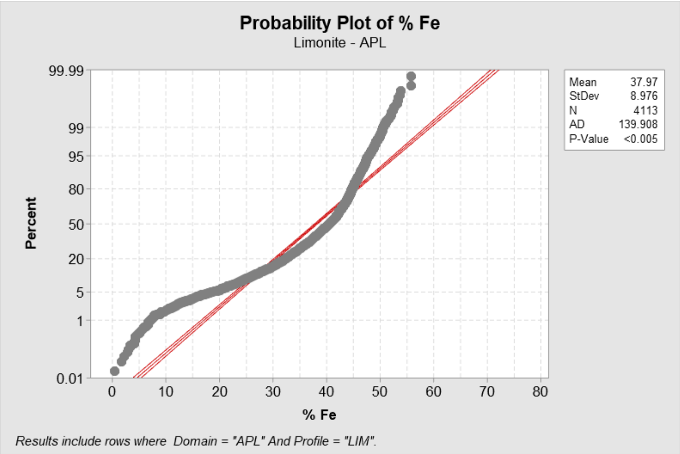

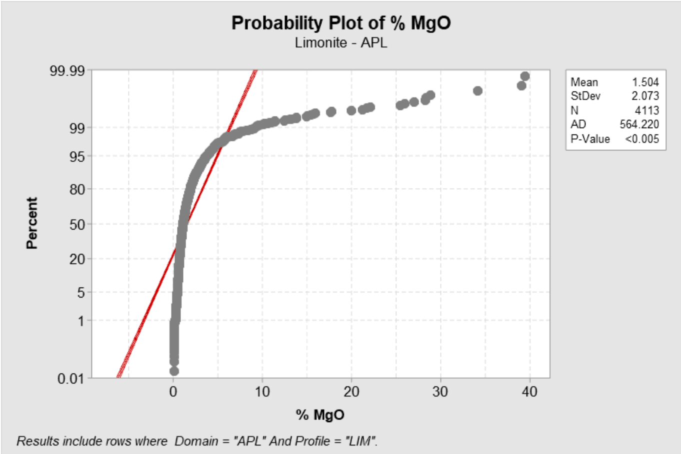

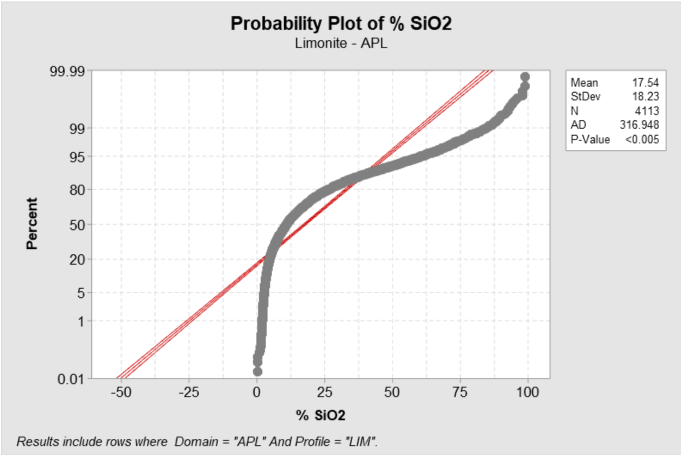

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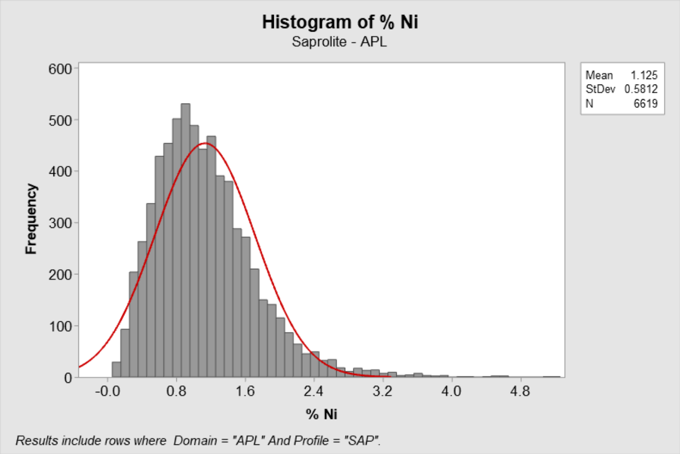

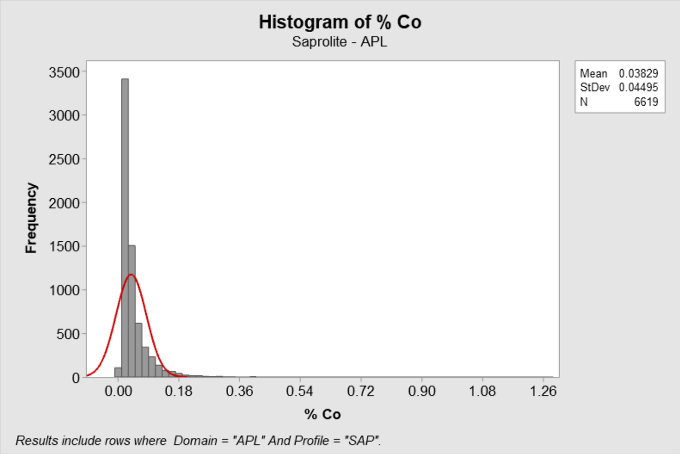

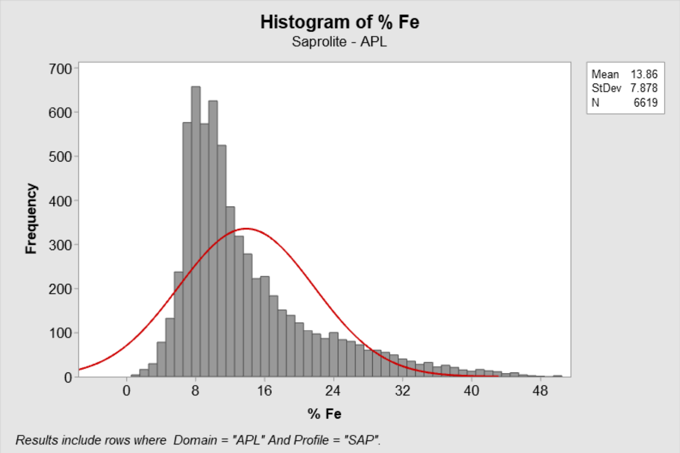

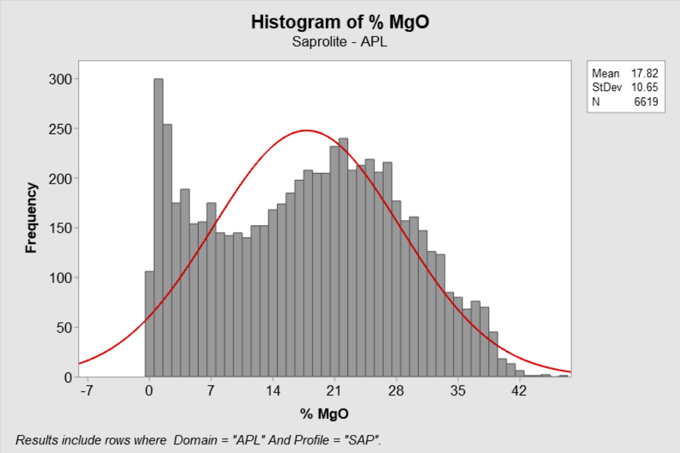

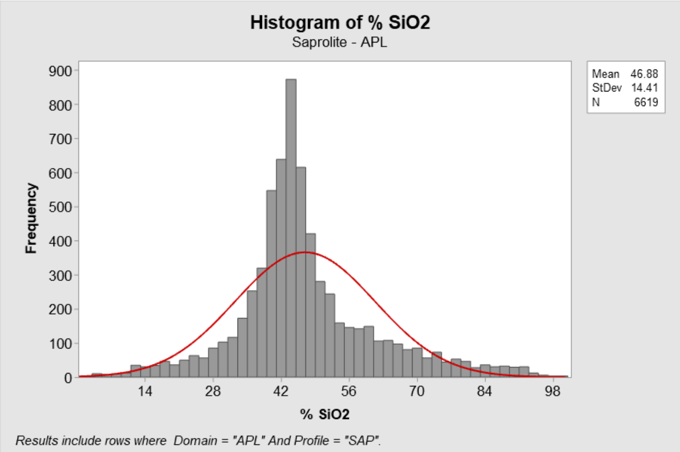

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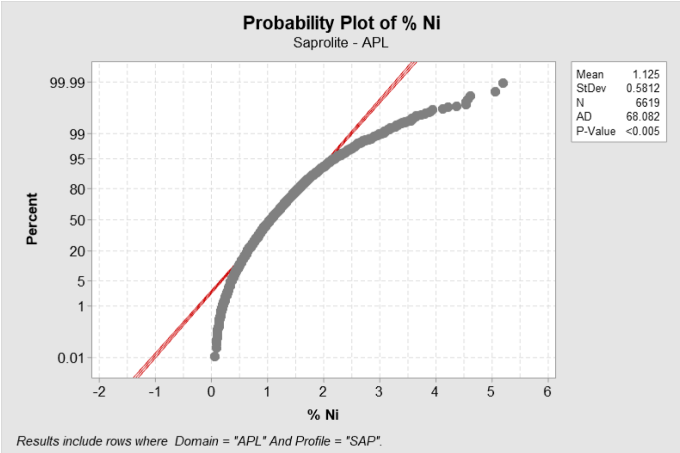

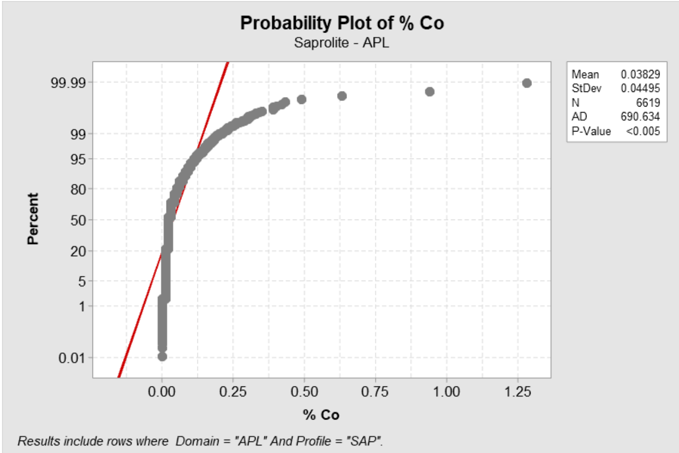

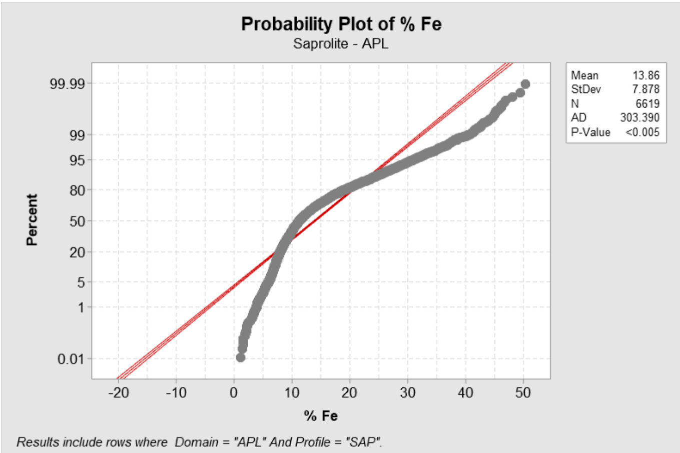

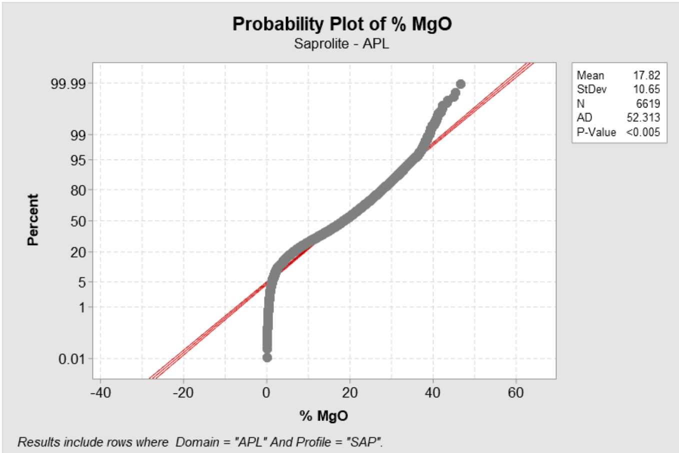

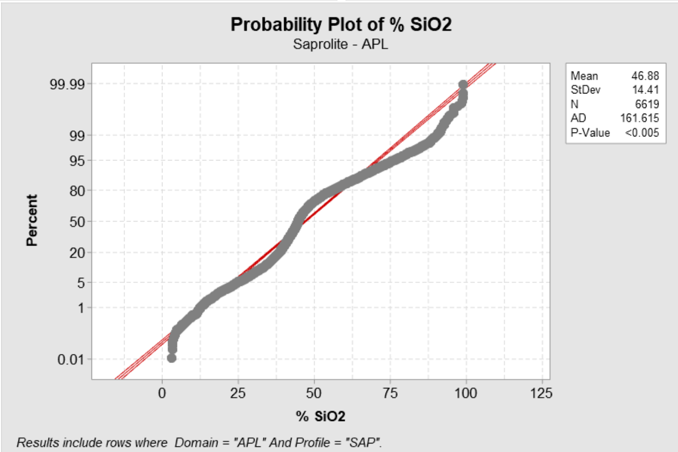

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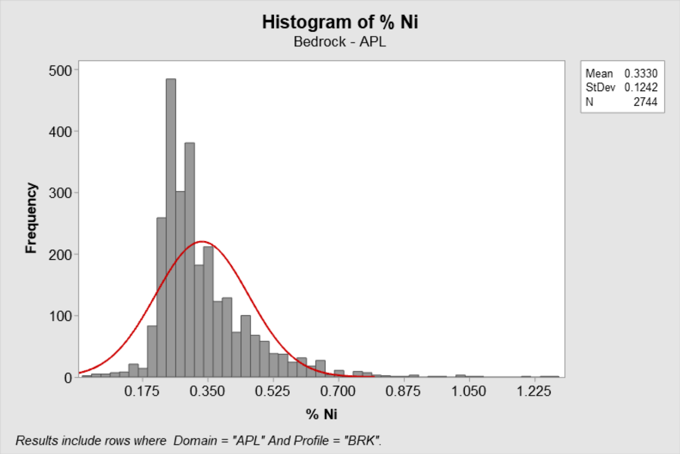

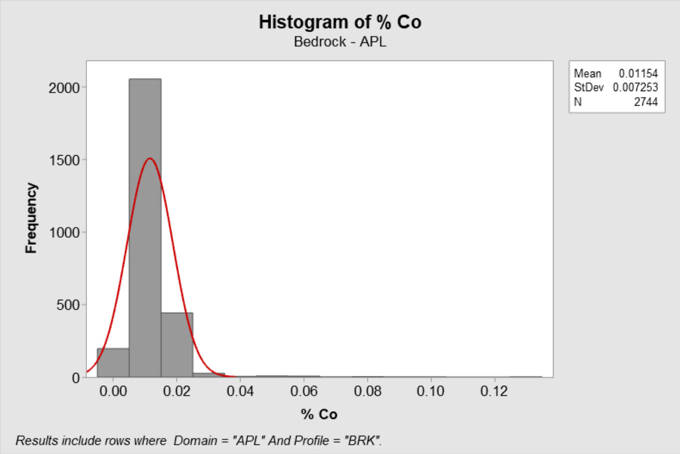

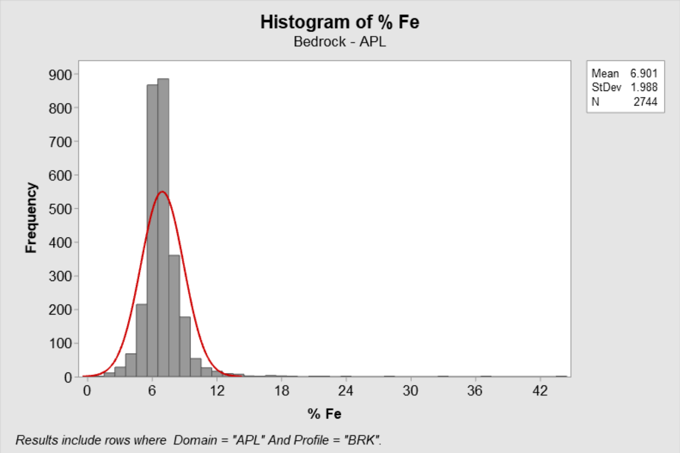

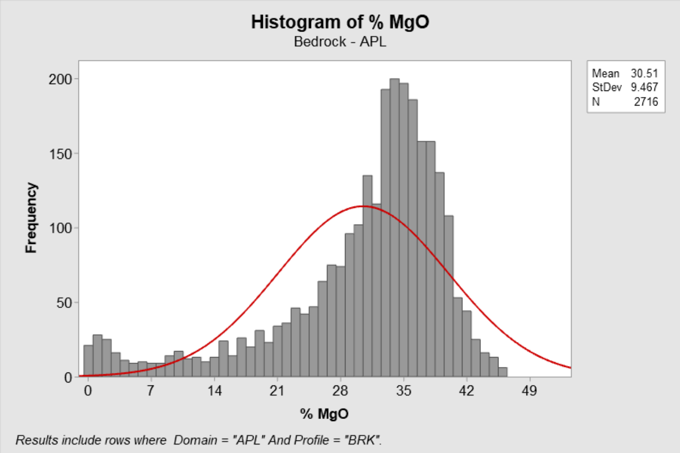

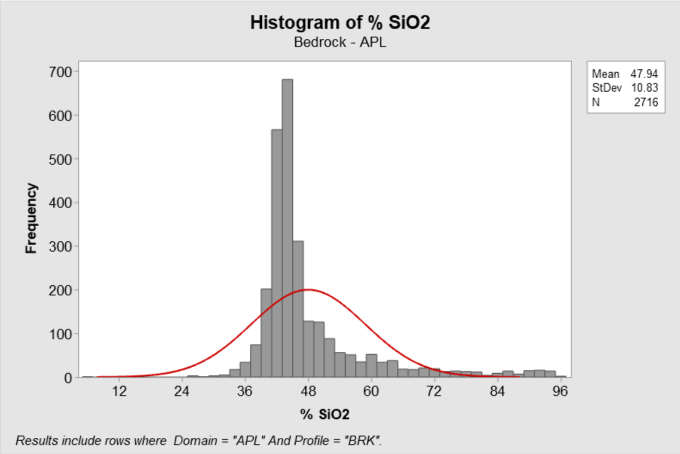

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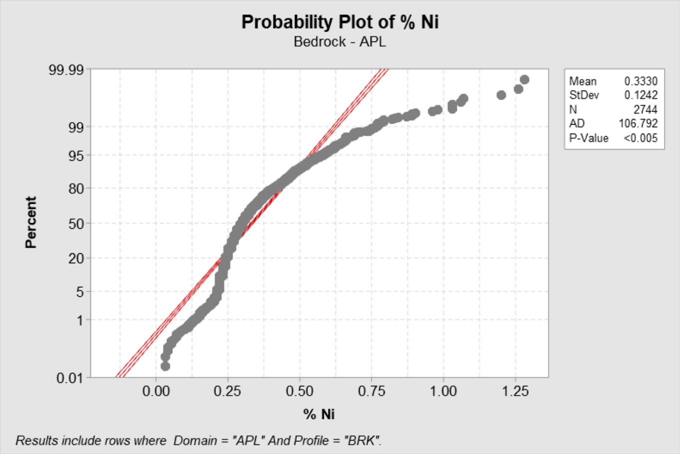

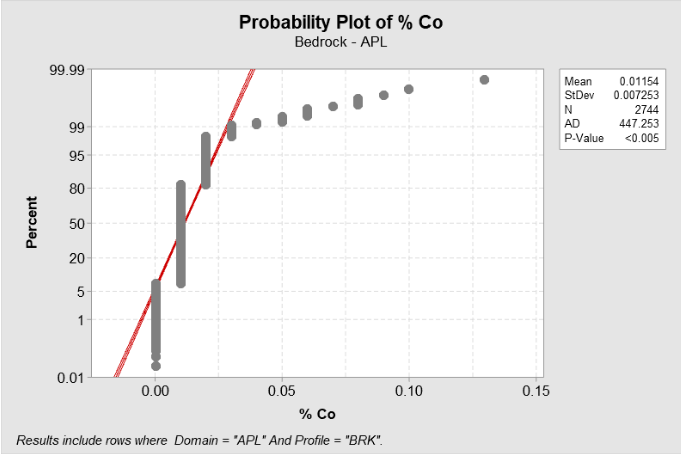

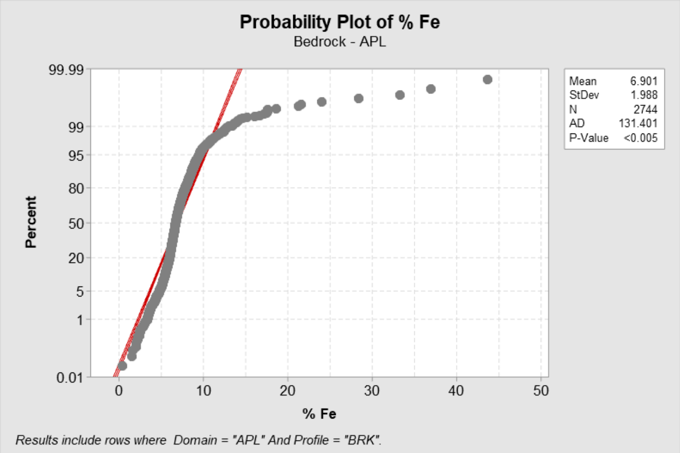

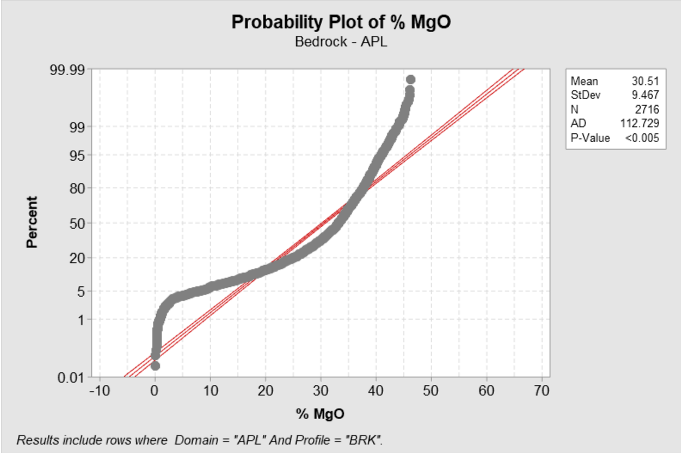

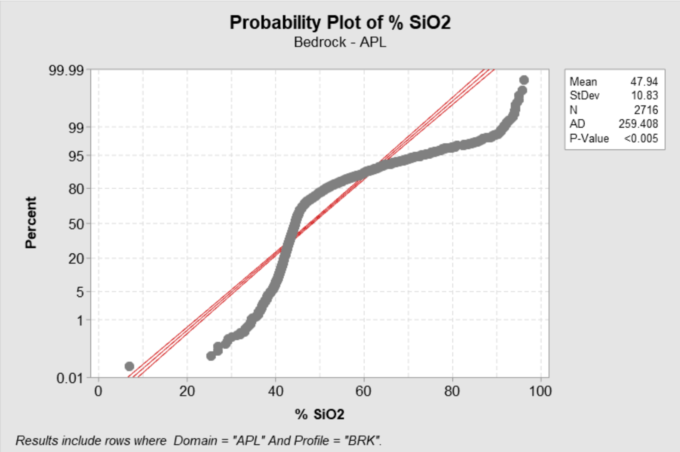

SWATH PLOTS

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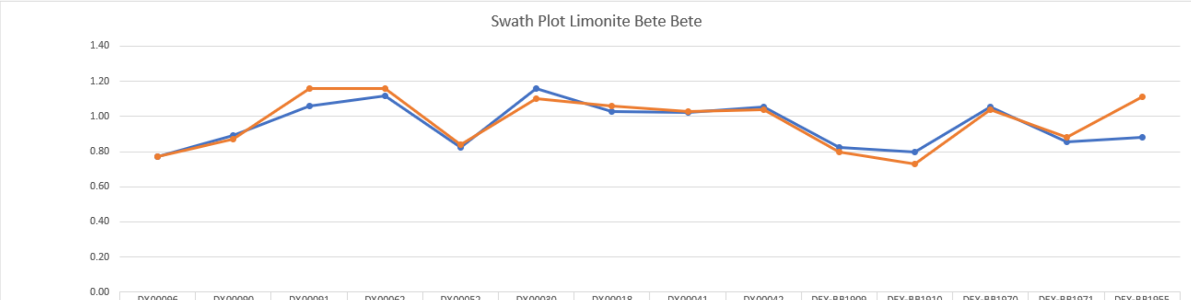

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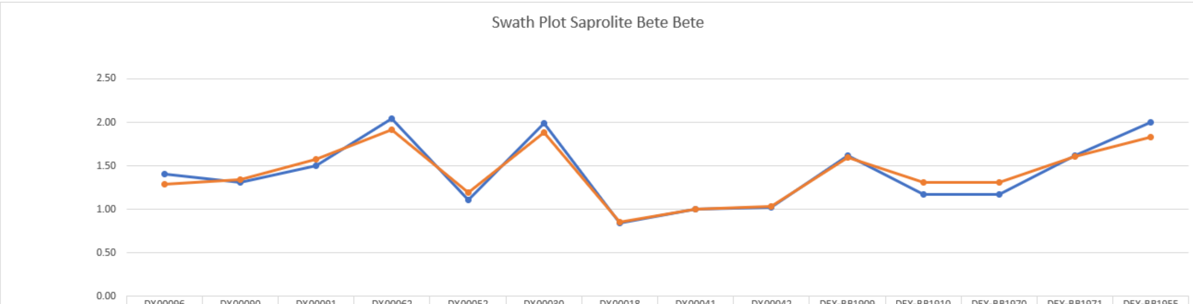
DH Composite	0.77	0.89	1.06	1.12	0.83	1.16	1.03	1.03	1.05	0.82	0.80	1.05	0.86	0.88
BM Composite	0.77	0.87	1.16	1.16	0.84	1.10	1.06	1.03	1.04	0.80	0.73	1.04	0.88	1.11

Bete Bete Saprolite



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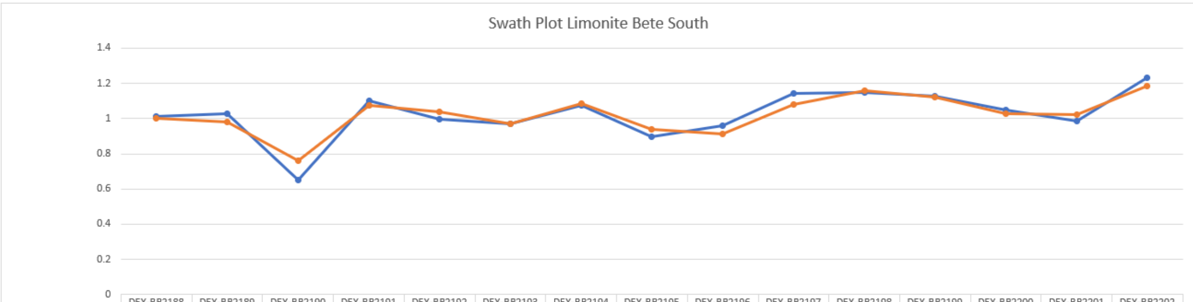
DH Composite	1.41	1.31	1.50	2.04	1.11	1.99	0.85	1.00	1.03	1.62	1.17	1.18	1.61	2.00
BM Composite	1.29	1.34	1.58	1.92	1.19	1.88	0.85	1.00	1.03	1.60	1.31	1.31	1.61	1.83

Bete South Limonite



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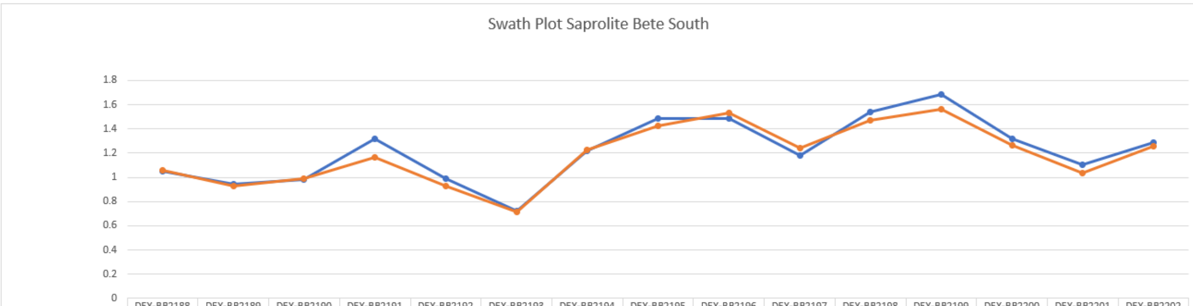
DH Composite	1.014	1.0267	0.65	1.1012	0.9975	0.968	1.0767	0.8953	0.9608	1.1425	1.1496	1.1258	1.051	0.987	1.2333
BM Composite	1	0.98	0.76	1.075	1.038	0.969	1.083	0.939	0.913	1.078	1.161	1.123	1.026	1.025	1.185

Bete South Saprolite



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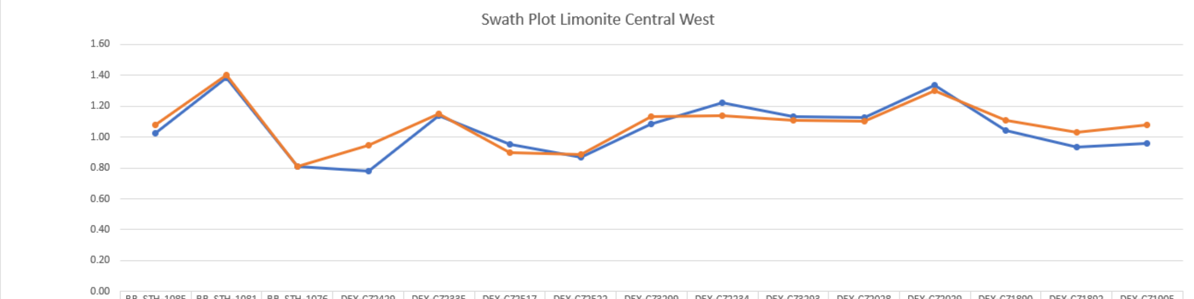
DH Composite	1.0533	0.945	0.9798	1.3167	0.9882	0.7182	1.2156	1.485	1.4891	1.1782	1.5367	1.6831	1.3164	1.1	1.2867
BM Composite	1.057	0.924	0.99	1.164	0.924	0.717	1.223	1.423	1.53	1.239	1.468	1.565	1.267	1.036	1.253

Central West Limonite



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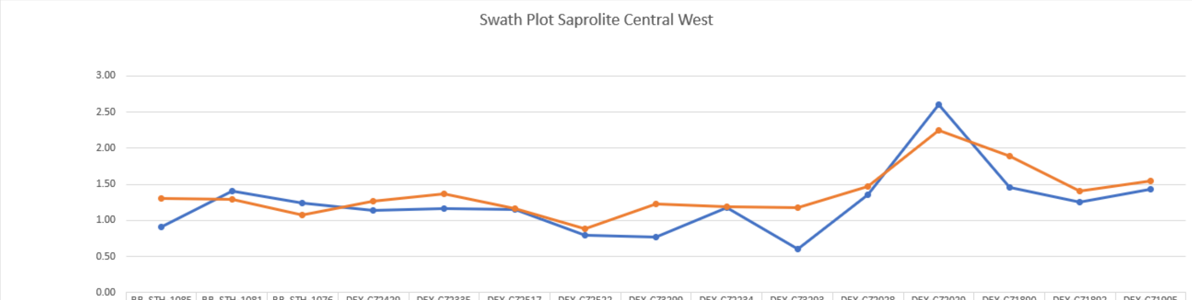
DH Composite	1.02	1.38	0.81	0.78	1.14	0.96	0.87	1.09	1.22	1.13	1.13	1.33	1.04	0.94	0.96
BM Composite	1.08	1.4	0.81	0.95	1.15	0.9	0.89	1.13	1.14	1.11	1.1	1.3	1.11	1.03	1.08

Central West Saprolite



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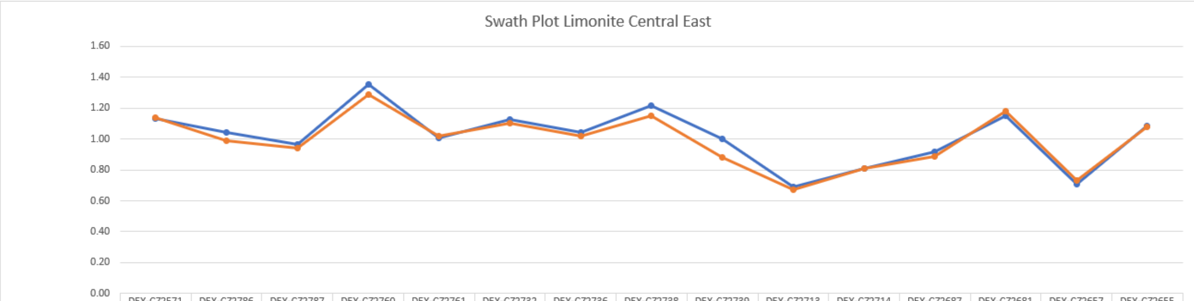
DH Composite	0.91	1.40	1.24	1.14	1.16	1.16	0.80	0.76	1.17	0.60	1.36	2.61	1.46	1.25	1.43
BM Composite	1.31	1.29	1.07	1.27	1.37	1.17	0.89	1.23	1.19	1.18	1.47	2.25	1.89	1.4	1.55

Central East Limonite



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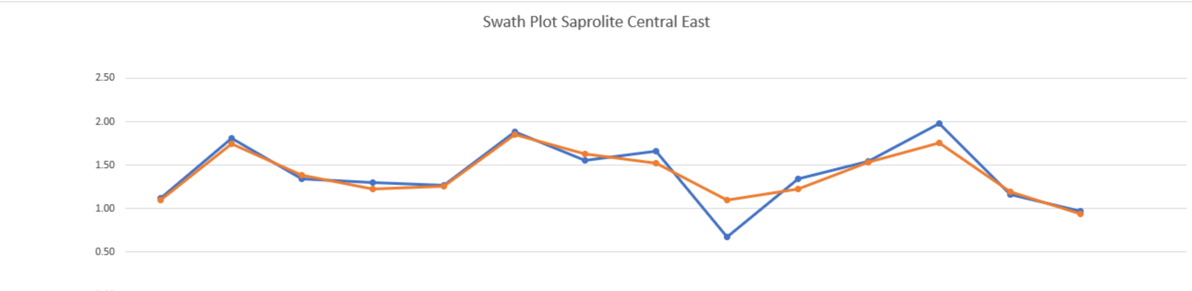
DH Composite	1.13	1.05	0.96	1.35	1.01	1.13	1.04	1.22	1.00	0.69	0.81	0.92	1.15	0.71	1.08
BM Composite	1.14	0.99	0.94	1.29	1.02	1.10	1.02	1.15	0.88	0.67	0.81	0.89	1.18	0.73	1.08

Central East Saprolite



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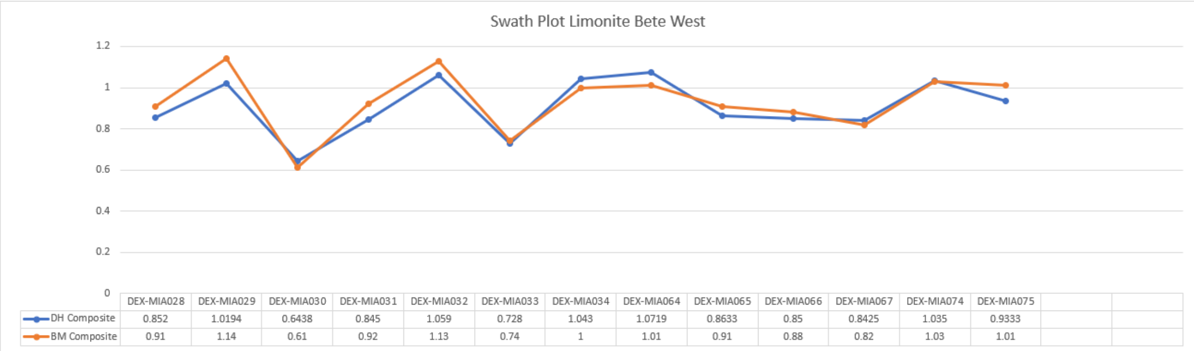
DH Composite	1.11	1.81	1.34	1.29	1.27	1.88	1.55	1.66	0.67	1.34	1.55	1.97	1.16	0.97	
BM Composite	1.10	1.74	1.38	1.23	1.26	1.85	1.63	1.52	1.10	1.23	1.53	1.76	1.19	0.94	

Bete West Limonite



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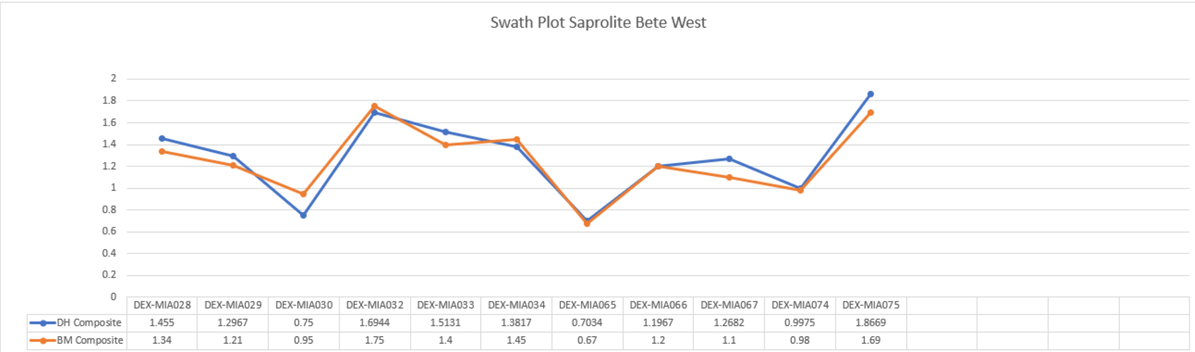
DH Composite	0.852	1.0194	0.6438	0.845	1.059	0.728	1.043	1.0719	0.8633	0.85	0.8425	1.035	0.9333
BM Composite	0.91	1.14	0.61	0.92	1.13	0.74	1	1.01	0.91	0.88	0.82	1.03	1.01

Bete West Saprolite



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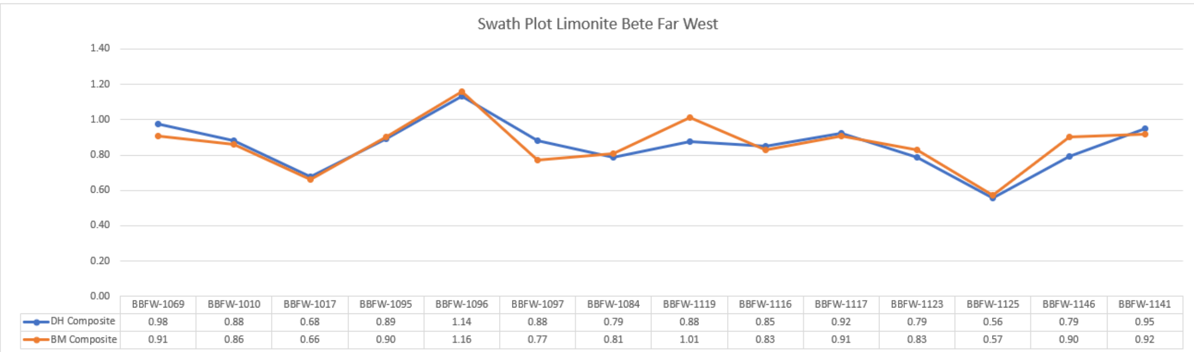
DH Composite	1.455	1.2967	0.75	1.6944	1.5131	1.3817	0.7034	1.1967	1.2682	0.9975	1.8669
BM Composite	1.34	1.21	0.95	1.75	1.4	1.45	0.67	1.2	1.1	0.98	1.69

Bete Far West Limonite



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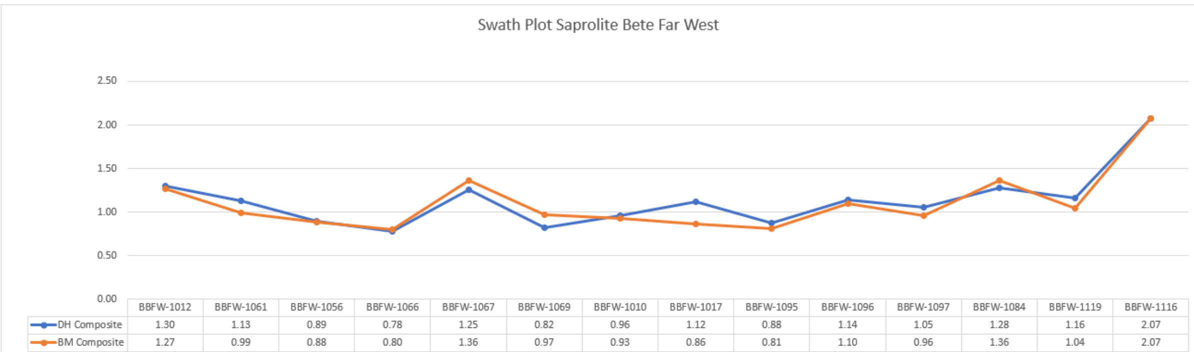
DH Composite	0.98	0.88	0.68	0.89	1.14	0.88	0.79	0.88	0.85	0.92	0.79	0.56	0.79	0.95
BM Composite	0.91	0.86	0.66	0.90	1.16	0.77	0.81	1.01	0.83	0.91	0.83	0.57	0.90	0.92

Bete Far West Saprolite



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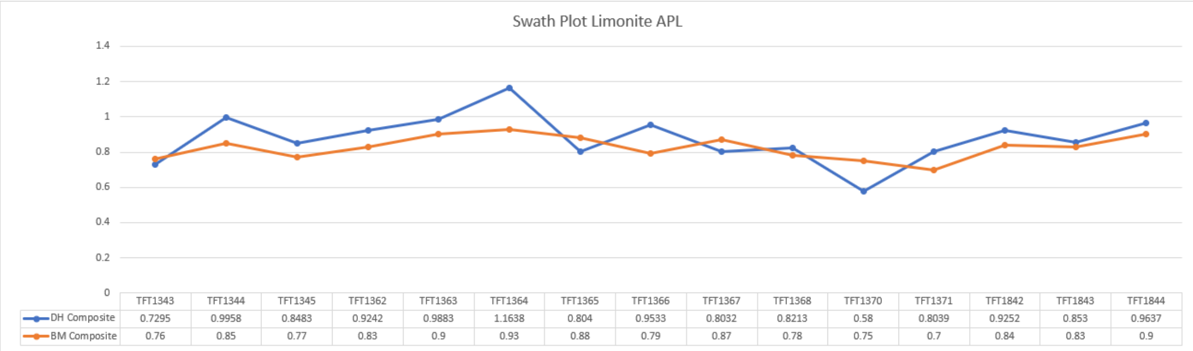
DH Composite	1.30	1.13	0.89	0.78	1.25	0.82	0.96	1.12	0.88	1.14	1.05	1.28	1.16	2.07
BM Composite	1.27	0.99	0.88	0.80	1.36	0.97	0.93	0.86	0.81	1.10	0.96	1.36	1.04	2.07

APL Limonite



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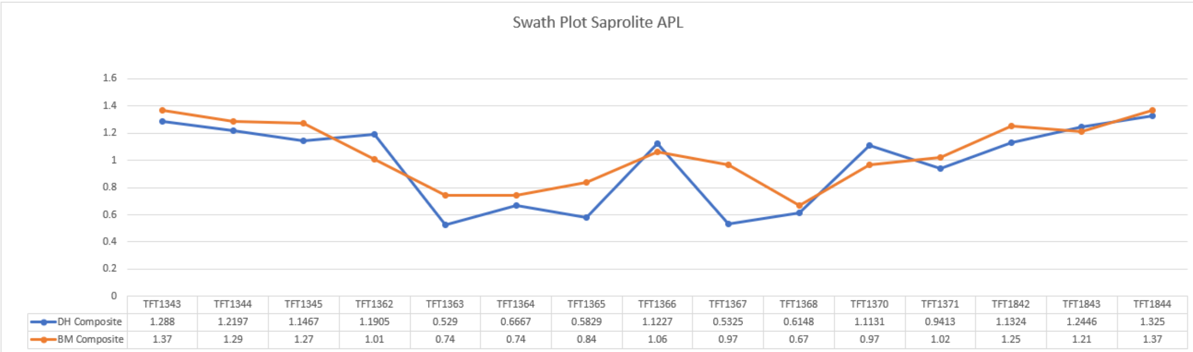
DH Composite	0.7295	0.9958	0.8483	0.9242	0.9883	1.1638	0.804	0.9533	0.8032	0.8213	0.58	0.8039	0.9252	0.853	0.9637
BM Composite	0.76	0.85	0.77	0.83	0.9	0.93	0.88	0.79	0.87	0.78	0.75	0.7	0.84	0.83	0.9

APL Saprolite



	TFT1343	TFT1344	TFT1345	TFT1362	TFT1363	TFT1364	TFT1365	TFT1366	TFT1367	TFT1368	TFT1370	TFT1371	TFT1842	TFT1843	TFT1844
DH Composite	1.288	1.2197	1.1467	1.1905	0.529	0.6667	0.5829	1.1227	0.5325	0.6148	1.1131	0.9413	1.1324	1.2446	1.325
BM Composite	1.37	1.29	1.27	1.01	0.74	0.74	0.84	1.06	0.97	0.67	0.97	1.02	1.25	1.21	1.37

Appendix 5
Laboratory QAQC Reports

Laboratory and Sample Analysis Procedures at the HM Laboratories JORC Compliant Report

C.E. Watson

August 2022

For:
Tony Green – Chief Operations Officer
Willem Dique – Operations Manager
Daniel Madre - Danmar

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PT Hengjaya Mineralindo
Laboratory and Sample Analysis Procedures at the HM Laboratories
JORC Compliant Report - August 2022

Introduction

This report on the QAQC Department's activities at the PT Hengjaya Mineralindo (HM) preparation and assay laboratories at their Tangofa Camp in Sulawesi, Indonesia, has been compiled as part of a JORC Compliant Report and according to the guiding principles of the JORC Code, 2012 Edition, which states: *"Transparency and Materiality are the guiding principles of the Code, and the Competent Person must provide explanatory commentary on the material assumptions underlying the declaration of Exploration Results, Mineral Resources or Ore Reserves."* This report endeavours to address the sections on Sub-sampling techniques and sample preparation and the Quality of assay data and laboratory tests in JORC TABLE 1, Section 1, Sampling Techniques and Data, a copy of which is attached.

PT Hengjaya Mineralindo (HM) has two separate facilities at the Tangofa Camp site for processing and assaying samples collected in the exploration (drilling) programme and mining (production) operations at the site. These two facilities are the Sample Preparation Laboratory (Prep Lab), where the samples are converted from raw samples into 200# (75 micron) pulp samples, and the Assay Laboratory, where the 200# pulp samples are assayed using XRF Spectrometers to provide the elemental composition of the drill and mine samples, in particular, the weight percent of nickel, iron, silicon dioxide and magnesium oxide, and the grade of the valuable elements, nickel and iron.

The purpose of sampling and sample preparation is described in the AusIMM Field Geologists Manual, Fifth Edition , 2011, as being *"…the reduction in particle size, through crushing and pulverising, and its sample size, through splitting, while retaining the representativeness of the medium being sampled."*

Roden & Smith describe three elements essential for a satisfactory assay and sampling system, these being: maintaining the integrity of the sample in the field, selecting the appropriate assay method and monitoring the complete sampling and assay process on a continuous basis.

At HM, mining samples of as much as 400 – 600 tons are mined and sampled (STP), and these samples processed at the Prep Lab to produce a 60 gm pulp sample from which a 10 gm pressed powder pellet is produced for XRF analysis.Exploration samples are submitted from the Danmar drill programme in batches of 100 samples, each sample representing a 1 meter advance in the drill hole and weighs approximately 8 kgs, wet, on its arrival at the prep lab. As with the mine samples, the drill samples are reduced in volume and sample particle size to produce a 60 gm pulp sample, from which a 10 gm sample is taken for a pressed pellet, or a fused bead, for XRF. The expectation is that the results obtained on the 10 gm pressed powder pellets or fused beads are produced from the 600 ton mine or 8 kg drill sample are, within acceptable limits, representative of the original samples. It is the primary responsibility of the HM QAQC Department to ensure that this is the case.

1.Quality Assurance and Quality Control

Quality Assurance and Quality Control (QAQC) are two separate processes, but are often combined and referred to as QAQC. The purpose of QAQC is determining the quantity and concentration of the economic element of interest and providing the confidence we have in these numbers to allow us to put them in context with where we are in the mining value chain. It ensures that the data we are going to collect and the data we are collecting are of suitable quality (Sterk, 2019).

Quality Assurance means assuring the quality of the data by having a set of standard operating procedures (SOPs) in place, aiming to prevent errors being made in the sampling or measuring process. Wikipedia describes QA as including two principles, the first being "fit for purpose", the product needs to be suitable for the intended purpose, and the second being "right first time", where mistakes should be eliminated. Sterk summarizes the above by saying Quality Assurance is about the prevention of errors, and it occurs before sampling or measurement, while Quality Control is about the detection and correction/rejection of errors as they occur during the sampling or measurement process.

1.1 Quality Assurance at PT HM

The primary Standard Operating Procedure (SOP) for the samples submitted by the exploration and mining operations at PT HM is the "JIS Method for Sampling and Method of Determination of Moisture Content of Garnierite Nickel Ore" JIS M-8109-1996, by H.Kanazawa, August 1996. This Japanese industrial Standard specifies the following methods for this purpose of determination of the average grade and moisture content of a lot of garnierite nickel ore as follows:

1. Method of taking the sample
2. Method of sample preparation for moisture test sample and quality sample.
3. Method of measuring the moisture content
4. Method of determination of the moisture content and dry mass of the lot.

The JIS standard addresses the reduction in particle size and of the sample size through incremental sample reduction according to different sized scoops depending upon the particle size of the material being sampled. This SOP is used in reducing the size of the sample in the mining operations and in the sample preparation laboratory at the sample receival area, after drying, after jaw crushing, Roll Crushing and pulverising, and at the assay laboratory prior to the production of a pressed pellet or fused bead prior to XRF spectroscopy.

1.2 Quality Control at PT HM Sample Prep Lab

Quality Control is ensuring that checks and balances are implemented and are constantly reviewed and assessed, in order to identify whether the sampling /measuring systems and the laboratory are providing quality assays, ie are "in control". In the minerals industry, the checks and balances commonly used to monitor the sample preparation and assaying processes includes standards, blanks and duplicates.

Sterk discusses how geoscientists should be aware of variance, and QA,QC and Acceptance Testing (Reporting and Review) are relevant at every stage of the sample collection, sample preparation and assaying treatment. This is important, and we should assess the QA, QC and AT at each and every one of our sample treatment stages. At HM, these could are considered as Primary Sample, 1st Split, 2nd Split, 3rd Split etc., and Analytical, and a short summary of these different stages is given below. These samples are collected at the HM Sample Prep Lab.

1.2.1 First Lab Split Stage Prior to Drying - Both the reduction in particle size and the reduction in sample size take place at the Sample Preparation Laboratory (the Prep Lab), where the mining samples and the exploration samples are submitted, checked, and the mining samples split according to the JIS standard.

The exploration samples have not been split at this stage, only the mining samples have been incrementally split as per the standard, with the objective of reducing the sample size before drying.

1.2.2.Drying Stage - Samples are dried as the first stage of in sample preparation at temperatures 105° or 110°, for different durations, depending on the source material:

Exploration samples	- 8 to 12 hrs at 105° to 110° C
Mining samples	- 6 to 8 hrs at 105° to 115° C

Moisture Content - 24 hrs at 105° C

Once the drying is complete, the samples are removed from the oven and weighed, and the weights recorded for data entry, the Moisture Content being the difference between the wet weight and the dry weight divided by the wet weight and shown as a % figure. The average figure for the saprolite samples recovered in the HM drill programme is around 40% moisture.

1.2.3 First Crushing Stage – Jaw Crusher - The first crushing stage of the oven dried drill sample occurs at the Jaw Crusher, where the two trays of dried sample are poured into the jaw crusher and reduced in size to a -10 mm product which is collected underneath the Jaw Crusher.

1.2.4 First Splitting Stage – Jones Riffle Splitter - The Jaw crusher product is now poured into a Jones Riffle Splitter which produces two similar products, one of which is taken forward to the next crushing stage, while the second Riffle Splitter product is discarded.

The first crushing stage and the first splitting stage are now complete, all part of the incremental crushing and splitting process in reducing the grain size and sample size of the original dried sample. These two stages continue to follow the details provided in the JIS standard, part of the HM Quality Assurance programme.

1.2.5 Second Crushing Stage – Roll Crusher - The second crushing stage comprises the Jones Riffle split product being poured into a Double Roll Crusher which reduces the -10 mm jaw crusher product into a – 3 mm product which is collected beneath the double roll crusher.

1.2.6 Second Splitting Stage – Manual Incremental Reduction - As described in the JIS M 8109 – 1996 standard, the second splitting stage consists of the - 3 mm double roll crusher product being reduced by manual incremental reduction into two incremental split samples weighing approximately 500 gms each, one is labelled and sent to sample storage, while the other sample will be sent to the next stage in the processing cycle, the pulveriser. In addition to the split samples collected above, before discarding the remaining double roll crusher product, a further sample is collected, one approximately every 20 samples, and placed in a brown paper envelope and numbered with a DR suffix, this being a Double Roll Crusher product sample that will be sent for assay to test the performance of the two crushing and splitting stages, often referred to as the Course Reject sample, or at HM, the Double Roll (DR) sample. This is the first of the Laboratory check samples to be collected as part of the HM Quality Control programme, and will be used to monitor the quality of the jaw crushing and roll crushing stages in reducing the particle size and the sample size during the sample preparation programme.

1.2.7 Pulverising Stage - The fifth stage consists of the 500 gm -3 mm double roll sample being placed into a pulverizing bowl, a puck added, the lid is replaced and this unit placed inside the Essa Pulverizer using a cradle. The cradle is removed and the machine turned on and run for 5 minutes, after which the pulverizer bowl is removed from the machine using the cradle, the lid removed, the puck taken out, and the pulverised sample, the “pulp”, placed onto a tray, and passed on to the next stage of incremental splitting.

This pulverising stage is third stage in the reduction in particle size in the sample preparation process, where the dried exploration sample of approximately >20 mm was reduced in size to -10 mm at the Jaw Crusher, and then to -3 mm at the Roll crusher, and finally to -200# at the pulverising stage

1.2.8 Third Splitting Stage – Manual Incremental Reduction - The sixth stage of sample preparation is where the pulp sample is incrementally reduced with enough pulp to place into two brown paper envelopes, one of which goes to the Assay Lab, and the second sample goes to storage.

A further check sample is taken from the residual pulp remaining from this second incremental splitting before being discarded to waste, and is placed into a brown sample bag and given the sample number with a DA suffix. This is the second check sample taken to monitor the pulverising quality at the HM Prep Lab and is referred to as the DA check sample, or Pulp Reject sample. This is part of the Quality Control programme to test the quality of the pulverising process.

1.3 Particle Sizing Test (PST) – Checking the Quality of the Pulverizing Process – A PST is taken on one in every ten of the pulverised product, the pulps, to ensure the pulverisation has been done properly. A small sample of material is weighed and then placed on a 200# (75 micron) stainless steel screen and screened until all the sample that can pass the 75 micron screen has passed The weights of the – 75 micron material and the+ 75 micron products are both weighed and recorded. If the weight of the – 75 micron product is more than 95% of the total pulp sample weight, then the pulverisation process is acceptable. If the weight of the – 75 micron product is less than 95% of the total weight then this is not acceptable and the process is repeated.

Other Sample Preparations - In addition to the standard sample processing procedures described above, two further sample processing techniques are performed at the PT HM sample preparation laboratory to provide additional information for the geological and mining databases, these being Specific Gravity (density) testing and the measurement of the Moisture Content of selected samples.

1.4 Specific Gravity Measurement

At the Sample Prep. Lab the specific gravity of the four different lithological samples, collected from the drilling operations, eg the soil or overburden, limonite, saprolite and bedrock are measured by the displacement method.

1.5 Moisture Content - Nickel ore is hygroscopic and it is important to ensure that all moisture is removed from the sample to prevent the assay results showing a low bias by an amount equivalent to the weight percent residual moisture. This has the potential to affect its behaviour during smelting, which in turn can result in a lower price received per ton of smelted ore. For this reason, accurate measurement of moisture content of the mining samples before the ore is shipped to the IMIP smelter is one of the important tasks undertaken at the Sample Prep Lab.

The moisture content of the drill samples is calculated through weighing the drill samples wet, before they are placed in the ovens for drying, and again when they have been removed from the ovens and prior to the first stage of crushing. The difference in weight between the weights of the samples before and after drying, divided by the original wet weight of the sample gives the moisture content as a percentage figure.

2. Quality Control at the PT HM Assay Lab

The pulp samples of 50 – 60 gms from each consignment completed at the sample prep lab are sent to the Assay Lab where they are recorded into the production register and then placed into an oven to protect the samples from absorbing atmospheric moisture. This is the analytical stage of the sample treatment, where the samples collected at the Prep Lab are snet to the Assay Lab for analysis.

A new assay lab number is assigned to each pulp sample packet, this is undertaken at the same time as Certified Reference Materials (CRMs), pulp duplicate samples, coarse rejects, blank check and replicate check samples are inserted into the sample streams as part of the Quality Control procedures. After checking that the renumbering of these samples has been completed correctly, the samples are then taken through to the preparation room and placed in a dessicator to await the production of pressed pellets or go to the room where they will be processed into fused beads using the Bruker xrFuse6 equipment.

Roden & Smith mention how XRF assay procedures have not changed significantly but the use of fused beads instead of pressed powder pellets have resulted in better precision and lower detection limits. They go on to say that XRF is an analytical method capable of producing very precise assays over wide concentration ranges and is therefore widely used for assaying nickel laterite ores and iron ores, a similar statement being made by Bruker claiming the S2 Puma XRF offers high accuracy and precision in determining the elemental composition of nickel laterite ores.

HM presently have two XRF Spectrometers at their Tangofa Assay Lab, one a Malvern Panalytical Epsilon 4 XRF, the other a Bruker S2 Puma XRF. These are compact energy dispersive spectrometers that are capable of undertaking elemental analysis and configured with dedicated software specifically for the nickel laterite suite of elements. Both the Epsilon 4 and the Puma S2 XEF's use a Nickel XRF 12 Element Suite for Ni, Fe, Co, MgO, SiO2, CaO, Al2O3, Cr2O3, MnO, P2O5, SO3 and TiO2.

Sample preparation quality, reflecting sub-sampling precision and contamination during sample preparation, are measured by the insertion of coarse grained control samples that are placed in the sample stream prior to or during the sample preparation phase. Samples used for these tests are coarse blanks and coarse duplicates.

2.1 Coarse Blanks

Contamination is assessed by using coarse blank samples, these being barren samples in which the elements being tested, at HM these are Ni and Fe. In order to be effective, coarse blank samples are inserted into the exploration sample batch streams at the rate of 4 coarse blanks, 4 CRM's and 92 original samples, prior to submission of the samples to the Prep Lab.

2.2 Coarse Duplicates

Coarse duplicate samples, often referred to as coarse rejects, and by HM QA/QC staff as DR samples. They are collected from the Double Roll crusher product, during the incremental splitting of this product, by the same operator, and at the same time and place as the sample is split to provide material for pulverising, and a representative sample of material is collected for storage. Coarse duplicate samples are used to test the sub-sampling precision of the first crushing and incremental splitting stages.

Figure 1: Scatterplot showing results of 1020 Coarse Reject original vs duplicate assays

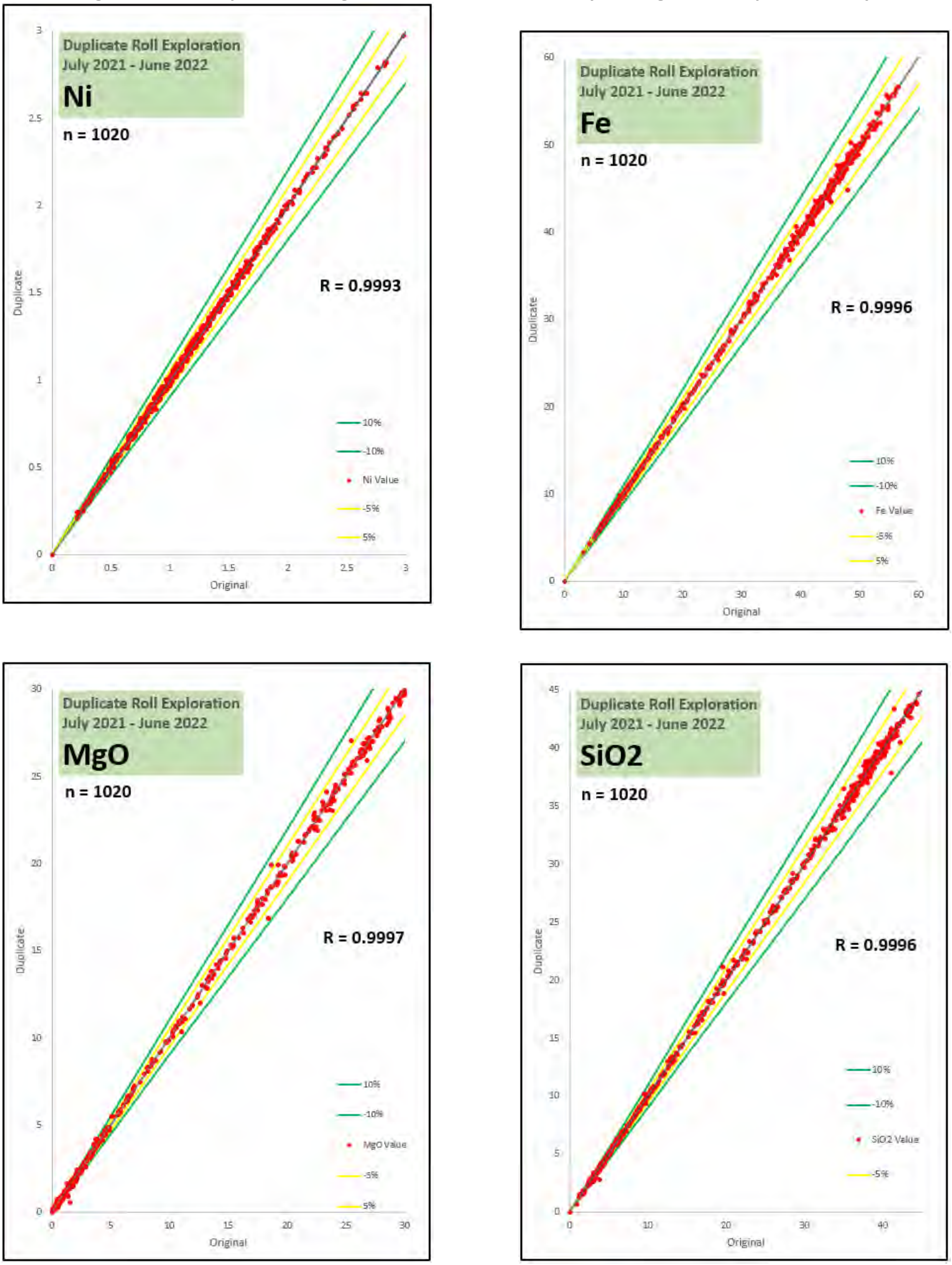


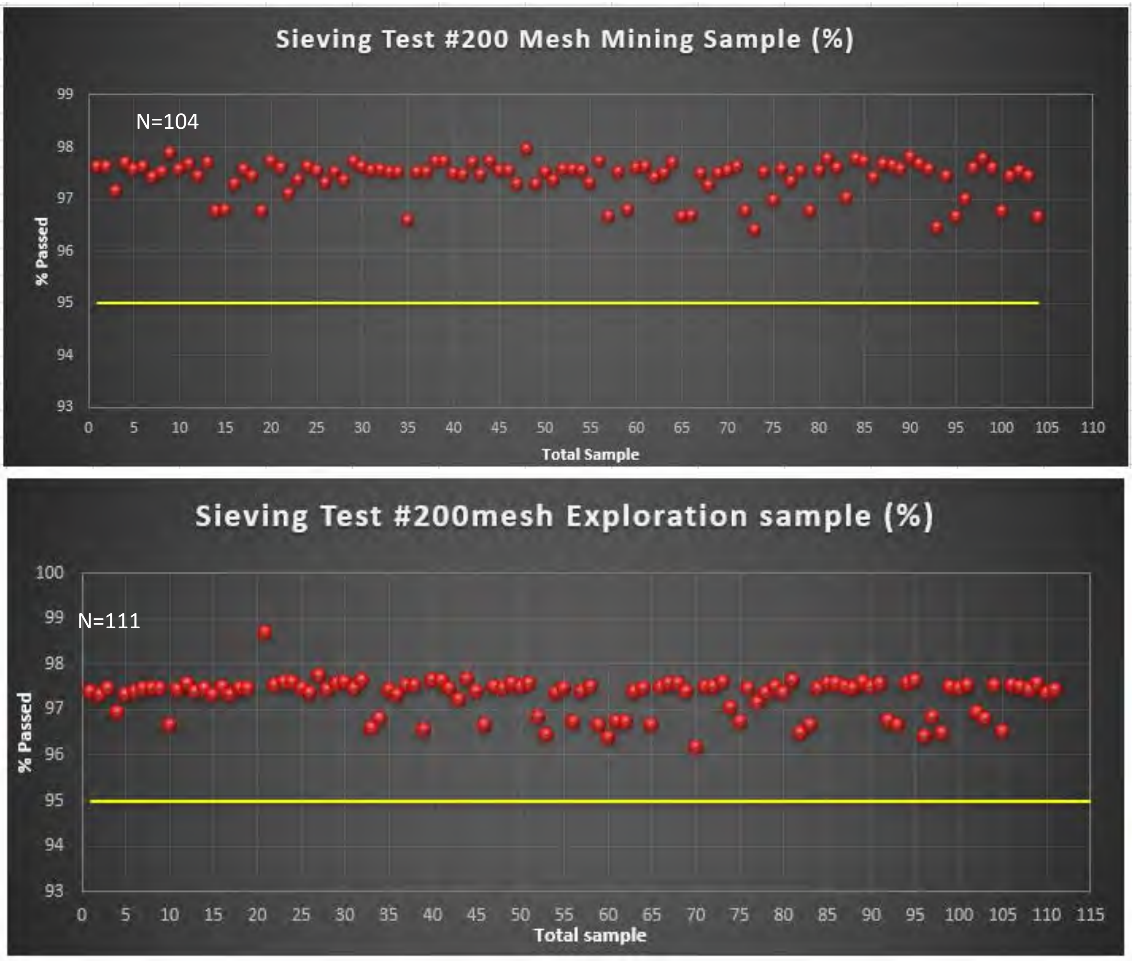
Figure 1 is a scatterplot showing the results for the four elements Ni, Fe, MgO and SiO2 from the original and duplicate roll sample results from 1,020 exploration assays undertaken over the period July 2021 to March 2022. The graphs show the original and duplicate elemental values in red plotted on a middle grey line representing the mean elemental values of these samples. The two yellow lines above and below the mean line represent the correlation between the assay variables with a variance of +5% and -5%, and the outer green lines represent the variance between the assay variables of +10% and -10%. Scatterplots where the results slope from the lower left to upper right indicate a positive correlation.

Figure 1 shows that with all four elements the red dots plot within the +10% and -10% variance lines. In fact, the majority plotting between the +5% and -5% yellow lines, showing there is a high correlation between the original and the duplicate assay values. This is further confirmed with the correlation coefficient (R^2) values of > 0.999 for the elements being assayed. These figures confirm the high precision of the jaw crushing, the first splitting and roll crushing stages and supports the use of the Coarse Duplicate assay data for resource estimation purposes.

2.3 Particle Sizing Test- -200# Screen Test

Figure 2 shows two graphs showing the results of the particles sizing tests undertaken on 111 exploration samples and 104 mining samples at the HM Prep Lab during March 2022. The yellow line is for 95% of the pulverised material passing the 200# screen, and shows the majority of the samples returning a figure of between 97% and 98% for both the exploration samples and the mining samples. These results show the repeatability precision of the pulverizing process in reducing the particle size of the samples to be high

Figure 2 : Screen Test Results – March 2022



3 Sample Assay Quality

What is quality, and how do we define it?

Sample assay quality is defined through analytical accuracy, analytical precision and contamination during assaying. It is assessed using fine grained, pulverised samples that are inserted into the sample stream after the preparation stage and before the assaying stage. Samples used in testing assay quality include pulp duplicates, Certified Reference Materials (CRMs) and fine blanks.

The AusIMM Field Geologists' Manual, (2011) defines accuracy as *"…the closeness of agreement between a test result and the 'true' value or accepted reference value."* Similarly, it defines precision as *"…the closeness of agreement between independent test results under stipulated conditions."*

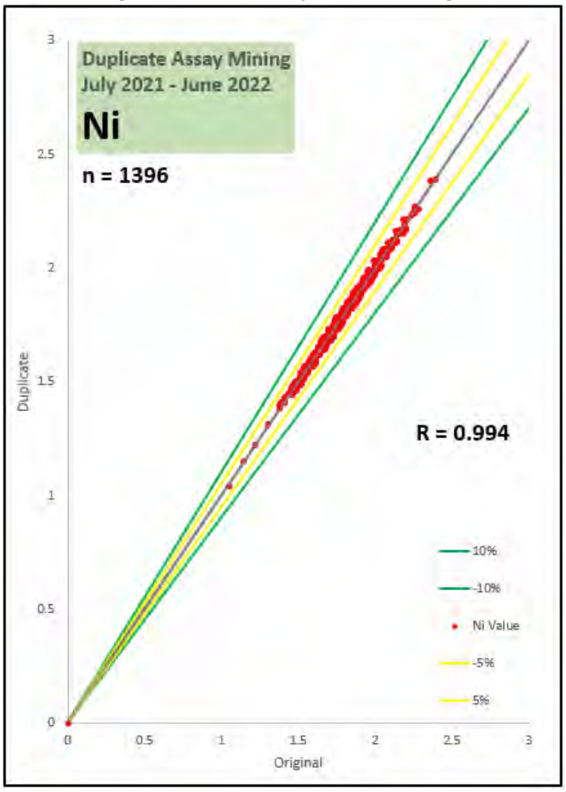
Accuracy and precision are the two key elements in understanding data quality, and are illustrated with the dartboard diagram. We need to quantify the precision and accuracy (bias). Sampling or analysis is said to be accurate when the mean error approaches zero. Sampling or analysis is said to be precise when there is a small spread of errors around the mean sampling error.

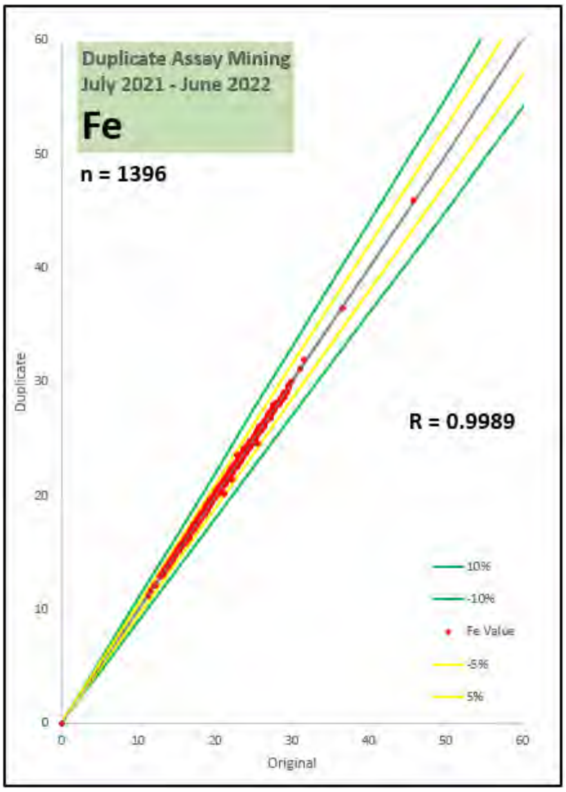
Date with "good" accuracy and "good" precision can be regarded as "Good Quality" and as such, will be "fit for purpose". We also use the terminology "representative", when the precision and accuracy are within acceptable tolerances.

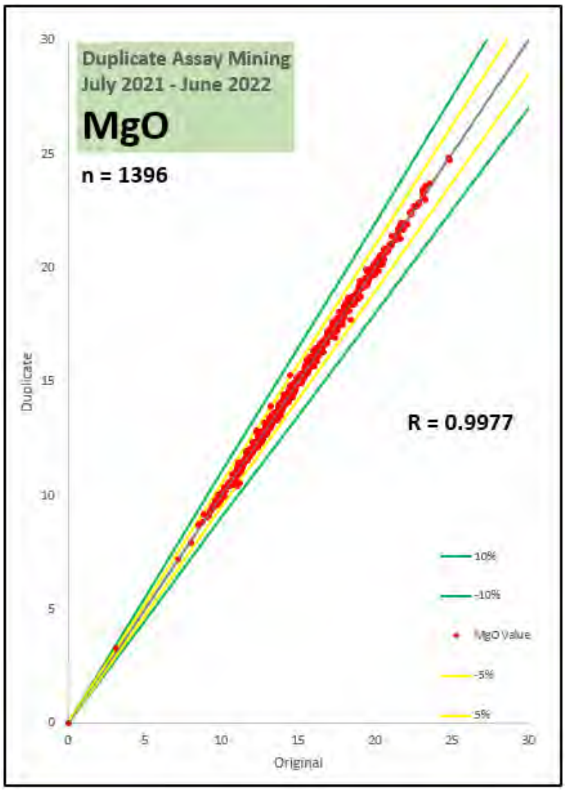
3.1 Pulp Duplicates, or Duplicate Assay

Pulp duplicates, or Duplicate Assays (DA) as they are called at HM, are second splits of the fine grained pulp samples that are collected in the final incremental splitting of the samples after pulverising. Along with the incremental split sample that is taken and bagged for XRF assay at the HM assay lab, and the sample taken for storage and future reference if required, a third sample is collected from each batch and analysed at the same time as the original sample, but with a different sample number. The pulp duplicates are indicators of the analytical precision, which can be affected by the quality of the pulverisation process and the homogenisation of the sample.

Figure 3: Scatterplot showing results of 1,396 plots for Pulp original vs duplicate assays







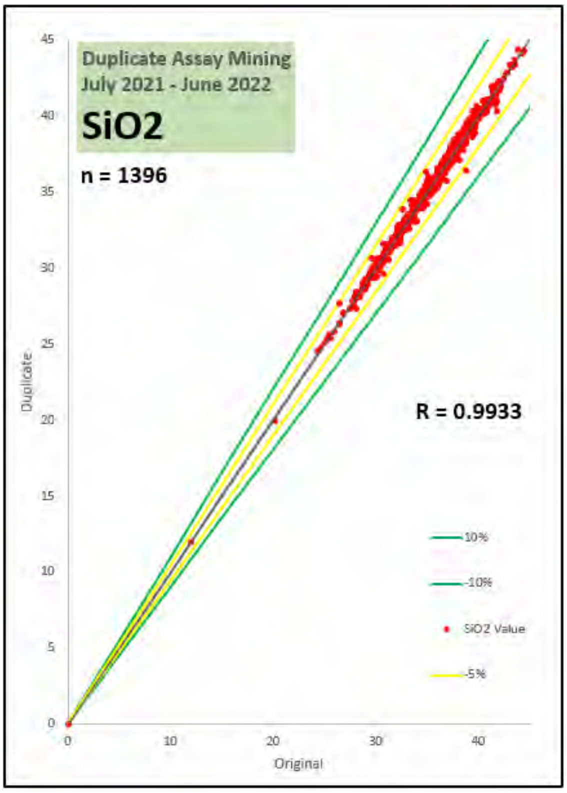


Figure 3 shows scatterplots for the elements Ni, Fe, MgO and SiO2 from original and duplicate assays from 1,396 pulp samples analysed between July 2021 and June 2022. The scatterplots are similar to those shown in Figure 1 for the Coarse Reject assays, with the majority of the Ni and Fe falling within the two yellow lines representing a +/- 5% variance from the assay, a high precision, and reflected with correlation coefficients of 0.994 and 0.9989 respectively.

One difference between the Pulp Duplicate and the Duplicate Roll Graphs shown in Figure 1 is the lack of data points for the lower values of Ni, Fe MgO and SiO2. The reason for this is that Figure 1 shows the wider range of elemental results for exploration samples, while Figure 3 shows results from mining samples with cut-off grades of 1.5% Ni reflected in the average saprolite grades of around 1.75% Ni. Similalrly, average saprolite Fe results are around 20%, for MgO an average of 23%, and for SiO2, around 38%.

3.2 Accuracy

Accuracy refers to the component of the measurement error that in replicate measurements remains constant or varies in a predictable manner. It is assessed by using Certified Reference Materials, eg OREAS 193, and by inserting these CRMs into the sample stream, it is possible to assess the performance of the assay lab undertaking the assay work for internal control. When sent to commercial laboratories with Interlaboratory Check samples it allows comparison of the HM Aassay Lab performance against commercial laboratories and assess for any bias.

Accuracy is treated as a qualitative attribute, ie low or lower accuracy, high or higher accuracy, and should not be given a quantitative value. Accuracy is measured through the bias, which is the difference between the expectation of the test results and an accepted reference value. There is an inverse relationship between accuracy and bias, the higher the absolute value of the bias, the lower the accuracy, and vice versa.

3.3 Check Standards, or Certified Reference Materials (CRM's)

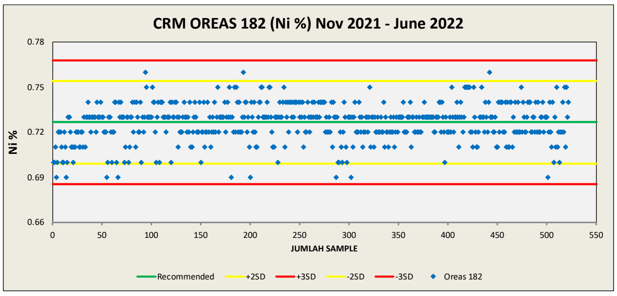
Certified Reference Materials, CRM's, are samples with certified grades, prepared under specially controlled conditions and have a certified mean value for the contained elements in that standard, along with associated confidence and tolerance limits. They are used in Quality Control to monitor the values of the standard against those of the unknown samples being assayed and allow the accuracy of the assay process to be monitored. HM use CRMs produced by OREAS (Ore Research & Exploration P/L, from Victoria, Australia. OREAS CRMs currently used are Standards 182, 187, 192, 193, 194 and 195 with certified Nickel values of 0.707, 1.37, 1.77, 1.93, 2.13 and 2.94 respectively. In addition, these standards have certified standard deviations and state the 95% Confidence and Tolerance Limits with low and high values.

CRMs are generally placed into the sample stream at a frequency of one in 20 samples with mine samples and higher frequency of one in 10 exploration samples, this higher value due to the first sample in each run on the Epsilon 4 and Puma S2 XRF spectrometers being a standard as described in the Standard Operating Procedure.

Figures 4, 5, 6, 7 and 8 are Shewart Control Charts for the results of assays using the OREAS standards 182, 187, 192 and 195 over an eight month period from November 2021 to June 2022. The assay results obtained over a period of time are plotted on a chart of showing certified values against the number of samples assayed, with one line showing the certified mean value, and two green lines showing the expected value plus/minus two standard deviations, also referred to as Upper and Lower Warning Limits, and two red lines representing the Upper and Lower Control Limits at three standard deviations.

Abzalov describes how specific analytical problems have recognizable patterns on certain diagrams , the different distribution patterns of the analytical results being indicative of the error sources and types, being most effective when applied to certified standards such as the OREAS CRM's. Good quality analyses will be characterised by a random distribution points around the certified mean value, with 95% of the data points lying within two standard deviations of the mean. The same number of analyses should fall above and below the mean.

Figure 4: CRM OREAS 182 - 537 Exploration Sample Analyses



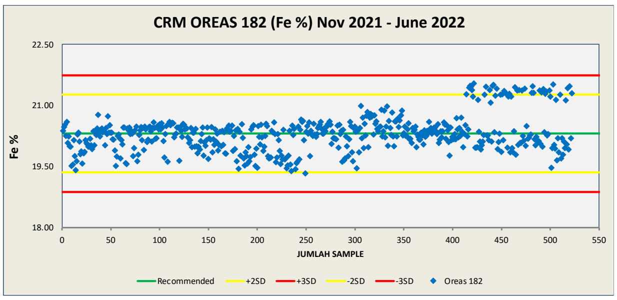


Figure 4, the OREAS Standard 182 shows the results plotting with 95% within two standard deviations of the mean for both Ni and Fe and showing good precision. However, with the Fe graph, the accuracy is not as good on the right hand side of the graph.

Figure 5: CRM OREAS 187 – 582 Exploration Analyses

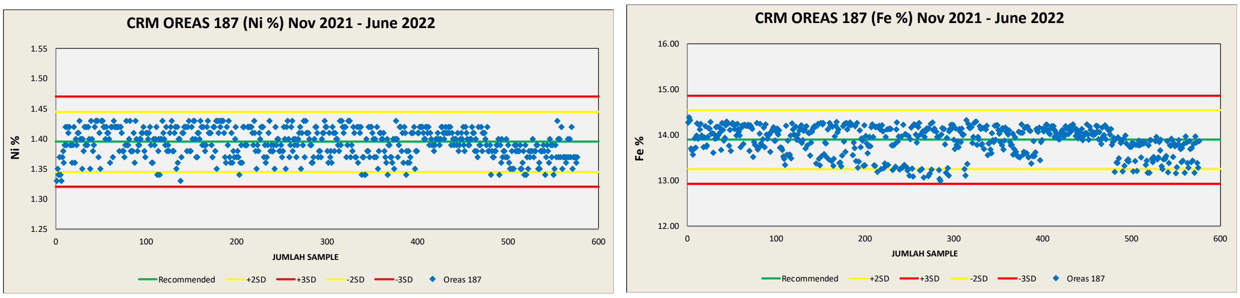


Figure 5 shows the results for 582 exploration samples for Ni and Fe, with both elements showing good precision, 95% of the results plotting within two standard deviations of the mean, and similar numbers of samples above and below the mean. Accuracy in the Fe graph is not as good, with the appearance of more samples below the mean value.

Figure 6: CRM OREAS 192 – 339 Exploration Analyses

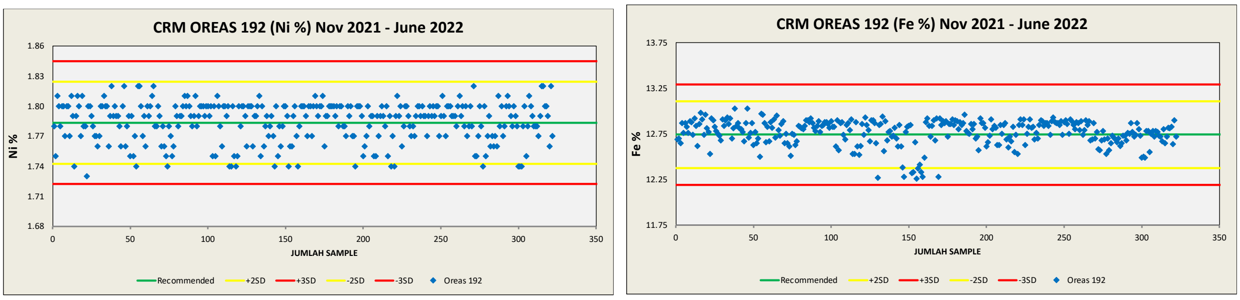


Figure 6 shows good distribution of 339 exploration data results, with 95% of the data points plotting within two standard deviations of the mean, and similar numbers of data points above and below the mean for excellent precision, but the Fe graph shows a number of data points close to the negative -10% warning line which reduces the accuracy in this graph.

Figure 7: CRM OREAS 195 – 193 Exploration Analyses

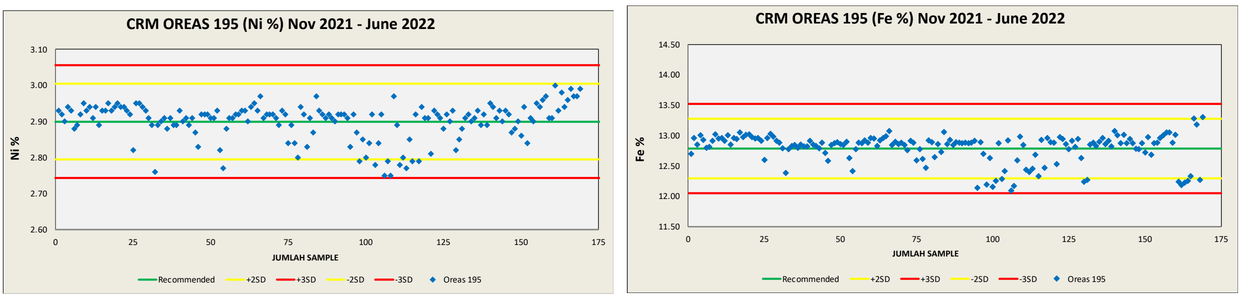


Figure 7 shows a good distribution of the 193 exploration data points with 95% of the results plotting within two standard deviations of the mean for both Ni and Fe, but as with the previous graphs, the accuracy appears to drop around the 100 sample mark for approximately 10 samples which indicates less accuracy.

These graphs show that for the 1,651 exploration samples assayed using 4 different OREAS Laterite Suite CRM's the precision between the original and the CRM values are generally excellent, whilst the accuracy for the Ni is good to excellent whilst for the Fe it is of lower quality.

3.4 Replicate Samples

These are two portions of the same pulp samples that are used to produce two separate pressed pellets or fused beads, that are given different sample numbers before being inserted into the same batch, or Job Sheet. At HM they are taken as part of the standard package of check samples, these being one DA or pulp assay, one DR or coarse reject assay, one REP or replicate sample and one CRM.

Figure 8: Scatterplot showing results of 2,130 plots for original vs replicate assays

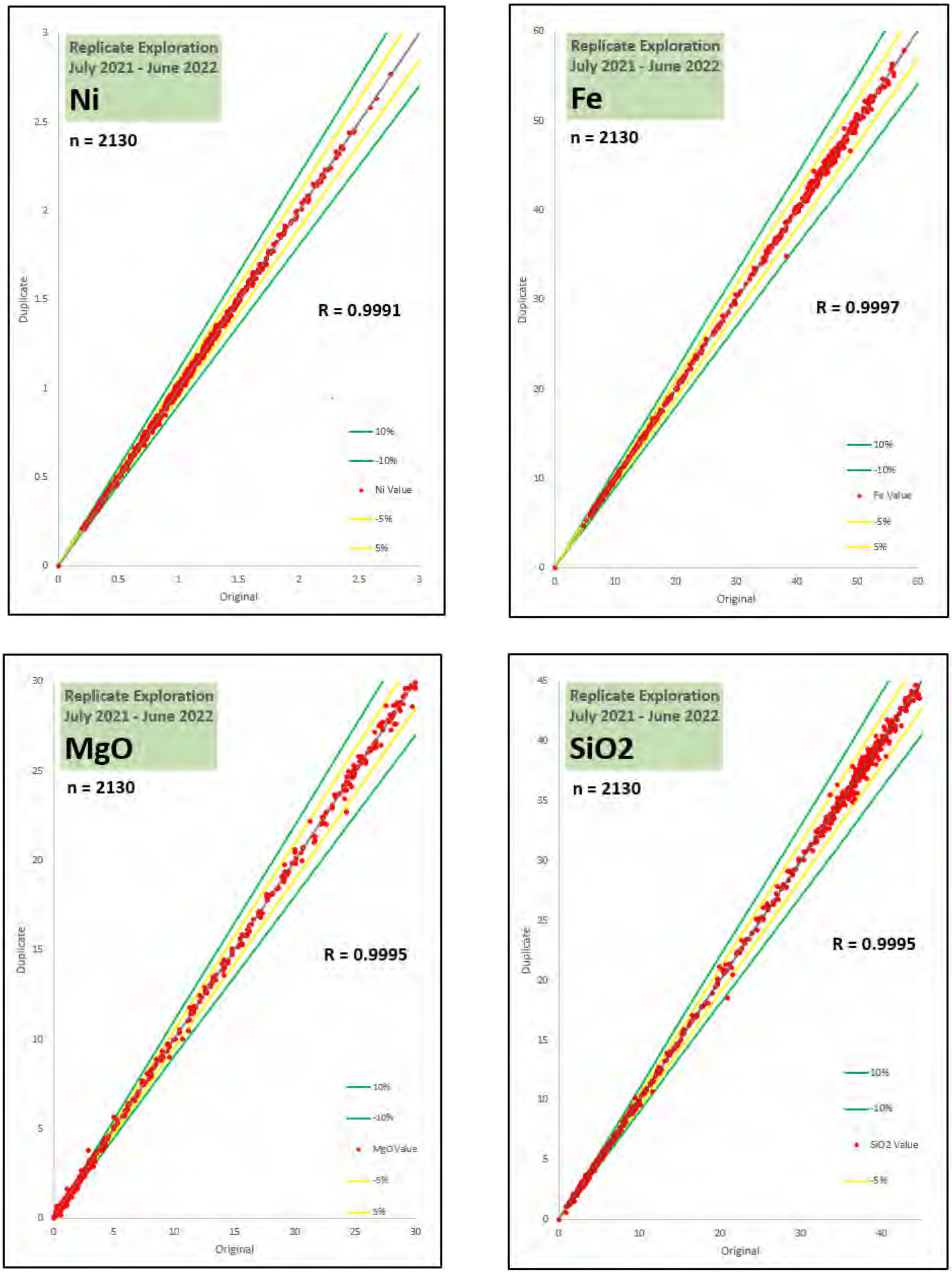


Figure 8 shows scatterplots for 2,130 replicate analyses undertaken between July 2021 and June 2022. The format of the scatterplots is the same as for the previous scatterplots for the Coarse Rejects (DR) and the Pulp Duplicates (DA), with these results showing the wider range in values for the elements due to the samples being tested originating from exploration samples.

The scatterplots for replicate sample assays show the majority of the results plotting within the two yellow lines indicating a 95% confidence in the result plotting withing these limits, and is considered an excellent result. The graphs also show correlation coefficients of more than 0.999, indicating high precision. Spreadsheet data shows there is also an even spread of the replicate assay being both similar to, higher than, and lower than the primary assay in the case of Ni, whilst for Fe, MgO and SiO2 there are slightly more duplicate assays in the Assay<Original category with a corresponding lower figure in the Assay=Original category. This confirms a normal distribution of assay values for these elements and indicates there is little evidence of systematic bias occurring in this replicate check assay programme.

3.5 Interlaboratory Check Samples

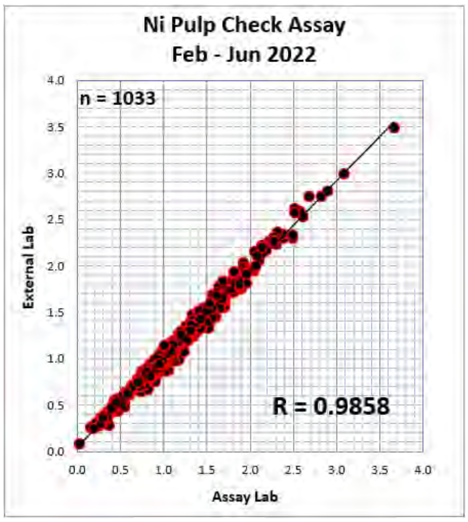
3.5.1 HM Lab vs PT Geoservices Lab

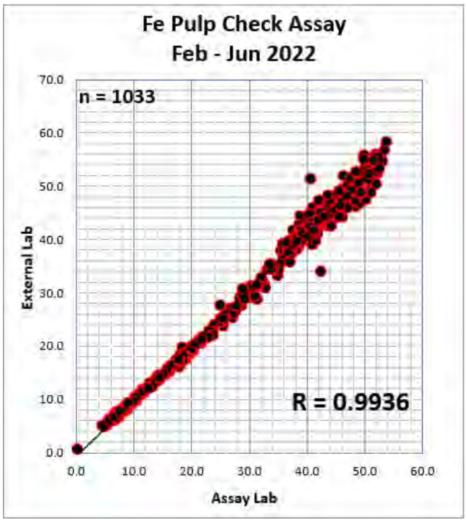
Interlaboratory Check samples are second splits of both the coarse reject samples and the finer 200 # pulp samples that are routinely assayed at the HM Assay Lab and submitted to second, commercial, laboratories under a different sample number. These samples are used to assess the assay accuracy of the HM laboratory relative to the secondary, Geoservices Laboratory.

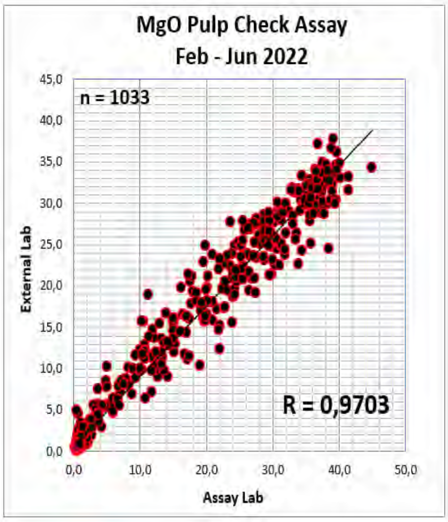
Batches of Exploration samples were sent to the Geoservices Laboratory in Kendari on a periodic basis where the coarse reject samples underwent pulverising and incremental splitting, to be sent off for XRF assay at the Geoservices Analytical Laboratory in Bandung, along with duplicate pulp assay samples. Geoservices then forwarded the HM pulp sample checks to their analytical lab as a different consignment, and once assayed, the results were returned to the Assay Laboratory at the Tangofa site.

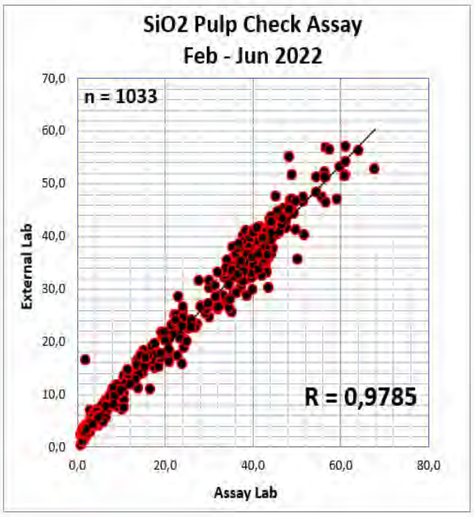
Figure 9 shows the results of the inter laboratory check sample tests comparing the results of 1033 split Exploration coarse reject and 200# pulp samples assayed at the original HM assay laboratory with samples sent to the Gesoservices assay Laboratory in Bandung.

Figure 9: Scatterplot showing results of 1033 plots of HM original vs Geoservices duplicate assays









The scatterplots show differing precision for the different elements, with the best correlation shown between the results for Fe and Ni, 0.9936 and 0.9858 respectively, SiO2 and SiO2 have lower correlations at 0.9785 and 0.9703.

Data for the results for the two laboratories shows a difference between the mean for the Ni and Fe values for the HM Lab as 1.15 % Ni and 27.52 % Fe against 1.13 % Ni and 26.93 % Fe for Geoservices, a difference of 1.74% for Ni and 2.14% for Fe. These represent a +/- 5% variance from the assay, a high precision, and reflected with correlation coefficients of 0.9858 and 0.9936.

These results show lesser precision than was the case with the internal checks using Coarse Rejects, Pulp Assays and Replicate Assays at the HM Lab. This indicates the difference is likely to be due to different sample processing procedures at the two laboratories, and different accuracies and precision due to different equipment. There is a difference between the pressed powder pellets used at the HM Lab with the Fused Bead system used at Geoservices. Similalrly, the HM Assay Lab uses a Malvern Panalytical Epsilon 4 XRF and a Buker Puma S2 XRF that was brought into operation in 2021 and any differences between these XRF Units and those used at Geoservices could result in small differences being recorded.

3.5.2 Comparison PT HM Assay Lab vs IMIP Smelter Results

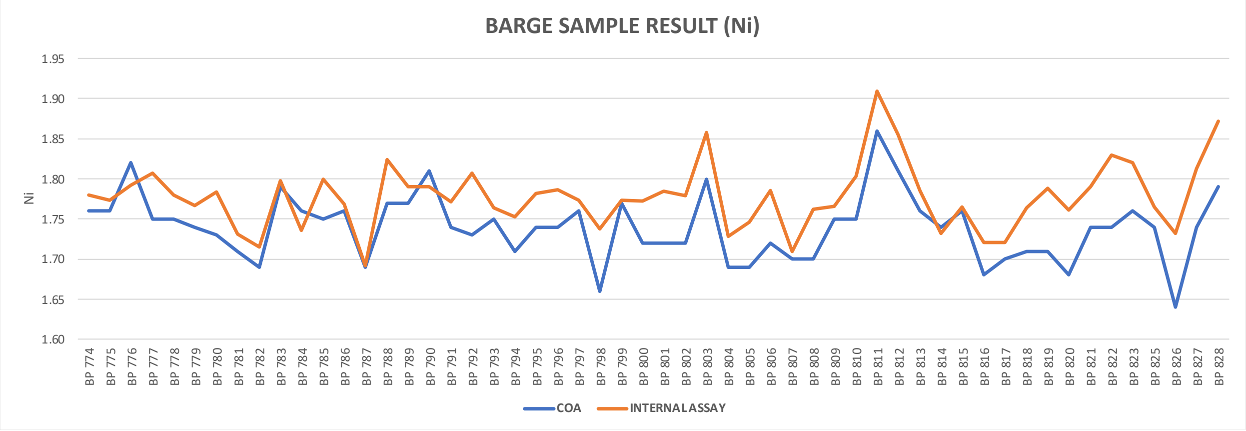
When the barges carrying ore from the HM Jetty to the IMIP smelter arrive, samples are collected from the saprolite ore and assayed at the IMIP facility. These results are used to determine the price paid for the nickel laterite ore. These results are provided in a Certificate of Assay (COA) and Certificate of Quality by PT Intertek Utama Services, Indonesia.

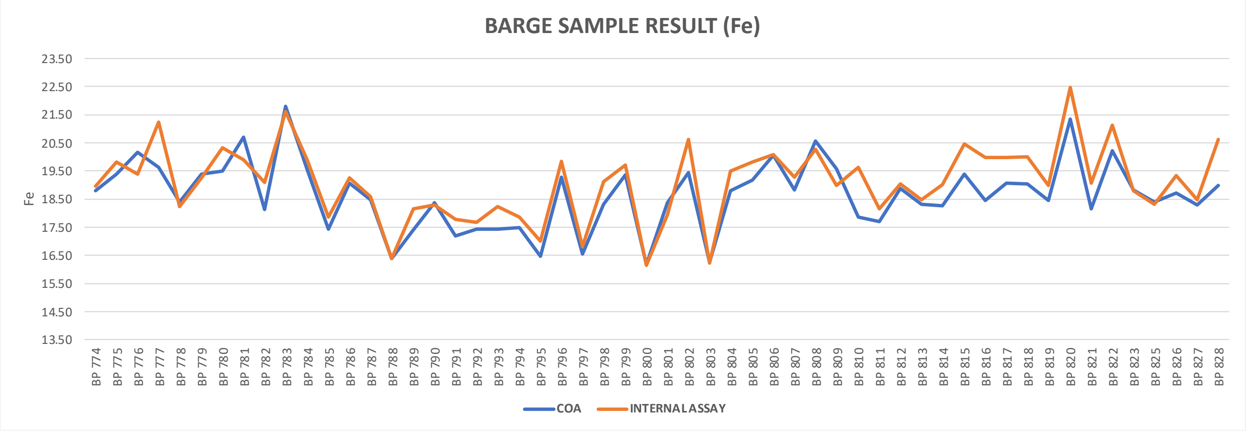
Figure 10 shows graphics of the plots of the Ni and Fe results from the HM Assay Lab and the IMIP COA for 54 samples from barge numbers BP 774 and BP 828 which delivered saprolite ore from the HM Mining Operations to the IMIP Smelter between May 2022 and July 2022.

These graphs represent HM assay results with means of 1.78% Ni and 19.10 % Fe, standard deviations of 0.04 and 1.30, and variances of 0.0016 and 1.6834 respectively. Similar results of 1.74% Ni and 18.66% Fe, standard deviations of 0.04 and 1.20, and variances of 0.0017 and 1.4441 were recorded on the IMIP COA's. Interestingly, the difference between the two sets of data shows a mean difference of 0.04, or 2.2% for the Ni values, with 50 of the 54 COA values being less than the HM assay values. With the Fe values, there is a 2.3% difference between the HM and COA values, with 41 of the 54 COA's returning lower values than HM.

The consistency of results from these 54 samples is interesting, and as before, can be the result of sample processing differences, eg pressed pellet vs fused bead, different equipment and calibration issues. The other problem is the hygroscopic nature of nickel ore, and how the increase in moisture content of the saprolite between leaving the HM stockpiles and being fed into the smelter is likely to result in differences in the Ni values, and may explain the variation between the Ni and Fe graphs.

Figure 10: Graphic showing results of 54 saprolite samples assayed at HM and IMIP Smelter





4. Control Sample Insertion Rates

HM operates a quality control programme at its Tangofa Laboratories where different types and sub-types of control samples are inserted into the sample stream in order to monitor precision, accuracy and possible contamination at the different stages in the sampling, sample preparation and sample assaying sequence.

Sample collection is usually controlled through the use of twin samples and field duplicates, but due to all the Jackro triple barrel drill core being sent for sample preparation and assay, these control samples are not sent for checking.

Sample preparation is controlled through the use of coarse blanks, coarse rejects (DR) and 200# particle sizing tests at the HM Prep Lab.

Sample assay is controlled through the use of pulp duplicates (DA), CRM's, Replicate samples and Interlaboratory check samples.

Mendez (2011) described the frequency of control samples using information from International QA/QC consultants, Exploration and Mining Companies, various authors and the Toronto Stock Exchange and found that a figure of 20% (1 in 5) of the total samples assayed comprise control samples of various types.

During the period July 2021 to June 2022 a total of 50,102 exploration samples were processed at the HM Sample Prep and Assay Labs. The following check samples were added into this original sample stream:

Table 1:
Exploration Control Sample Insertion Rates
July 2021 - June 2022

Period	Exploration	Coarse Rejects/DR		Pulp Duplicates/DA		Replicates		CRM's		Interlab Checks	
	Samples	No.	%	No.	%	No.	%	No.	%	Checks	%
May - July 2022	50,102	1,020	2.0%	1,110	2.2%	2,130	4.2%	1,997	4.0%	1,951	3.9%

The Coarse Reject and Pulp Duplicate samples comprise 2.0% and 2.2% of the samples submitted. These figures correspond to those proposed by Mendez, of 2% and 2% respectively.

Replicate samples and CRMs comprise 4.2% and 3.98% respectively of the samples submitted. Although Mendez does not appear to specifically include replicates, this figure of 4.2% allows an additional measurement of the Assay Quality at the HM labs, and is due to two replicate samples being inserted into the sample stream instead of the one coarse reject and one pulp duplicate sample per batch.

The differences between the % of check samples proposed by Mendez, 1 in 5, or 20%, and the 12.5% at HM is due to the lack of Twin Samples collected at the sample collection stage, 2%, because the whole drill core is sent for sample preparation and assay, and a further 2% by way of pulp blanks are also not collected at HM. With 4% of the samples being CRM's this is less than the 6% CRM's suggested by Mendez, but 1,951 Interlaboratory Check samples were sent for assay at Geoservices, 3.9% of the total exploration samples, and in line with the 4% suggested by Mendez.

In summary, a total of 8,208 check samples were inserted into the sample stream of 50,102 exploration samples and submitted for assay ay the Geoservices Assay Laboratory, a total of 16.4% as compared to the 20% suggested by Mendez.

5.Review, Reporting and Continuous Improvement

This section covers three aspects of of the activities undertaken at the QAQC Department thatdeserve a mention.

The Review section is similar to the Acceptance Testing that Sterk discusses, and which he believes should accompany each QA and QC stage in the sample collection, preparation and analysis stages of the sample processing stream. At present, the HM QC team undertake the following:

- Receive printout of assay results for the batches/consignments of exploration samples.
- Check results to confirm check samples inserted into sample stream by HM staff/client.
- Identify check samples and compare CRM results with original results to confirm acceptable precision and accuracy, and present to Supervisor to confirm acceptability of results, and whether or not samples need to be re-assayed in the event of contamination, bias or poor precision.
- If CRM results not acceptable, the analyst and Foreman will consult and clean the Tube Filter and repeat the analysis. If the next analysis is in order the sample assaying will continue.
- If the repeat assay is not acceptable, the next assay will be conducted with a different CRM. If this assay produces an acceptable result, the assay sampling will continue. If this assay produces an unacceptable result, the Supervisor will inform the Lab Superintendent and the Supervisor will undertake recalibration of the unit.
- Lab Foreman then decides and approves circulation of results internally.
- Lab Superintendent decides and approves results going out to client.
- Lab Foream decides and approves entry of sample results data onto HM database.
- Lab Supervisor checks and confirms data entry is correct and in order.

In addressing any issues with Interlaboratory Check Samples, Sterk emphasises the importance of communicating with the commercial laboratory which undertook the assaying of check samples, and discussing what may have caused any serious differences in precision or accuracy.

Reporting of the analysis of the Quaity Control samples is continual, ongoing process and the HM QAQC Department issues a Monthly Report detailing the activities of the department for each calendar month. Sections covered in the QAQC Laboratory Monthly Report for June 2022 are:

- Health & Safety – Near Miss Report
- Accident Report
- Radiation Accident Report
- Preparation Lab Production Report
- Assay Lab Production Report
- Sample Type Statistics
- Monthly Sample Split eg Mining, Exploration, Barging, QAQC
- Quality Control – Sieving Test
- Precision
- Accuracy
- CRM’s
- InterLaboratory Check Samples
- Personnel
- Planning, Implementation and Constraints
- Photos

Continuous Improvement is an ongoing procedure that is necessary to maintain the quality of the sample preparation and assay at the HM Laboratories in response to the increase in production at the PT HM Tangofa Mine, from 75,000 wmt per month during 2019 to 300,000 wmt per month in June 2022. Accompanying this three fold increase in the production of saprolite ore, Nickel Industries is now commencing the mining of limonite to feed an HAPAL Plant at IMIP to produce batteries for electric vehicles in Sulawesi. This increase in production has seen a corresponding increase in the staffing levels at the Sample Prep and Assay laboratories, as well as the purchase of additional equipment to meet the increased production with upgrading the equipment at the sample prep lab, the assay lab and associated storage.Nickel Industries have signed MOU’s and other agreements in order to acquire additional resources to provide additional feedstock for additional RKEF lines at IMIP at Morowali and IWIP at Halmahera.

To meet the challenges of the increased production and implementation of additional technologies and equipment to handle these increases it will be important to upgrade the skill sets of the staff to ensure that the increase in production will see a corresponding increase in the quality of the data generated at the labs, and continue to seek higher standards of precision and accuracy through improved techniques.

Current international standards for the reporting of exploration and mining results, such as JORC Code 2012 and Canadian NI43-101, require that a programme of data verification is included with any exploration programme to confirm the validity of the exploration data, and this is normally done by inclusion of JORC Code , 2012 Edition – Table 1 Report Template, a copy of which is attached as Table 2.

6. Conclusions

This report has been submitted as part of a JORC Code 2012 Edition Compliant report following the guiding principles of Transparency, Materiality and Competence with the author providing details of the QAQC activities at the HM operations at their Tangofa Camp.

The purpose of Quality Assurance and Quality Control is to determine the quantity and concentration of Ni and Fe and associated lateritic nickel elements and provide confidence in the numbers to allow us to use these numbers in resource estimation, and ensuring that the data we are going to collect and the data we are collecting are of suitable quality. Quality Assurance is about the prevention of errors occurring before the sampling or measurement and Quality Control is about the detection/correction of errors as they occur during the sampling or measurement process (Sterk, 2019).

The Standard Operating Procedure (SOP) for the samples submitted by the exploration and mining operations at PT HM is the "JIS Method for Sampling and Method of Determination of Moisture Content of Garnierite Nickel Ore" JIS M-8109-1996, by H.Kanazawa, August 1996. Other SOP's are added as new equipment and technologies are introduced into the Sample Prep and Sample Assay Labs.

Descriptions of the various splitting, drying, crushing and pulverising stages are given and what check samples are collected from and introduced into the sample stream at those times. This is where *"…the reduction in particle size, through crushing and pulverising, and its sample size, through splitting, while retaining the representativeness of the medium being sampled"* is our mantra.

Sample preparation quality is measured using Coarse Blanks, Coarse Rejects/Coarse Duolicates and Sample Sizing Tests: Figure 1 shows plots for the four elements with the majority of the data points plotting between the +5% and -5% yellow lines, showing there is a high correlation between the original and the duplicate assay values, with correlation coefficient (R^2) values of > 0.999 for the elements being assayed. These figures confirm the high precision of the jaw crushing, the first splitting and roll crushing stages and supports the use of the Coarse Duplicate assay data for resource estimation purposes.

Figure 2 shows two graphs showing the results of the particle sizing tests undertaken on 111 exploration samples and 104 mining samples at the HM Prep Lab during March 2022. The yellow line is for 95% of the pulverised material passing the 200# screen, and shows the majority of the samples returning a figure of between 97% and 98% for both the exploration samples and the mining samples. These results show the repeatability precision of the pulverizing process in reducing the particle size of the samples to be high.

Sample assay quality is measured using Pulp Duplicate/DA's, CRM's, Replicates and Inter Laboratory Checks. Figure 3 shows scatterplots for the elements Ni, Fe, MgO and SiO2 from original and duplicate assays from 1,396 pulp samples analysed between July 2021 and June 2022. The scatterplots show the majority of the Ni and Fe falling within the two yellow lines representing a +/- 5% variance from the assay, a high precision, and reflected with correlation coefficients of 0.994 and 0.9989 respectively.

Figures 4, 5, 6 and 7 are Shewart Control Charts for the results of assays undertaken using OREAS Standards 18, 187, 192 and 195 for Ni and Fe. They show the data points falling within the 2 SD and 3 SD lines, with generally 95% of the Ni and Fe assays falling within 2 standard deviations of the mean, and similar numbers of assays faling above and below the mean line, indicating good precision and accuracy. The results for Fe also show good precision, but the accuracy is not as good for some of the Fe assay results, where we believe some calibration issues occurred following the installation of a new XRF machine.

Figure 8 shows scatterplots for replicate sample assays show the majority of the results plotting within the two yellow lines indicating a 95% confidence in the result plotting withing these limits, and is considered an excellent result. The graphs also show correlation coefficients of more than 0.999, indicating high precision. Spreadsheet data shows there is also an even spread of the replicate assay being both similar to, higher than, and lower than the primary assay for Ni, an excellent result.

Figure 9 shows the results of Inter Laboratory checks between HM Assay Lab and Geoservices.The scatterplots show excellent precision for Ni and good precision for Fe, with the best correlation shown between the results for Fe and Ni, 0.9936 and 0.9858 respectively, SiO2 and SiO2 have lower correlations at 0.9785 and 0.9703.Data for the results for the two laboratories shows a difference between the mean for the Ni and Fe values for the HM Lab as 1.15 % Ni and 27.52 % Fe against 1.13 % Ni and 26.93 % Fe for Geoservices, a difference of 1.74% for Ni and 2.14% for Fe. These represent a +/- 5% variance from the assay, a high precision, and reflected with correlation coefficients of 0.9858 and 0.9936.

Figure 10 shows graphics of the plots of the Ni and Fe results from the HM Assay Lab and the IMIP COA for 54 samples from barge numbers BP 774 and BP 828 which delivered saprolite ore from the HM Mining Operations to the IMIP Smelter between May 2022 and July 2022.These graphs represent HM assay results with means of 1.78% Ni and 19.10 % Fe, standard deviations of 0.04 and 1.30, and variances of 0.0016 and 1.6834 respectively. Similar results of 1.74% Ni and 18.66% Fe, standard deviations of 0.04 and 1.20, and variances of 0.0017 and 1.4441 were recorded on the IMIP COA's. Interestingly, the difference between the two sets of data shows a mean difference of 0.04, or 2.2% for the Ni values, with 50 of the 54 COA values being less than the HM assay values. With the Fe values, there is a 2.3% difference between the HM and COA values, with 41 of the 54 COA's returning lower values than HM.

Table 1. is a summary showing a total of 8,208 check samples were inserted into the sample stream of 50,102 exploration samples and submitted for assay ay the Geoservices Assay Laboratory, a total of 16.4% as compared to the 20% suggested by Mendez. The difference is due to the lack of Twin Samples from the drill site, due to the complete drill core being submitted for sample prep and assay, and 4% CRM's as opposed to the 6% suggested by Mendez.

It was suggested that data with "good" accuracy and "good" precision can be regarded as "Good Quality" and as such, will be "fit for purpose" when the precision and accuracy are within acceptable tolerances. It is the author's belief that the Quality Assurance and Quality Control team at the HM Sample Prep Lab and Assay Lab have shown in the work described in this report that the data generated from the labs is of Good Quality and Fit for Purpose, with the precision and accuracy within acceptable limits and is suitable for inclusion in the calculation of mineral resources for the JORC Compliant Report for PT Hengjaya Mineralindo.

Charles Watson
24th August 2022

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C.E.Watson
August 2022

Table 2: JORC Table 1 - Sample Prep & Assay

Criteria	JORC Code explanation	Commentary
	• *Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography.* • *The total length and percentage of the relevant intersections logged.*	
Sub-sampling techniques and sample preparation	• *If core, whether cut or sawn and whether quarter, half or all core taken.* • *If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry.* • *For all sample types, the nature, quality and appropriateness of the sample preparation technique.* • *Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.* • *Measures taken to ensure that the sampling is representative of the in situ material collected, including for instance results for field duplicate/second-half sampling.* • *Whether sample sizes are appropriate to the grain size of the material being sampled.*	• With the exception of a small density sample of approximately 700 to 800 gms taken from each of the four geological horizons observed in each drill hole, all the drill core submitted to the lab for analysis • Reduction in size of large primary drill sample to small pulp sample used in pressed powder pellet for XRF assay without affecting accuracy or precision follows JIS Method for Sampling and Method of Determination of Moisture Content of Garnierite Nickel Ore, JIS M-8109-1996,with drill core submitted to HM Prep Lab where it is dried for 12 hrs at 105 °C and then crushed, riffle split, crushed again, split and pulverized to a particle size that corresponds to 95% passing 75 micron Test Screen. Pulp samples of approx. 50 gms are taken from the pulverized samples for assay. Coarse reject and pulp duplicates taken after splitting to monitor precision of products; 200# Screen tests indicate precision of pulverising in reducing sample size is high.
Quality of assay data and laboratory tests	• *The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total.* • *For geophysical tools, spectrometers, handheld XRF instruments, etc, the parameters used in determining the analysis including instrument make and model, reading times, calibrations factors applied and their derivation, etc.* • *Nature of quality control procedures adopted (eg standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie lack of bias) and precision have been established.*	• Assaying and lab procedures follow JIS M-8109-1996 SOP to ensure representivity of the sample presented for XRF analysis. Pressed pellets comprising 10 gm sample pulp used for assay using Bruker and Panalytical EDXRF Spectrometers to determine 12 most important elements in Nickel laterite ores. XRF the preferred assay method for nickel laterite ores, capable of very high degree of accuracy and precision. • No field duplicates are submitted as all sample core submitted for sample prep and assay. • Sub-sampling precision and contamination controlled during sample preparation with coarse blanks, coarse rejects and 200# screen tests. • Sub-sampling analytical accuracy, analytical precision and contamination during assaying controlled by pulp duplicates, OREAS CRM's, replicates and checks by external laboratories. • Scatterplots and comparative statistics for coarse rejects confirm high precision of crushing & splitting stages and 200# screen tests show repeatability of pulverising stages to be high. • Scatterplots and comparative statistics for pulp duplicate assays and replicate assays confirm high precision repeatability and no systemic bias in these check analyses programmes.

		• OREAS CRM's 182, 187,192, 193 and 194 yielded Control charts with high precision but less accuracy, and with 95% of analyses plotting within 2 standard deviations of the mean which is acceptable. • Check samples sent to Geoservices for Interlab Checks showed a high correlation between the results for Ni and Fe, with differences of 1.74% for Ni and 2.14% for Fe between the two labs, an approx. 5% variance from the assay.
Verification of sampling and	• *The verification of significant intersections by either independent or alternative company personnel.* • *The use of twinned holes.*	

Appendix 6

Hengjaya Geotechnical & Hydrogeological Report

KAJIAN GEOTEKNIK DAN HIDROLOGI/HIDROGEOLOGI DEPOSIT NIKEL TAMBANG HENGJAYA MINERALINDO

PT. HENGJAYA MINERALINDO

Disiapkan Untuk

PT HENGJAYA MINERALINDO

Desember 2021

GEOMINE
MINING AND GEOTECHNICAL CONSULTANT

DAFTAR ISI

DAFTAR GAMBAR

DAFTAR TABEL

LAMPIRAN

EXECUTIVE SUMMARY

PT Hengjaya Mineralindo ("HM") saat ini sedang melakukan pengkinian terhadap laporan Studi Kelayakan terkait dengan rencana untuk melakukan peningkatan kapasitas produksi nikel dan untuk pengembangan area tambang. Untuk mendukung pengkinian studi tersebut, salah satu aspek yang diidentifikasi memerlukan studi lanjutan adalah kajian yang terkait geoteknik dan hidrologi/hidrogeologi. Untuk keperluan tersebut HM telah meminta Geomine Mining and Geotechnical Consultant ("GEOMINE") untuk melakukan kajian geoteknik dan hidrologi/hidrogeologi. Laporan ini menampilkan data-data yang dikumpulkan, analisis dan hasil kajian geoteknik dan hidrologi/hidrogeologi, serta rekomendasi terkait kedua kajian tersebut.

Kajian Hidrologi dan Hidrogeologi

Berdasarkan hasil interpretasi kondisi hidrogeologi di PT Hengjaya Mineralindo diketahui bahwa lapisan penyusun hidrostratigrafi sistem airtanah ini dibagi menjadi tiga, yaitu tanah laterit berukuran lempung (laterit atas), laterit bawah dan batuan ultramafik terkekarkan, serta batuan ultramafik tidak terkekarkan. Lapisan yang membentuk zona akuifer utama pada sistem airtanah ini adalah laterit bawah dan batuan ultramafik terkekarkan. Lapisan laterit bawah dan batuan ultramafik terkekarkan dikelompokkan menjadi satu zona akuifer utama dengan ketebalan berkisar 10-30 m. Tanah laterit berukuran lempung (limonit) berfungsi sebagai lapisan akuiklud. Lapisan batuan ultramafik yang tidak terkekarkan bertindak sebagai lapisan akuifug, diasumsikan kontinu hingga ketebalan lebih dari 100 meter.

Kebutuhan data untuk keperluan muka airtanah dan konduktivitas hidraulik dianggap telah memenuhi kebutuhan data minimal untuk analisis, data tersebut didapatkan dari pengukuran lapangan pada sembilan lubang bor geoteknik dan dari data-data yang dikumpulkan pada lubang eksplorasi dan sumber referensi lainnya untuk daerah tersebut.

Berdasarkan model prediksi, didapatkan hasil estimasi *groundwater inflow* pada tahun pertama sebesar 22.19 liter/detik dan berangsur turun menuju garis konstan (*steady*) di sekitar 19.00 liter/detik pada tahun-tahun berikutnya. Debit *groundwater inflow* secara umum cenderung kecil karena posisi muka airtanah yang relatif telah turun, sehingga sedikit yang berpotongan dengan bukaan tambang.

Rekomendasi teknis terkait rencana penyaliran meliputi desain saluran drainase, sump dan pemompaan, serta sediment pond telah diberikan di dalam laporan ini.

Kajian Geoteknik

Pengumpulan data properties material HM dilakukan melalui logging geoteknik terhadap core-core dari sembilan lubang pengeboran geoteknik dan hasil pengujian sifat fisik dan mekanik. Validasi terhadap properties menggunakan geometri aktual dan analisis balik menggunakan indikasi ketidakstabilan dilakukan untuk menentukan properties yang merepresentasikan karakteristik domain geoteknik di area HM.

Analisis kestabilan lereng tunggal menunjukkan mayoritas geometri lereng tunggal memenuhi kriteria Faktor Keamanan minimum terutama untuk domain *saprolite* dan *bedrock*. Untuk domain *limonite* tinggi jenjang 3 meter dengan kondisi *saturated* memenuhi kriteria, namun untuk tinggi jenjang 5 meter perlu berada pada kondisi *dry* untuk dapat memenuhi kriteria.

Analisa kestabilan lereng keseluruhan menunjukkan *design* akhir *pit* PT Hengjaya Mineralindo telah memenuhi kriteria dan menunjukkan kondisi yang stabil dengan nilai Faktor Keamanan (FK) di atas 1.3 untuk kondisi statik dan di atas 1.05, kecuali pada Sec_KK' yang berlokasi di Central East. Hasil analisis pada Sec_KK' menunjukkan nilai FK dan PoF berada di bawah batas kriteria minimum dan menunjukkan kondisi *marginally stable*. Untuk membuat kondisi *stable* pada Sec_KK perlu dilakukan pelandaian sudut *overall* menjadi 29° atau penurunan muka air tanah sedalam 6 m dengan pemasangan *drain hole*.

Analisis kestabilan lereng juga dilakukan pada waste dump yang berlokasi di Bete-bete (titik bor geoteknik DHG-02). Berdasarkan kondisi *waste dump* aktual di area DHG-02 yang terpantau mengalami ketidakstabilan, dilakukan analisis balik untuk mendapatkan properties material *waste* yang sedekat mungkin untuk merepresentasikan kondisi aktual yang diamati dan dapat digunakan dalam analisis selanjutnya. Hasil analisis balik terhadap properties *waste* menghasilkan properties *waste* pada Tabel A. Dengan properties *waste* dari hasil analisis balik, untuk menjaga kestabilan lereng pada area *waste dump*, perlu dilakukan penurunan sudut *overall* sekitar 2° dari kondisi aktual untuk memperoleh nilai FK yang sesuai dengan ketentuan. Sudut *overall slope* yang menunjukkan nilai FK aman adalah sebesar 18° dengan tinggi 33 m.

Tabel A Properties Material Hasil Analisis Balik

Litologi	*Unit Weight* (kN/m³)	Mohr Coloumb	
		C (KPa)	Phi (Degree)
Limonite	18.77	11	27
Saprolite	20.21	61	18
Bedrock	26.71	217	35
Waste	21.9	9	20

Analisis kemampugalian dan kemampugaruan dilakukan pada masing-masing domain berdasarkan data parameter nilai kuat tekan batuan dan spasi kekar yang di-*plot* ke dalam grafik Pettifer-Fookes. Dari grafik dapat disimpulkan bahwa karakteristik setiap domain terdistribusi dalam kategori yang relatif homogen sehingga perlakuan penggalian atau penggaruan juga relatif sama untuk masing-masing domain tersebut seperti pada Tabel B.

Tabel B Kemampugalian dan Kemampugaruan per Litologi

Litologi	Metode
Limonite	*Easy Digging*
Saprolite	*Hard Digging*
Bedrock	*Easy-Hard Ripping*

1. PENDAHULUAN

1.1. Latar Belakang

PT Hengjaya Mineralindo ("HM") merupakan salah satu perusahaan yang bergerak di bidang usaha pertambangan nikel laterit di Morowali, Sulawesi Tengah. HM telah melakukan kegiatan penambangan nikel dengan sistem tambang terbuka (open pit mining) sejak tahun 2011.

Saat ini HM sedang melakukan pengkinian terhadap laporan Studi Kelayakan terkait dengan rencana untuk melakukan peningkatan kapasitas produksi nikel dan untuk pengembangan area tambang. Untuk mendukung pengkinian studi tersebut, salah satu aspek yang diidentifikasi memerlukan studi lanjutan adalah kajian yang terkait geoteknik dan hidrologi/hidrogeologi.

Untuk keperluan tersebut HM telah meminta Geomine Mining and Geotechnical Consultant ("GEOMINE") untuk melakukan kajian geoteknik dan hidrologi/hidrogeologi. Laporan ini menampilkan data-data yang dikumpulkan, analisis dan hasil kajian geoteknik dan hidrologi/hidrogeologi, serta rekomendasi terkait kedua kajian tersebut.

1.2. Lingkup Kerja

Ruang lingkup kerja adalah melakukan kajian geoteknik dan kajian hidrologi/hidrogeologi untuk deposit nikel PT Hengjaya Mineralindo.

1.3. Metode Kerja

1.3.1. Kajian Geoteknik

Keperluan kajian geoteknik ini adalah untuk melakukan karakterisasi terhadap massa batuan, melakukan analisa kestabilan terhadap lereng pit dan waste dump, mengidentifikasi resiko dan memberikan saran/rekomendasi terhadap desain tambang. Kajian geoteknik akan dilakukan melalui tahapan berikut:

- **Studi Literatur**

  Studi literatur dilakukan terhadap laporan-laporan dan data yang ada sebelumnya termasuk studi geologi, model geologi dan struktur, rencana tambang, dan data dari program pemboran yang sudah dilakukan.

- **Planning Pengeboran/Pengumpulan Data Lapangan untuk Karakterisasi Massa Batuan**

  Planning pengeboran geoteknik dan pengumpulan data lapangan akan dilakukan berdasarkan lokasi yang akan disepakati antara GEOMINE dan HM. Rekomendasi pengeboran geoteknik dilakukan di beberapa titik yang berlokasi di sekitar area rencana pit PT Hengjaya Mineralindo untuk mengetahui karakteristik material yang ada. Pemilihan titik bor tersebut disesuaikan dengan rencana pengeboran eksplorasi yang akan dilakukan oleh PT HM, rencana penambangan 5 tahun ke depan, lokasi *waste dump* dan area IPPKH tahap III, dengan pertimbangkan titik bor meng-cover domain dan seluruh area tambang.

- **Standard Penetration Test (SPT)**

  Standard Penetration Test (SPT) bertujuan untuk mendapatkan nilai N-SPT, yang dapat memberikan nilai densitas relatif dari granular material yang secara virtual sulit didapatkan dari sampel undisturbed. SPT perlu dilakukan apabila kondisi material pada waste dump terdiri dari kombinasi boulder dan rock. Apabila material waste dump cenderung kepada soil dan limonit, maka hanya perlu dilakukan pengambilan sampel untuk di uji laboratorium.

- **Uji Geoteknik di Laboratorium**

  Kebutuhan uji geoteknik terhadap sampel coring akan dipilih untuk memberikan gambaran yang cukup mengenai properti dari masing-masing domain. Domain dalam geoteknik didefinisikan sebagai batuan yang mempunyai karakter atau behavior yang sama. Umumnya di deposit nikel, domain ini dikontrol oleh tipe deposit limonit, saprolite, dan bedrock.

- **Analisa Kestabilan Pit dan Waste Dump**

  Analisa kestabilan dilakukan dengan mempertimbangkan properti dari masing-masing domain dan dilakukan terhadap existing pit dan waste dump plan dan geometri.

Nilai kekuatan *rockmass* dari masing-masing domain akan diestimasi berdasarkan (i) evaluasi hasil data uji laboratorium, (ii) evaluasi data karakterisasi dari lapangan dan (iii) analisa balik terhadap pit atau waste dump failure yang pernah terjadi. Analisa akan dilakukan mengacu kepada Kepmen ESDM No 1827.k/30/MEM/2018. Final rekomendasi untuk pit dan waste dump geometri akan dihasilkan.

1.3.2. Kajian Hidrologi/Hidrogeologi

Kajian hidrologi/hidrogeologi dilakukan dengan tujuan sebagai berikut:

- Merangkum pemahaman mengenai kondisi dan karakteristik hidrologi-hidrogeologi di lokasi studi, berdasarkan data-data studi terdahulu.
- Memprediksi potensi jumlah aliran air permukaan dan aliran air tanah yang masuk ke dalam tambang, serta yang mempengaruhi area sekitar tambang.
- Memprediksi perubahan sistem air permukaan dan airtanah yang disebabkan oleh proses penambangan.

Perencanaan dan Pengumpulan Data

Melakukan pengumpulan data-data yang dibutuhkan terkait studi, berdasarkan data dari penelitian sebelumnya dan data lain yang tersedia, dan melakukan analisis kesenjangan terhadap kebutuhan dan keterbatasan data. Jika terdapat kekurangan data utama yang diperlukan untuk analisis, rekomendasi pengambilan data dan atau pengujian akan disarankan.

Analisis Hidrologi Air Permukaan

- Mendeskripsikan kondisi dan karakteristik hidrologi daerah studi dan sekitarnya berdasarkan data-data studi terdahulu dan data lapangan.
- Melakukan analisis perubahan sistem dan pola air permukaan akibat kegiatan penambangan yang direncanakan.
- Melakukan analisis debit puncak air permukaan yang mungkin mempengaruhi rencana tambang, dan area sekitar tambang, serta dampak yang mungkin disebabkan.

Analisis Hidrogeologi

- Mendeskripsikan kondisi dan karakteristik hidrogeologi daerah studi dan sekitarnya berdasarkan data-data terdahulu dan data lapangan.

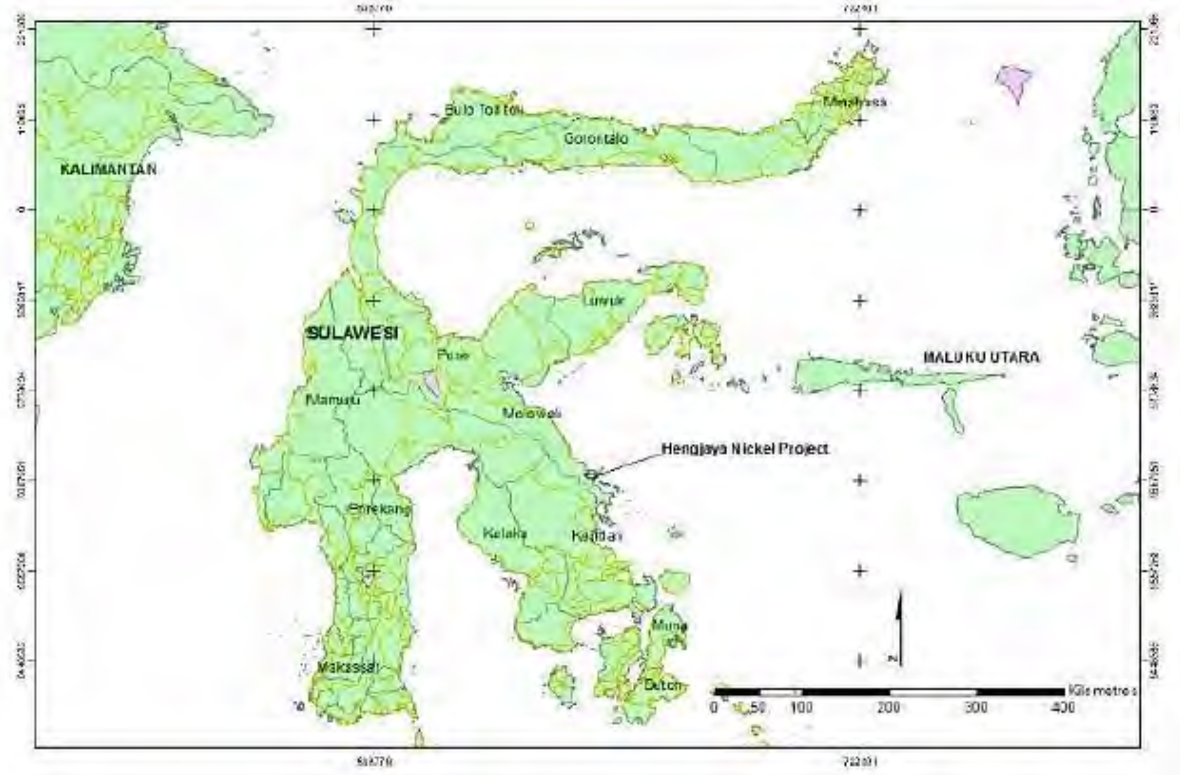
- Membuat model konseptual dan model numerik dari kondisi hidrogeologi dan aliran air tanah di sekitar lokasi studi.
- Melakukan analisis perubahan sistem dan pola airtanah akibat kegiatan penambangan yang direncanakan berdasarkan model hidrogeologi dan air tanah.
- Melakukan analisis debit maksimum airtanah yang mungkin masuk ke dalam tambang, dan area sekitar tambang berdasarkan model hidrogeologi dan air tanah.

Penulisan Laporan dan Rekomendasi

- Memberikan rekomendasi teknis terkait aspek hidrologi dan hidrogeologi berdasarkan hasil analisis yang dilakukan.

1.4. Kesampaian Lokasi

Area penambangan milik PT Hengjaya Mineralindo berada di Desa Tangofa Kecamatan Bungku Pesisir dan Desa Bete – Bete Kecamatan Bahodopi Kabupaten Morowali, Provinsi Sulawesi Tengah dimana untuk menuju lokasi konsesi ini di tempuh dengan menggunakan pesawat terbang dari Jakarta menuju Kota Kendari atau penerbangan dari Jakarta transit Makassar dan diteruskan ke Morowali. Kemudian diteruskan dengan perjalanan darat selama ± 6 jam melewati Kabupaten Konawe Utara (Asera) namun apabila melewati Morowali maka hanya dibutuhkan waktu ± 3 jam yang melintasi PT Bintang Delapan Mineral hingga menuju ke Desa Tangofa, Kecamatan Bungku Pesisir, Kabupaten Morowali, Provinsi Sulawesi Tengah.



Gambar 1.1 Letak Konsesi PT Hengjaya Mineralindo

Untuk menuju ke lokasi kegiatan penambangan atau Lokasi Izin Usaha Pertambangan PT Hengjaya Mineralindo dari Desa Tangofa diperlukan waktu ± 30 menit dengan kendaraan roda empat (disarankan *double* gardan, 4 x 4). Sementara untuk lokasi dermaga yang digunakan sebagai *entry point* dimana kebutuhan alat berat akan masuk dan juga sebagai dermaga saat pengapalan material *ore* yang akan dikapalkan berada di Desa Tangofa yang terdapat di tepi pantai bagian timur laut wilayah IUP PT Hengjaya Mineralindo.

2. KONDISI GEOLOGI

2.1. Geologi Regional

Peta geologi regional yang digunakan dalam laporan ini adalah Peta Geologi Lembar Bungku, Sulawesi (Simandjuntak dkk., 1993). Morfologi di daerah Lembar Bungku dapat dibagi menjadi lima satuan, yaitu:

A. Dataran rendah

   Morfologi dataran rendah umumnya mempunyai ketinggian 0 – 50 mdpl.

B. Dataran menengah

   Morfologi dataran menengah menempati daerah sekitar Desa Tokolimbu dan Tosea, memiliki ketinggian 50 – 100 mdpl.

C. Perbukitan menggelombang

   Morfologi perbukitan menggelombang memiliki ketinggian 100 – 400 mdpl.

D. Karst

   Morfologi karst memiliki ketinggian 400 – 800 mdpl yang dicirikan oleh adanya perbukitan kasar, sungai bawah tanah, maupun dolina.

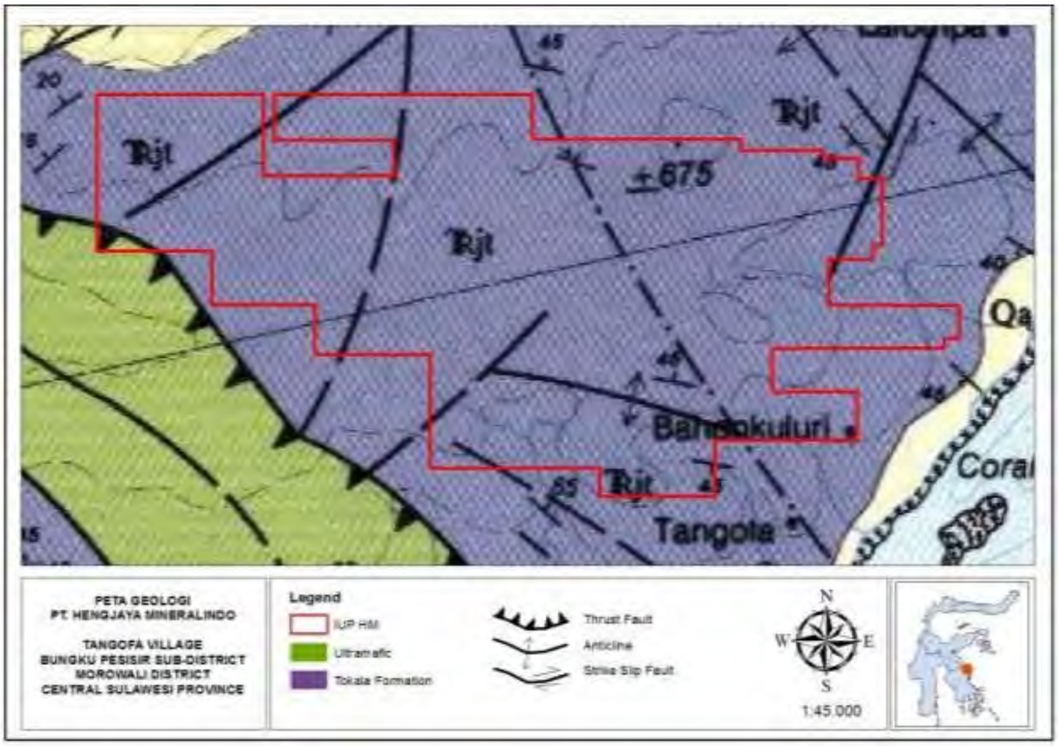
E. Pegunungan

F. Morfologi pegunungan memiliki ketinggian lebih dari 800 mdpl.

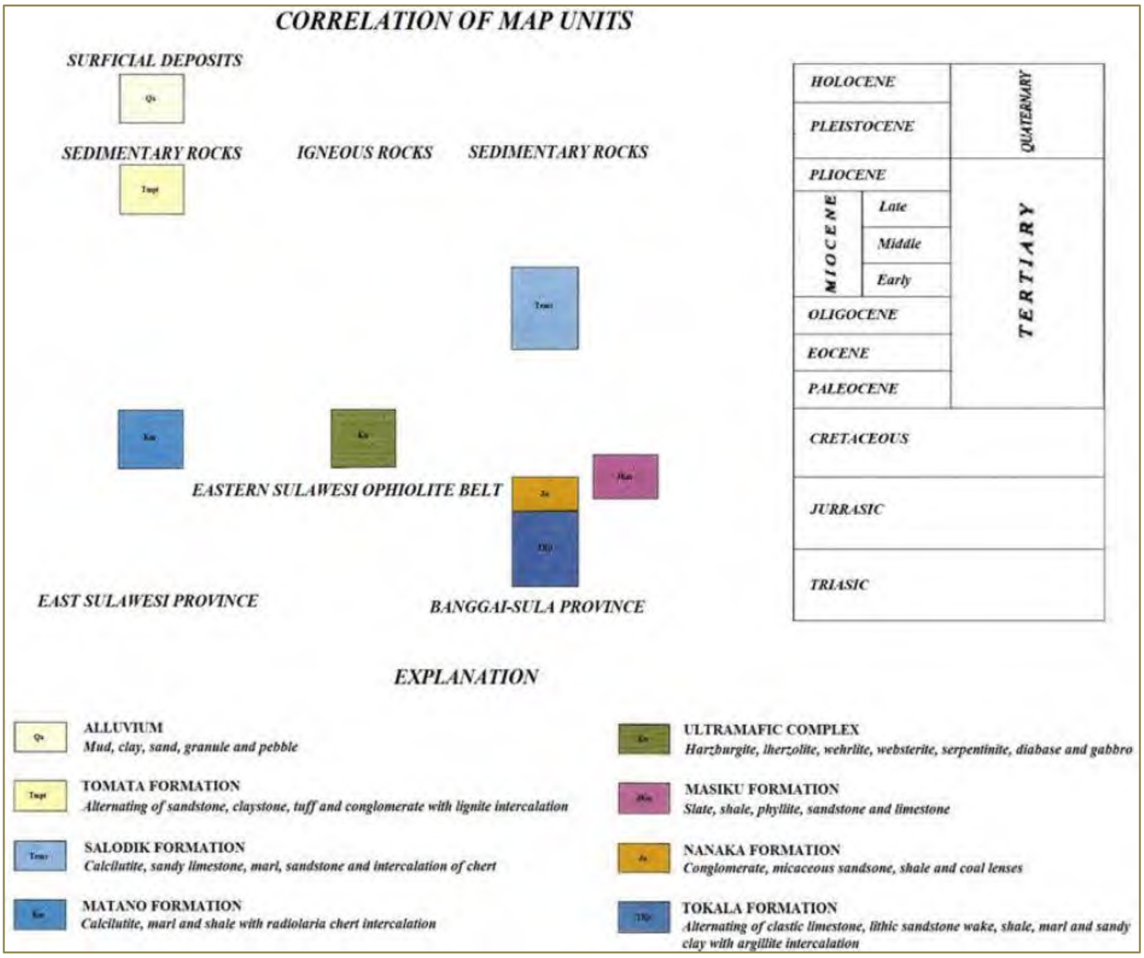
Satuan batuan di Peta Geologi Lembar Bungku (Simandjuntak dkk., 1993) (Gambar 2.1), satuan batuan dapat dikelompokkan dalam dua mandala geologi, yaitu Mandala Banggai-Sula dan Mandala Sulawesi Timur (Sukamto, 1975). Pembagian stratigrafinya berturut-turut dari muda ke tua adalah sebagai berikut (Gambar 2.2):

1. ALUVIUM (Qa) : lumpur, lempung, pasir, kerikil, serta kerakal.
2. FORMASI TOMATA (Tmpt) : perselingan batupasir konglomerat, batulempung, tufa dengan sisipan lignit.
3. FORMASI SALODIK (Tems) : kalsilutit, batugamping pasiran, napal, batupasir juga rijang.
4. FORMASI MATANO (Km) : kalsilutit, napal, serpih dan rijang. Kalsilutit, berbutir halus, berwarna kelabu, padat-keras, lapisannya baik, tebal lapisan berkisar antara 10 – 15 cm.

5. KOMPLEKS ULTRAMAFIK (Ku) : harzburgit, lherzolit, wehrlit, websterit, serpentinit, dunit, diabas dan batuan gabro.
6. FORMASI MASIKU (JKm) : batusabak, serpih, flit, batupasir, batugamping dengan buncak rijang. Batusabak, berwarna kelabu sampai coklat kehitaman, berlapis baik, padat.
7. FORMASI NANAKA (Jn) : konglomerat, batupasir mikaan, serpih dan lensa batubara.
8. FORMASI TOKALA (TRJt) : perselingan batugamping klastika, batu pasir sela, wake, serpih, napal, lempung pasiran dengan sisipan argilit.



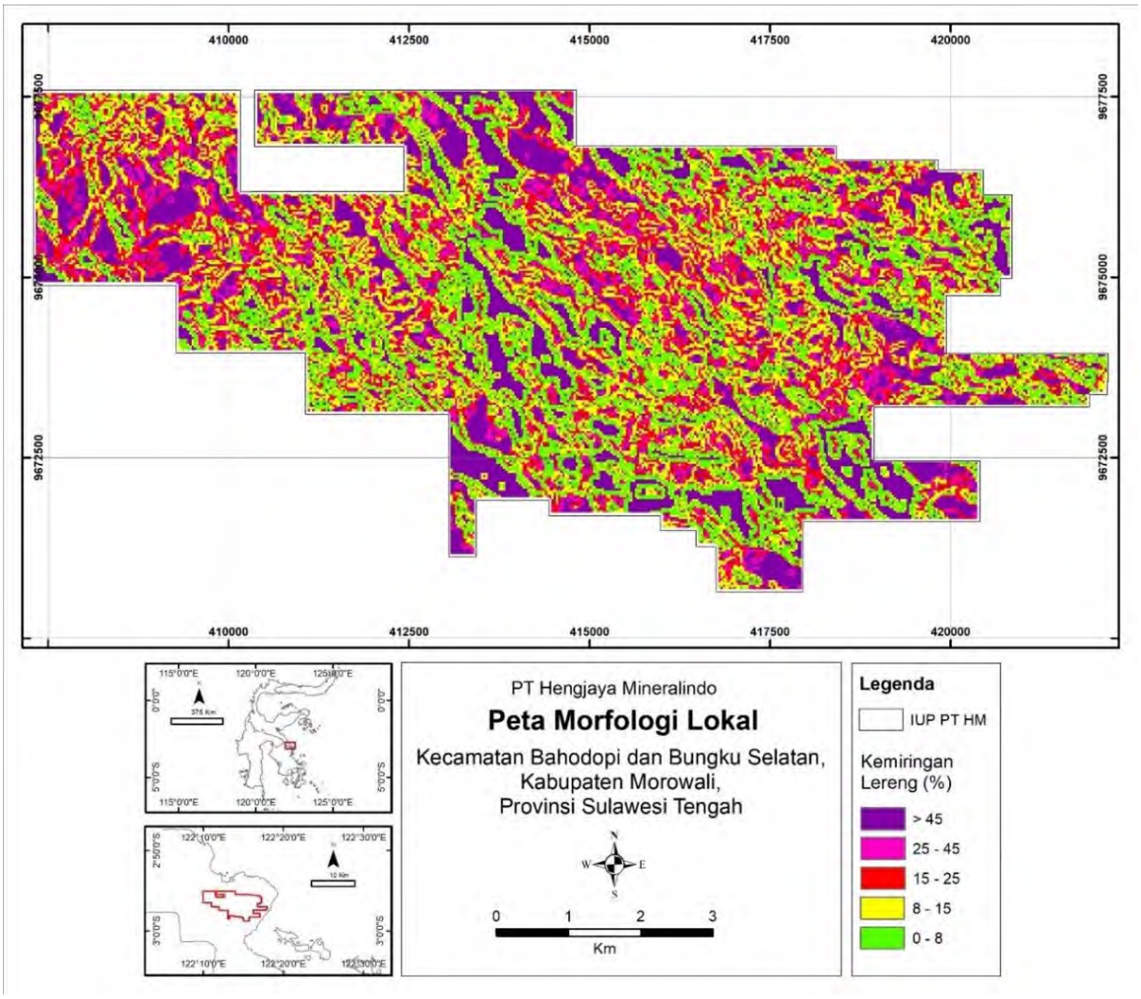
Gambar 2.1 Peta geologi regional lembar Bungku, Sulawesi (Simandjuntak dkk., 1993) yang telah ditambahkan dengan batas IUP



Gambar 2.2 Korelasi unit stratigrafi pada peta geologi lembar Bungku (Simandjuntak dkk., 1993)

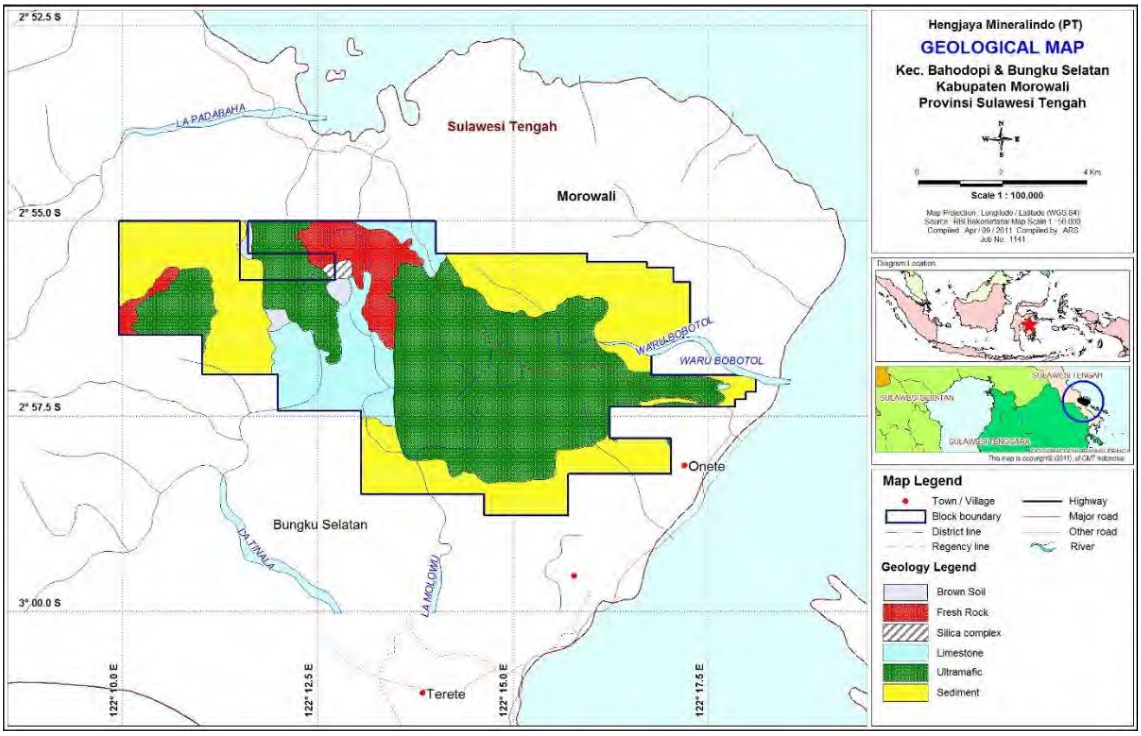
2.2. Geologi Lokal

Secara deskripsi kuantitatif/morfometri, morfologi masing-masing daerah wilayah penelitian dengan wilayah sekitarnya dapat dikelompokkan berdasarkan arah umum kemiringan lereng menjadi lima satuan morfologi, yaitu datar (0 – 8%) ditunjukkan dengan warna hijau, landai (8 – 15%) ditunjukkan dengan warna kuning, agak curam (15 – 25%) ditunjukkan dengan warna merah, curam (25 – 45%) ditunjukkan dengan warna merah muda, dan sangat curam (> 45%) ditunjukkan dengan warna ungu (Gambar 2.3).



Gambar 2.3 Peta morfologi lokal

Peta geologi lokal yang digunakan dibuat oleh HM sebagai acuan untuk melihat kondisi geologi permukaan selama program eksplorasi berlangsung saat ini (Gambar 2.4). Reliabilitas data yang digunakan sudah dikonfirmasi pada Desember 2019 selama pemetaan yang dilakukan oleh ahli geologi PT Danmar Eksplorindo dalam pencarian batugamping dan agregat untuk pembangunan proyek jalan. Pada peta geologi lokal, terdapat perbedaan yang signifikan dengan Peta Geologi Regional Lembar Bungku (lihat Gambar 2.1) yang memperlihatkan wilayah konsesi HM seluruhnya disusun oleh Formasi Tokala. Faktanya, Kompleks Ultramafik adalah batuan penyusun dominan di kawasan HM dan menyebar lebih dari 60% wilayah konsesi. Formasi Tokala adalah batuan yang lebih tua dan secara stratigrafi terdapat di bawah Kompleks Ultramafik.



Gambar 2.4 Peta geologi lokal

Lapisan yang kaya akan bijih nikel umumnya terdapat di bawah zona pelapukan dan di atas batuan dasar. Di bagian atas zona pelapukan ini umumnya ditumbuhi pepohonan (hutan) yang mengindikasikan bahwa lapisan tersebut cukup subur.

Pada daerah penelitian di wilayah IUP dari hasil pengamatan survei geologi banyak dijumpai blok-blok/spot area yang merupakan zona laterit, dengan ketebalan rata-rata ± 10 meter. Penampakan laterit secara visual terutama dari sisi warna permukaan memiliki perubahan-perubahan yang cukup drastis, hal ini sebagai akibat adanya perbedaan derajat serpentinisasi pada batuan ultramafik di wilayah tersebut. Sedangkan keberadaan mineral pembawa nikel seperti garnierit dan krisopras berada pada bongkah-bongkah dan membentuk zona serta jalur-jalur tertentu dalam satu zona *vein*. Kondisi ini menyebabkan tingginya kandungan silika (SiO_2). Kondisi ini dapat dilihat pada lereng sepanjang jalan Trans Sulawesi yang melintasi wilayah IUP Produksi PT Hengjaya Mineralindo.

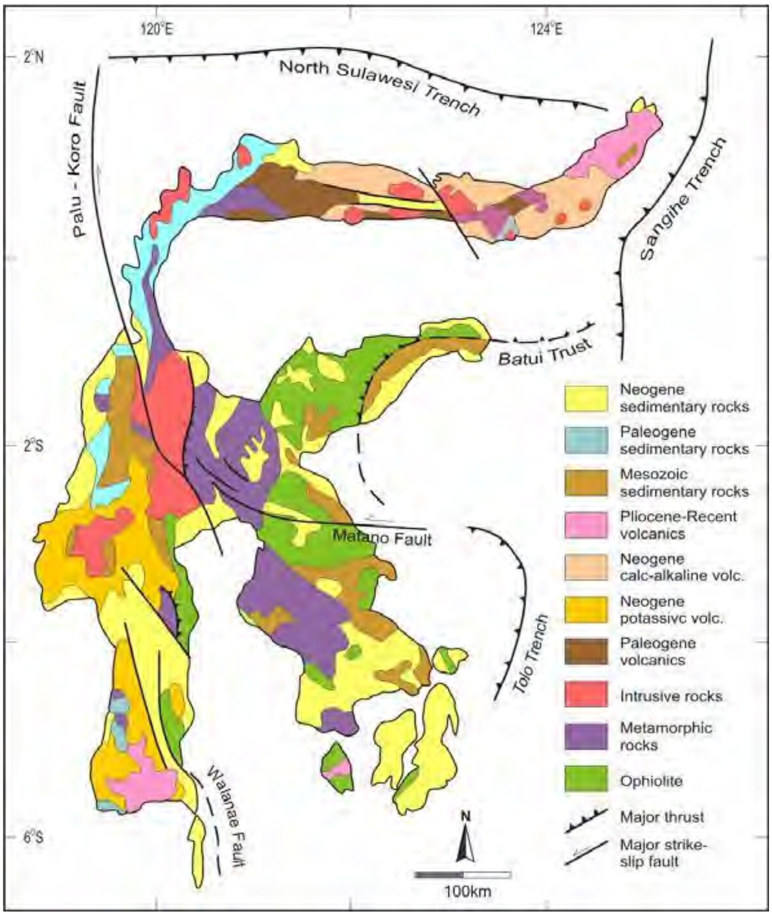
Pada blok-blok daerah penelitian di wilayah IUP sudah dilakukan pengeboran detail dengan *grid* 100 – 25 m, terdapat singkapan saprolit yang cukup meyakinkan, adanya indikasi mineral-mineral garnierit yang berkembang ke arah utara dan selebihnya perkembangan ke arah timur, terjadi perubahan kualitas menjadi batuan ultramafik (serpentinit) yang masih segar.

Beberapa bagian terutama di sisi utara-timurlaut dari konsesi wilayah IUP Produksi PT Hengjaya Mineralindo, terdapat zona serpentinisasi yang sangat dangkal lateritnya, namun kaya akan mineral garnierit yang terdapat pada rekahan batuannya, memungkinkan kandungan unsur nikel yang sangat tinggi dan memungkinkan bisa menjadi sebuah *injector* pada saat pengapalan dengan hasil penambangan yang memiliki kandungan kadar nikel yang rendah.

Berdasarkan hasil analisis singkapan endapan nikel dan korelasi terhadap penampang bor dangkal dan data sumur uji, tebal endapan bijih berkisar 1,20 – 20,00 m yang di bagian atasnya terkadang ditutupi oleh lapisan oksida besi atau goetit-aluminiun setebal 15 – 30 cm, atau disebut juga *iron capping*.

2.3. Struktur Geologi

Sulawesi secara tektonik merupakan wilayah yang disusun oleh benturan dua massa kerak benua, yaitu Sundaland yang menyusun Sulawesi Barat dan Australoid yang menyusun sebagian Sulawesi sebelah timur (Banggai-Sula) dan tenggara (Buton) (Gambar 2.5). Terjepit di tengahnya adalah kerak samudera yang kini menjadi ofiolit dan terangkat ke permukaan melalui mekanisme obduksi. Ofiolit yang naik ke permukaan tersebut menjadi sumber batuan utama penghasil mineral logam dasar nikel dan besi.



Gambar 2.5 Peta geologi Sulawesi (Van Leeuwen dkk., 2011)

Pada periode 70 – 15 juta tahun yag lalu (Ma), hanya ada Sulawesi Barat yang masih menjadi bagian Sundaland dan tambahan massa kerak Bumi di sebelah timurnya. Sulawesi Barat kala itu adalah sebuah busur kepulauan/busur magmatik-vulkanik hasil subduksi kerak samudera terhadapnya yang menghasilkan beberapa periode magmatik dan volkanik di Sulawesi bagian barat. Perubahan-perubahan tektonik seperti pembukaan Selat Makassar, pembukaan Teluk Bone, pembukaan Teluk Tomini/Cekungan Gorontalo, subduksi Laut Sulawesi pada 50 – 15 Ma menyebabkan perubahan arah/polaritas busur magmatik dan subduksi Sulawesi dari cembung ke arah samudera menjadi agak lurus

Pada periode 15 – 5 Ma, Sulawesi mengalami collision dan docking dua mikrokontinen Australia ke arah Sulawesi dari sebelah tenggara (mikrokontinen Buton-Tukangbesi) dan dari sebelah timur (mikrokontinen Banggai-Sula). Pada periode ini diperkirakan terjadi pembalikan utama arah/polaritas busur-busur Sulawesi dari semula cembung ke arah samudera menjadi cekung ke arah samudera (ke arah timur pada kala ini).

Pembalikan polaritas busur-busur Sulawesi ini secara frontal adalah akibat benturan mikrokontinen d Banggai-Sula yang membenturnya di titik pusat Sulawesi. Yang mengakibatkan rotasi. Lengan Tenggara berotasi melawan arah jarum jam sehingga membuka melebarkan Teluk Bone di sebelah baratnya, Lengan Utara berotasi searah jarum jam sehingga menutup Cekungan Gorontalo.

Periode 5 – 0 Ma adalah finalisasi pembalikan busur-busur Sulawesi dan periode tectonic escape di Sulawesi. Setelah benturan Buton-Tukangbesi dan benturan Banggai-Sula, terjadilah tectonic escape berupa sesar-sesar mendatar besar yang meretakkan dan menggeser-geser Sulawesi. Sesar-sesar ini mengarah ke timur umumnya, yaitu ke arah free oceanic edge saat itu. Sesar-sesar mendatar besar Palu-Koro, Matano, Lawanopo, Kolaka, dan Balantak terjadi melalui mekanisme post-collision tectonic escape.

Namun faktanya, jika dilihat dari peta geologi lokal yang dibuat oleh HM (Gambar 2.4), struktur geologi tidak begitu berkembang seperti yang diinterpretasikan pada peta geologi regional. Hal tersebut kemungkinan karena wilayah IUP yang sudah mengalami pelapukan dan lateritisasi, sehingga sulit untuk menemukan bukti-bukti keberadaan jejak struktur geologi di lapangan.

3. KAJIAN HIDROLOGI DAN HIDROGEOLOGI

3.1. Akuisisi Data

Kebutuhan data terkait analisis hidrologi dan hidrogeologi sangat bergantung pada tujuan, ketersediaan data yang dimiliki, dan tingkat ketelitian hasil yang diharapkan. PT Hengjaya Mineralindo ("HM") memiliki beberapa data primer yang dibutuhkan untuk melakukan analisis dasar hidrologi dan hidrogeologi. Namun tidak semua data yang dimiliki HM cukup untuk memenuhi kebutuhan dasar analisis. *Gap* data analisis dilakukan terhadap ketersediaan data yang dimiliki HM. Hasil tersebut selanjutnya menentukan bagaimana kekurangan terhadap data dapat dipenuhi, dan pendekatan metode ilmiah yang digunakan sesuai dengan jumlah dan ketersediaan data.

3.1.1. Jenis, Jumlah, dan Sebaran Data

Tabel 3.1 memperlihatkan rekapitulasi ketersediaan data yang dimiliki HM terkait kebutuhan analisis hidrologi dan hidrogeologi, resume dari data gap, dan bagaimana pelengkapan terhadap gap data dipenuhi. Penjelasan rinci dari Tabel 3.1 mengenai jenis, jumlah, dan persebaran data yang dimiliki HM, serta pelengkapan data sekunder/literatur dibahas selanjutnya pada subbab 3.1.2 hingga subbab 3.1.4.

Tabel 3.1 Jenis dan jumlah ketersediaan data PT HM, pelengkapan, dan data *gap* terkait analisis hidrologi dan hidrogeologi

Jenis Data	Jumlah/Keterangan	Kelengkapan Data/ *Gap* Data Analisis	Pelengkapan *Gap* Data/ Keterangan
Data Hujan	Tidak ada data rekaman hujan yang diperoleh dari HM	Data curah hujan harian kontinu minimal 10 tahun diperlukan untuk menentukan persentil-95 (*95th percentile*) kejadian hujan pada suatu lokasi.	Pelengkapan data hujan menggunakan data sekunder dari stasiun terdekat milik BMKG atau PUSAIR. Pelengkapan data juga didekati dengan data hujan satelit (TRMM)
Data Topografi	Hasil Survei Topografi, HM 2021	Data topografi terbatas pada area IUP HM. Kebutuhan analisis *catchment* mencakup area di luar konsesi HM	Data topografi di luar IUP HM menggunakan data DEM Nasional (Badan Informasi Geografis Indonesia)

Jenis Data	Jumlah/Keterangan	Kelengkapan Data/ *Gap* Data Analisis	Pelengkapan *Gap* Data/ Keterangan
Muka Airtanah	Data pengukuran lapangan pada 9 titik bor geoteknik tahun (Geomine, 2021)	Data pengukuran muka airtanah mencerminkan *total head* dari semua litologi yang hadir	Kebutuhan data muka airtanah dianggap telah memenuhi kebutuhan data minimal untuk analisis lanjutan.
Parameter Hidraulik	1. Uji akuifer lapangan dilakukan pada 9 sumur bor geoteknik (Geomine, 2021) 2. Uji permeabilitas laboratorium pada 6 sampel batuan dari hasil core pengeboran (Geomine, 2021)	Data konduktivitas hidraulik dianggap telah memenuhi kebutuhan data untuk analisis lanjutan, di mana nilai konduktivitas hidraulik didapatkan pada masing-masing litologi	Selain data konduktivitas hidraulik, data parameter hidraulik lainnya, seperti storativitas dan porositas dibutuhkan untuk kepentingan analisis selanjutnya. Pelengkapan data nilai stortativitas dan porositas menggunakan data literatur pada litologi sejenis.
Data Kondisi Umum Hidrologi dan Hidrogeologi	Kondisi umum hidrologi dan hidrogeologi, seperti: batas DAS, jaringan sungai, batas Cekungan Airtanah, Peta hidrogeologi regional	Pengambilan Data Sekunder dari instansi terkait	Untuk mendapatkan gambaran umum kondisi hidrologi dan hidrogeologi daerah studi data sekunder diambil dari instansi terkait, seperti: - Batas DAS regional: Sistem Informasi Pengelolaan DAS KLHK - Peta jaringan sungai: Badan Informasi Geografis (BIG) - Peta Batas CAT

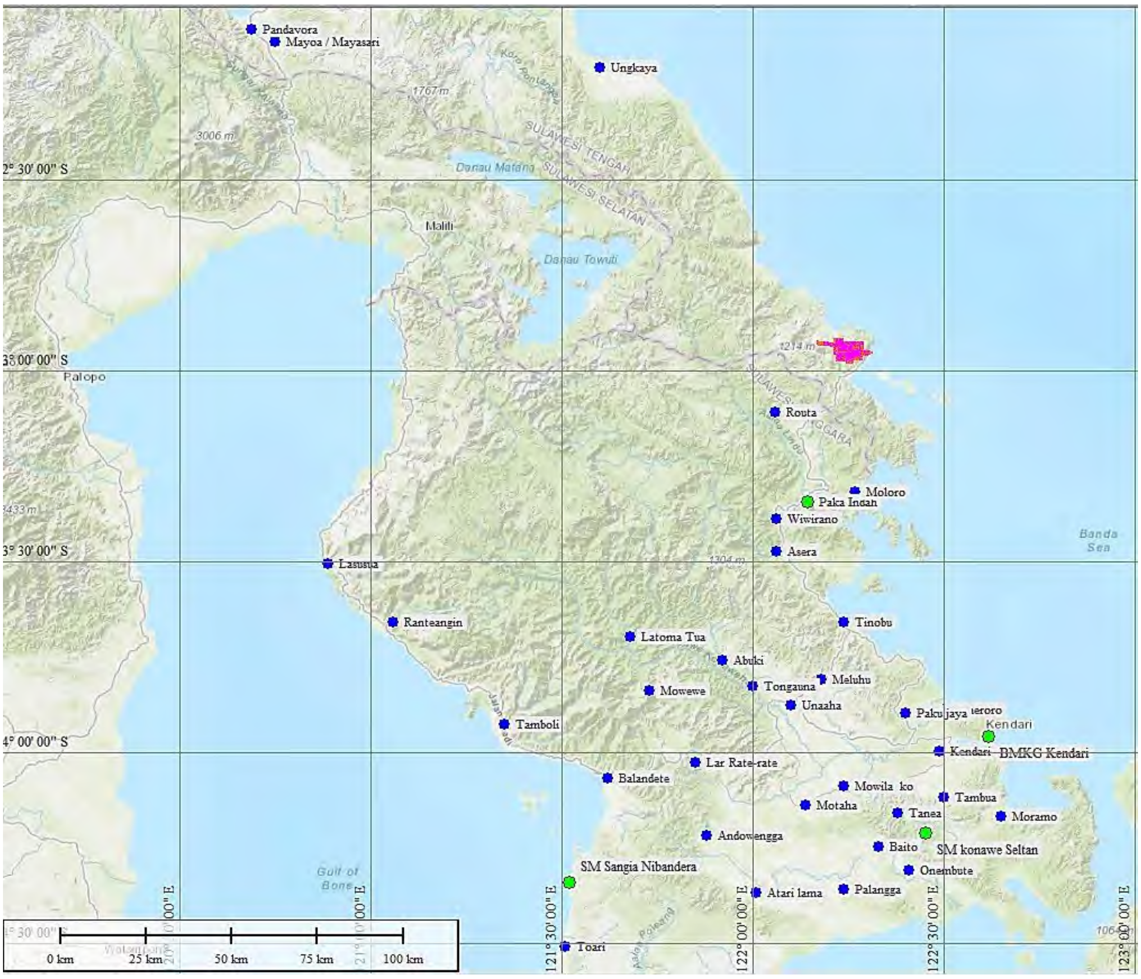
3.1.2. Data Hujan

Tidak ada data pencatatan hujan yang dimiliki HM. Data curah hujan yang panjang, yaitu minimal data 10 tahun kontinu diperlukan untuk menentukan persentil-95 (95th percentile) kejadian hujan pada suatu lokasi. Data pemantauan tiga puluh tahun atau lebih sangat diharapkan untuk melakukan analisis statistik yang tidak bias (US EPA, Technical Guidance on Implementing the Stormwater Runoff Requirements, 2009). Untuk melengkapi data hujan yang akan digunakan dalam analisis selanjutnya, pengambilan data dilakukan melalui Badan Meteorologi Klimatologi dan Geofisika (BMKG) serta Badan Penelitian dan Pengembangan Sumber Daya Air (PUSAIR).

Evaluasi ketersediaan data stasiun BMKG dan PUSAIR di sekitar area lokasi studi ditunjukkan pada Tabel 3.2. Peta lokasi stasiun klimatologi di sekitar wilayah studi dapat dilihat pada Gambar 3.1.

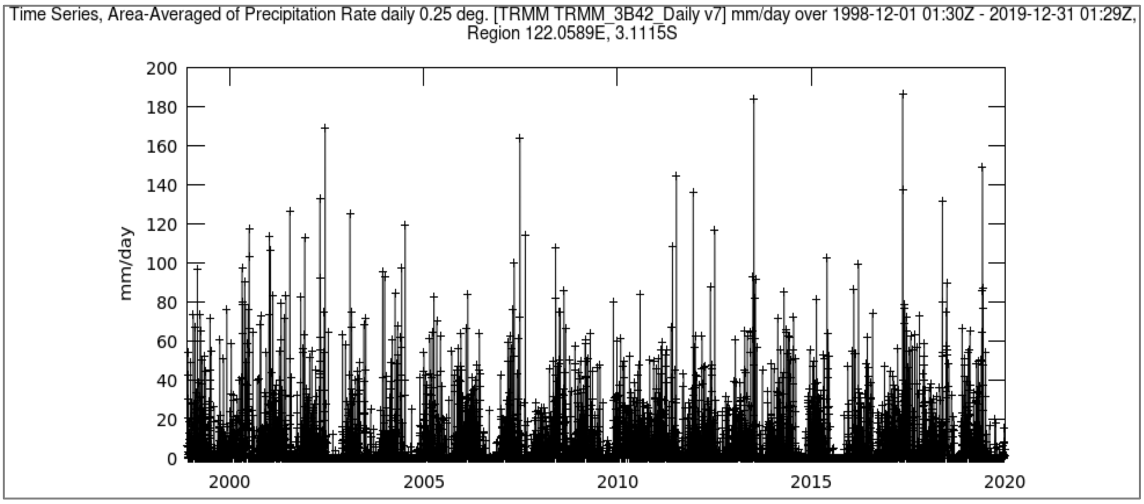
Tabel 3.2 Evaluasi ketersediaan data dari stasiun klimatologi terdekat dan stasiun hujan di sekitar lokasi studi (data BMKG dan PUSAIR)

No.	Nama Stasiun	Periode Observasi	Periode Data Lengkap	Jarak	Data Tersedia	Sumber
1	Routa	2014-2019	6 tahun	27 Km	Hujan Harian	PUSAIR
2	Moloro	2018-2019	2 tahun	35 Km	Hujan Harian	PUSAIR
3	Paka Indah	1991-2019	2 tahun	45 Km	Klimatologi Harian	PUSAIR
4	Wiwirano	2010-2019	10 tahun	53 Km	Hujan Harian	PUSAIR
5	Asera	1995-2019	12 tahun	62 Km	Hujan Harian	PUSAIR
6	Ungkaya	2007-2017	11 tahun	109 Km	Hujan Harian	PUSAIR



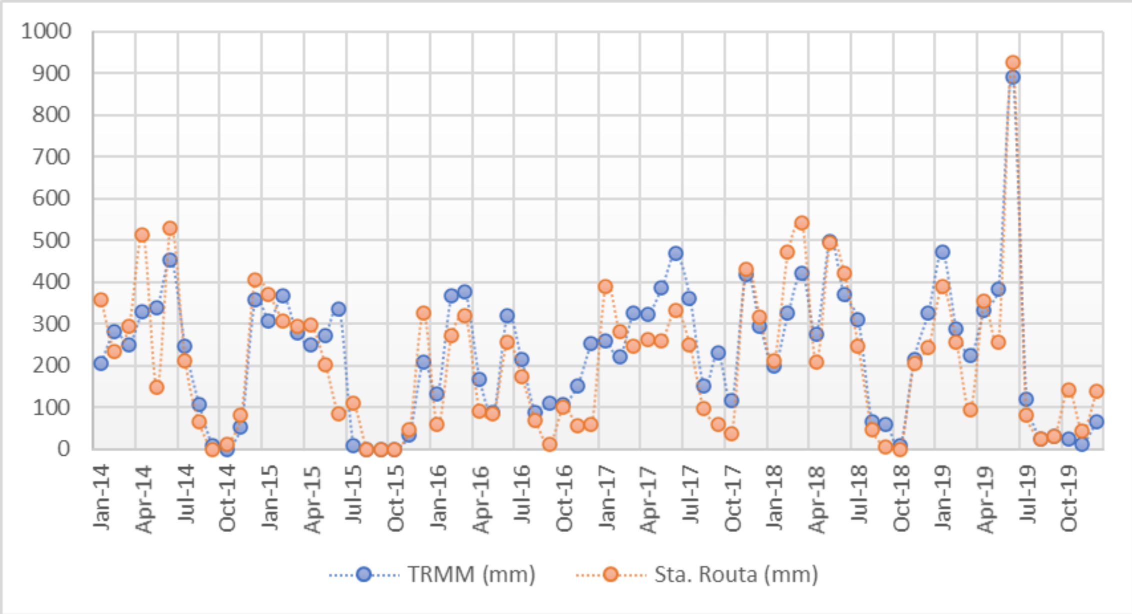
Gambar 3.1 Peta distribusi ketersediaan stasiun hujan di sekitar IUP HM

Berdasarkan data yang tersedia dari BMKG dan PUSAIR, stasiun terdekat dengan lokasi studi adalah Stasiun Routa. Namun seperti dapat dilihat pada Tabel 3.2, data hujan pada stasiun Routa hanya meliputi data untuk 6 tahun periode (2014-2019). Untuk melengkapi data hujan lebih panjang, pengambilan data hujan satelit dilakukan. Data curah hujan satelit diperoleh dari produk penelitian Tropical Rainfall Measuring Mission (TRMM) yang diambil dari produk opensource NASA, GES DISC. Data curah hujan dari TRMM yang diperoleh merupakan data hujan harian (versi 3B42), dengan grid resolusi spasial 0,25°, dan tersedia sepanjang periode 1999-2019 (Gambar 3.2).

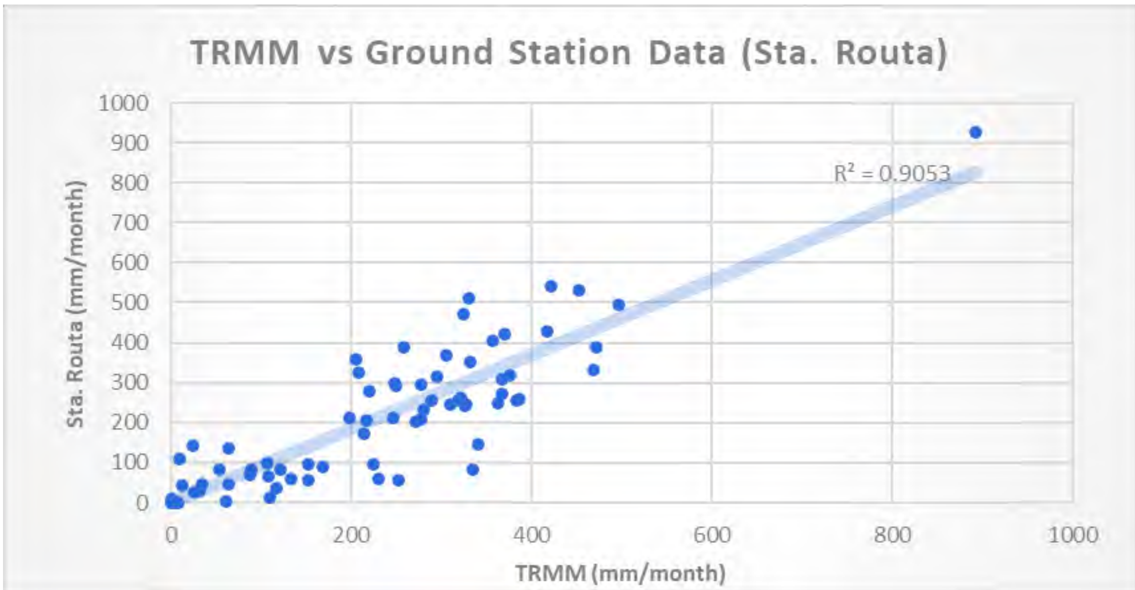


Gambar 3.2 Data produk hujan Satelit TRMM versi 3B42 pada titik Stasiun Routa

Untuk memverifikasi keakuratan data curah hujan satelit, dilakukan uji komparasi antara data satelit dan data Stasiun Routa pada tahun yang sama. Perbandingan data hujan bulanan antara Stasiun Routa dan data satelit pada *time series* dan *scatter plot* ditunjukkan pada **Error! Reference source not found.** dan **Error! Reference source not found.**. Berdasarkan hasil komparasi dapat terlihat bahwa pola *series* grafik hujan bulanan dari Satelit TRMM memiliki keseragaman dengan data hujan stasiun Routa (**Error! Reference source not found.**). Selain itu nilai hasil perbandingan memperlihatkan koefisien korelasi antara data curah hujan satelit dan data Stasiun Routa memiliki nilai sebesar 0.9 (**Error! Reference source not found.**). Hasil ini menunjukkan data curah hujan produk satelit berkorelasi sangat baik dengan data hujan Stasiun Routa, sehingga dapat digunakan untuk kepentingan analisis selanjutnya.

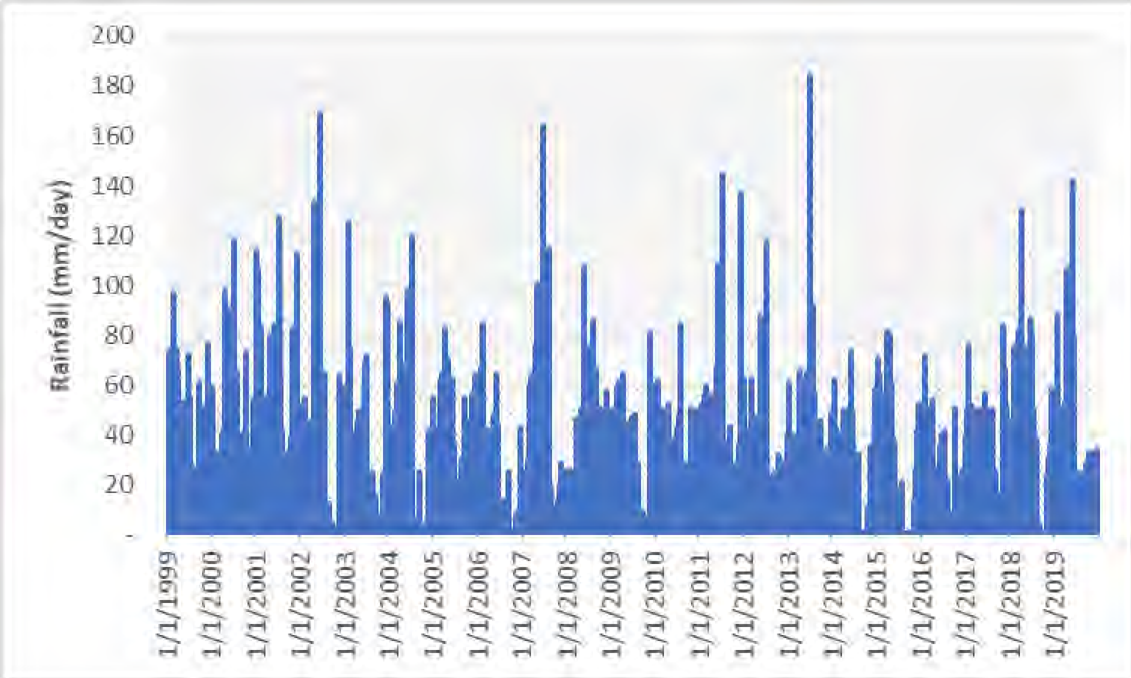


Gambar 3.3 Perbandingan *time series* antara hujan Stasiun Routa dan hujan satelit (TRMM)



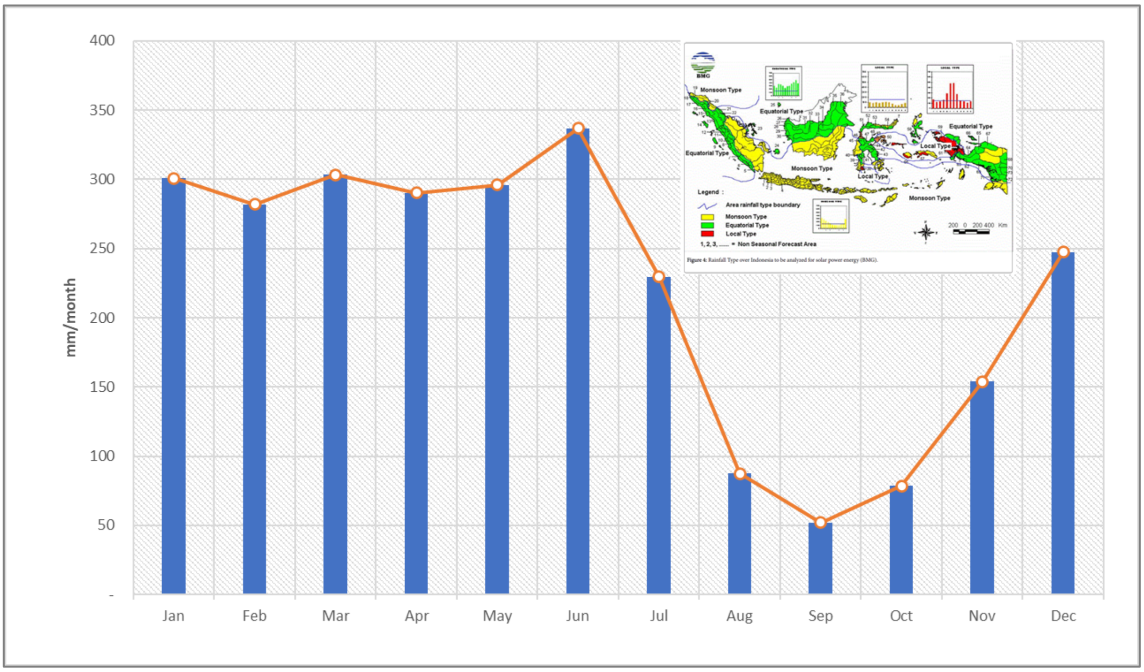
Gambar 3.4 Diagram *scatter* dari data hujan Stasiun Routa dan hujan satelit (TRMM)

Setelah data ter-verifikasi dan dinyatakan berkorelasi dengan baik, selanjutnya data curah hujan satelit akan digunakan untuk mengisi kekosongan data pada stasiun darat tersedia. Sehingga data hujan selanjutnya menggunakan data Satelit TRMM untuk periode tahun 1999-2013 dan rata-rata data Stasiun Routa untuk periode tahun 2004-2019. Plot data hujan harian dari stasiun PUSAIR dikombinasikan dengan data hujan produk satelit TRMM dapat dilihat pada Gambar 3.5.



Gambar 3.5 Rekapitulasi hujan bulanan wilayah studi (kombinasi data Stasiun Routa dengan data hujan produk Satelit TRMM)

Berdasarkan data akuisisi diketahui jumlah rata-rata curah hujan tahunan daerah studi selama periode tahun 1999-2019 (20 tahun) adalah sebesar 2658 mm/tahun. Curah hujan harian rata-rata selama 20 tahun (1999-2019) adalah 7,27 mm dengan curah hujan harian maksimum selama 20 tahun adalah 184 mm yang terjadi pada 10 Juli 2013. Berdasarkan pola data hujan klasifikasi BMKG, jenis pola hujan di daerah studi masuk dalam tipe lokal. Tipe Lokal umumnya merupakan kebalikan dari pola hujan monsun, yaitu jika di daerah dengan pola monsun mengalami musim hujan maka daerah dengan pola lokal mengalami musim kemarau atau sebaliknya. Grafik rata-rata hujan bulanan daerah studi selama 20 tahun (1999-2009) dapat dilihat pada Gambar 3.6 yang memperlihatkan tipe pola hujan di daerah studi.



Gambar 3.6 Grafik rata-rata curah hujan bulanan daerah studi

3.1.3. Data Level Muka Airtanah

Pengukuran kedalaman muka air tanah dilakukan pada 9 lokasi lubang bor geoteknik yang tersebar pada lokasi rencana pengembangan tambang HM. Berdasarkan hasil pengukuran lapangan, diketahui kedalaman muka airtanah di lokasi penambangan HM berkisar antara 6,15 s/d 23,78 meter di bawah permukaan, dengan rata-rata sebesar 16 meter kedalaman di bawah permukaan. Data hasil pengamatan kedalaman muka air tanah hasil investigasi lapangan tahun 2021 dapat dilihat pada Tabel 3.3, dengan sebaran data pengukuran yang dapat dilihat pada Gambar 3.8.

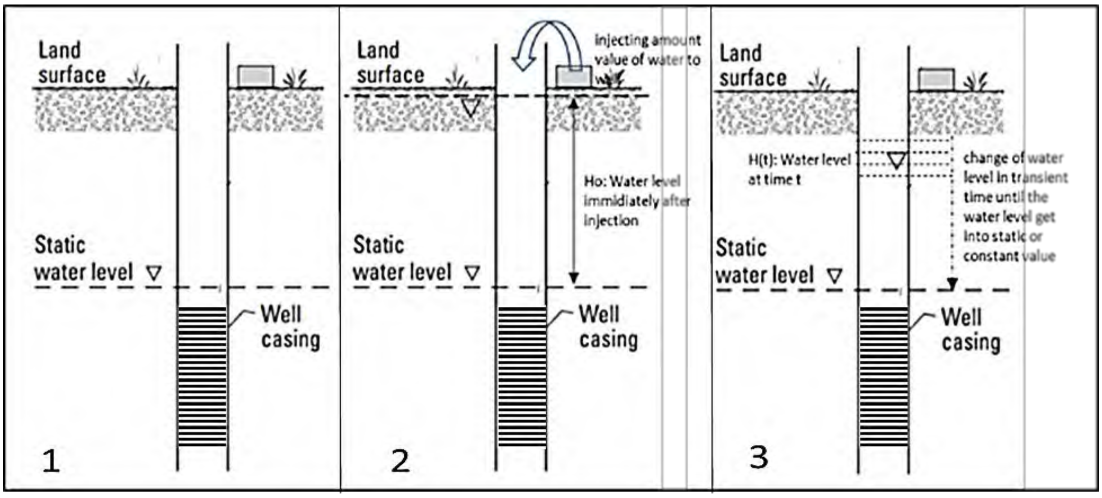
Tabel 3.3 Hasil pengukuran kedalaman muka airtanah

Hole ID	Easting	Northing	Elevation (m RL)	Total Depth (m)	GWL Depth (m)	GWL Elevation (m RL)
DHG-01	413455	9675637	380.127	17	13	367.127
DHG-02	414147	9675839	519	14	8.58	510.42
DHG-03	415011	9675627	445.292	31	6.15	439.142
DHG-04	414243	9674697	402.991	35	27	375.991
DHG-05	415969	9674988	433.43	23	8.7	424.73
DHG-06	415447	9673487	329	35	23.78	305.22
DHG-07	416755	9674354	407.194	15	14.2	392.994

Hole ID	Easting	Northing	Elevation (m RL)	Total Depth (m)	GWL Depth (m)	GWL Elevation (m RL)
DHG-08	417317	9673539	358.125	20	19.2	338.925
DHG-09	418482.3	9673633	411.148	30	23.2	387.948

3.1.4. Data Konduktivitas Hidraulik

Data konduktivitas hidraulik didapatkan dari hasil pengujian langsung di lapangan dan hasil uji laboratorium yang diambil dari lubang pengeboran. Uji akuifer di lapangan dilakukan pada 8 sumur bor menggunakan metode *slug test* (*falling head*). *Slug test* (dalam Bouwer dan Rice, 1976) diterapkan untuk menentukan konduktivitas hidraulik dari tes sumur tunggal menggunakan metode *falling head*. Dalam metode ini, level airtanah statis di dalam sumur diukur sebelum pengujian. Sejumlah air kemudian dimasukkan ke dalam sumur. Pengukuran level air dilakukan secara berkala oleh *level logger* dan setiap perubahan level air dicatat sampai level air mencapai nilai statis/konstan kembali. Ilustrasi *slug test* menggunakan metode *falling head* dapat dilihat pada Gambar 3.7.



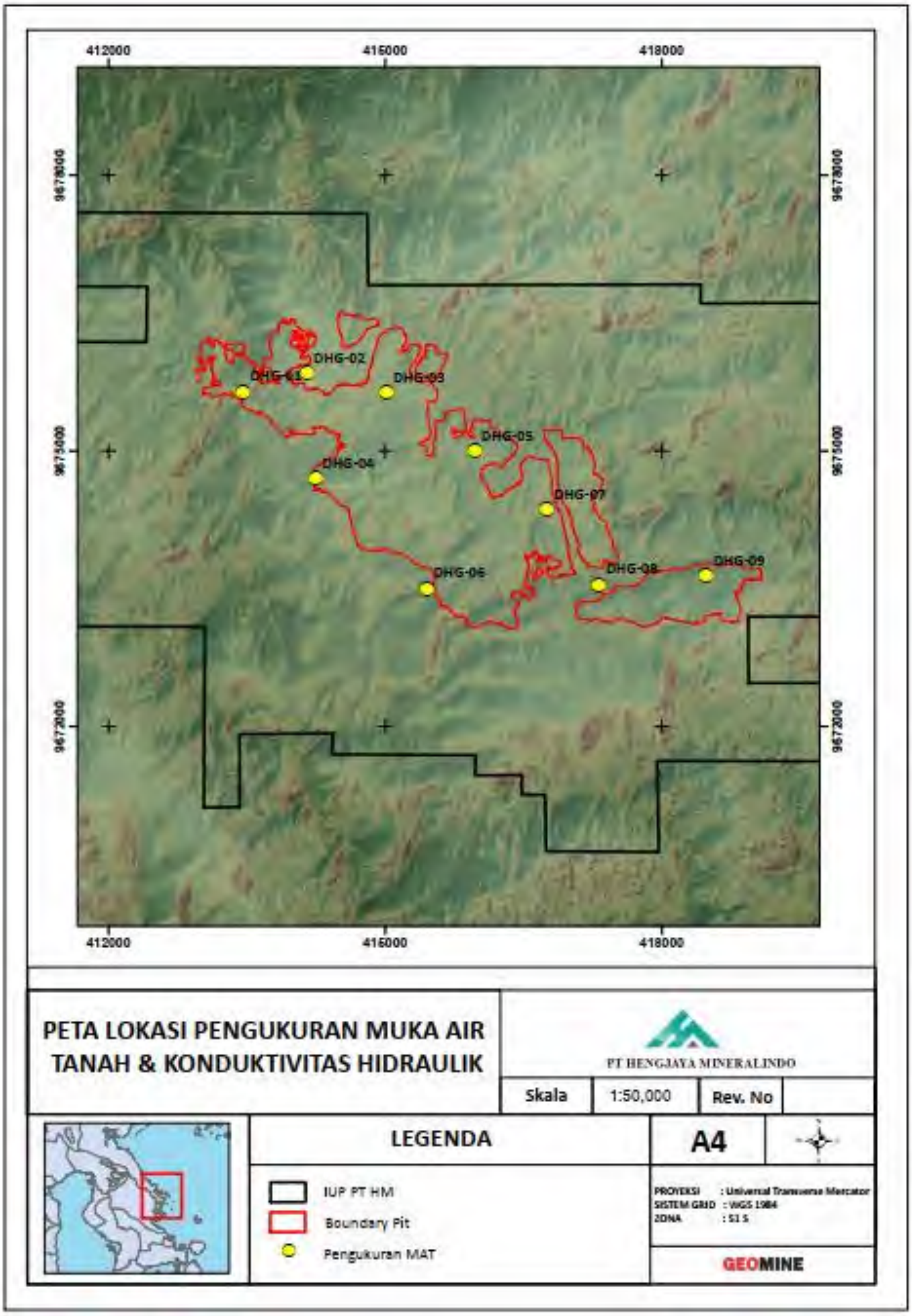
Gambar 3.7 Praktik lapangan *slug test* menggunakan metode *falling head*

Data dari hasil uji lapangan selanjutnya diproses untuk mendapatkan parameter konduktivitas hidraulik menggunakan metode Hvorslev. Resume nilai konduktivitas hidraulik hasil slug test dapat dilihat pada Tabel 3.4, dengan sebaran titik data yang dapat dilihat pada Gambar 3.8.

Selain itu untuk melengkapi data konduktivitas hidraulik, pengujian laboratorium juga dilakukan pada beberapa sampel tanah dan litologi batuan yang hadir. Uji konduktivitas hidraulik laboratorium dilakukan di laboratorium hidrogeologi dan hidrogeokimia Institut Teknologi Bandung, menggunakan vacuum permeameter constant head, dengan standar pengujian mengacu pada ASTM D 5084. Rekapitulasi hasil uji konduktivitas hidraulik laboratorium dapat dilihat pada Tabel 3.4.

Tabel 3.4 Resume nilai konduktivitas hidraulik hasil uji lapangan dan uji laboratorium

Method	Hole ID / Sample ID	Coordinate UTM 51S		Hydraulic Conductivity (m/s)	Lithology
		Easting	Northing		
Uji Lapangan-Slug test	DHG-01	413400.4	9675826	2.52E-05	Saprolit
	DHG-02	414146	9675839	9.50E-05	Saprolit
	DHG-03	415097.6	9675904	4.48E-06	Saprolit
	DHG-04	414286.9	9674645	1.15E-05	Saprolit
	DHG-05	415735.3	9674946	4.35E-06	Saprolit
	DHG-06	415097	9673413	1.26E-04	Saprolit
	DHG-07	416875.6	9674311	3.33E-05	Saprolit
	DHG-08	417733	9673383	2.82E-05	Saprolit
Laboratorium Permeability Test	DHG-01	413400.4	9675826	1.06E-06	Saprolit
	DHG-05	415735.3	9674946	7.18E-04	Saprolit
	DHG-06	415097	9673413	1.83E-05	Saprolit
	DHG-08	417733	9673383	<1.00E-12	Dunit



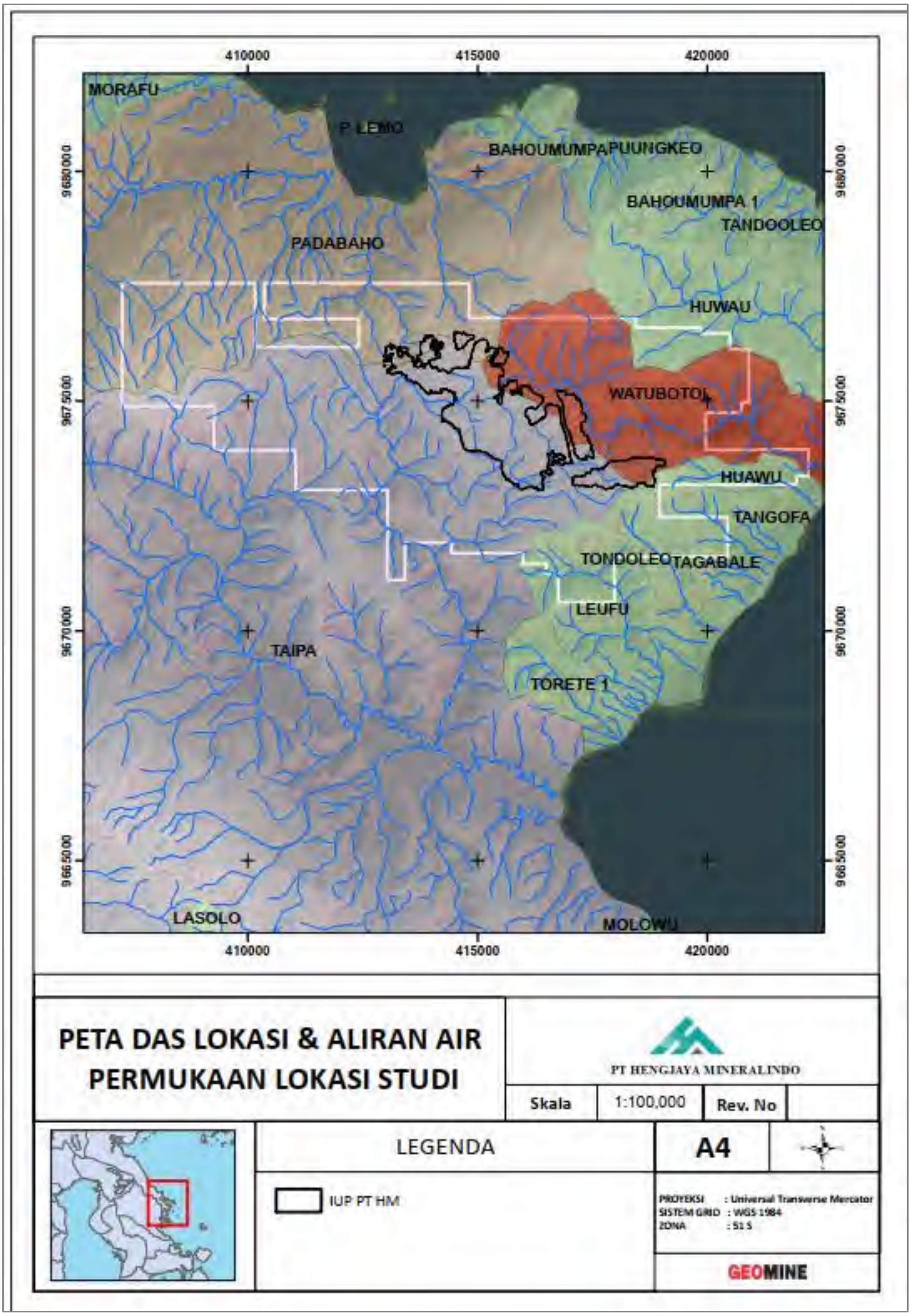
Gambar 3.8 Peta distribusi lokasi pengukuran muka airtanah dan titik pengujian konduktivitas hidraulik lapangan

3.1.5. Kondisi Hidrologi dan Hidrogeologi Umum

3.1.5.1. Daerah Aliran Sungai

Berdasarkan data Sistem Informasi Pengelolaan DAS Kementerian Lingkungan Hidup dan Kehutanan, lokasi rencana pengembangan tambang HM masuk ke dalam 2 Daerah Aliran Sungai (DAS), yaitu DAS Taipa (Kode DAS= DAS530815) dan DAS Watubotol (Kode DAS= DAS 510808). Luas DAS Taipa adalah sebesar 204,37 Km2, dengan aliran sungai utama yang mengalir pada DAS ini adalah Sungai La Tinala. Luas DAS Taipa adalah sebesar 18,24 Km2, dengan aliran sungai utama yang mengalir pada DAS ini adalah Sungai La Watubotol.

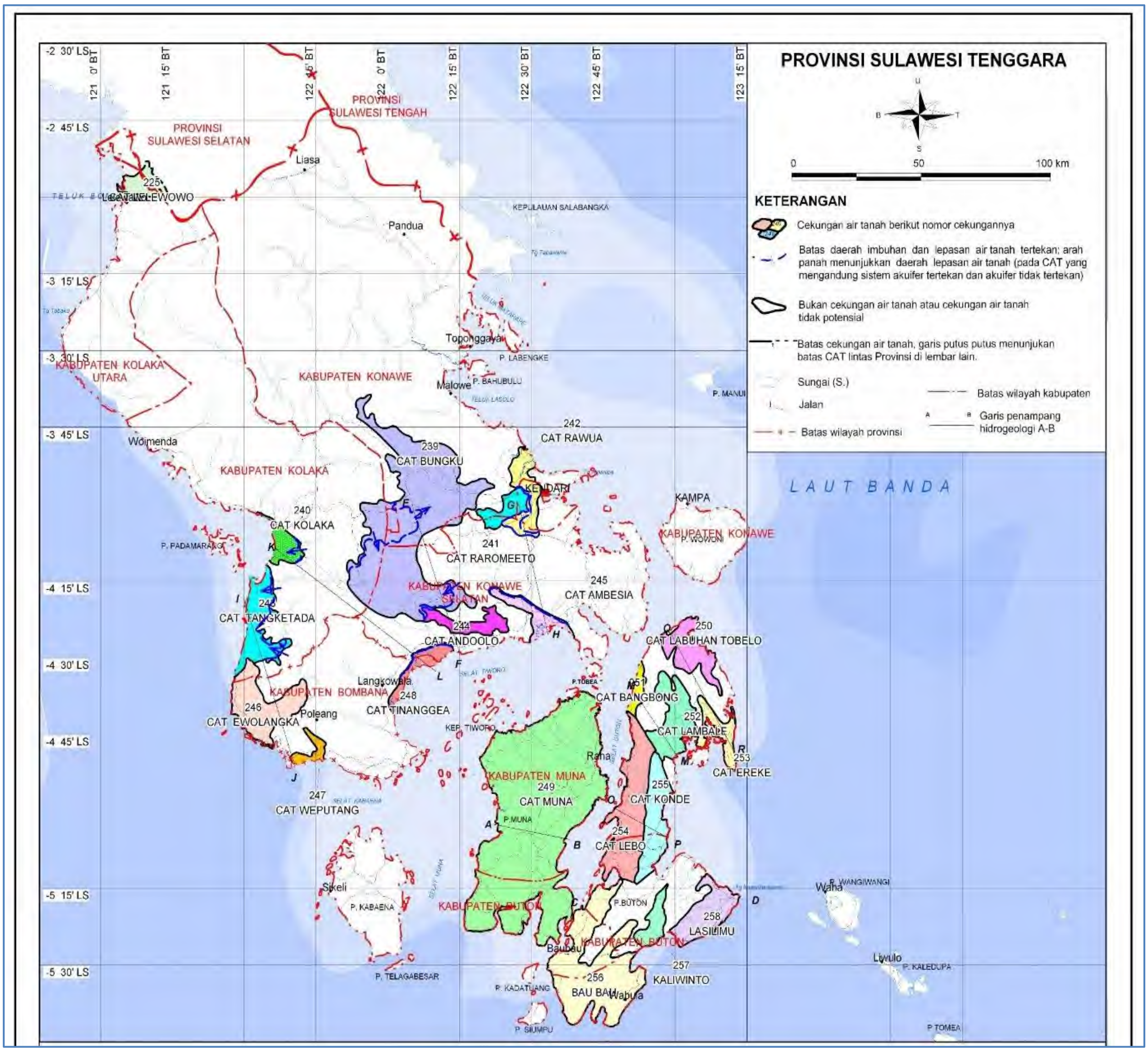
Secara posisi, rencana lokasi pengembangan tambang HM terletak pada bagian paling hulu dari salah satu lembah DAS Taipa dan DAS Watubotol. Lokasi aliran sungai terdekat dan terkait rencana pengembangan tambang HM antara lain anak sungai Molowu yang merupakan anak-anak sungai Tinala, serta La Watubotol. Peta batas DAS dan aliran air permukaan daerah studi dapat dilihat pada Gambar 3.9.



Gambar 3.9 Peta daerah aliran sungai dan aliran air permukaan regional daerah studi

3.1.5.2. Hidrogeologi Umum

Cekungan Air Tanah (CAT) diartikan sebagai suatu wilayah yang dibatasi oleh batas hidrogeologi di mana semua kejadian hidrogeologi seperti terjadinya proses pengimbuhan, pengaliran, dan pelepasan airtanah berlangsung. CAT mempunyai batas yang secara langsung dikontrol oleh kondisi geologi dan hidraulik, CAT mempunyai daerah imbuhan airtanah dan daerah lepasan airtanah serta memiliki satu kesatuan sistem akuifer berdasarkan peta cekungan air tanah daerah Sulawesi Tenggara. Daerah lokasi studi berada pada daerah yang bukan merupakan cekungan air tanah atau cekungan air tanah yang tidak potensial (Gambar 3.10).



Gambar 3.10 Peta cekungan air tanah regional lokasi studi

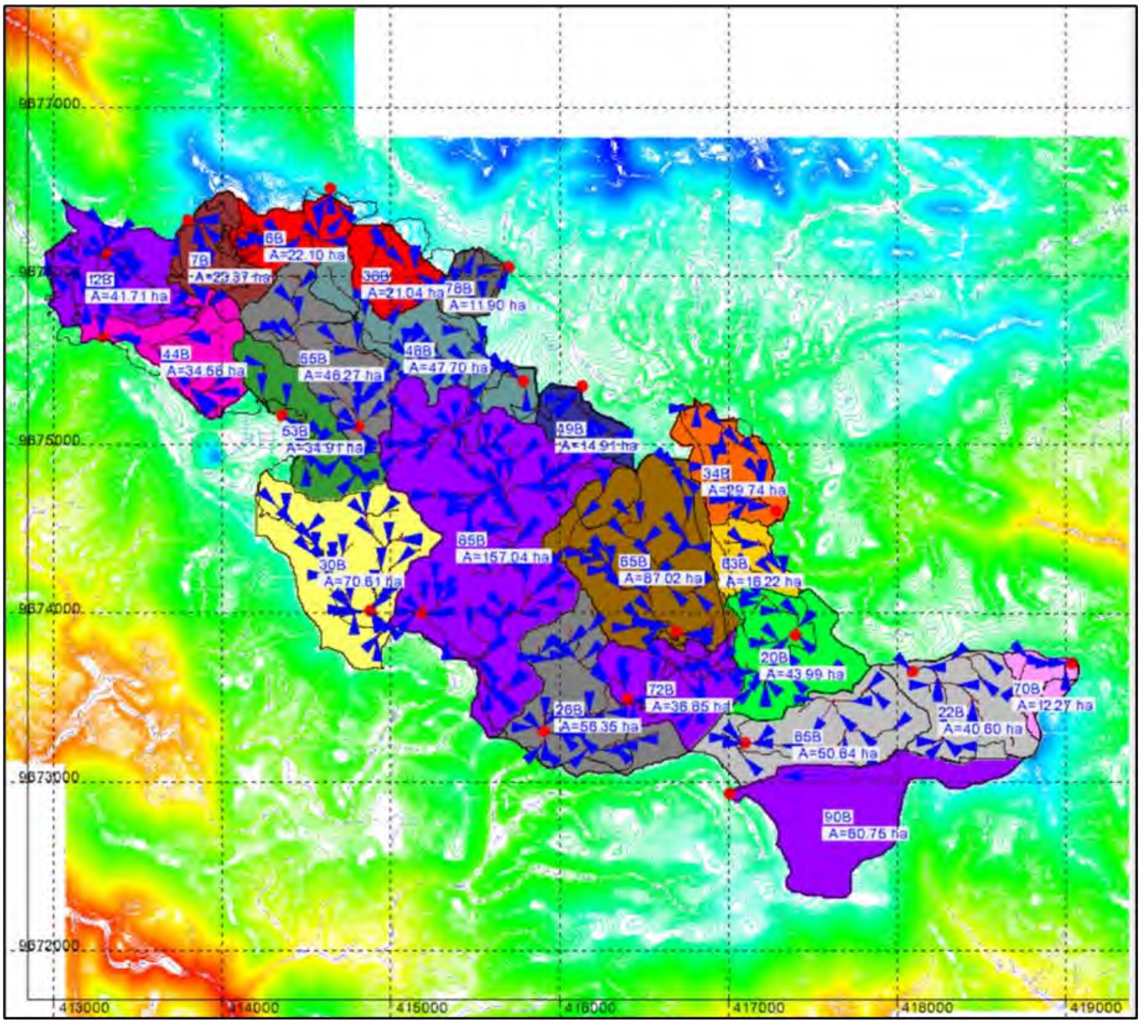
3.2. Analisis Hidrologi

3.2.1. Analisis *Catchment*

3.2.1.1. *Catchment Area* Rencana Tambang

Perubahan morfologi akibat bukaan tambang akan mengubah aliran air permukaan alami khususnya pada lokasi rencana bukaan tambang. Pada kondisi tambang, air permukaan secara dominan mengalir menuju titik terendah menuju lubang bukaan tambang, dengan terdapat sebagian kecil aliran air permukaan yang tetap mengalir mengikuti aliran alaminya. Delineasi *catchment* rencana bukaan tambang dilakukan menggunakan desain bukaan tambang kondisi akhir. Pada kondisi aktualnya, perubahan *sub-catchment* perlu disesuaikan mengikuti *sequence* dari kemajuan tambang.

Catchment area yang terbentuk dari rencana bukaan tambang HM dapat dilihat pada Gambar 3.11. Berdasarkan hasil delineasi, aliran air permukaan pada rencana bukaan tambang HM dapat dibagi menjadi 18 *sub-catchment*. Beberapa *sub-catchment* memiliki aliran yang cukup besar dari luar pit, sehingga perimeter *drainage* dibutuhkan pada beberapa area untuk mencegah aliran dan mengurangi jumlah air permukaan yang masuk ke dalam pit. Luas masing-masing *sub-catchment* dan karakteristik fisik aliran dari rencana bukaan tambang HM dapat dilihat pada Tabel 3.5.



Gambar 3.11 *Sub-catchment* area rencana tambang HM

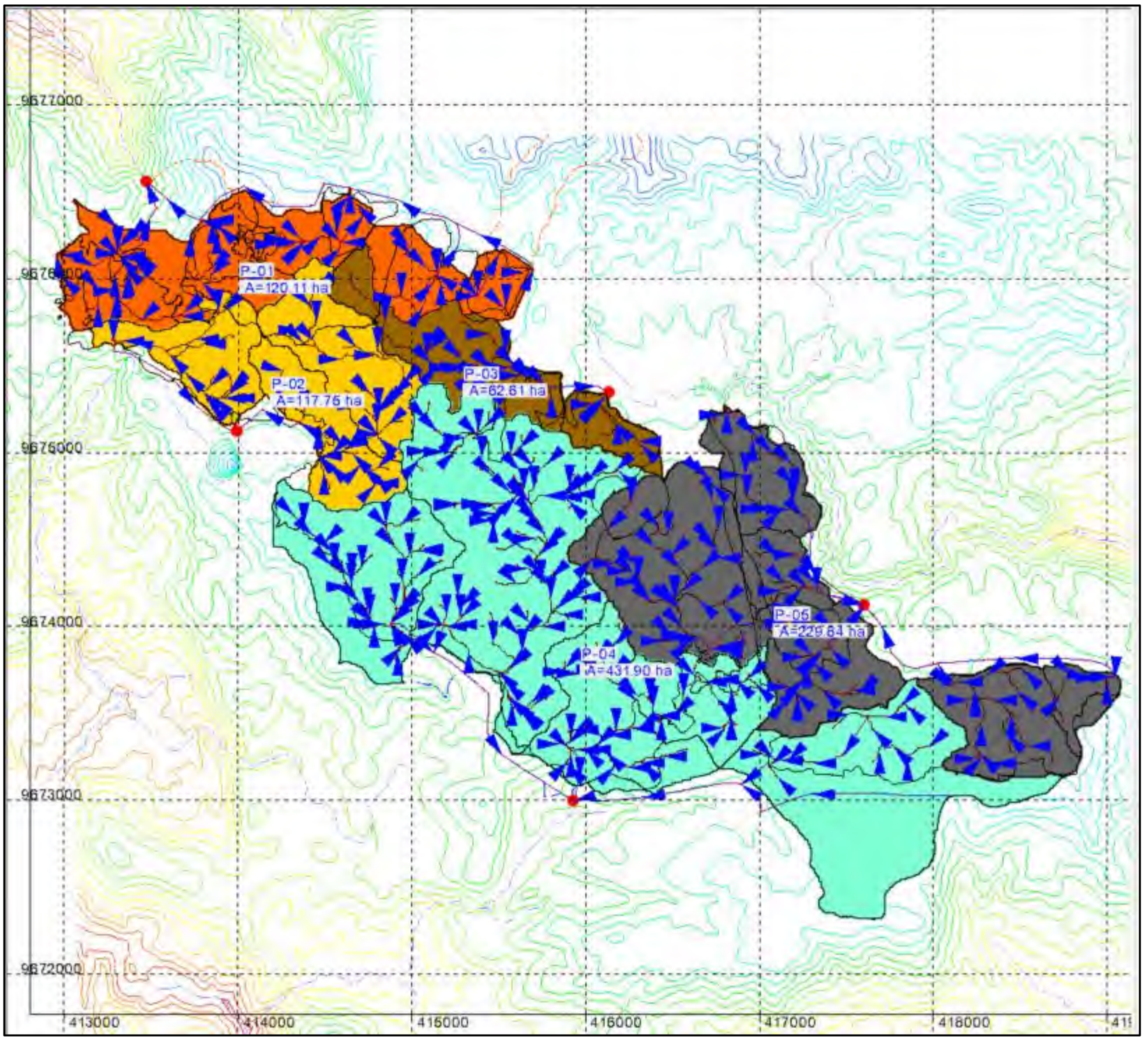
Tabel 3.5 Luas dan karakteristik fisik *sub-catchment area* rencana bukaan tambang

Sub-Catch	Basin Area (A)	Basin Slope (BS)	Basin Length (L)	Basin Perimeter (P)	Maximum Flow Disctance (MFD)	Maximum Flow Slope (MFS)
	Ha	m/m	m	m	m	m
90B	60.75	0.1677	1763.837	5831.0201	1922.19	0.0638
72B	36.85	0.2684	767.7083	4031.4898	1139.84	0.0474
70B	12.27	0.3989	496.3386	2194.1339	856.8	0.171
65B	87.02	0.2605	1067.7	5507.2013	1687.2	0.0744
63B	16.22	0.2826	572.8804	2494.0209	719.72	0.1265
55B	48.27	0.2162	1081.961	4704.3886	1765.09	0.0646
53B	34.91	0.2321	724.6296	4291.2807	981.7	0.0451
49B	14.91	0.2277	612.6794	2438.9548	709.53	0.0791
48B	47.7	0.1976	1401.445	5854.7629	1801.59	0.0677
44B	34.58	0.3007	910.1121	4516.9167	1170.39	0.1251

Sub-Catch	Basin Area (A)	Basin Slope (BS)	Basin Length (L)	Basin Perimeter (P)	Maximum Flow Disctance (MFD)	Maximum Flow Slope (MFS)
	Ha	m/m	m	m	m	m
38B	21.04	0.1707	458.1703	2473.4198	794.25	0.0733
34B	29.74	0.2517	846.7632	3370.16	1362.28	0.0521
78B	11.9	0.1932	478.2803	1784.6887	723.36	0.0484
30B	70.61	0.2994	1036.378	5122.3505	1272.68	0.0966
26B	56.35	0.256	879.6818	5425.3145	1426.41	0.0736
22B	40.6	0.3551	873.1552	3794.3871	1062.01	0.1411
20B	43.99	0.1977	620.8768	4111.5782	948.35	0.059
12B	41.71	0.3281	645.6748	4117.9297	1021.62	0.1496
7B	23.37	0.2437	636.088	3190.1908	1143.23	0.0701
6B	22.1	0.1827	680.2941	3150.7921	1179.8	0.0695
85B	50.84	0.3086	1108.52	4602.3301	1556.96	0.0556
85B	157.04	0.2427	1504.766	9670.0309	3120.85	0.0423

3.2.1.2. Catchment Area Rencana Pond

Catchment area dari *settling pond* dihitung sebagai titik akhir penyaliran dari lokasi tambang (pit dan *disposal*) sebelum dibuang ke perairan bebas. Secara umum konsep rencana *settling pond* terdiri dari lima lokasi utama, seperti dapat dilihat pada Gambar 3.12. Hasil delineasi luas masing-masing *sub-catchment* dan karakteristik fisik dari rencana *pond* dapat dilihat pada Tabel 3.6.



Gambar 3.12 *Sub-catchment area* rencana *settling pond*

Tabel 3.6 Luas dan karakteristik fisik *sub-catchment area* rencana *settling pond*

Sub-Catch	Basin Area (A)	Basin Slope (BS)	Basin Length (L)	Basin Perimeter (P)	Maximum Flow Disctance (MFD)	Maximum Stream Slope (MSS)
	Ha	m/m	m	m	m	m
P-01	120.11	0.2437	2307.6915	14708.4894	3352.18	0.1353
P-02	117.75	0.2455	1117.2108	13507.1236	2903.71	0.1739
P-03	62.61	0.2048	1724.464	8289.3021	2160.32	0.0543
P-04	431.9	0.2532	2820.4794	31951.1715	4548.61	0.0972
P-05	229.84	0.2726	1690.3491	21418.362	2971.23	0.1507

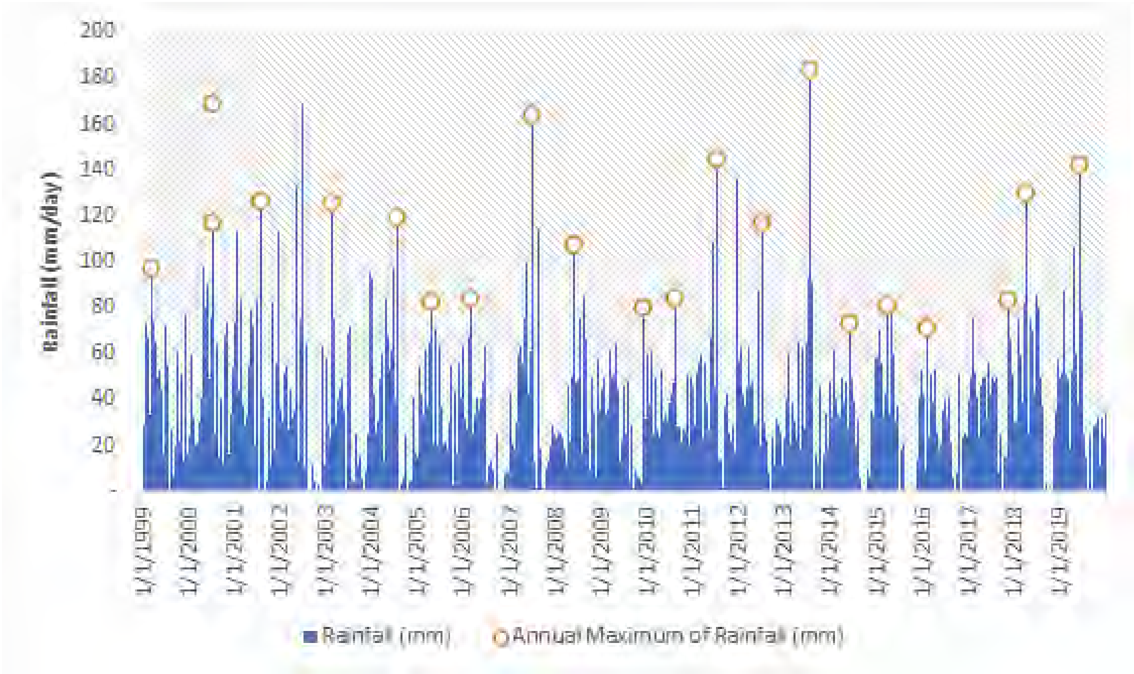
3.2.2. Desain Hujan Puncak

Desain hujan puncak diprediksi melalui analisis frekuensi. Analisis frekuensi bertujuan untuk mencari hubungan antara besarnya suatu kejadian (maksimum atau minimum) dan frekuensinya berdasarkan distribusi probabilitas. Hubungan antara besarnya kejadian dan frekuensinya, atau peluang kejadiannya adalah berbanding terbalik. Pengambilan seri data untuk tujuan analisis frekuensi dilakukan terhadap data maksimum tahunan (*annual maximum series*).

Data hujan maksimum tahunan diambil dari hasil data akuisisi yang diambil satu data maksimum untuk setiap tahunnya. Tabel 3.7 dan Gambar 3.13 memaparkan nilai curah hujan harian maksimum tahunan (*annual maximum*) untuk lokasi studi.

Tabel 3.7 Nilai hujan maksimum harian (*annual maximum*) lokasi studi

Tahun	Annual Maximum of Rainfall (mm)	Tanggal Kejadian
1999	97.05	4-Mar-99
2000	117.38	4-Jul-00
2001	126.76	22-Jul-01
2002	168.87	5-Jul-00
2003	125.50	8-Feb-03
2004	119.67	12-Jul-04
2005	82.65	9-Apr-05
2006	83.98	22-Feb-06
2007	164.11	28-Jun-07
2008	107.55	29-May-08
2009	80.34	24-Nov-09
2010	84.21	3-Aug-10
2011	144.88	11-Jul-11
2012	117.06	6-Jul-12
2013	184.07	10-Jul-13
2014	73.30	4-Jun-14
2015	81.10	31-Mar-15
2016	71.70	6-Feb-16
2017	83.50	15-Nov-17
2018	130.00	10-Apr-18
2019	142.00	7-Jun-19



Gambar 3.13 Grafik hujan maksimum harian (*annual maximum*) lokasi studi.

Frekuensi data hujan dapat diartikan sebagai suatu cara untuk memprediksi suatu besaran curah hujan di masa yang akan datang dengan menggunakan data curah hujan di masa yang lalu berdasarkan distribusi frekuensi. Dalam studi ini fungsi distribusi yang dianalisis menggunakan fungsi distribusi normal, distribusi log-normal, distribusi log Pearson III, dan distribusi Gumbel. Untuk mendapatkan fungsi distribusi yang sesuai digunakan, uji kompatibilitas dilakukan dengan metode Kolmogorov Smirnov dan Chi-Square. Hasil uji kesesuaian distribusi ditunjukkan pada Tabel 3.8. Hasil analisis distribusi yang paling mendekati adalah distribusi Normal.

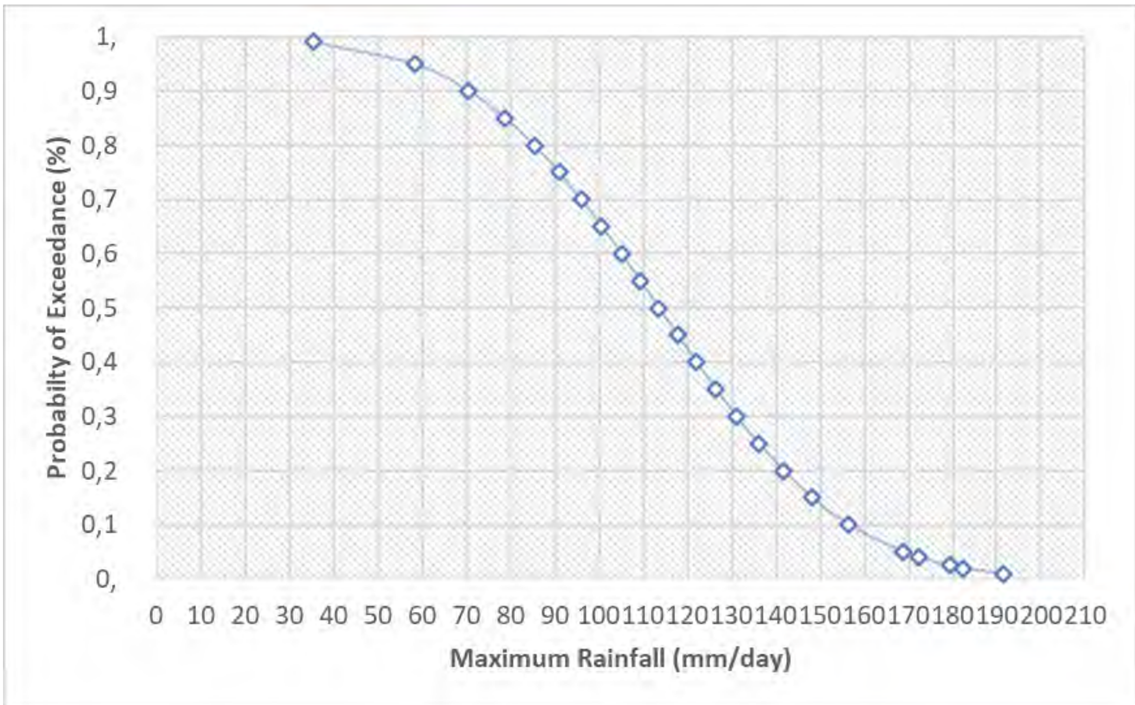
Tabel 3.8 Hasil uji kecocokan distribusi data hujan maksimum

Kolmogorov-Smirnov Test	**Normal**	**Log Normal**	**Gumbel**	**Log Pearson III**
D-value	0.173	0.177	0.186	0.176
D-Critical	0.284	0.284	0.284	0.284
Chi-Square Test	**Normal**	**Log Normal**	**Gumbel**	**Log Pearson III**
Chi-square (Observed value)	4.667	7.333	4.667	7.333
Derajat Kebebasan	4	4	4	3
Chi-square (Critical value)	9.448	9.448	9.448	7.815

Selanjutnya perhitungan hujan rencana (hujan puncak) dihitung dengan menggunakan fungsi distribusi Normal. Resume hasil perhitungan hujan puncak dengan probabilitas atau periode ulang tertentu dapat dilihat pada Tabel 3.9 dan Gambar 3.14.

Tabel 3.9 Hasil perhitungan hujan puncak pada periode ulang tertentu

P(x >= Xm) Probabilitas	Tahun Kala-Ulang	Hujan Puncak (mm/hari)
0.99	1	35.644
0.5	2	113.604
0.2	5	141.809
0.1	10	156.552
0.05	20	168.727
0.04	25	172.273
0.025	40	179.287
0.02	50	182.429
0.01	100	191.565



Gambar 3.14 Grafik probabilitas analisis hujan rencana (hujan puncak).

Intensitas Hujan Maksimum

Hasil yang didapatkan dari analisis frekuensi hujan masih berupa curah hujan harian (akumulasi selama 24 jam). Selanjutnya data hujan harian perlu diubah terlebih dahulu menjadi data intensitas. Intensitas hujan dapat dikatakan sebagai ketinggian atau kederasan hujan per satuan waktu, biasanya dinyatakan dalam satuan yang lebih pendek (mm/jam). Jika volume hujan adalah tetap, maka intensitas hujan akan makin tinggi seiring dengan durasi hujan yang makin singkat, sebaliknya intensitas hujan makin rendah seiring dengan durasi hujan yang makin lama. Nilai intensitas hujan dapat dinyatakan sebagai intensitas pada satu titik, yang dinyatakan melalui kurva IDF (*Intensity Duration Frequency*) atau hujan yang terdistribusi dalam hujan jam-jaman.

Jika data hujan jangka pendek tidak tersedia dan data hujan harian tersedia, maka persamaan regresi kurva IDF diturunkan dengan persamaan:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^m$$

R_{24} = curah hujan untuk satu hari

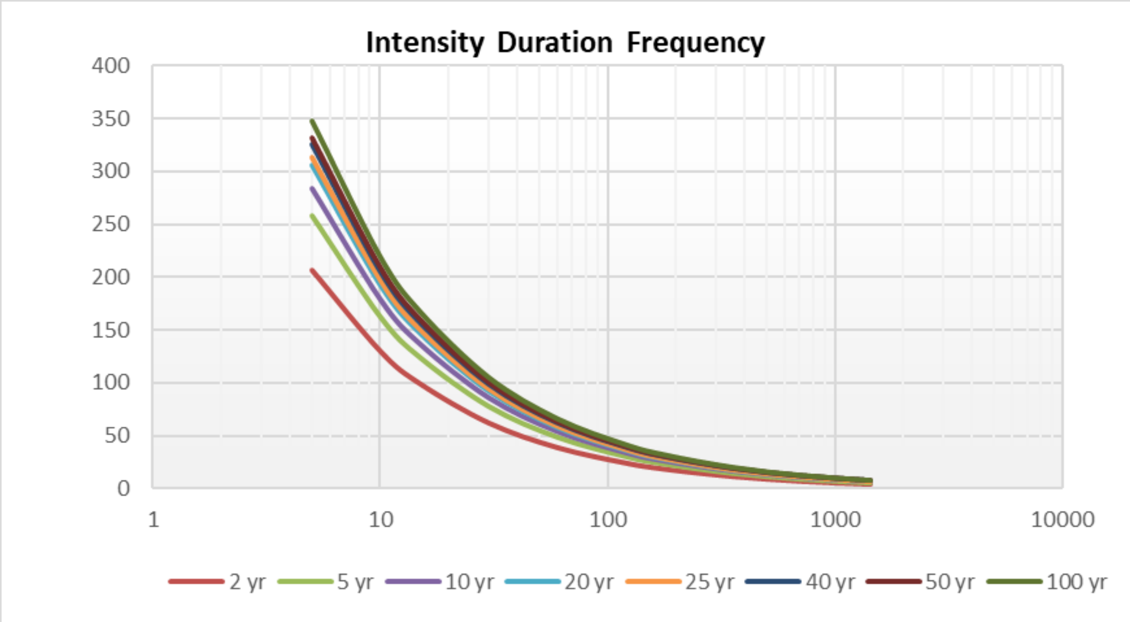
t = periode ulang (2, 5, 10, 15, 20, 25, 40, 50, dan 100 tahun)

m = koefisien hujan

Hasil perhitungan intensitas hujan periode ulang tertentu (*Intensity Duration Frequency*) dapat dilihat pada Tabel 3.10 dan Gambar 3.15.

Tabel 3.10 Hasil perhitungan intensitas periode ulang hujan (*Intensity Duration Frequency*) lokasi rencana tambang HM

Duration (minutes)	Rainfall Intensity (mm/hour)						
	2 yr	5 yr	10 yr	20 yr	25 yr	50 yr	100 yr
5	210.56	266.31	302.97	338.13	349.31	383.97	418.84
10	132.64	167.76	190.86	213.01	220.05	241.89	263.85
15	101.23	128.03	145.65	162.55	167.93	184.60	201.36
30	63.77	80.65	91.76	102.40	105.79	116.29	126.85
60	40.17	50.81	57.80	64.51	66.64	73.26	79.91
120	25.31	32.01	36.41	40.64	41.98	46.15	50.34
180	19.31	24.43	27.79	31.01	32.04	35.22	38.42
360	12.17	15.39	17.51	19.54	20.18	22.19	24.20
720	7.66	9.69	11.03	12.31	12.71	13.98	15.25
1440	4.83	6.11	6.95	7.75	8.01	8.80	9.60



Gambar 3.15 Kurva *Intensity Duration Frequency* (IDF) lokasi rencana tambang HM

3.2.3. Koefisien Limpasan

Koefisien limpasan adalah persentase jumlah air yang dapat melalui permukaan tanah dari keseluruhan air hujan yang jatuh pada suatu daerah. Semakin kedap suatu permukaan, maka semakin tinggi nilai koefisien pengalirannya. Nilai koefisien pengaliran (C) berkisar antara 0 – 1. Nilai C= 0 menunjukkan bahwa semua air hujan terintersepsi dan terinfiltrasi ke dalam tanah, sebaliknya untuk nilai C= 1 menunjukkan bahwa air hujan mengalir sebagai aliran permukaan.

Penentuan nilai faktor C dihitung dengan mengintegrasikan beberapa faktor yang mempengaruhi, yaitu: topografi, kapasitas infiltrasi, tutupan lahan, dan *surface storage*. Nilai koefisien C merupakan kombinasi dari beberapa faktor tersebut, dihitung berdasarkan referensi yang dapat dilihat pada Tabel 3.11 (*Hydraulic Design Manual*, TxDOT, 2016). Hasil perhitungan koefisien pengaliran (C) untuk masing-masing *sub-catchment* yang mempengaruhi tambang HM dapat dilihat pada Tabel 3.12.

Tabel 3.11 Kurva perhitungan koefisien limpasan (*Hydraulic Design Manual*, TxDOT, 2016)

Watershed characteristic	Extreme	High	Normal	Low
Relief - C_r	0.28-0.36	0.20-0.28	0.14-0.20	0.08-0.14
	Steep, rugged terrain with average slopes above 30%	Hilly, with average slopes of 10-30%	Rolling, with average slopes of 5-10%	*Relatifl*y flat land, with average slopes of 0-5%
Soil infiltration - C_i	0.12-0.16	0.08-0.12	0.06-0.08	0.04-0.06
	No effective soil cover; either rock or thin soil mantle of negligible infiltration capacity	Slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	Normal; well drained light or medium textured soils, sandy loams	Deep sand or other soil that takes up water readily; very light, well-drained soils
Vegetal cover - C_v	0.12-0.16	0.08-0.12	0.06-0.08	0.04-0.06
	No effective plant cover, bare or very sparse cover	Poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area has good cover	Fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in crops	Good to excellent; about 90% of drainage area in good grassland, woodland
Surface Storage - C_s	0.10-0.12	0.08-0.10	0.06-0.08	0.04-0.06
	Negligible; surface depressions few and shallow, no marshes	Well-defined system of small drainage ways, no ponds or marshes	Normal; considerable surfacedepression, e.g., storage lakes and ponds	Much surface storage, large number of ponds or marshes

Tabel 3.12 Estimasi nilai koefisien limpasan pada *catchment* tambang HM

Parameter	Bukaan Tambang	Rencana Pond
Relief - Cr	0.32	0.28
Soil infiltration - Ci	0.16	0.14
Vegetal cover - Cv	0.16	0.16
Surface Storage - Cs	0.12	0.12
Total	**0.76**	**0.70**

3.2.4. Debit Puncak Air Permukaan

Estimasi debit puncak air permukaan dihitung untuk kepentingan rencana penyaliran tambang. Secara umum debit puncak dihitung untuk kepentingan:

1. Desain *sump* atau sumuran pit pada bukaan tambang
2. Desain saluran
3. Desain *setlling pond*

Berdasarkan data yang diterima, desain tambang merupakan desain pada kondisi tambang akhir, sehingga estimasi debit puncak menghitung kondisi maksimum. Analisis debit puncak air permukaan dihitung dengan menggunakan metode rasional. Berdasarkan SNI 2415:2016 metode rasional dapat digunakan untuk luas DAS yang relatif kecil. Metode rasional adalah metode empiris dari hubungan sederhana antara intensitas curah hujan dengan debit puncak. Persamaan pada metode rasional adalah sebagai berikut:

$$Q = C.I.A$$

Q = debit banjir maksimum (m^3/dtk)

C = koefisien pengaliran/limpasan

I = intensitas curah hujan rata-rata (mm/jam)

A = luas daerah pengaliran (m^2)

Metode rasional pada prinsipnya menggunakan beberapa dasar asumsi, sebagai berikut:

- Curah hujan didistribusikan secara merata ke seluruh area drainase dan konstan sepanjang waktu
- Estimasi debit puncak memiliki probabilitas kejadian yang sama (periode ulang) seperti yang digunakan pada distribusi intensitas hujan (I)
- Estimasi debit puncak dapat direpresentasikan oleh intensitas curah hujan rata-rata selama periode waktu yang sama dengan waktu konsentrasi (Tc)
- Koefisien pengaliran dianggap konstan

Penentuan intensitas hujan yang digunakan mengacu kepada asumsi bahwa hujan terdistribusi merata dengan intensitas hujan terjadi selama periode waktu yang sama dengan waktu konsentrasi.

Dalam hal ini perhitungan waktu konsentrasi menggunakan metode Kirpich dengan persamaan:

$$tc = 0.0195\ L^{0.77}\ S^{-0.385}$$

tc = waktu konsentrasi

L = panjang *basin* (m)

S = *slope* rata-rata *catchment*

Debit Puncak Rencana Bukaan Tambang

Hasil estimasi debit puncak air permukaan dengan metode rasional pada rencana bukaan tambang HM dapat dilihat pada Tabel 3.13. Hasil tersebut merupakan estimasi debit puncak menggunakan periode ulang 25 tahun.

Tabel 3.13 Estimasi debit dan volume maksimum aliran air permukaan pada masing-masing *sub-catchment* rencana bukaan tambang HM

Sub-Catchment	Runoff Coefficient (C)	Rainfall Intensity (mm/hour)	Catchment Area (A) (Ha)	Time of Concentration (minutes)	Peak Flow Rate (m3/sec)
90B	0.76	31.12	60.75	159.39	3.99
72B	0.76	37.71	36.85	119.51	2.93
70B	0.76	60.69	12.27	58.52	1.57
65B	0.76	34.63	87.02	135.82	6.36
63B	0.76	61.43	16.22	57.47	2.10
55B	0.76	32.62	48.27	148.52	3.32
53B	0.76	40.21	34.91	108.52	2.96
49B	0.76	54.85	14.91	68.11	1.73
48B	0.76	32.68	47.70	148.16	3.29
44B	0.76	47.73	34.58	83.93	3.48
38B	0.76	50.77	21.04	76.50	2.25
34B	0.76	35.27	29.74	132.15	2.21
78B	0.76	47.88	11.90	83.53	1.20
30B	0.76	42.79	70.61	98.86	6.38
26B	0.76	0.00	56.35	119.86	0.00
22B	0.76	51.74	40.60	74.35	4.43
20B	0.76	43.85	43.99	95.29	4.07
12B	0.76	53.59	41.71	70.54	4.72
7B	0.76	41.63	23.37	103.02	2.05
6B	0.76	40.87	22.10	105.90	1.91
85B	0.76	30.56	50.84	150.76	3.28

<u>Debit Puncak Rencana *Pond*</u>

Hasil estimasi debit puncak air permukaan dengan metode rasional pada rencana *pond* dapat dilihat pada Tabel 3.14. Hasil tersebut merupakan estimasi debit puncak dengan periode ulang 100 tahun.

Tabel 3.14 Estimasi debit dan volume maksimum aliran air permukaan pada masing-masing *sub-catchment* rencana *settling pond*

Sub-Catchment	Runoff Coefficient	Rainfall Intensity	Catchment Area (A)	Time of Concentration	Peak Flow Rate
	(C)	(mm/hour)	(Ha)	(minutes)	(m3/sec)
P-01	0.7	31.45	120.11	135.56	7.34
P-02	0.7	36.12	117.75	240.27	8.27
P-03	0.7	31.17	62.61	91.89	3.79
P-04	0.7	24.67	431.90	69.02	20.72
P-05	0.7	34.40	229.84	63.96	15.37

3.3. Analisis Hidrogeologi

3.3.1. Latar Belakang Geologi

Lokasi rencana penambangan HM secara keseluruhan terbentuk oleh Kompleks Ultramafik yang terdiri dari litologi peridotit, harzburgit, Iherzolit, wherkit, serpentinit, dan dunit. Unit stratigrafi ini berumur Kapur hingga Oligosen (Simandjuntak dkk., 1991). Pada bagian permukaan, pelapukan batuan ultrabasa di lokasi IUP HM menghasilkan bijih nikel yang dikenal sebagai nikel laterit. Secara umum profil endapan laterit pada lokasi HM adalah sebagai berikut:

1. Lapisan Penutup

   Lapisan ini berwarna coklat kemerahan, merupakan kumpulan massa goetit, hematit, dan limonit, mempunyai kadar besi yang tinggi tetapi kandungan nikel yang relatif rendah.

2. Lapisan Limonit

   Lapisan ini berbutir halus, berwarna coklat muda sampai kekuningan dengan komposisi mineral terdiri dari goetit, limonit, hematit, magnetit, kromit, dan kuarsa sekunder. Kadang-kadang juga dijumpai mineral talk, tremolit, kuarsa, dan maghemit. Pada mineral goetit terikat nikel, krom, kobalt, vanadium, dan aluminium. Lapisan ini umumnya tipis pada daerah yang terjal hingga hilang karena erosi.

3. Zona Saprolit

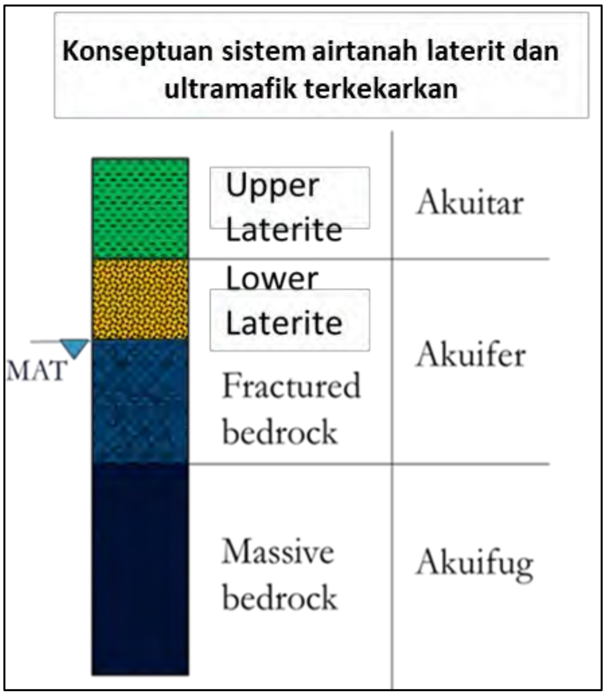
Lapisan ini umumnya berwarna coklat kekuningan sampai kehijauan, merupakan lapisan batuan dasar yang sudah lapuk. Struktur dan tekstur batuan asal masih bisa terlihat. Perubahan geokimia zona ini yang terletak di atas bantuan asal tidak banyak H_2O dan nikel bertambah, sedangkan magnesium dan silika hanya sedikit yang hilang terlindi, zona ini terdiri dari campuran sisa-sisa batuan asal, butiran halus limonit, urat garnierit, kuarsa, mangan, dan kadang-kadang terdapat silika *boxwork*.

4. Zona batuan dasar (*bedrock*)

   Merupakan bagian terbawah dari profil laterit, tersusun dari bongkah-bongkah yang lebih besar dari 75 cm dan blok batuan dasar. Umumnya zona ini berwarna abu-abu kehijauan dan tidak mengandung mineral ekonomis. Kadar mineral logam mendekati atau sama dengan batuan asal.

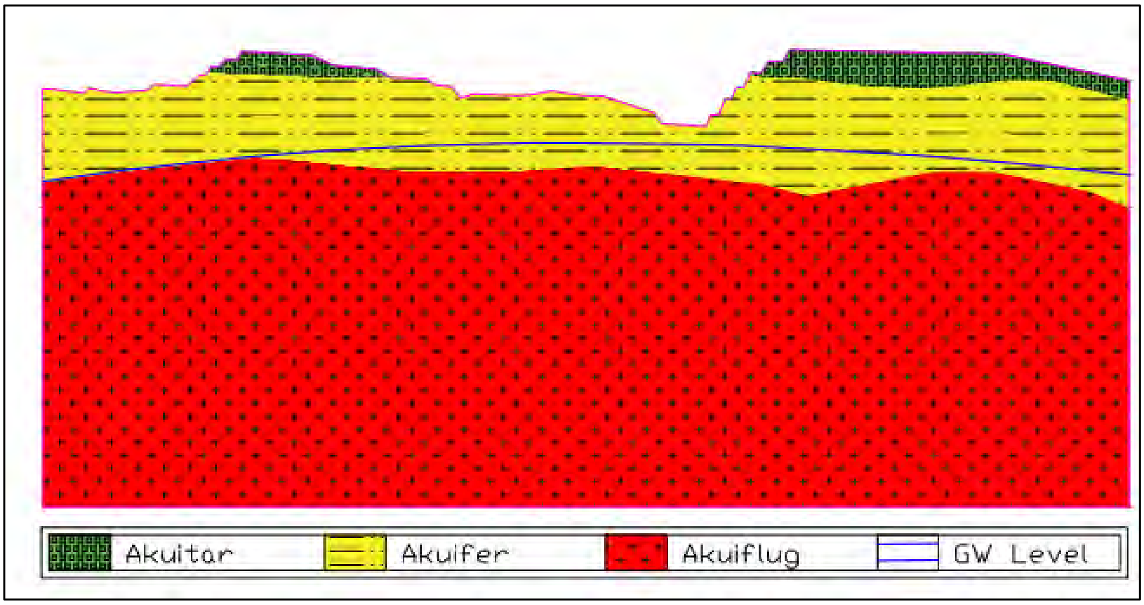
3.3.2. Sistem Hidrogeologi

Sistem airtanah laterit dan ultramafik terkekarkan hadir pada Formasi Ultrabasa, di mana lokasi rencana tambang HM terletak pada sistem airtanah ini. Berdasarkan hasil interpretasi diketahui bahwa lapisan penyusun hidrostratigrafi sistem airtanah ini dibagi menjadi tiga, yaitu tanah laterit berukuran lempung (laterit atas), laterit bawah dan batuan ultramafik terkekarkan, serta batuan ultramafik tidak terkekarkan. Lapisan yang membentuk zona akuifer utama pada sistem airtanah ini adalah laterit bawah dan batuan ultramafik terkekarkan. Lapisan laterit bawah dan batuan ultramafik terkekarkan dikelompokkan menjadi satu zona akuifer utama. Tanah laterit berukuran lempung (limonit) berfungsi sebagai lapisan akuiklud, sedangkan lapisan batuan ultramafik yang tidak terkekarkan bertindak sebagai lapisan akuifug (Gambar 3.16). Ketebalan lapisan akuifer sangat bervariasi yaitu berkisar antara 10-30 m dan lapisan akuifug (batuan dasar yang tidak terkekarkan) diasumsikan kontinu hingga ketebalan lebih dari 100 meter.



Gambar 3.16 Konseptual sistem hidrogeologi lokasi IUP HM

Berdasarkan interpolasi data pengeboran geoteknik, selanjutnya interpretasi hidrostratigrafi di lokasi rencana tambang HM dibuat dengan representatif penampang seperti dapat dilihat pada Gambar 3.17. Lapisan limonit yang berada pada bagian paling atas sangat dipengaruhi oleh aktivitas permukaan yang kuat. Hal ini mengakibatkan lapisan limonit secara umum memiliki ukuran butir yang halus (lempung-lanau) yang membuat lapisan ini diklasifikasikan sebagai akuiklud. Lapisan saprolit atau yang merupakan zona bijih tersusun atas fragmen-fragmen batuan induk yang ter-alterasi, namun pengaruh aktivitas permukaan cenderung minimal. Akibat hasil tersebut maka ukuran butir pada lapisan ini cenderung sangat heterogen, namun berdasarkan hasil uji lapangan lapisan saprolit masuk dalam klasifikasi akuifer. Lapisan terbawah dari nikel laterit merupakan *bedrock*.

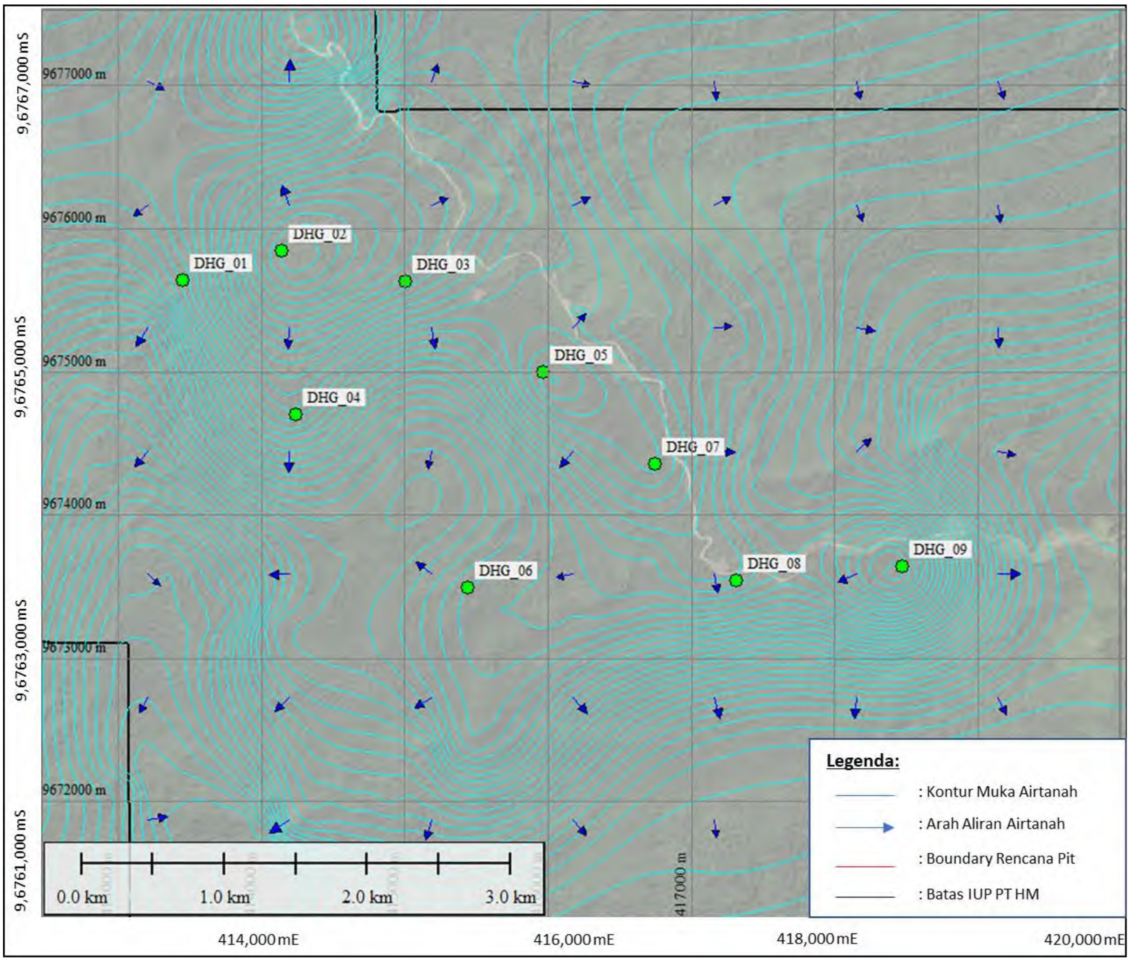


Gambar 3.17 Representatif penampang hidrostratigrafi lokasi IUP HM

Secara umum, berdasarkan hasil pengamatan lapangan, *bedrock* dapat dibagi menjadi dua bagian, yaitu *fractured bedrock* dan *unfractured bedrock*. *Fractured bedrock* hadir dominan pada bagian atas dari *bedrock* yang hadir dengan ketebalan variatif. Kondisi batuan dasar yang terkekarkan membuat zona ini menjadi potensial sebagai zona akuifer dengan medium sistem rekahan. Zona *unfractured bedrock* terletak pada bagian bawah merupakan batuan yang masih segar dan tidak terkekarkan. Zona *unfractured bedrock* diklasifikasikan sebagai akuifug.

3.3.3. Pola Aliran dan Muka Airtanah

Berdasarkan data hasil pengukuran level muka airtanah, interpolasi kontur muka airtanah dilakukan untuk mengetahui gambaran umum pola dan aliran airtanah pada kondisi yang ada saat ini. Selain data muka airtanah, interpretasi juga dibangun berdasarkan fitur hidrologi lainnya, seperti batas sungai dan batas laut. Peta kontur muka airtanah dan interpretasi alirannya dapat dilihat pada Gambar 3.18.



Gambar 3.18 Pola umum aliran airtanah lokasi studi

Berdasarkan hasil interpretasi dapat terlihat bahwa kondisi aliran airtanah saat ini telah terpengaruh oleh aktivitas penambangan yang telah berjalan. Pada area tambang kontur airtanah berada lebih rendah dari daerah sekitarnya dan aliran airtanah cenderung mengarah pada area bukaan tambang. Penurunan atau perubahan aliran airtanah akibat aktivitas tambang berjalan saat ini relatif bersifat lokal, yaitu perubahan tidak memengaruhi aliran secara regional. Airtanah mengalir cenderung dari arah baratlaut menuju tenggara.

3.3.4. Model Hidrogeologi

Model hidrogeologi dibuat untuk dapat memahami kondisi airtanah pada lokasi tambang HM, memprediksi pola perubahan airtanah, serta memprediksi *inflow* airtanah pada kondisi penambangan selanjutnya.

Metode, Pendekatan, dan Asumsi

Pemodelan aliran airtanah (*flow model*) bertujuan untuk mendapatkan gambaran perubahan pola aliran tanah antara kondisi *existing* dan penambangan. Beberapa pendekatan dan asumsi yang digunakan dalam model aliran antara lain:

- Simulasi menggunakan metode *finite difference.*
- Airtanah dianggap sebagai satu sistem besar dengan koneksi hidraulik melalui semua litologi yang hadir.
- *Input* awal parameter hidraulik (K) menggunakan data hasil pengujian lapangan dan penyesuaian nilai parameter hidraulik (K) dilakukan selama proses kalibrasi model.
- Parameter hidraulik lainnya (storativitas, porositas efektif, dan laju infiltrasi aktual) diasumsikan berdasarkan literatur dan merupakan bentuk ketidakpastian.
- *Initial head* menggunakan hasil interpretasi kontur muka airtanah yang telah dijelaskan pada sub-bab sebelumnya.
- Kalibrasi model dilakukan pada kondisi tunak (*steady state*), menggunakan data elevasi airtanah hasil pengukuran lapangan kondisi *existing*.

Model kondisi tunak dijalankan untuk memverifikasi model secara fisik. Model kondisi transien yang dikalibrasi perlu dibangun selanjutnya menggunakan data pemantauan airtanah yang dikumpulkan selanjutnya untuk memberikan hasil yang lebih akurat.

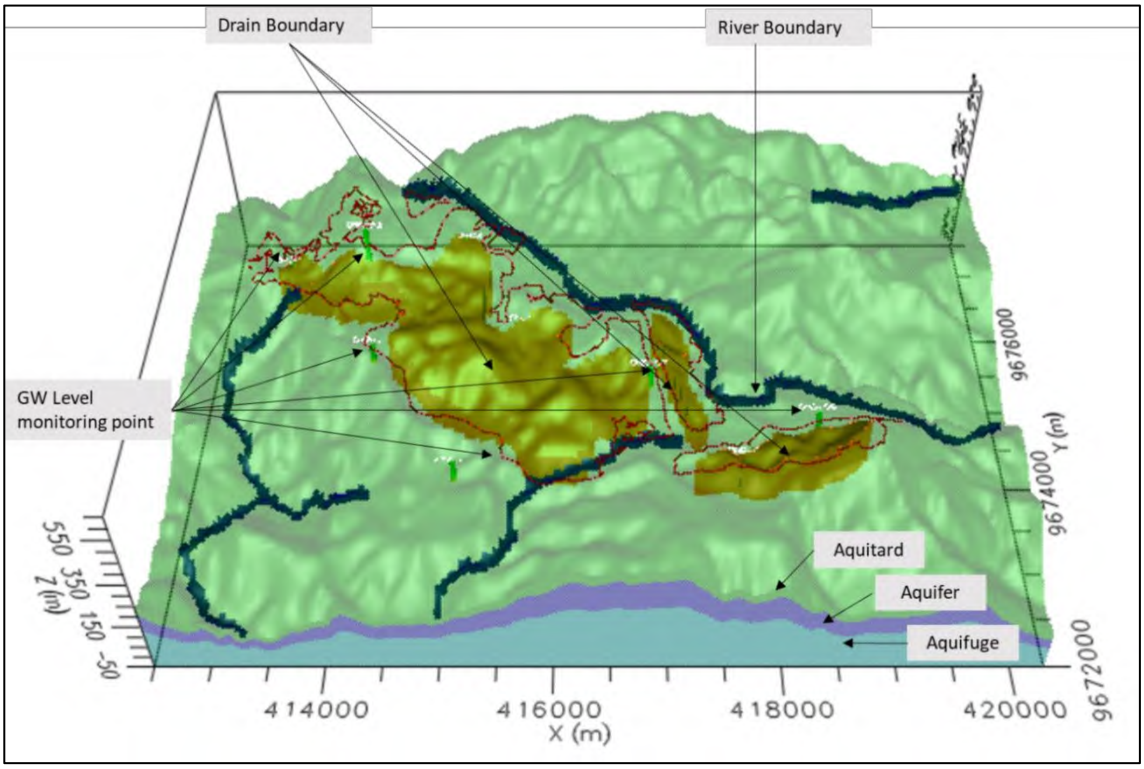
Dimensi Model Fisik

Model hidrogeologi dibangun dengan dimensi 7,8 km pada arah barat-timur dan 5,5 km pada arah utara-selatan dengan luas model sekitar 42,9 km^2. Model dibuat lebih luas dari area *interest* untuk dapat melihat pola perubahan aliran airtanah secara lebih luas. Model ini menggunakan ukuran *grid* berukuran 50 m x 50 m dengan total jumlah sel sebanyak 51.480. Batas dimensi serta ukuran *grid* dari model fisik dapat dilihat pada Tabel 3.15.

Tabel 3.15 Dimensi dan ukuran *grid* dari model fisik hidrogeologi

Dimensi Model			Jarak (m)	Ukuran Grid (m)	Jumlah Grid/Layer
Easting (column)	Min	412500	7800	50	156
	Max	420300			
Northing (row)	Min	9672000	5500	50	110
	Max	9677500			
Elevasi	Min	-50	550	-	3
	Max	500			

Aliran airtanah dimodelkan berdasarkan pendekatan hidrostratigrafi, sehingga layer dibentuk dengan mengikuti hidrostratigrafi berdasarkan interpretasi data bor, atau dengan kata lain masing-masing layer yang terbentuk akan memuat nilai parameter hidraulik tertentu. Selanjutnya data topografi digunakan sebagai batas permukaan dalam pemodelan, sedangkan batas bawah dibatasi pada elevasi -50 mdpl yang diklasifikasikan sebagai lapisan akuifug. Gambaran model fisik hidrogeologi dapat dilihat pada **Error! Reference source not found.**.



Gambar 3.19 Gambaran model hidrogeologi pada bidang tiga dimensi

Initial Head

Distribusi *initial head* airtanah dimodelkan secara spasial berdasarkan pengukuran air tanah yang dilakukan pada tahun 2021. Secara umum, aliran airtanah pada kondisi awal mengalir cenderung berarah barat-timur (lihat Gambar 3.18).

Parameter Hidraulik

Data parameter hidraulik dibuat berdasarkan model konseptual yang telah dijelaskan sebelumnya. Penyesuaian nilai parameter hidraulik dilakukan selama pembuatan model *steady-state*. Data kondisi parameter hidraulik yang digunakan dalam pemodelan dapat dilihat pada Tabel 3.16.

Tabel 3.16 *Input* parameter hidraulik untuk model airtanah

Layer	Litologi	Hidrostratigrafi	K	S			
			(m/s)	Ss	Sy	Eff. Por.	Tot. Por.
1	Limonit	Akuiklud	1.40E-09	3.00E-04	0.12	0.21	0.41
2	Saprolit	Akuifer	5.00E-06	4.90E-03	0.30	0.26	0.53
3	Bedrock	Akuifug	1.00E-12	3.00E-07	0.08	0.03	0.35

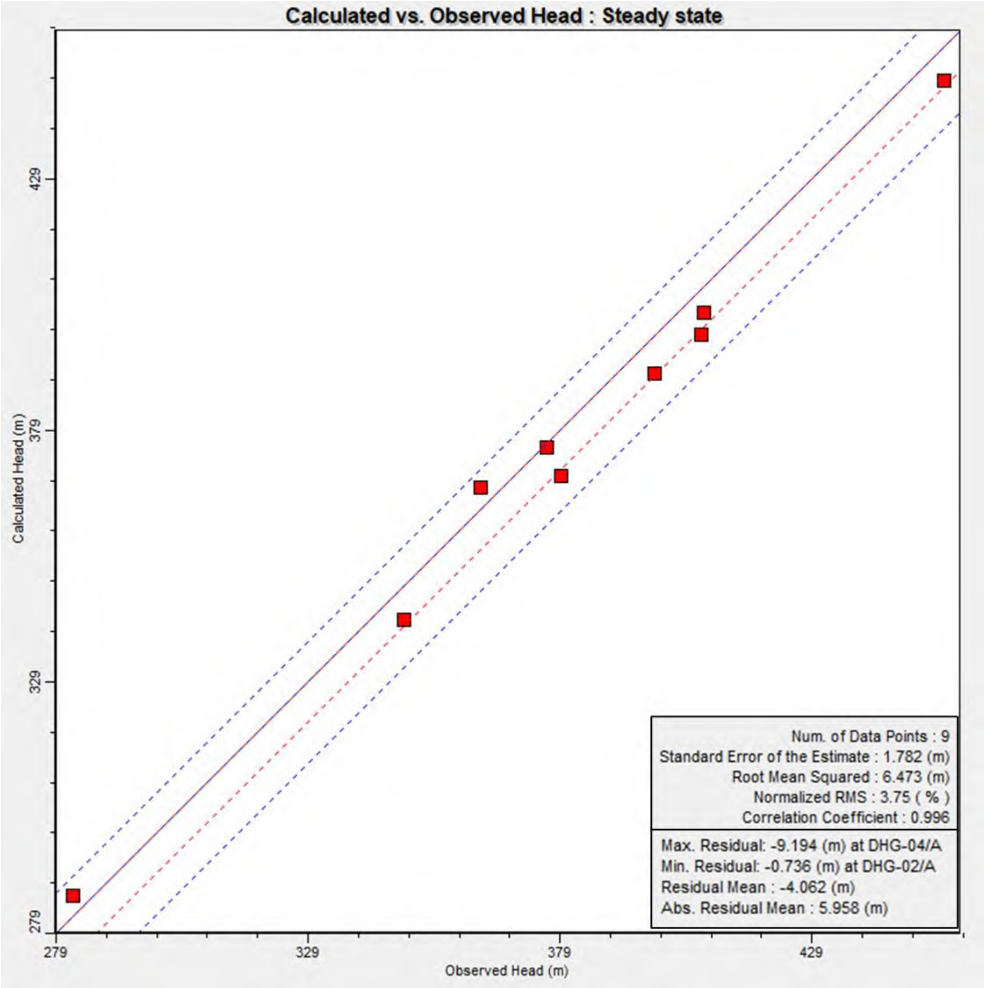
Kondisi Batas

Beberapa penyesuaian ilmiah seperti kondisi batas digunakan pada pembuatan model. Sungai menjadi kondisi batas aliran (*river boundary*) di permukaan dan memiliki hubungan hidraulik dengan akuifer. Untuk “mengisi” kekosongan data muka airtanah, maka digunakan kondisi batas *general head* di bagian tepi model. Rencana bukaan pit yang dibentuk penggalian tambang digunakan sebagai kondisi batas *drain*. Pada batas kedalaman tertentu (-50 mbgs), diasumsikan tidak ada aliran (*no flow boundary*). Skema kondisi batas untuk model aliran airtanah dapat dilihat pada Gambar 3.19.

3.3.4.1. Model Kalibrasi (Steady State)

Kalibrasi model diperlukan untuk memastikan bahwa properti, asumsi, dan metodologi yang digunakan telah mendekati kondisi sebenarnya. Kalibrasi model dalam maknanya yang paling sederhana adalah modifikasi data *input* model untuk tujuan memastikan model lebih sesuai dengan nilai yang diamati (misal *head* dan *flow*). Model pada awalnya dikalibrasi berdasarkan kondisi *steady* yang menggambarkan tatanan/*setting* pemodelan hidrogeologi pada kondisi awal. Kondisi *steady* adalah suatu kondisi di mana jumlah airtanah yang masuk (*recharge*) adalah sama dengan jumlah airtanah yang keluar (*discharge*). Simulasi pada kondisi ini bertujuan untuk mendapatkan gambaran model fisik telah mendekati dengan kondisi sebenarnya.

Grafik kalibrasi antara model dan data yang diukur ditunjukkan pada Gambar 3.20, yang merupakan grafik kalibrasi model pada kondisi *steady state*. Grafik tersebut membandingkan antara kondisi model (*calculated*) dengan kondisi lapangan (*observed*). Model kalibrasi menunjukkan koefisien korelasi sebesar 0,996 dengan *standard error of the estimate* sebesar 1,782 m. Berdasarkan hal tersebut model dianggap sudah mendekati kondisi lapangan dan dapat digunakan untuk memprediksi perubahan *head* dalam kondisi transien dengan perubahan aliran airtanah.



Gambar 3.20 Kalibrasi model kondisi *steady state*, perbandingan *head* airtanah model dengan data observasi lapangan

3.3.4.2. Model Prediksi Rencana Pengembangan Tambang

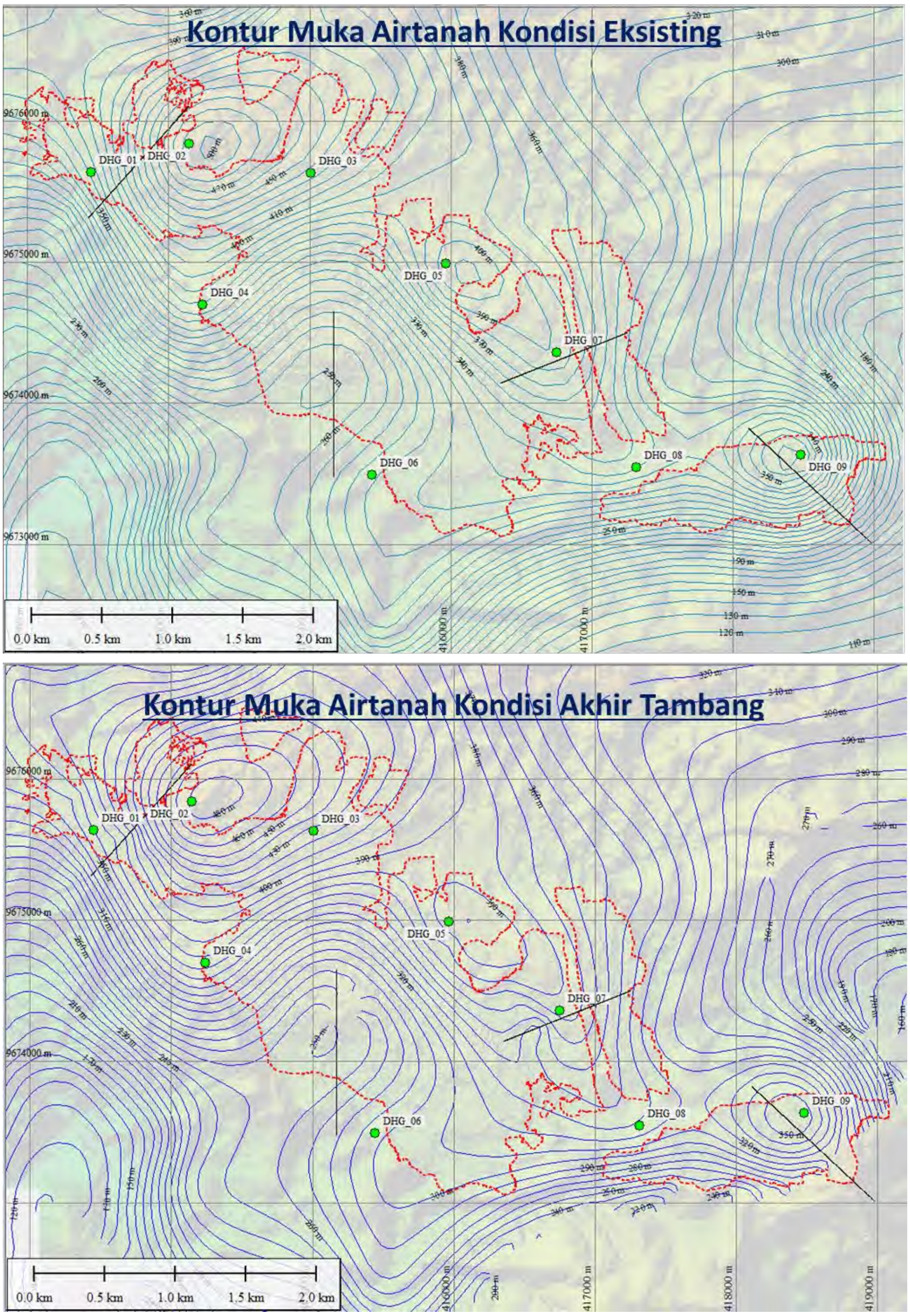
Setelah didapatkan kalibrasi yang diharapkan, dibuat model untuk memprediksi aliran airtanah berdasarkan rencana pit yang diberikan oleh PT HM. Hasil pemodelan airtanah kondisi *steady* akan menjadi dasar model prediksi. *Head* airtanah akan digunakan sebagai *initial head* untuk model transien. Secara umum, asumsi dan parameter yang digunakan pada model prediksi adalah sebagai berikut:

- *Initial head* awal model prediksi adalah *head* airtanah hasil pemodelan *steady state.*
- Air yang keluar melalui dinding bukaan tambang dianggap akan dikeringkan, dalam hal ini kondisi batas *drain* (*drain boundary*) dibuat pada lantai dan dinding tambang dari rencana *open* pit.
- Perubahan morfologi menggunakan data desain bukaan tambang akhir PT HM.

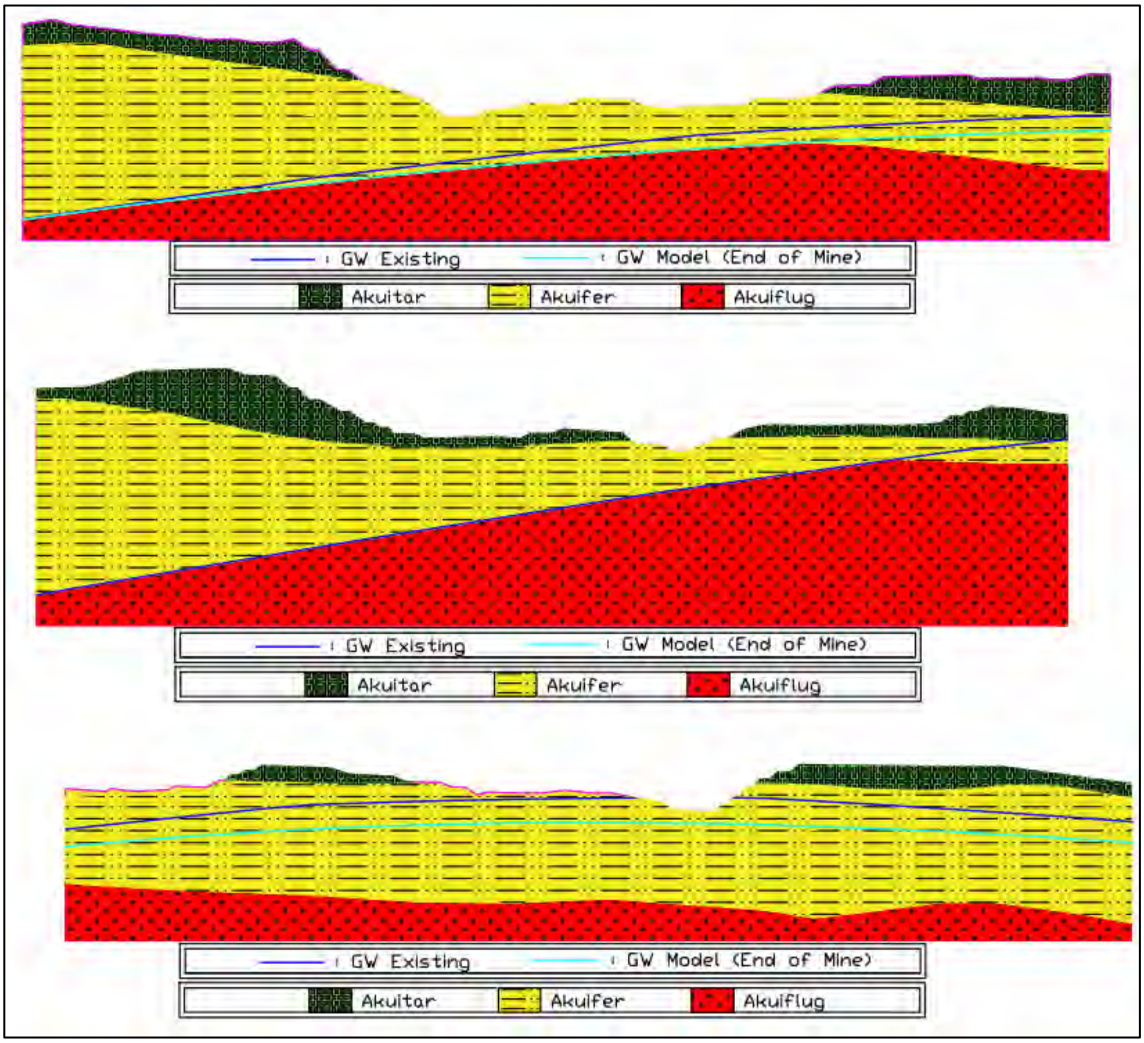
Pola Perubahan *Head* Airtanah

Secara umum, kemajuan penambangan akan berpotensi mengubah pola aliran airtanah, karena operasi penambangan dapat memotong lapisan airtanah alami yang memungkinkan adanya aliran airtanah ke dalam bukaan tambang sehingga menyebabkan terjadinya *drawdown* (penurunan *head* airtanah).

Hasil pemodelan transien menunjukkan bahwa tidak ada perubahan pola aliran airtanah secara regional, namun tampak bahwa ada perubahan kontur airtanah terutama pada daerah-daerah bukaan tambang dengan radius yang terbatas (< 500 meter) (Gambar 3.21). Perubahan muka airtanah pada kondisi akhir tambang dengan kondisi *existing* tidak jauh berbeda secara signifikan, di mana diketahui posisi muka airtanah saat ini sudah relatif mengikuti pola bukaan tambang berjalan. Penampang tipikal perubahan airtanah kondisi *existing* dan kondisi akhir tambang dapat dilihat pada Gambar 3.22.



Gambar 3.21 Pola aliran *head* airtanah *existing* (atas) dan akhir tambang (bawah)



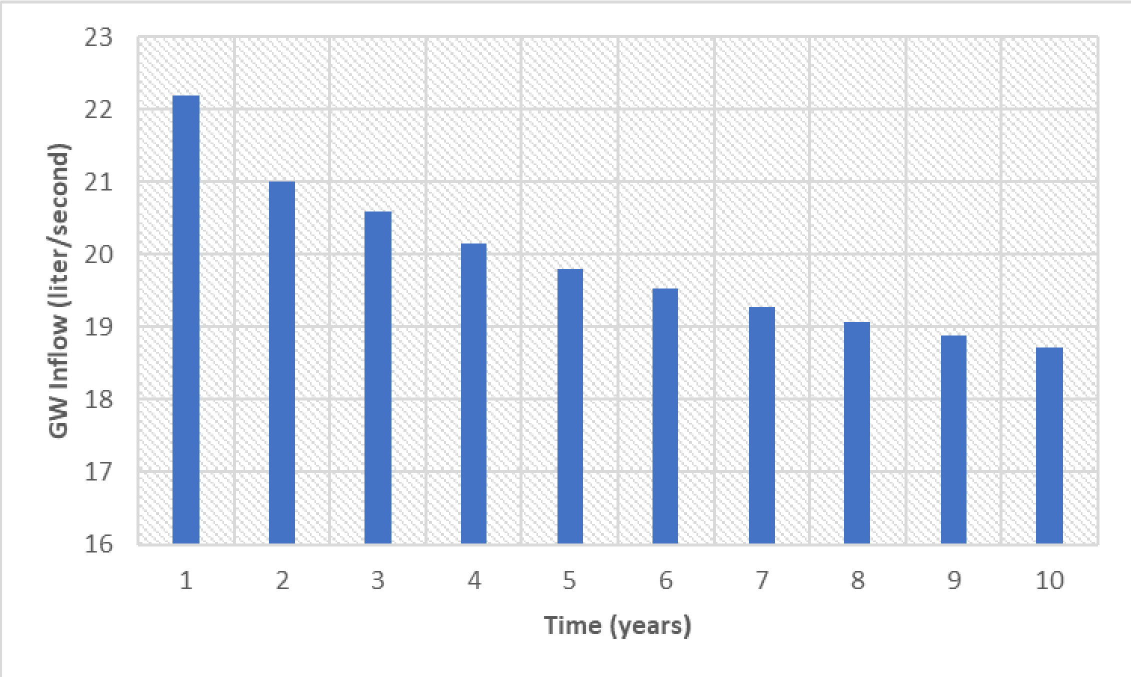
Gambar 3.22 Representatif penampang airtanah kondisi *existing* dan akhir tambang

Estimasi *Groundwater Inflow*

Estimasi debit airtanah yang masuk ke dalam bukaan tambang berdasarkan model prediksi/transien dapat dilihat pada Tabel 3.17 dan direpresentasikan pada grafik di Gambar 3.23. Dari hasil simulasi didapatkan bahwa debit *groundwater inflow* secara umum cenderung kecil. Hal ini disebabkan karena posisi muka airtanah yang relatif telah turun, sehingga sedikit yang berpotongan dengan bukaan tambang. Pola grafik pada Gambar 3.23 menunjukkan debit airtanah yang besar di tahun awal dan berangsur turun menuju garis konstan (*steady*). Pada kondisi aktualnya debit airtanah yang masuk ke dalam tambang dapat bersifat lebih rendah maupun lebih tinggi, menyesuaikan kemajuan tambang (luas dan kedalaman).

Tabel 3.17 Estimasi *groundwater inflow*

Time [years]	Rates [m^3/day]	GW Inflow (liter/second)
1	1917.7	22.19
2	1814.4	21.45
3	1779.5	20.59
4	1740.2	20.14
5	1711.2	19.80
6	1686.8	19.52
7	1665.6	19.27
8	1646.8	19.06
9	1631.6	18.88
10	1616.4	18.70



Gambar 3.23 Representasi grafis debit *groundwater inflow* ke dalam pit

3.4. Rekomendasi Teknis

3.4.1. Saluran Drainase

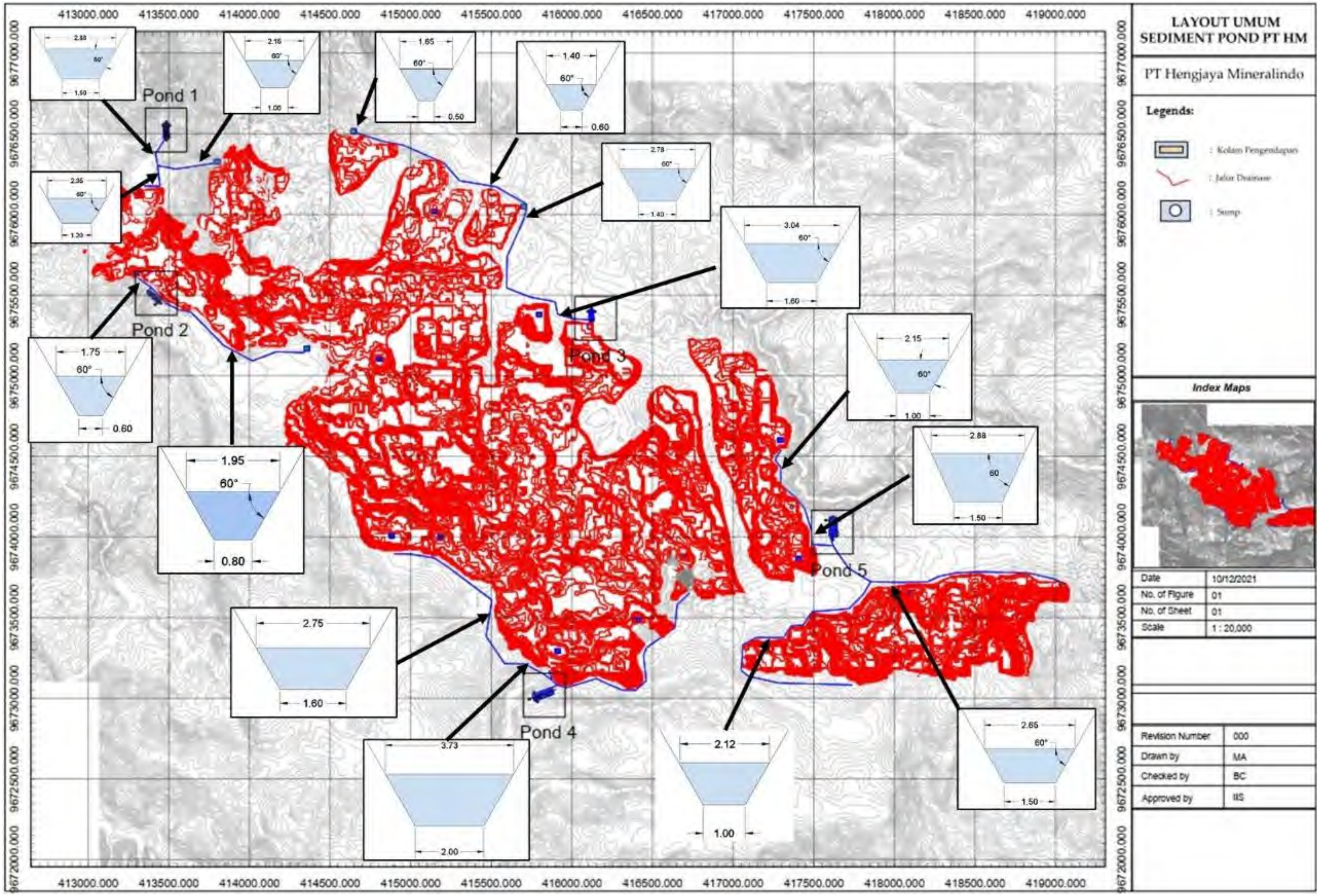
Perimeter Drainase

Saluran perimeter dibutuhkan khususnya pada bagian Selatan dari area pit *central east* (Gambar 3.24). Saluran ini dibuat untuk mencegah masuknya air permukaan yang cukup besar dari luar ke dalam pit.

Rekomendasi dimensi perimeter drainase ditentukan berdasarkan hasil analisis yang dilakukan pada debit rencana yang telah dihitung sebelumnya. Pembuatan perimeter drainase direkomendasikan dengan bentuk saluran berupa trapesium. Dimensi perimeter drainase untuk masing-masing lokasi dapat dilihat pada Tabel 3.18. *Layout* rekomendasi perimeter drainase, serta tipikal dimensi saluran dapat dilihat pada Gambar 3.24.

Drainase Antara

Saluran antara dari lokasi tambang menuju *pond* dibutuhkan untuk mengalirkan air tambang sebelum masuk dan diproses pada *settling pond*. Rekomendasi drainase antara ditentukan berdasarkan hasil analisis yang dilakukan pada debit rencana yang telah dihitung sebelumnya. Pembuatan drainase antara di rekomendasikan dengan bentuk saluran berupa trapesium. Dimensi drainase antara untuk masing-masing lokasi dapat dilihat pada Tabel 3.18. *Layout* rekomendasi perimeter drainase serta tipikal dimensi saluran dapat dilihat pada Gambar 3.24.



Gambar 3.24 Rekomendasi sistem penyaliran rencana tambang PT HM