

Appendix 3.3 Calculation of EPP Emission Source

CHP1

Peak Exhaust Flow rate
(standard condition, dry)= 4,029 Nm³/hr at 273K

Actual Flow rate
(actual condition,
wet)= 7,540 m³/hr at 453K

Parameter	Oa (%)	Os (%)	%H ₂ O	Ta (K)	Ts (K)	Hourly Average Emission Limit (mg/Nm ³ , dry)	Emission Rate* (g/s)	Remarks
RSP	5	6	11	453	273	15	0.0179	[1] [3]
Carbon Monoxide	5	5	11	453	273	650	0.7275	[2] [4]
NO _x	5	5	11	453	273	250	0.2798	[2] [4]
SO ₂	5	6	11	453	273	50	0.0597	[1] [3]
Methane	5	6	11	453	273	150	0.1792	[1] [3]
HCl	5	6	11	453	273	10	0.0119	[1] [3]
HF	5	6	11	453	273	1	0.0012	[1] [3]
Formaldehyde (CH ₂ O)	5	6	11	453	273	14	0.0167	[3] [5]

CHP2

Peak Exhaust Flow rate
(standard condition, dry)= 4,029 Nm³/hr at 273K

Actual Flow rate
(actual condition,
wet)= 7,540 m³/hr at 453K

Parameter	Oa (%)	Os (%)	%H ₂ O	Ta (K)	Ts (K)	Hourly Average Emission Limit (mg/Nm ³ , dry)	Emission Rate* (g/s)	Remarks
RSP	5	6	11	453	273	15	0.0179	[1] [3]
Carbon Monoxide	5	5	11	453	273	650	0.7275	[2] [4]
NO _x	5	5	11	453	273	250	0.2798	[2] [4]
SO ₂	5	6	11	453	273	50	0.0597	[1] [3]
Methane	5	6	11	453	273	150	0.1792	[1] [3]
HCl	5	6	11	453	273	10	0.0119	[1] [3]
HF	5	6	11	453	273	1	0.0012	[1] [3]
Formaldehyde (CH ₂ O)	5	6	11	453	273	14	0.0167	[3] [5]

CHP3

Peak Exhaust Flow rate
(standard condition, dry)= 4,029 Nm³/hr at 273K

Actual Flow rate
(actual condition,
wet)= 7,540 m³/hr at 453K

Parameter	Oa (%)	Os (%)	%H ₂ O	Ta (K)	Ts (K)	Hourly Average Emission Limit (mg/Nm ³ , dry)	Emission Rate* (g/s)	Remarks
RSP	5	6	11	453	273	15	0.0179	[1] [3]
Carbon Monoxide	5	5	11	453	273	650	0.7275	[2] [4]
NO _x	5	5	11	453	273	250	0.2798	[2] [4]
SO ₂	5	6	11	453	273	50	0.0597	[1] [3]
Methane	5	6	11	453	273	150	0.1792	[1] [3]
HCl	5	6	11	453	273	10	0.0119	[1] [3]
HF	5	6	11	453	273	1	0.0012	[1] [3]
Formaldehyde (CH ₂ O)	5	6	11	453	273	14	0.0167	[3] [5]

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Remarks:

Oa : Oxygen concentration at actual condition
Os : Oxygen concentration at reference condition
Ta : Temperature at actual condition
Ts : Temperature at reference condition

All Hourly emission limits are referenced at standard air condition (i.e. 273K, 101,325 Pa, 0% H_2O), and at oxygen content as shown under column Os (%)

*Emission Rate is calculated by Peak Exhaust Flow Rate (at 273K, 101,325 Pa, 0% H_2O) *Hourly Average Emission Limit/3600/1000, with corrections of oxygen content where actual (Oa) and reference (Os) conditions differ.

Remarks:

Unit CHP exhaust flow rate calculation based on supplier information:

CHP supplier exhaust flow rate (at 0% v/v water vapor) = 3,297 Nm^3/hr (dry)

CHP supplier exhaust flow rate (at 11% v/v water vapor) = 3,297 / (1 - 11.32%) = 3,718 Nm^3/hr (wet)

CHP supplier equipment model rated power = 851kWe

CHP power output designed = 800kWe

Maximum exhaust flow from CHP = $800/851 \times 3,718 \times 1.3^{\wedge} = 4,544 \text{ Nm}^3/hr$ (wet)

4,544 Nm^3/hr equivalent power output of CHP = $800 \times 1.3 = 1,040kWe$ (max)

^1.3 factor applied to accommodate variation in biogas production during operation

Actual Exhaust Flow rate conversion from standard condition

CHP exhaust at standard condition: 4,544 Nm^3/hr (273K, 101,325 Pa, wet)

CHP exhaust at actual condition (453K, ^101,325 Pa): $4,544 \times 453 / 273 \times 101,325 / 101,325 = 7,540 \text{ m}^3/hr = 2.09m^3/s$ (wet)

^Assume air pressure is same as standard condition.at altitude of exhaust discharge point.

Moisture concentration correction factor from references condition to actual condition

moisture content in exhaust as per supplier : 3,297 Nm^3/hr (dry exhaust) / 3,718 Nm^3/hr (wet exhaust) = 11.3%

dry exhaust to wet exhaust pollutant concentration correction factor : (1-11.3%) = 0.887

For dry exhaust flow : $4,544 \times (3,297/3,718) = 4,029 \text{ Nm}^3/hr$ (dry) (for emission rate calculation)

Oxygen concentration correction factor from references condition to actual condition

Only adopted for emission rates referenced at oxygen concentrations different from the actual condition

actual oxygen concentration in exhaust : 5% (condition adopted in air models)

referenced oxygen concentration in exhaust : 6% as per emission rate references of RSP, SO2, Methane, HCl and HF

referenced oxygen concentration in exhaust : 5% as per emission rate references of CO and NO3

oxygen correction factor : $(20.9-5)/(20.9-6) = 1.067$ (applicable for RSP, SO2, Methane, HCl and HF only)

Example pollution emission rate for CHP

RSP = $4029Nm^3/hr \times 15mg/Nm^3 \times 1.067 / 3,600s/1,000g/kg = 0.0179g/s$

CO = $4029Nm^3/hr \times 650mg/Nm^3 \times 1.000 / 3,600s/1,000g/kg = 0.7275g/s$

NOX = $4029Nm^3/hr \times 250mg/Nm^3 \times 1.000 / 3,600s/1,000g/kg = 0.2798g/s$

SO2 = $4029Nm^3/hr \times 50mg/Nm^3 \times 1.067 / 3,600s/1,000g/kg = 0.0597g/s$

Methane = $4029Nm^3/hr \times 150mg/Nm^3 \times 1.067 / 3,600s/1,000g/kg = 0.1792g/s$

HCl = $4029Nm^3/hr \times 10mg/Nm^3 \times 1.067 / 3,600s/1,000g/kg = 0.0119g/s$

HF = $4029Nm^3/hr \times 1mg/Nm^3 \times 1.067 / 3,600s/1,000g/kg = 0.0012g/s$

Formaldehyde emission estimate

Formaldehyde emission based on research paper (reference no. [5]) = 14 g/GJ

Formaldehyde emission of the designed CHP = 800 kWe x 1.3 x 14 g/GJ = 0.01456 g/s

Formaldehyde emission concentration (dry exhaust) = $0.01456 \text{ g/s} / (4,029 \text{ Nm}^3 / 3,600 \text{ s}) = 0.01301 \text{ g/Nm}^3 = 13.01 \text{ mg/Nm}^3$, dry

Formaldehyde emission limit = 14 mg/Nm^3 (round up from 13.01 mg/Nm^3)

Formaldehyde emission rate for modelling = $14mg/Nm^3 \times 4,029Nm^3/hr = 56.4 \text{ g/hr} = 0.0157 \text{ g/s}$

with correction factor for O2 content in exhaust $0.0157 \times (20.9-5) / (20.9-6) = 0.0167g/s$

* Assume oxygen concentration at 6% for referenced formaldehyde emission rate

References

[1] Agreement No. CE 7/2008 (EP) Organic Waste Treatment Facilities, Phase I - Feasibility Study Table 3.5

[2] CHP Supplier's information

[3] The emission limit refers to an oxygen content of 6% and dry basis.

[4] The emission limit refers to an oxygen content of 5% and dry basis.

[5] Valerio Paolini, Francesco Petracchini, Marco Segreto, Laura Tomassetti, Nour Naja & Angelo Cecinato (2018) Environmental Impact of Biogas: A short review of current knowledge, Journal of Environmental Science and Health, Part A, 53:10, 899-906, DOI: 10.1080/10934529.2018.1459076

Appendix 3.3 Calculation of EPP Emission Source

Emissions from Boiler (BO)

Maximum biogas to be utilized in Boiler	=	374	m ³ /hr	(a) 35°C (0%H ₂ O), w/ 60% CH ₄ content (Provided by the engineer according to the sludge treatment process)
No. of exhaust from the Boiler	=	1		
Standard Condition	=	0	C°	at 101,325 Pa
	=	273	K	(b)
Temperature of Biogas	=	35	C°	at 101,325 Pa
	=	308	K	(c)
By Ideal Gas Law, V1/V2 = T1/T2	=	0.88636	Nm ³ /m ³	(d) = (b) / (c)
Estimated biogas (CH ₄) to be burned in boiler	=	224.4	m ³ /hr	at actual condition (e) = (a) x 60% CH ₄ content 35°C
	=	198.90	Nm ³ /hr	at standard condition (f) = (e) x (d)

Boiler Emission

Exhaust flow rate at standard condition at 273K (dry) 2,999 Nm³/hr
Exhaust flow rate at actual condition at 453K (wet) 5,611 m³/hr

Parameter	Oa (%)	Os (%)	%H2O	Ta (K)	Ts (K)	Emission Limit for Boiler Exhaust (mg/ Nm ³ , dry)	Emission Rate (g/s)	Remarks
RSP	5	6	11	453	273	15	0.0133	[1] [3]
Carbon Monoxide	5	5	11	453	273	650	0.5415	[2] [4]
NO _x	5	5	11	453	273	250	0.2083	[2] [4]
SO ₂	5	6	11	453	273	50	0.0444	[1] [3]
Methane	5	6	11	453	273	150	0.1333	[1] [3]
HCl	5	6	11	453	273	10	0.0089	[1] [3]
HF	5	6	11	453	273	1	0.0009	[1] [3]
Formaldehyde (CH ₂ O)	5	6	11	453	273	14	0.0124	[3] [5]

Note

1. All Hourly emission limits are referenced at standard air condition (i.e. 273K, 101,325 Pa, 0%H₂O), and at oxygen content as shown under column Os (%)

2. Given CHP and boiler emissions are both generated from combustion of the same biogas generated at the effluent polishing plant. Therefore, CHP emission limit of the respective pollutants are used to estimate those in the boiler emissions.

CHP Exhaust gas flow rate to CH₄ consumption flow rate proportion based on CHP supplier information

CHP exhaust flow rate per unit : 3,297 Nm³/hr (273K, 101,325 Pa, dry - 0% moisture concentration)

CHP exhaust flow rate per unit : 3,718 Nm³/hr (273K, 101,325 Pa, wet - 11% moisture concentration)

CHP Biogas consumption rate per unit 361 Nm³/hr (273K, 101,325Pa, dry, without oxygen)

Biogas methane content : 60% v/v

CH₄ flow : 361 x 0.6 = 217Nm³/hr - i.e. 217Nm³/hr CH₄ is consumed to produce 3,718 Nm³/hr (wet) exhaust gas as per supplier

Exhaust (wet) to CH₄ flow ratio : 3,718 / 217 = 1:17 (a)

above ratio adopted to prorrate boiler exhaust flow rate with reference to biogas consumption rate.

Appendix 3.3 Calculation of EPP Emission Source

Boiler Exhaust flow rate estimate

Boiler biogas maximum demand: 374 m³/hr (308K, 101,325 Pa, dry, without oxygen)

(provided by the Engineer, based on sludge treatment process requirements)

CH₄ consumed by boiler : 374 x 60% x 0.88636 = 198.90 Nm³/hr (273K, 101,325 Pa dry, without oxygen)

Using ratio from (a) : Wet boiler exhaust flow rate at standard condition

198.90 x 17 = 3,381.3Nm³/hr (273K, 101,325 Pa, wet)

Wet boiler exhaust flow rate at actual condition

$3,381.3 / 273K \times 453K \times 101,325/101,325 = 5,611 \text{ m}^3/\text{hr} = 1.56 \text{ m}^3/\text{s}$ (453K, 101,325 Pa, wet)

Dry boiler exhaust flow rate at standard condition

$3,381.3 \times (3,297 / 3,718) = 2,999 \text{ Nm}^3/\text{hr}$ (273K, 101,325 Pa, 0% moisture)

^Assume air pressure is equivalent to standard condition.at altitude of exhaust discharge point.

Emission rate for boiler calculations

Boiler RSP emission rate = $15 \times 2,999 \times (20.9-5) / (20.9-6) / 3,600\text{s} / 1,000\text{g}/\text{kg} = 0.0133 \text{ g}/\text{s}$

Boiler Carbon Monoxide emission rate = $650 \times 2,999 \times (20.9-5) / (20.9-6) / 3,600\text{s} / 1,000\text{g}/\text{kg} = 0.5415 \text{ g}/\text{s}$

Boiler NO_x emission rate = $250 \times 2,999 \times (20.9 - 5) / (20.9-5) / 3,600\text{s} / 1,000 \text{ kg}/\text{kg} = 0.2083 \text{ g}/\text{s}$

Boiler SO₂ emission rate = $50 \times 2,999 \times (20.9 - 5) / (20.9 - 6) / 3,600\text{s} / 1,000 \text{ kg}/\text{kg} = 0.0444 \text{ g}/\text{s}$

Boiler Methane emission rate = $150 \times 2,999 \times (20.9-5) / (20.9-6) / 3,600\text{s} / 1,000\text{g}/\text{kg} = 0.133 \text{ g}/\text{s}$

Boiler HCL emission rate = $10 \times 2,999 \times (20.9-5) / (20.9-6) / 3,600\text{s} / 1,000\text{g}/\text{kg} = 0.0089 \text{ g}/\text{s}$

Boiler HF emission rate = $1 \times 2,999 \times (20.9-5) / (20.9-6) / 3,600\text{s} / 1,000\text{g}/\text{kg} = 0.0009 \text{ g}/\text{s}$

Boiler Formaldehyde (CH₂O) emission rate = $14 \times 2,999 \times (20.9-5) / (20.9-6) / 3,600\text{s} / 1,000\text{g}/\text{kg} = 0.0124 \text{ g}/\text{s}$

References

[1] Agreement No. CE 7/2008 (EP) Organic Waste Treatment Facilities, Phase I - Feasibility Study Table 3.5

[2] CHP Supplier's information

[3] The emission limit refers to an oxygen content of 6% and dry basis.

[4] The emission limit refers to an oxygen content of 5% and dry basis.

[5] Valerio Paolini, Francesco Petracchini, Marco Segreto, Laura Tomassetti, Nour Naja & Angelo Cecinato (2018) Environmental Impact of Biogas: A short review of current knowledge, Journal of Environmental Science and Health, Part A, 53:10, 899-906, DOI: 10.1080/10934529.2018.1459076

Appendix 3.3 Calculation of EPP Emission Source

Emission Sources Listing in AERMOD

Description	Source ID	Type	X	Y	Height (mAG)	Exit Temp (K)	Exit Velocity (m/s)	Stack Diameter (m)	Working Hours	RSP Emission Rate (g/s)	FSP Emission Rate (g/s) ²	NOx Emission Rate (g/s)	SO2 Emission Rate (g/s)	CO Emission Rate (g/s)
biogas engine	CHP1	POINTCAP	824746.32	839130.96	46.50	453.00	18.30	0.45	0000 - 2400	1.792E-02	1.792E-02	2.798E-01	5.972E-02	7.275E-01
biogas engine	CHP2	POINTCAP	824746.32	839130.96	46.50	453.00	18.30	0.45	0000 - 2400	1.792E-02	1.792E-02	2.798E-01	5.972E-02	7.275E-01
biogas engine	CHP3	POINTCAP	824746.32	839130.96	46.50	453.00	18.30	0.45	0000 - 2400	1.792E-02	1.792E-02	2.798E-01	5.972E-02	7.275E-01
fire tube boiler	BO	POINTCAP	824746.32	839130.96	46.50	453.00	17.27	0.40	0000 - 2400	1.333E-02	1.333E-02	2.083E-01	4.445E-02	5.415E-01

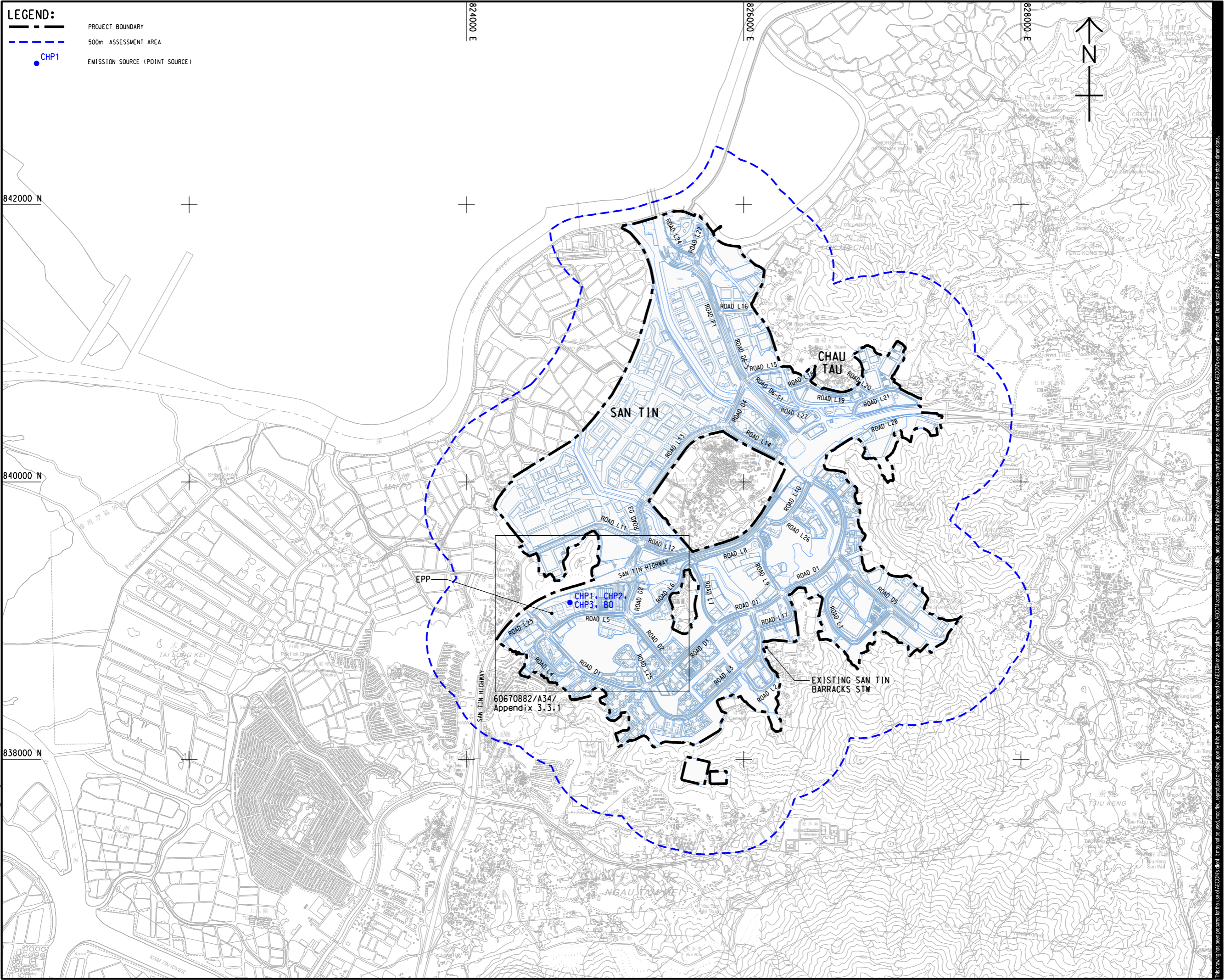
Description	Source ID	Type	X	Y	Height (mAG)	Exit Temp (K)	Exit Velocity (m/s)	Stack Diameter (m)	Working Hours	Methane Emission Rate (g/s)	HCL Emission Rate (g/s)	HF Emission Rate (g/s)	Formaldehyde Emission Rate (g/s)
biogas engine	CHP1	POINTCAP	824746.32	839130.96	46.50	453.00	18.30	0.45	0000 - 2400	1.792E-01	1.194E-02	1.194E-03	1.672E-02
biogas engine	CHP2	POINTCAP	824746.32	839130.96	46.50	453.00	18.30	0.45	0000 - 2400	1.792E-01	1.194E-02	1.194E-03	1.672E-02
biogas engine	CHP3	POINTCAP	824746.32	839130.96	46.50	453.00	18.30	0.45	0000 - 2400	1.792E-01	1.194E-02	1.194E-03	1.672E-02
fire tube boiler	BO	POINTCAP	824746.32	839130.96	46.50	453.00	17.27	0.40	0000 - 2400	1.333E-01	8.890E-03	8.890E-04	1.245E-02

Description	Source ID	Non-AQO Pollutant Emission Rate (g/s) ¹	Scaling Factor for Cumulative Concentration ¹			
			Methane	HCL	HF	Formaldehyde (CH2O)
biogas engine	CHP1	1.000E+00	1.792E-01	1.194E-02	1.194E-03	1.672E-02
biogas engine	CHP2	1.000E+00	1.792E-01	1.194E-02	1.194E-03	1.672E-02
biogas engine	CHP3	1.000E+00	1.792E-01	1.194E-02	1.194E-03	1.672E-02
fire tube boiler	BO	7.443E-01	1.792E-01	1.194E-02	1.194E-03	1.672E-02

Remarks

1. A single non-AQO AERMOD model is employed for Methane, HCL, HF and Formaldehyde. Respective scaling factor is applied to the model output to obtain the emission rate shown in P.3.
e.g. Methane emission rate of CHP1 = 1 x 1.792E-01 = 1.792E-01
Methane emission rate of BO = 7.443E-01 x 1.792E-01 = 1.333E-01.
2. RSP emission rate is adopted for FSP emission as a conservative approach.
3. No dry deposition applied for RSP and FSP.
4. The stack parameters, i.e. exit temperature, exit velocity and stack diameter, are provided by design engineer.
5. Monitoring of these emission rates upon commissioning will be conducted to ensure the actual emission rate complies with the design.

ISO A1 594mm x 841mm
 Approved:
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 Designer:
 Project Management Initials:
 Plot File by: haiguang.zhao 11/14/2023
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LEGEND:

- PROJECT BOUNDARY
- 500m ASSESSMENT AREA
- CHP1
- EMISSION SOURCE (POINT SOURCE)



PROJECT
 項目
 FIRST PHASE DEVELOPMENT OF
 THE NEW TERRITORIES NORTH –
 SAN TIN / LOK MA CHAU
 DEVELOPMENT NODE –
 INVESTIGATION

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NO.	DATE	DESCRIPTION	CHK.

STATUS
 階段

SCALE
 比例
 A3 1 : 25000

DIMENSION UNIT
 尺寸單位
 METRES

KEY PLAN
 索引圖

PROJECT NO.
 項目編號
 60670882

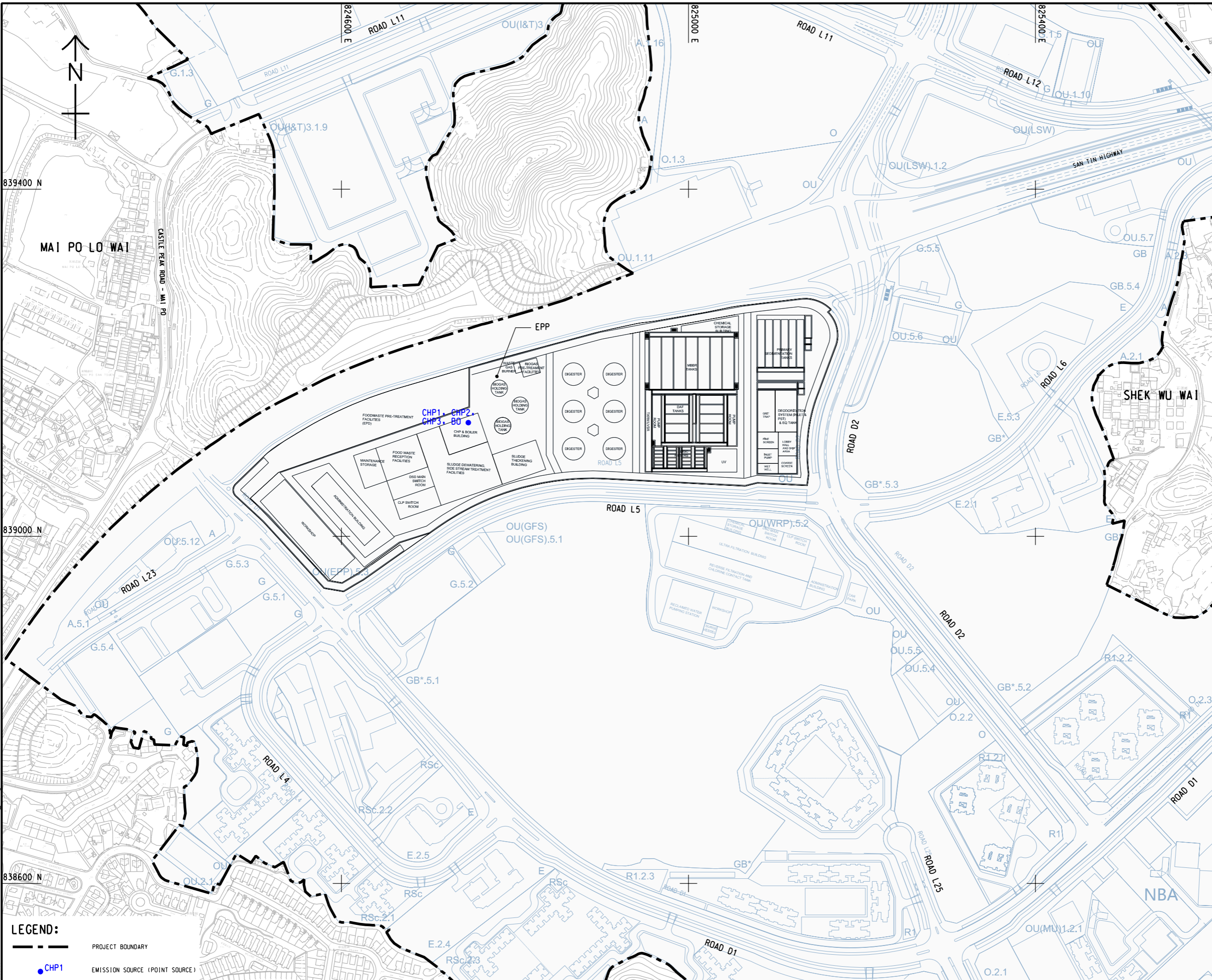
AGREEMENT NO.
 協議編號
 CE 20/2021

SHEET TITLE
 圖紙名稱
 LOCATION OF EMISSION SOURCE
 AT EPP (OVERVIEW)

SHEET NUMBER
 圖紙編號
 60670882/A34/Appendix 3.3

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LEGEND:

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	EMISSION SOURCE (POINT SOURCE)



PROJECT
 項目
 FIRST PHASE DEVELOPMENT OF THE NEW TERRITORIES NORTH – SAN TIN / LOK MA CHAU DEVELOPMENT NODE – INVESTIGATION

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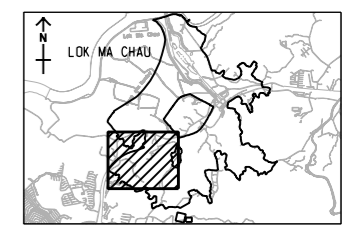
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STATUS
 階段

SCALE
 比例
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DIMENSION UNIT
 尺寸單位
 METRES

KEY PLAN A3 1 : 150000
 索引圖



PROJECT NO.
 項目編號
 60670882

AGREEMENT NO.
 協議編號
 CE 20/2021

SHEET TITLE
 圖紙名稱
 LOCATION OF EMISSION SOURCE AT EPP (OVERVIEW)

SHEET NUMBER
 圖紙編號
 60670882/A34/Appendix 3.3.1