



Australian Government

Department of Climate Change, Energy,
the Environment and Water

DRAFT Greenhouse Gas Emissions Estimation and Reporting Guidelines for Agriculture, Fisheries and Forestry

Methodological Guidance

Chapter 4: Manure Management



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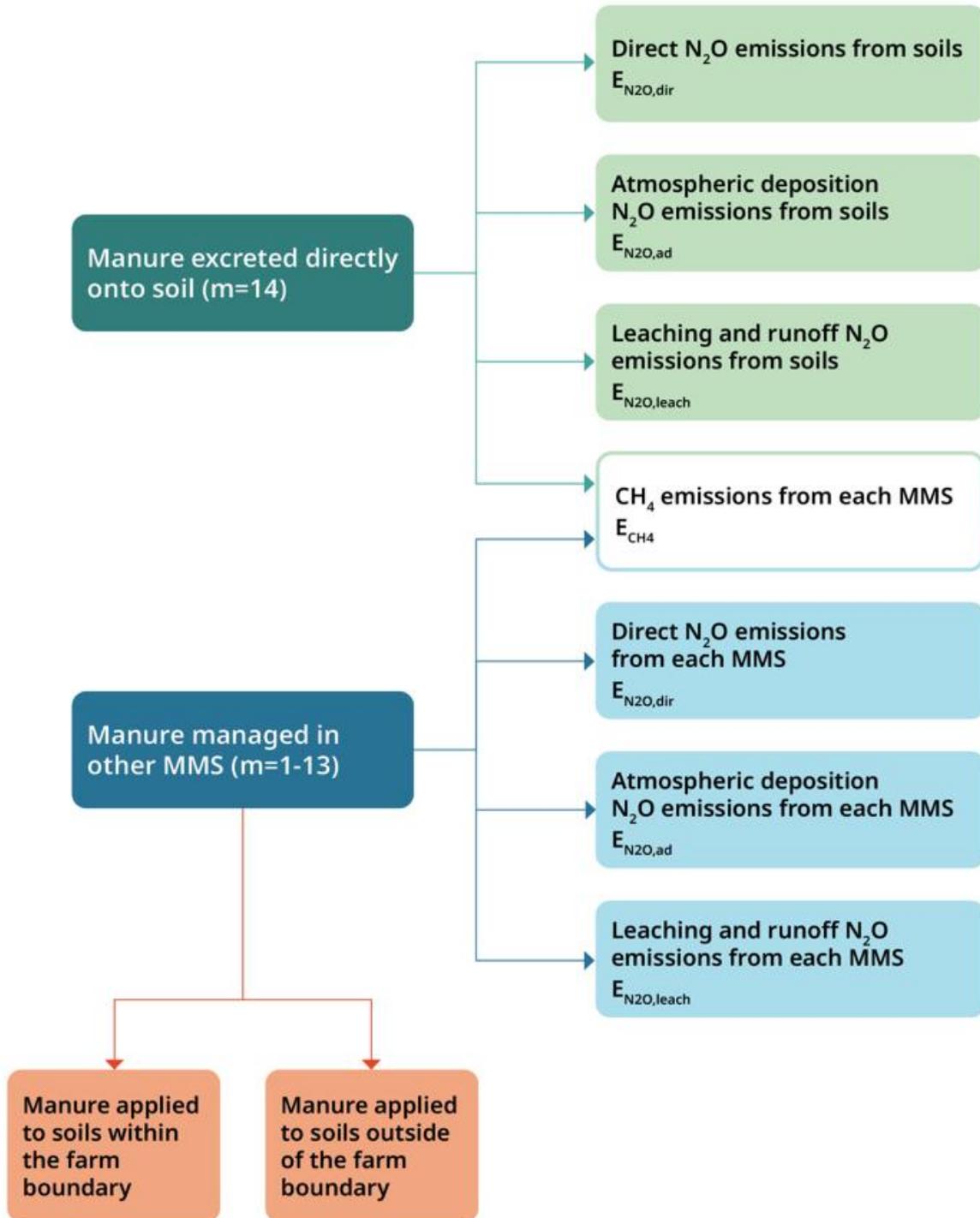
137 **4 Scope 1 – Manure Management**

138 Where appropriate, for each sector this chapter covers the following manure management
139 systems:

Manure Management Systems (MMS)	
Subscript (m)	MMS
1	Anaerobic lagoon
2	Liquid systems
3	Daily spread
3a	Sump and dispersal
3b	Drains to paddock
4	Solid storage
5	Drylot
6	Composting (passive windrow)
7	Digestor/Covered lagoon
8	Deep litter
9	Pit storage (<1 month)
10	Poultry manure with litter
11	Poultry manure without litter
12	Direct processing into pelletised fertiliser
13	Direct application
14	Pasture range and paddock

140

141 Figure 4.1 demonstrates the relevant emissions calculations outlined in this chapter to each
142 of these MMS. There two main components to methane emission estimates – manure
143 excreted directly onto pasture, and managed manure through treatment systems. Managed
144 manure also results in direct and indirect nitrous oxide emissions. For manure excreted onto
145 pasture there are no nitrous oxide emissions from manure management, however emissions
146 occur from the soil due to the metabolism of the deposited urine and faeces, and indirectly
147 through atmospheric deposition and leaching and runoff. Emissions associated with manure
148 from management systems that is subsequently applied to soils are covered in the organic
149 fertiliser section in Chapter 5 Section 5.1 Fertiliser module.



150

151

Figure 4.1: Example possible emissions sources from manure for livestock enterprises

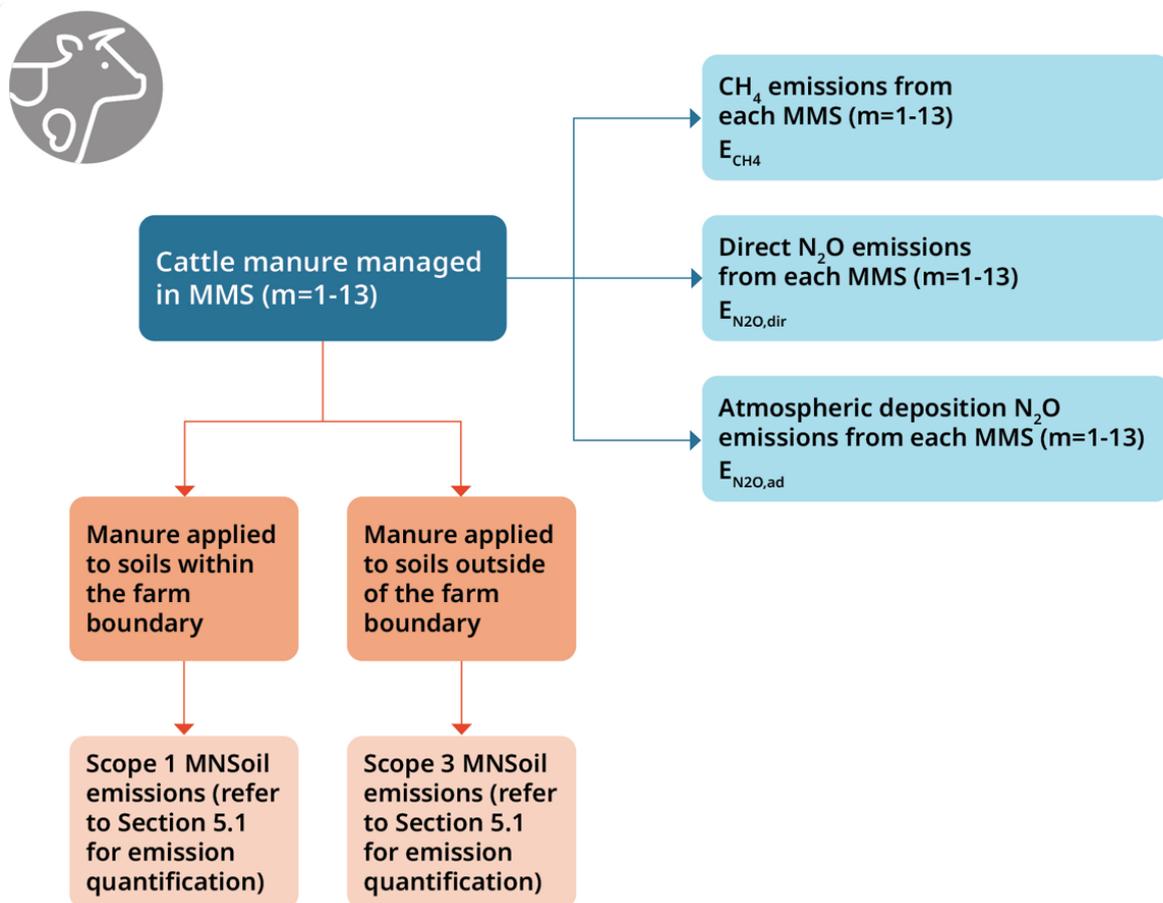
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154

155 4.1 Beef Feedlot

156 This module covers the estimation of methane and nitrous oxide that results from beef
 157 feedlot cattle manure management. Figure 4.2 summarises the emission sources associated
 158 with the manure from beef feedlot cattle. As cattle are housed the pasture, range and
 159 paddock MMS is not applicable in this chapter. However, emissions associated with manure
 160 from management systems that is subsequently applied to soils are covered in the organic
 161 fertiliser section in Chapter 5 Section 5.1 Fertiliser module.



162 Figure 4.2: Summary of emissions sources associated with manure management in beef
 163 feedlot systems
 164

165 The following subscripts are used in this module:

Subscript	Meaning
<i>i</i>	Temperature zone
<i>j</i>	Cattle group
<i>m</i>	Manure Management System (MMS)
T	Treatment Stage

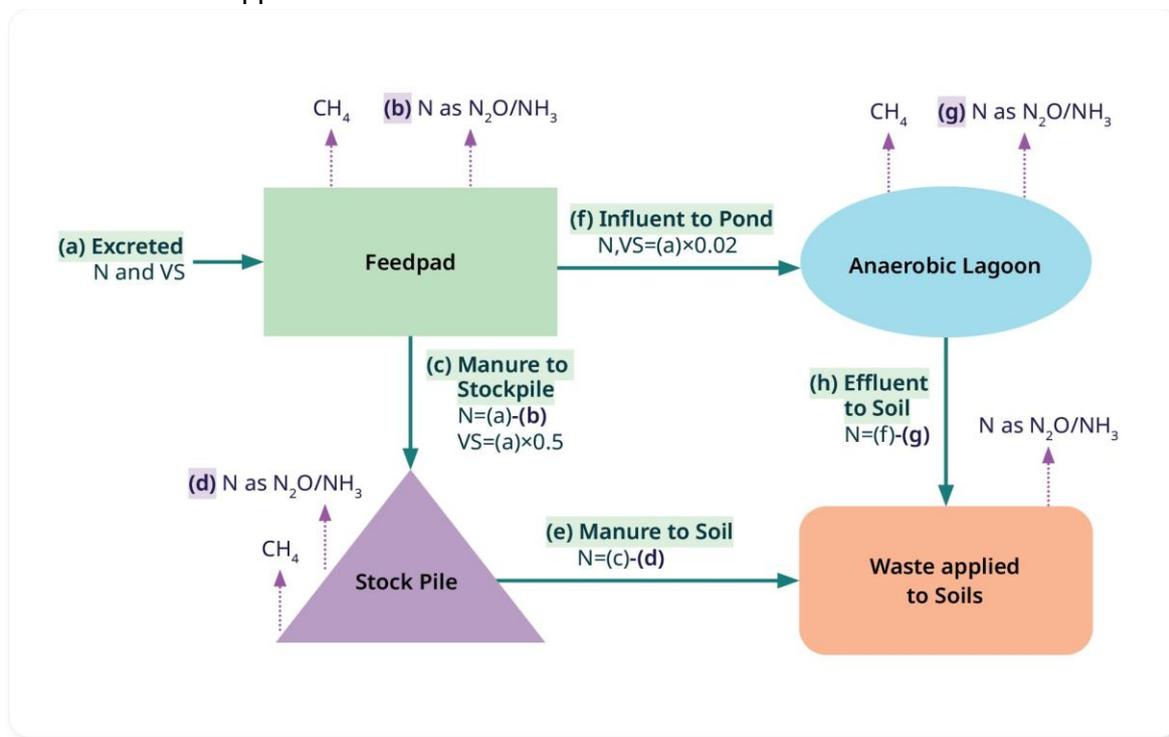
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167 Emissions are estimated based on groups of cattle with similar intake requirements and
 168 lengths of stay on the feed pad and the different stages and systems of manure treatment.
 169 The temperature zone will affect the selection of appropriate emission factors. The
 170 emissions are summed across each group and manure management system within the
 171 feedlot operation during the reporting period.

172 The number of groups per farm within the reporting period will depend on the size of the
 173 feedlot operation and the diversity of the intake and length of stay of the groups of cattle on
 174 the feed pad. Groups may be labelled as numbers e.g. Group 1, Group 2, Group 3 or given
 175 relevant names based on age or breed of group e.g. R2 Wagyu, R3 Angus, R3 Mixed for
 176 data entry purposes.

177 Manure from feedlot cattle may pass through multiple treatment stages. Therefore, volatile
 178 solid and nitrogen inputs and losses are estimated at each treatment stage (see Figure 4.3).
 179 It is assumed that the primary treatment stage (T=1) of all manure is the feedpad
 180 (considered to be a drylot system). Manure may then be transferred to a secondary
 181 treatment stage (T=2), such as a stock pile, after which the waste is assumed to be applied
 182 to soils. A fixed amount (2%) of manure is assumed to runoff from the feedpad into an
 183 anaerobic lagoon, tertiary treatment stage (T=3), before also being applied to soils.

184 The manure management system (m) for secondary treatment stage (T=2) will need to be
 185 input so that the appropriate constants and emissions factors can be applied. Additionally,
 186 the temperature zone (i) the feedlot is operating in is needed to inform the methane
 187 conversion factor applied.



188

189 Figure 4.3 Example of the possible different stages of manure management in beef feedlot
 190 systems from the Australian National Inventory Report [1].

191

192 **4.1.1 Estimation methodology**193 **4.1.1.1 METHOD 1 — MANURE METHANE BEEF FEEDLOT**

194 (1) Total annual methane emissions from manure management E_{CH_4} (t CH₄) is
195 calculated as:

$$196 \quad E_{CH_4} = \sum_j \sum_m \sum_T (D_j \times M_{jmT} \times N_j) \times 10^{-3}$$

197 Where D_j = length of stay of each cattle group (days)

198 M_{jmT} = methane production from manure per cattle group, MMS, and
199 treatment stage (kg CH₄/head/day)

200 N_j = numbers of beef cattle in each group (head)

201

202 **Treatment stage 1 (primary system)**

203 (2) In equation (1) production of methane in treatment stage 1 MMS $M_{jm=5 T=1}$ (kg
204 CH₄/head/day) is calculated as:

$$205 \quad M_{jm=5 T=1} = VS_j \times B_o \times MMS_{m=5 T=1} \times MCF_{im=5} \times \rho$$

206 Where VS_j = volatile solid production from feedlot cattle in each group (kg/head/day)

207 B_o = emissions potential (m³ CH₄/kg VS)

208 $MMS_{m=5 T=1}$ = the fraction of manure in each primary system. Assumed to be
209 1 for the drylot MMS

210 $MCF_{im=5}$ = methane conversion factor for temperature zone and system.
211 Under Method 1, the default state temperature zone is applied

212 ρ = density of methane (kg/m³)

213

214 **Treatment stage 2 (secondary system)**

215 (3) In equation (2) production of methane in each treatment stage 2 MMS $M_{ijmT=2}$ (kg
216 CH₄/head/day) is calculated as:

$$217 \quad M_{jmT=2} = (1 - VSL) \times VS_j \times B_o \times MMS_{mT=2} \times MCF_{im} \times \rho$$

218 Where VSL = fraction of volatile solids lost during storage in the primary system.
219 (kg/head/day)

220 $MMS_{mT=2}$ = the fraction of manure in each secondary system

221 MCF_{im} = methane conversion factor for temperature zone and MMS. Under

222 Method 1, the default state temperature zone is applied

223 Note: if all manure is directly applied to soils after it is scraped from the feed pad then
224 methane emissions from the secondary stage is assumed to be zero i.e. if $MMS_{jm=13T=2} = 1$
225 then $M_{ijm=13T=2} = 0$.

226

227 Treatment stage 3 (tertiary system)

228 (4) In equation (2) production of methane in treatment stage 3 MMS $M_{ijm=1T=3}$ (kg
229 CH₄/head/day) is calculated as:

$$230 \quad M_{ijm=1T=3} = VS_j \times B_0 \times MMS_{m=1T=3} \times MCF_{im=1} \times \rho$$

231 Where $MMS_{m=1T=3}$ = the fraction of manure to the tertiary system. Assumed to be
232 0.02 to an anaerobic lagoon MMS

233 $MCF_{im=1}$ = methane conversion factor for temperature zone and anerobic
234 lagoon system. Under Method 1, the default state temperature zone is applied

235

236 (5) In equation (3) – (5) volatile solid production VS_j (kg/head/day) based on the BeefBal
237 model (McGahan et al. (2004)) [2] is calculated as:

$$238 \quad VS_j = I_j \times (1 - DMD_j) \times (1 - A)$$

239 Where I_j = dry matter intake for each group (kg DM/head/day)

240 DMD_j = dry matter digestibility for each group (fraction)

241 A = ash content of manure (fraction)

242 4.1.1.2 METHOD 2 — MANURE METHANE BEEF FEEDLOT

243 Method 2 is the same as Method 1 except that under equations 4.1.1.1 (2) – (4) farm specific
244 temperature zone is required for $MCF_{im=1}$.

245

246 4.1.1.3 METHOD 1 — MANURE DIRECT N₂O BEEF FEEDLOT

247 (1) The total annual direct nitrous oxide emissions from manure management systems
248 $E_{N_2O,dir}$ (t N₂O) is calculated as:

$$249 \quad E_{N_2O,dir} = \sum_j \sum_m \sum_T (MN_{jmT} \times EF_{jm} \times C_{N_2O}) \times 10^{-3}$$

250 Where: MN_{jmT} = nitrogen per cattle group, MMS and treatment stage (kg N₂O)

251 EF_{jm} = nitrous oxide emission factor for MMS (kg N₂O-N/kg N)

252 C_{N_2O} = factor to convert elemental mass of nitrous oxide to molecular mass

253 Note: exclude $MN_{jm=13T=2}$ which moves directly to MN_{soil} calculation (equation 4.1.1.7(1))

254 **Treatment stage 1 (primary system)**

255 (2) In equation (1) nitrogen in the treatment stage 1 MMS $MN_{jm=5 T=1}$ (kg N₂O) is
 256 calculated as:

$$257 \quad MN_{jm=5 T=1} = AE_j \times MMS_{jm=5 T=1}$$

258 Where: AE_j = total nitrogen excreted by each cattle group (kg N)

259 $MMS_{jm=5 T=1}$ = fraction of manure in primary system. Assumed to be 1 for the
 260 drylot MMS

261

262 (3) In equation (2) annual nitrogen excretion AE_j (kg N) from each feedlot cattle group is
 263 calculated as:

$$264 \quad AE_j = N_j \times NE_j \times D_j$$

265 Where N_j = number of cattle in each group (head)

266 NE_j = nitrogen excretion (kg N/head/day)

267 D_j = Duration of stay of cattle group (days)

268

269 (4) In equation (3) nitrogen excretion NE_j (kg/head/day) is calculated by:

$$270 \quad NE_j = NI_j \times (1 - NR_j)$$

271 Where NI_j = nitrogen intake (kg/head/day)

272 NR_j = nitrogen retention expressed as a fraction of intake (per cent). Under
 273 Method 1, default NR_j values are applied.

274

275 (5) In equation (4) nitrogen intake NI_j (kg/head/day) of feedlot cattle is calculated by:

$$276 \quad NI_j = I_j \times CP_j \div 6.25$$

277 Where I_j = dry matter intake (kg DM/head/day)

278 CP_j = crude protein content of feed (fraction)

279 6.25 = factor for converting crude protein into nitrogen

280 Under Method 1, default CP_j values are applied.

281

282

283 **Treatment stage 2 (secondary system)**

284 (6) In equation (1) nitrogen in each treatment stage 2 MMS $MN_{jmT=2}$ (kg N₂O) is
285 calculated as:

$$286 \quad MN_{jmT=2} = NT_{jmT=2} \times MMS_{jmT=2}$$

287 Where $NT_{jmT=2}$ = nitrogen transferred to secondary treatment MMS (kg N)

288 $MMS_{jmT=2}$ = fraction of manure in each to secondary system.

289 Note: if direct application occurs at treatment stage 2 the nitrogen ($MN_{jm=13T=2}$) moves
290 directly to MN_{soil} calculation (equation 4.1.1.7(1)) and is not included in direct nitrous oxide
291 from manure management equation (Equation 4.1.1.3 (1)).

292 (7) In equation (6) nitrogen transferred to treatment stage 2 MMS $NT_{jmT=2}$ (kg N) is
293 calculated as:

$$294 \quad NT_{jmT=2} = \left(MN_{jm=5T=1} \times (1 - FracGASM_{m=5} - EF_{m=5}) \right) - MN_{jmT=3}$$

295 Where $MN_{jmT=1}$ = nitrogen in MMS treatment stage 1 (kg N)

296 $FracGASM_{m=5}$ = fraction of N volatilised from drylot MMS

297 $MN_{jmT=3}$ = nitrogen in MMS treatment stage 3 (kg N)

298 $EF_{m=5}$ = nitrous oxide emission factor for each MMS (kg N₂O-N/kg N
299 deposited)

300

301 **Treatment stage 3 (tertiary system)**

302 (8) In equation (1) nitrogen in treatment stage 3 MMS $MN_{jm=1T=3}$ (kg N) is calculated
303 as:

$$304 \quad MN_{jm=1T=3} = AE_j \times MMS_{jm=1T=3}$$

305 Where $MMS_{m=1T=3}$ = fraction of manure to tertiary system. Assumed to be 0.02 to
306 anaerobic lagoon MMS

307

308 **4.1.1.4 METHOD 2 — MANURE DIRECT N₂O BEEF FEEDLOT**

309 Method 2 is the same as Method 1 except that under equation 4.1.1.3 (4) - (5) farm specific
310 data for I_j , and CP_j is required and farm specific NR_j may be applied.

311

312 **4.1.1.5 METHOD 1 — MANURE ATMOSPHERIC DEPOSITION BEEF FEEDLOT**

313 (1) Total annual atmospheric deposition emissions from manure management $E_{N_{2O,ad}}$ (t

314 N₂O) is calculated as:

$$315 \quad E_{N_{2O,ad}} = (MMS_{ATMOS} \times EF_{N_{2O}} \times C_{N_{2O}}) \times 10^{-3}$$

316 Where MMS_{ATMOS} = mass of N volatilised from MMS (kg N)

317 $EF_{N_{2O}}$ = nitrous oxide emission factor for atmospheric deposition (kg N₂O-
318 N/kg N)

319

320 (2) In equation (1) volatilised nitrogen from manure management MMS_{ATMOS} (kg N) is
321 calculated as:

$$322 \quad MMS_{ATMOS} = \sum_j \sum_m \sum_T MN_{jmT} \times FracGASM_{mT}$$

323 Where MN_{jmT} = nitrogen in each treatment stage MMS (kg N) (excluding
324 $MN_{jm=13T=2}$)

325 $FracGASM_{mT}$ = fraction of N volatilised in each MMS ((kg NH₃-N + NO_x-N)/kg
326 N)

327 Note: in the case of direct application at treatment stage 2 the nitrogen ($MN_{jm=13T=2}$) moves
328 directly to $MNSoil$ calculation (equation 4.1.1.7 (1)) and is not included in the atmospheric
329 deposition from manure management calculation.

330 4.1.1.6 METHOD 2 — MANURE ATMOSPHERIC DEPOSITION BEEF FEEDLOT

331 There is no Method 2 quantification option for this emission source

332 4.1.1.7 METHOD 1 — MANURE LEACHING AND RUNOFF N₂O BEEF FEEDLOT

333 Due to strict environmental controls leaching from feedlot MMS are assumed to be zero.

334 Run-off from MMS is included in the treatment stage 3 of the direct MMS estimates.

335 4.1.1.8 METHOD 2 — MANURE LEACHING AND RUNOFF N₂O BEEF FEEDLOT

336 There is no Method 2 quantification option for this emission source

337 4.1.1.9 MANURE APPLIED TO SOILS

338 It is assumed that all manure managed through MMS (m=1-13) will eventually be applied to
339 soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value is
340 transferred to Chapter 5 Section 5.1 to estimate emissions associated with the application of
341 organic fertilisers, including the associated atmospheric deposition, and leaching and run-off
342 emissions.

343 This manure may be applied to soils within the boundary of the feedlot or may be sent off-
344 site and applied to another farming system or enterprise. Where manure is applied to soils
345 within the boundary of the farming enterprise $MNSoil_{scope1}$, the emissions from shall be
346 estimated and reported as Scope 1 emissions. Where the manure is used on other farming
347 enterprises $MNSoil_{scope3}$, the emissions from shall be estimated and reported as Scope 3
348 emissions under Scope 3 Category 5 – waste generated in operations (see Chapter 7
349 Section 7.10).

350 (1) The mass of nitrogen applied to soils for scope 1 emissions $MNSoil_{scope1}$ (kg N) is
 351 calculated as:

$$352 \quad MNSoil_{scope1} = \sum_j \sum_m \sum_T MN_{jmT=2,3} \times (1 - EF_{mT=2,3} - FracGASM_{mT=2,3}) \times PF$$

353 Where $MN_{jmT=2,3}$ = mass of N in secondary and tertiary treatment MMS stages as
 354 calculated for manure management (kg N)

355 $EF_{mT=2,3}$ = nitrous oxide emission factor for each MMS (kg N₂O-N/kg N)

356 $FracGASM_{mT=2,3}$ = fraction of animal waste N volatilised in each MMS for
 357 each cattle group ((kg NH₃-N + NO_x-N)/kg N)

358 PF = fraction of manure applied to soil within the feedlot boundary

359

360 Note: where direct application occurs at treatment stage 2 ($MN_{jm=13T=2,3}$), $EF_{jm=13T=2}$ and
 361 $FracGASM_{jm=13T=2}$ are set to zero.

362 (2) The mass of nitrogen applied to soils for scope 3 emissions $MNSoil_{scope3}$ (kg N) is
 363 calculated as:

$$364 \quad MNSoil_{scope3} = \sum_j \sum_m \sum_T MN_{jmT=2,3} \times (1 - EF_{mT=2,3} - FracGASM_{mT=2,3}) \times (1 - PF)$$

365

366

367 **4.1.2 Data/Parameters**368 **4.1.2.1 INPUT DATA (REQUIRED)**

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each cattle group
Data source	Farm stock records; system type records or purchase and sales records and National Vendor Declarations or NLID transfer records may be evaluated to determine average length of stay
Quality assurance / quality control considerations	The length of stay may be cross checked with duration of stay expected for the National Inventory Report feedlot cattle classes in the Appendix Table A.1.1.1. Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may also be used for data assurance and control of entered values.

369

Data / Parameter	N_j
Data unit	head
Description	Number of beef cattle in each group
Data source	Farm stock records e.g. head counts, diary entries, purchase, and sales records
Quality assurance / quality control considerations	All animals purchased or sold in the reporting period are assumed to be reported. Number of cattle reported may be cross checked with average stocking density for farm size and system (if known). The classes of animals on farm may be checked against reported products from farm.

370

371

372

Data / Parameter	$MMS_{mT=2}$
Data unit	fraction
Description	Fraction of manure at treatment stage 2 for each manure management system i.e. what fraction of manure goes to what MMS once it has been removed from the feed pad. If there is only one available MMS then this should be equal to 1. This may be different for different cattle groups.
Data source	Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). This fraction should be based on either weight or volume of manure. If treatment is different for different cattle groups this may also be recorded per cattle group.
Quality assurance / quality control considerations	The fraction of manure to each secondary manure management system should sum to one. If only one is MMS used to treat manure, then $MMS_{mT=2}$ shall be equal to 1. Note: if manure is directly applied to soils after it is scraped from the feedlot then methane and nitrous oxide emissions will be zero for this secondary treatment stage MMS. The nitrogen in the manure ($MN_{jm=13T=2}$) moves directly to $MN_{soil_{jm}}$ calculation (equation 4.1.17(1)) (see also Chapter 5 Section 5.1). It is excluded from equation 4.1.1.3 (1) and 4.1.1.4 (2)

373

Data / Parameter	PF
Data unit	fraction
Description	Fraction of manure applied to soil within the feedlot boundary
Data source	Farmer records of manure sales or transport weights compared to total manure treated on farm. When all manure treated in MMS is applied within the entity boundary and none is sold off-site to be used in a different enterprise, then $PF = 1$.
Quality assurance / quality control considerations	If all of manure is not applied to soil within the feedlot boundary ensure it is appropriately tracked what proportion is sent off-site to other entities. If it is not known what proportion is sent off-site to other entities assume all manure is applied within the feed lot boundary until better data can be collected.

374

375

376 4.1.2.2 DATA (METHOD 1 AND 2 OPTIONS)

Data / Parameter	lj
Data unit	kg DM/head/day
Description	Average dry matter intake per head per day of each lot of cattle.
Method 1 data source	See Appendix Table A.1.1.3
Method 1 value	Select the default value appropriate to the length of stay of each cattle lot.
Method 2 data source	Farm records of dry matter content of total mixed ration (TMR), and daily feed and feed waste weights for each lot Noting that TMR may change over the duration of the stay therefore a weighted average of intake should be calculated based on the composition of feed throughout the stay of the cattle lot
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with the Method 1 defaults for the relevant cattle class.

377

Data / Parameter	DMD _i
Data unit	fraction
Description	Dry matter digestibility of diet used within feedlot system
Method 1 data source	See Appendix Table A.1.1.3
Method 1 value	Apply the dry matter digestibility that best represents the duration of stay of each cattle class.
Method 2 data source	Farm records or feed receipt stating dry matter digestibility of TMR
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.

378

379

Data / Parameter	CP _j
Data unit	fraction
Description	Average crude protein content of the feed given to each cattle group. National default data based on length of stay is available if crude protein content of TMR for a group is not known.
Method 1 data source	See Appendix Table A.1.1.3
Method 1 value	Apply the crude protein per cent that best represents the duration of stay of each cattle class.
Method 2 data source	Farm records or feed receipt stating crude protein of TMR
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.

380

Data / Parameter	MCF _{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.1.4
Method 1 value	Choose appropriate default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting an appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.1.4 and A.1.8.1 for data source information).

381

Data / Parameter	NR _j
Data unit	per cent
Description	Nitrogen retention expressed as a per cent of intake based on length of stay of each cattle group on the feed pad.
Method 1 source	See Appendix Table A.1.1.2
Method 1 value	Apply the nitrogen retention that best represents the duration of stay of each cattle class.
Method 2 data source	Farm specific estimates of nitrogen retention estimated by a mass balance, as the difference between the amount in the ingested feed and the amount retained by the animal as live weight gain and the nitrogen in the waste feed.

Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.
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382

383

4.1.2.3 CONSTANTS

Data / Parameter	B_0
Data unit	$m^3 CH_4/kg VS$
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	0.19
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

384

Data / Parameter	$MMS_{m=5T=1}$
Data unit	fraction
Description	Fraction of volatile solids to each primary system, assumed all primary systems are drylot.
Data source	Table A5.5.3.4, National Inventory Report, Volume 2 [4]
Value	1
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

385

Data / Parameter	ρ
Data unit	kg/m^3
Description	Density of methane.
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

386

Data / Parameter	VSL
Data unit	Fraction
Description	Fraction of volatile solids lost during storage in the primary system.

Data source	McGahan, et al. (2004) [2] and Wiedemann et al. (2014) [6]
Value	0.5
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

387

Data / Parameter	$MMS_{m=1T=3}$
Data unit	fraction
Description	Fraction of volatile solids to each tertiary system assumed that 2 per cent is run-off from the feed pad.
Data source	Table A5.5.3.4, National Inventory Report, Volume 2 [4]
Value	0.02
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

388

Data / Parameter	A
Data unit	fraction
Description	Ash content of manure.
Data source	National Greenhouse Gas Inventory Report Vol 1. (2023) [1]
Value	0.16
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

389

Data / Parameter	C_{N_2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

390

391

Data / Parameter	EF_{mT}
Data unit	kg N ₂ O-N/kg N
Description	Nitrous oxide emission factor for each MMS.
Data source	See Appendix Table A.1.1.5
Value	Apply the EF that best represents the MMS in each treatment stage.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

392

Data / Parameter	$FracGASM_{mT}$
Data unit	(kg NH ₃ -N + NO _x -N)/kg N
Description	Fraction of N volatilized in each MMS.
Data source	See Appendix Table A.1.1.6
Value	Apply the FracGASM that best represents the MMS in each treatment stage.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

393

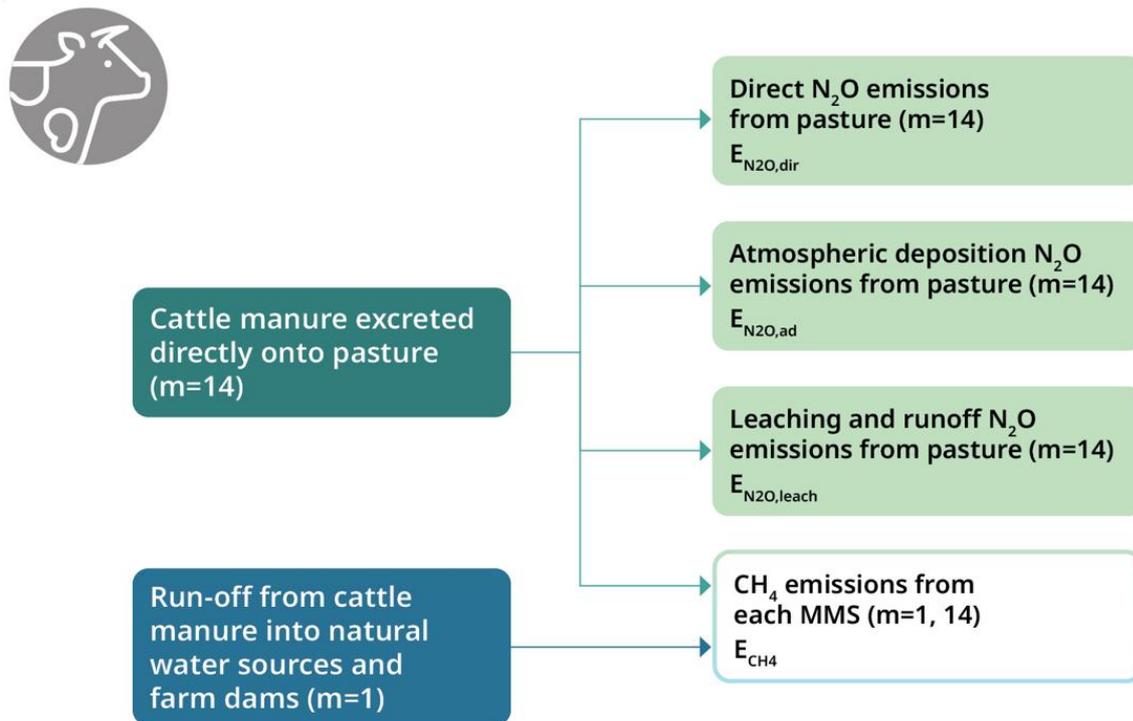
Data / Parameter	EF_{N2O}
Data unit	kg N ₂ O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition
Data source	See Appendix Table A.2.2.1
Value	Apply the atmospheric deposition EF that best represent the production systems immediately surrounding the feedlot. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on determining the relevant rainfall zone.
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is used in alignment with the Australian National Inventory Report.

394

395

396 4.2 Beef Pasture, Range, and Paddock

397 This module covers the estimation of methane and nitrous oxide emission that results from
 398 grazing beef cattle manure management. Figure 4.4 summarises the emission sources
 399 associated with the manure of beef cattle on pasture, rangeland and paddock (PRP). There
 400 are two components to methane emission estimates –manure excreted directly onto PRP,
 401 and manure that runs-off into natural water sources and farm dams. There are no nitrous
 402 oxide emissions from manure management for manure excreted to PRP, however emissions
 403 from the soil occur from the metabolism of the deposited urine and faeces, and indirectly
 404 through atmospheric deposition and leaching and runoff.



405
 406 Figure 4.4: Emissions that result from manure of beef cattle on pasture, rangeland and
 407 paddock

408 The following subscripts are used in this module:

Subscript	Meaning
<i>i</i>	Temperature zone
<i>j</i>	Time-period (e.g season or month)
<i>k</i>	Beef cattle class
<i>l</i>	Beef cattle subclass
<i>m</i>	Manure management system

409

410 Emissions are estimated based on age and sex classes of cattle, time of the year and
 411 manure management system. The temperature zone will affect the selection of appropriate

412 emissions factors. The emissions are summed across each class (and subclass), manure
 413 management system and time-period spent on farm during the reporting period.

414 The classes of cattle on the farm ('Beef cattle input class') will depend on the diversity of the
 415 farming operation. These classes need to be mapped back to default categories ('Beef
 416 Cattle Classes (l) and Subclass (n)') to allow the use of default values under Method 1.

417 The time-period selected will depend on availability of stock numbers and liveweight and
 418 liveweight gain data (see Herd Flow modelling guidance in Section 1.9).

Beef Cattle Classes (l)	Beef Cattle Subclass (n) ^(a)	Beef Cattle input classes
1 = Bulls < 1 year	1 = Bulls < 1 year	Bulls < 1 year
2 = Bulls > 1 year	2 = Bulls > 1 year	Bulls > 1 year
3 = Cows < 1 year	3 = Cows < 1 year	Cows < 1 year
4 = Cows 1-2 years	4 = Cows 1-2 years	Cows 1-2 years
5 = Cows > 2 years	5a = Cows 2-3 years	Cows 2-3 years
	5b = Cows > 3 years	Cows > 3 years
6 = Steers < 1 year	6 = Steers < 1 year	Steers < 1 year
7 = Steers > 1 year	7a = Steers 1-2 years	Steers 1-2 years
	7b = Steers 2-3 years	Steers 2-3 years
	7c = Steers >3 years	Steers >3 years

419 (a) Only available for cattle in QLD and NT

420 The only relevant manure management systems (m) for grazing beef are PRP (m=14) and
 421 anaerobic lagoons (m=1). Where farmers have unfenced natural water sources and farm
 422 dams, anaerobic lagoons are used as a proxy to estimate the runoff of manure into these
 423 water sources.

424

425 **4.2.1 Estimation methodology**426 **4.2.1.1 METHOD 1 — MANURE METHANE BEEF GRAZING**

427 (1) Total annual methane production from manure management E_{CH_4} (t CH₄) for grazing
428 beef cattle is calculated as:

$$429 \quad E_{CH_4} = \sum_j \sum_k \sum_l \sum_m (N_{jkl} \times M_{jklm} \times D_j) \times 10^{-3}$$

430 Where N_{jkl} = number of beef cattle in each time-period, class and sub class (head)

431 M_{jklm} = methane production from manure in each time-period, class, sub
432 class and MMS (kg/head/day)

433 D_j = number of days in each time-period for each input class (days). This is
434 91.25 days under Method 1 as the default time-period is a season (quarter of
435 a calendar year)

436 (2) In equation (1) methane production from the manure of grazing beef cattle M_{jkl}
437 (kg/head/day) is calculated as:

$$438 \quad M_{jklm} = VS_{jkl} \times B_o \times MMS_m \times MCF_{im} \times \rho$$

439 Where VS_{jkl} = volatile solid production (kg/day)

440 B_o = emissions potential (m³ CH₄/kg VS)

441 MMS_m = fraction of waste in each manure management system

442 MCF_{im} = Methane conversion factor for temperature zone and MMS. Under
443 Method 1, the default state temperature zone is applied

444 ρ = density of methane (kg/m³)

445

446 The primary manure management system (MMS) for pasture-fed beef is pasture range and
447 paddock (m=14). Where natural water sources and farm dams are present the anaerobic
448 lagoon (m=1) MMS is used to estimate the run-off of manure into these water sources.
449 Where farmers can demonstrate animals are on bore or reticulated water systems, where
450 water is provided in troughs (i.e., no unfenced natural water sources or farm dams), then the
451 only relevant MMS to be considered shall be pasture range and paddock (m=14).

452 (3) In equation (2) volatile solid production from grazing beef VS_{jkl} (kg/head/day) is
453 calculated by:

$$454 \quad VS_{jkl} = (I_{jkl} \times (1 - DMD_{jkl}) + (0.04 \times I_{jkl})) \times (1 - A)$$

455 Where I_{jkl} = dry matter intake as calculated in Chapter 3 Section 3.2.1
456 (kg/head/day)

457 DMD_{ijk} = dry matter digestibility expressed as a fraction. Default values
458 applied under Method 1

459 A = ash content of feed intake expressed as fraction

460 4.2.1.2 METHOD 2 — MANURE METHANE BEEF GRAZING

461 Method 2 is the same as Method 1 except that under equations 4.2.1.1 (3) feed intake I_{jkl} is
 462 estimated as per section 3.2.1.2 and farm specific data for the selected time-period (i.e.
 463 seasonal, monthly or other) and for farm specific temperature zone is used for MCF_{im} . Farm
 464 specific data may be applied for DMD_{jk} .

465 Under Method 2 the selected time-period and associated D_j used in equation 4.2.1.1 (1) may
 466 be a season ($D_j = 91.25$ days), month ($D_j = 28-31$ day depending on month) or a specific
 467 number of days in a month or season if the entry and exit from farm of a specific cohort of
 468 animals is being estimated

469 4.2.1.3 METHOD 1 — SOIL DIRECT N₂O BEEF GRAZING

470 (1) Total annual direct nitrous oxide emissions from agricultural soils from deposition of
 471 urine and dung $E_{N_2O,dir}$ (t N₂O) is calculated as:

$$472 \quad E_{N_2O,dir} = (AE \times EF_{PRP} \times C_{N_2O}) \times 10^{-3}$$

473 Where AE = total mass of nitrogen excreted on PRP for beef cattle (kg N)

474 EF_{PRP} = emission factor for nitrous oxide from urine and dung deposited to soil
 475 (kg N₂O-N/kg N deposited)

476 C_{N_2O} = factor to convert elemental mass of nitrous oxide to molecular mass

477

478 (2) In equation (1) the total nitrogen excreted to pasture, range and paddock AE (kg N) is
 479 calculated as:

$$480 \quad AE = \sum_j \sum_k \sum_l (N_{jkl} \times NE_{jkl} \times D_j)$$

481 Where N_{jkl} = number of beef cattle by time-period, class and sub class (head)

482 NE_{jkl} = nitrogen excreted in each time-period, by each class and subclass (kg
 483 N/head/day)

484 D_j = number of days in each time-period (days). This is 91.25 days under
 485 Method 1 as the default time-period is a season

486 (3) In equation (2) the nitrogen excreted NE_{jkl} (kg N/head/day) is calculated as:

$$487 \quad NE_{jkl} = (I_{jkl} \times CP_j \div 6.25) + (0.032 \times MC_{jk=1,3,6} \div 6.38) - NR_{jkl}$$

$$488 \quad - \left[(1.1 \times 10^{-4} \times W_{jkl}^{0.75}) \div 6.25 \right]$$

489 Where I_{jkl} = dry matter intake as calculated in Chapter 3 Section 3.2.1
 490 (kgDM/head/day)

491 CP_j = crude protein content of dry matter intake

492 $MC_{jk=1,3,6}$ = milk intake (kg/head/day)

493 NR_{jkl} = the amount of nitrogen retained by the body (kg N/head/day)

494 W_{jkl} = liveweight (kg/head)

495 Under Method 1, default CP_j and W_{jkl} values are applied.

496 (4) In equation (3) the amount of nitrogen retained by the body NR_{jkl} (kg N/head/day) is
497 calculated as:

$$498 \quad NR_{jkl} = (0.032 \times MP_{jk=5} \div 6.38) + \left\{ \left\{ 0.212 - 0.008 \times (L_{jkl} - 2) - \right. \right. \\ 499 \quad \left. \left. \frac{[0.140 - 0.008 \times (L_{jkl} - 2)]}{1 + e^{(-6 \times (Z_{jkl} - 0.4))}} \right\} \times (LWG_{jkl} \times 0.92) \right\} \div 6.25$$

500 Where $MP_{jk=5}$ = milk production (kg/head/day)

501 L_{jkl} = intake relative to that needed for maintenance

502 Z_{jkl} = relative size

503 LWG_{jkl} = liveweight gain (kg/head/day). Under Method 1, default LWG_{jkl}
504 values are applied.

505

506 (5) In equation (4) milk production for the season of calving and season after calving
507 $MP_{jk=5}$ (kg/head/day) is calculated as:

$$508 \quad MP_{jk=5} = LC_{jk=5} \times DMP_{jk=5}$$

509 Where $LC_{jk=5}$ = proportion of cows > 2 years (k=5) lactating for the season of calving
510 and season after calving noting that for all other seasons $LC_{jk=5} = 0$

511 $DMP_{jk=5}$ = daily milk production (kg/head/day)

512 For farms with multiple calving seasons, the proportion of cows > 2 years in calf ($LC_{jk=5}$)
513 should be reported separately for each season.

514

515 (6) In equation (4) intake relative to that needed for maintenance L_{jkl} is calculated as:

$$516 \quad L_{jkl} = \frac{I_{jkl}}{(1.185 + 0.00454 \times W_{jkl} - 0.0000026 \times W_{jkl}^2)^2}$$

517

518 (7) In equation (4) The relative size of the cattle Z_{jkl} , is calculated as:

$$519 \quad Z_{jkl} = \frac{W_{jkl}}{SRW_k}$$

520 Where SRW_k = standard reference weight (kg)

521 4.2.1.4 METHOD 2 — SOIL DIRECT N₂O BEEF GRAZING

522 Method 2 is the same as Method 1 except that under equations 4.2.1.3 (3), and (6) feed
523 intake I_{jkl} is estimated as per section 3.2.1.2 and farm specific data is required for the

524 selected time-period (i.e. seasonal, monthly or other) for W_{jkl} (Eq 4.2.1.3 (3), (6) and (7)),
 525 and LWG_{jkl} (Eq 4.2.1.3 (4)) and farm specific data may be applied for CP_{jkl} (Eq 4.2.1.3 (3)).

526 Under Method 2 the selected time-period and associated D_j used in equation 4.2.1.3 (2) may
 527 be a season ($L_j = 91.25$ days), month ($L_j = 28-31$ day depending on month) or a specific
 528 number of days in a month or season if the entry and exit from farm of a specific cohort of
 529 animals is being estimated

530 4.2.1.5 METHOD 1 — SOIL ATMOSPHERIC DEPOSITION N₂O BEEF GRAZING

531 (1) Atmospheric deposition emissions from urine and dung deposited on pasture $E_{N_2O,ad}$
 532 (t N₂O) are calculated as:

$$533 \quad E_{N_2O,ad} = M_{vol} \times EF_{N_2O} \times C_{N_2O} \times 10^{-3}$$

534 Where M_{vol} = mass of nitrogen volatilised from urine and faeces deposited on
 535 pasture (kg N)

536 EF_{N_2O} = nitrous oxide emission factor for atmospheric deposition (kg N₂O-
 537 N/kg N)

538

539 (2) In equation (1) the mass of nitrogen volatilised M_{vol} (kg N) is calculated as:

$$540 \quad M_{vol} = AE \times FracGASMsoil$$

541 Where AE = total mass of nitrogen excreted on PRP for beef cattle (kg N)

542 $FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces
 543 deposited on pasture ((kg NH₃-N + NO_x-N)/kg N)

544 4.2.1.6 METHOD 2 — SOIL ATMOSPHERIC DEPOSITION N₂O BEEF GRAZING

545 There is no Method 2 quantification option for this emission source.

546 4.2.1.7 METHOD 1 — SOIL LEACHING AND RUNOFF N₂O BEEF GRAZING

547 (1) Leaching and runoff emissions from urine and dung deposited on pasture $E_{N_2O,leach}$
 548 (t N₂O) are calculated as:

$$549 \quad E_{N_2O,leach} = M_{leach} \times EF_{leach} \times C_{N_2O} \times 10^{-3}$$

550 Where M_{leach} = mass of nitrogen lost to leaching and runoff (kg N)

551 EF_{leach} = emission factor for leaching and runoff (kg N₂O-N/kg N)

552

553 (2) In equation (1) the mass of nitrogen lost to leaching and runoff M_{leach} is calculated
 554 as:

$$555 \quad M_{leach} = AE \times FracWet \times FracLEACH$$

556 Where AE = total mass of nitrogen excreted on PRP for beef cattle (kg N)

557 *FracWet* = fraction of N available for leaching and runoff.

558 *FracLEACH* = fraction of all N that is lost through leaching and runoff

559

560 4.2.1.8 METHOD 2 — SOIL LEACHING AND RUNOFF N₂O BEEF GRAZING

561 There is no Method 2 quantification option for this emission source

562

563 **4.2.2 Data/Parameter tables**564 **4.2.2.1 INPUT DATA (REQUIRED)**

Data / Parameter	N_{jkl}
Data unit	head
Description	Number of pasture beef cattle per time-period, class and sub class
Data source	Farm stock records and herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	Number of cattle reported may be cross checked with average stocking density for farm size and system (if known). The class of animals on farm may be crossed checked with expected enterprise on farm. For example, self-replacing systems vs purchased breeder or trading systems.

565

Data / Parameter	$LC_{jk=5}$
Data unit	fraction
Data source	Proportion of cows > 2 years in calf in the season of calving. This is used as a proxy for cows >2 lactating
Value	<p>Farm records: Proportion of cows > 2 may be based on scanning numbers where available.</p> <p>If scanning results are not available weaning numbers may also be used to approximate the proportion of cows > 2 years lactating.</p> <p>For farms with multiple calving seasons, the proportion of cows > 2 years in calf $LC_{jk=5}$ should be reported separately for each season or time period.</p> <p>Noting that the calving season should be considered 3 months from the calving month if Method 2 herd flow data is used (see Chapter 1 Section 1.9) and that for all other time periods $L_{jk=5} = 0$</p>
Quality assurance / quality control considerations	<p>Scanning records may be used to check input data.</p> <p>If scanning or weaning results are not recorded proportion of cows > 2 years may be cross checked from number of cows and calves in the reporting period.</p>

566

567

568 4.2.2.2 DATA (METHOD 1 AND 2 OPTIONS)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each cattle, class and sub class
Method 1 data source	National Inventory Report Volume 1 [1]
Method 1 value	91.25 as the default time period is a season (quarter of a calendar year).
Method 2 data source	Farm stock records; system type records or purchase and sales may be evaluated to determine average duration of each cattle input class (see Chapter 1 Section 1.9 for more details on herd flow modelling)
Quality assurance / quality control considerations	<p>Ensure that if animals are on the farm all year round the duration of stay is 365 days</p> <p>Ensure that if animals are only born part way through the reporting period their duration of stay reflect this.</p> <p>If Method 1 is used inputs should be completed seasonally throughout the calculations.</p> <p>Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values.</p>

569

Data / Parameter	DMD_j
Data unit	fraction
Description	Dry matter digestibility
Method 1 data source	See Appendix Table A.1.2.5
Method 1 value	Select the appropriate default value for location of cattle and season
Method 2 data source	Farm source records for seasonally dry matter digestibility of feed.
Quality assurance / quality control considerations	<p>In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.</p> <p>If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.</p> <p>If farm data is only available for one (or more) seasons, use data available for season(s) and supplement missing data with inventory data.</p>

570

571

572

Data / Parameter	CP _j
Data unit	fraction
Description	Crude protein content of feed dry matter
Method 1 data source	See Appendix Table A.1.2.6
Method 1 value	Select the appropriate default value for location of cattle and season
Method 2 data source	Farm source records for seasonally crude protein of feed.
Quality assurance / quality control considerations	<p>In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.</p> <p>If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.</p> <p>If farm data is only available for one (or more) seasons, use data available for season(s) and supplement missing data with inventory data.</p>

573

Data / Parameter	W _{jkl}
Data unit	kg
Description	Average liveweight of beef pasture cattle per time-period, class and subclass
Method 1 data source	See Appendix Table A.1.2.1 & A.1.2.2
Method 1 value	Select the appropriate default value for location of cattle, class/subclass and season
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	<p>If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.</p> <p>It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. if autumn calving, ensure default weights reflect this with lowest weight value applied in autumn for stock <1 year and/or that default weights reflect when stock are expected to be at the lightest and heaviest.</p> <p>If Method 2 is used purchase and sale weight records (invoices) may be used for data assurance and control of entered values.</p> <p>Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.</p>

574

Data / Parameter	LWG _{ijkl}
Data unit	kg/head/day
Description	Average liveweight gain of beef pasture cattle per time-period, class and sub class
Method 1 data source	See Appendix Table A.1.2.2 & A.1.2.3
Method 1 value	Select the appropriate default value for location of cattle, class/subclass and season
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	<p>If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.</p> <p>It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. that default liveweight gain reflects when stock are expected to be growing more due to feed quality and availability.</p> <p>If Method 2 is used purchase and sale weight records (invoices) may be used for data assurance and control of entered values.</p> <p>Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.</p>

575

Data / Parameter	MCF _{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.2.10
Method 1 value	Select default value based on State, Region and MMS.
Method 2 data source	<p>Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1.</p> <p>See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.</p>
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

576

577 **4.2.2.3 CONSTANTS**

Data / Parameter	B ₀
Data unit	m ³ CH ₄ /kg VS
Description	Emissions potential
Data source	IPCC (2019), Chapter 10 [3]
Value	0.19

**Quality assurance /
quality control
considerations**

Ensure alignment with the latest version of the Australian National Inventory Report.

578

Data / Parameter	MMS _m
Data unit	fraction
Description	Fraction of waste in each MMS
Data source	See Appendix Table A.1.2.9
Value	Where a producer cannot demonstrate water bodies are stock excluded MMS _m values shall be selected based on State, Region and MMS. If animals are on bore or reticulated water systems where water is provided in troughs (i.e. no unfenced natural water sources) then all waste should be allocated to pasture range and paddock and MMS _{m=14} = 1.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report. High resolution aerial imagery may be used to cross check that water sources are stock excluded.

579

Data / Parameter	ρ
Data unit	kg/m ³
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

580

Data / Parameter	A
Data unit	fraction
Description	Ash content of feed intake
Data source	National Greenhouse Gas Inventory Report Vol 1. (2023)
Value	0.08
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

581

582

Data / Parameter	C _{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

583

Data / Parameter	MC _{jk=1,3,6}
Data unit	kg/head/day
Description	Milk intake
Data source	See Appendix Table A.1.2.7
Value	Select the appropriate default value based on the cattle breed. Noting that the calving season should be considered 3 months from the calving month if Method 2 herd flow data is provided (see Chapter 1 Section 1.9) and the season after calving the 3 months after this period.
Quality assurance / quality control considerations	Ensure all other stock classes other than cattle <1 year old are defaulted to zero. Ensure alignment with the latest version of the Australian National Inventory Report.

584

Data / Parameter	DMP _{jk=5}
Data unit	kg/head/day
Description	Daily milk production
Data source	See Appendix Table A.1.2.7
Value	Select the appropriate default value based on the cattle breed. Noting that the calving season should be considered 3 months from the calving month if Method 2 herd flow data is provided (see Chapter 1 Section 1.9) and the season after calving the 3 months after this period.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

585

586

Data / Parameter	SRW _k
Data unit	kg
Description	Standard reference weight
Data source	See Appendix Table A.1.2.8
Value	Select the appropriate default value based on cattle class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

587

Data / Parameter	EF _{PRP}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for urine and dung deposited on pasture, range or paddock
Data source	See Appendix Table A.2.2.2.
Value	The appropriate EF _{PRP} shall be selected by using the IPCC values for EF _{PRP} specific to the climate zone in which the farm is located. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

588

Data / Parameter	EF _{N₂O}
Data unit	kg N ₂ O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Apply the EF that best represent the production system In some farm systems animals may graze on crops. Apply the inorganic fertiliser EF that best representing how the cattle are grazed for the majority of the year or calculate a weighted average if the number of days on each grazing system is known. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on determining the relevant rainfall zone.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

589

Data / Parameter	FracGASMsoil
-------------------------	--------------

Data unit	(kg NH ₃ -N + NO _x -N)/kg N
Description	Fraction of nitrogen volatilised from urine and faeces deposited on pasture
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [8]
Value	0.21
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

590

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

591

Data / Parameter	FracLEACH
Data unit	fraction
Description	Default fraction of N that is lost through leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.24
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

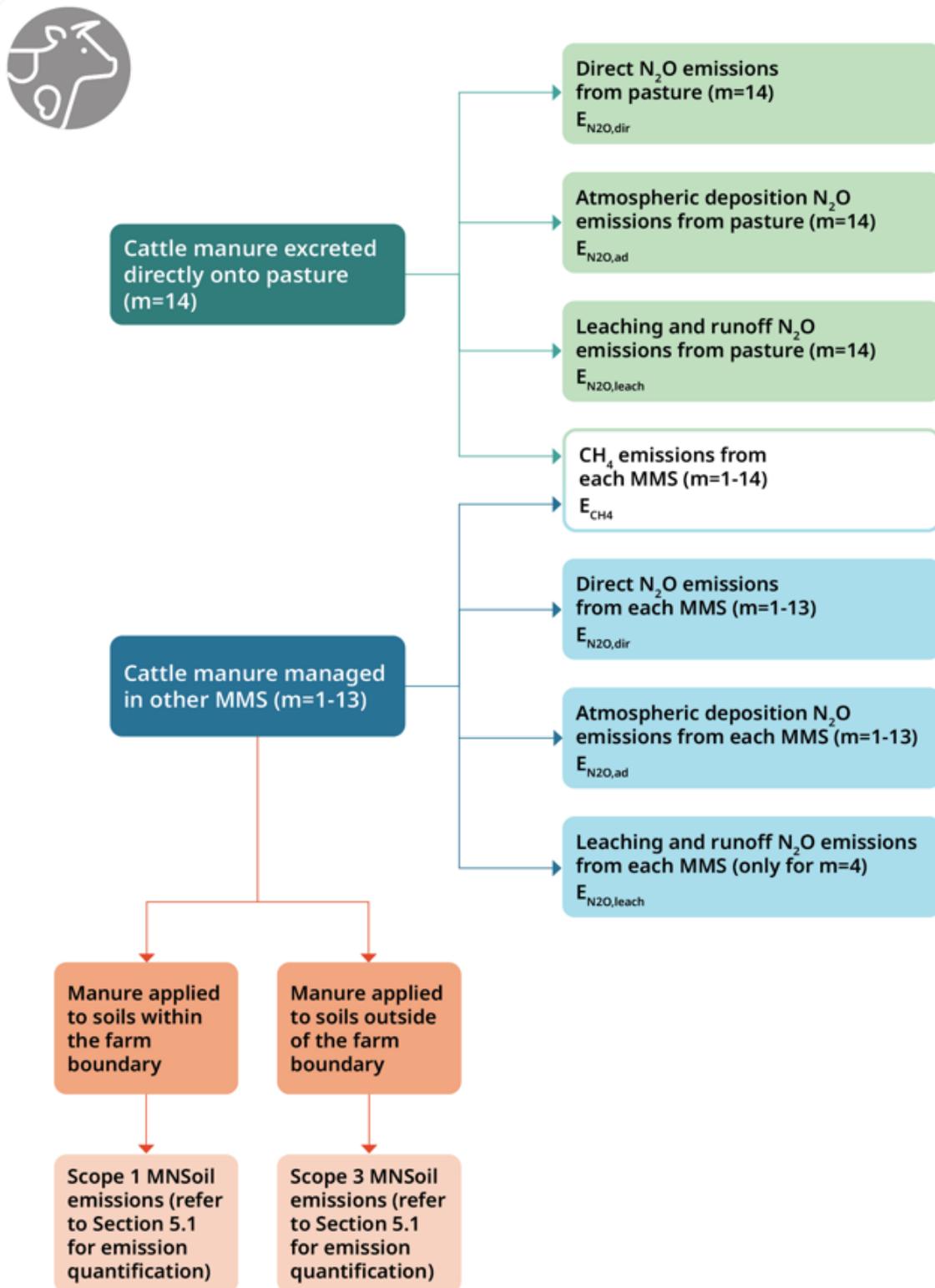
592

Data / Parameter	EF _{leach}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.011
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

593

594 4.3 Dairy

595 This module covers the estimation of methane and nitrous oxide emission that results from
596 dairy cattle manure management. Figure 4.5 summarises the emission sources associated
597 with the manure from dairy cattle. There are two components to methane emission estimates
598 – manure excreted directly onto pasture, and managed manure from the milking shed or and
599 feedpad. Managed manure also results in direct and indirect nitrous oxide emissions. For
600 manure excreted to pasture there are no nitrous oxide emissions from manure management,
601 however emissions from the soil occur from the metabolism of the deposited urine and
602 faeces, and indirectly through atmospheric deposition and leaching and runoff. Note that
603 emissions associated with manure from management systems that is subsequently applied
604 to soils are covered in the organic fertiliser section in Chapter 5 Section 5.1 Fertiliser
605 module.



606
607 Figure 4.5: Emissions that result from dairy cattle manure

608
609
610

611 The following subscripts are used in this module:

Subscript	Meaning
<i>I</i>	Temperature zone
<i>J</i>	Livestock class
<i>M</i>	Manure management system

612
 613 Emissions are estimated based on age and sex classes of cattle and the manure
 614 management system. The temperature zone will affect the selection of appropriate
 615 emissions factors. The emissions are summed across each class, manure management
 616 system and time-period spent on farm during the reporting period.

617 The classes of cattle on the farm ('dairy input class') will depend on the diversity of the
 618 farming operation. The number of heifer and bull calves should be reported separately to
 619 weaned stock less than 12 months in age to capture emissions from calves sold at weaning.
 620 These classes need to be mapped back to default categories ('dairy cattle class j') to allow
 621 the use of default inventory values under Method 1.

Dairy Cattle Class j	Possible Dairy Input Class
1 = Milking cows	Milking cows
2 = Heifers > 1 year	Heifers > 1 year
3 = Heifers < 1 year	Replacement heifers < 1 year, weaned
	Heifer Calves, <1 year, preweaning
4 = Bulls > 1 year	Mature bulls
5 = Bulls < 1 year	Other weaned stock < 1 (non-replacement heifers, steers or bulls)
	Bull Calves, <1 year, preweaning

622
 623 The National Inventory Report and Method 1 defaults for dairy assume that all "other stock"
 624 will be sold from the dairy at 12 months or less. In cases where other stock such as steers or
 625 bulls are retained beyond 12 months Method 1 default values for liveweight and liveweight
 626 gain may be taken from the appropriate beef pasture, range and paddock defaults (see
 627 Section **Error! Reference source not found.** for more detail).

628 Nitrous oxide emissions from managed manure are only relevant for milking cows (j=1). The
 629 manure management systems (m) will differ for manure excreted while animals are grazing
 630 or in the milking shed or feedpad. Manure from other dairy cattle classes (j=2-5) is all
 631 assumed to be excreted to pasture (m=14)

632 **4.3.1 Estimation methodology**633 **4.3.1.1 METHOD 1 — MANURE METHANE DAIRY**

634 (1) Total annual methane production from manure management E_{CH_4} (t CH₄) is
 635 calculated as the sum of methane from manure from dairy cows, bulls, young stock
 636 and pre-weaned calves:

$$637 \quad E_{CH_4} = \sum_j \sum_m \left((N_{j=1,2,4} \times M_{j=1,2,4,m} \times D_{j=1,2,4}) + (N_{j=3,5} \times M_{j=3,5,m} \times D_{j=3,5}) \right. \\ 638 \quad \left. + (N_{j=3,5} \times MPW_{manure,j=3,5} \times D_{j=3,5}) \right) \times 10^{-3}$$

639 Where N_j = number of dairy cattle in each class

640 M_{jm} = methane production from manure of weaned dairy cattle in each class
 641 in each MMS (kgCH₄/head/day)

642 $MPW_{manure,j=3,5}$ = methane production from manure of pre-weaned heifer and
 643 bulls calves (<1 year) (kg CH₄/head/day)

644 D_j = Duration of stay on the farm (days). Method 1 default values for these
 645 time periods are provided in data tables.

646 (2) Methane from manure production M_{jm} (kgCH₄/head/day) from weaned dairy cattle is
 647 calculated by:

$$648 \quad M_{jm} = VS_j \times FVS_{jm,T=1} \times MCF_{im} \times B_o \times \rho$$

649 Where: VS_j = daily volatile solids production per head for dairy cattle (kg/head/day)

650 FVS_{jm} = fraction of waste from each class in each management system

651 MCF_{im} = methane conversion factor for temperature zone and MMS. Under
 652 Method 1, the default state temperature zone is applied

653 B_o = emissions potential (m³ CH₄/kgVS)

654 ρ = density of methane (kg/m³)

655

656 (3) In equation (2), for weaned dairy cattle, volatile solids VS_j (kg/head/day) are
 657 calculated as:

$$658 \quad VS_j = \left(I_j \times (1 - DMD_j) + (0.04 \times I_j) \right) \times (1 - A)$$

659 Where I_j = dry matter feed intake as calculated in Chapter 3 Section 3.3.1
 660 (kgDM/head/day)

661 DMD_j = dry matter digestibility. Default values applied under Method 1

662 A = ash content of feed intake

663 Note: volatile solids values for pre-weaned cattle $VS_{j=3,5}$ are provided as constants in
 664 Section 4.3.2.3

665 (4) In equation (2) the fraction of volatile solids in each system FVS_{jm} , other than solid

666 storage ($m=4$), is calculated as:

$$667 \quad FVS_{jm} = MMS_{jm} \times (1 - SS_m)$$

668 Where:

669 SS_m = fraction of volatile solids separated to solid storage for each MMS

670 MMS_{jm} = fraction of manure to each primary MMS for each class prior to solid
671 separation

672

673 (5) In equation (3) the fraction of volatile solids in solid storage, $MMS_{jm=4}$ is calculated
674 as:

$$675 \quad FVS_{jm=4} = MMS_{jm=4} + (MMS_{jm=1,7,9} \times SS_m)$$

676

677 Note: Where solid separation systems are applied, the separated solids are currently
678 assumed to be treated through solid storage.

679

680 4.3.1.2 METHOD 2 — MANURE METHANE DAIRY

681 Method 2 is the same as Method 1 except that under equations 4.3.1.1 (3) feed intake I_j is
682 estimated as per section 3.3.1.2 and farm specific data is required for MCF_{im} . Farm specific
683 data may be applied for DMD_k .

684 Under Method 2 the selected time-period and associated D_j used in equation 4.3.1.1 (1) may
685 be a year, $D_{j=1,2,4} = 365$ days, or $D_{j=3,5} = 284$ or 84 days depending on pre or post weaning or
686 a specific number of days if the entry and exit from farm of a specific cohort of animals is
687 being estimated

688 4.3.1.3 METHOD 1 — MANURE DIRECT N₂O DAIRY

689 (1) The total annual direct nitrous oxide emissions from manure management systems
690 $E_{N_2O,dir}$ (t N₂O) is calculated as:

$$691 \quad E_{N_2O,dir} = \sum_j \sum_m (MN_{jm} \times EF_m \times C_{N_2O}) \times 10^{-3}$$

692 Where MN_{jm} = total nitrogen in each MMS for dairy cattle classes (kg N)

693 EF_m = nitrous oxide emission factor for each MMS (kg N₂O-N/kg N deposited)

694 C_{N_2O} = factor to convert elemental mass of N₂O to molecular mass

695 (2) In equation (1) total nitrogen in each MMS MN_{jm} (kg N) is calculated as:

$$696 \quad MN_{jm} = AE_j \times MMS_{jm}$$

697 Where AE_j = total nitrogen excreted by each dairy class (kg N)

698

699 (3a) In equation (2) total annual nitrogen excreted by dairy cattle >1 year old, $AF_{j=1,2,4}$ (kg
700 N) is calculated as:

$$701 \quad \quad \quad AE_{j=1,2,4} = (N_{j=1,2,4} \times NE_{j=1,2,4} \times 365)$$

702

703 Where: $NE_{j=1,2,4}$ = nitrogen excreted by dairy cattle >1 year old (kg N/head/day)

704 (3b) In equation (2) total annual nitrogen excreted by dairy cattle <1 year old, $AF_{j=3,5}$ (kg
705 N) is calculated as:

$$706 \quad \quad \quad AF_{j=3,5} = (N_{j=3,5} \times NE_{j=3,5} \times 281) + (N_{j=3,5} \times NPW_{j=3,5} \times 84)$$

707

708 Where: $NE_{j=3,5}$ = nitrogen excreted by weaned dairy cattle <1 year old (kg
709 N/head/day)

710 $NPW_{j=3,5}$ = nitrogen excreted by pre-weaned calves (kg N/head/day)

711

712 (4) In equation (3) nitrogen excreted NE_j (kg N/head/day) by dairy cattle >1 year old is
713 calculated as:

$$714 \quad \quad \quad NE_j = \left(\frac{CPI_j}{6.25} \right) - NR_j - \left[\frac{1.1 \times 10^{-4} \times W_j^{0.75}}{6.25} \right]$$

715 Where CPI_j = crude protein intake (kg/head/day)

716 NR_j = amount of nitrogen retained by the body (kg N/head/day)

717 W_j = liveweight (kg). Default values applied under Method 1

718

719 (5) In equation (4) the crude protein intake CPI_j (kg/head/day) of dairy cattle is calculated
720 as:

$$721 \quad \quad \quad CPI_j = I_j \times CP_j$$

722 Where CP_j = crude protein content of feed intake (fraction). Default values applied
723 under Method 1

724

725

726 (6) In equation (4) the amount of nitrogen retained by the body NR_j is calculated as:

$$\begin{aligned}
 727 \quad NR_j &= \left(\frac{0.032 \times MP_j \times 1.03}{6.38} \right) \\
 728 \quad &+ \left\{ \left\{ 0.212 - 0.008 \times (L_j - 2) - \left[\frac{0.140 - 0.008 \times (L_j - 2)}{1 + e^{-6 \times (Z_j - 0.4)}} \right] \right\} \times (LWG_j \right. \\
 729 \quad &\left. \times 0.92) \right\} \times \frac{1}{6.25}
 \end{aligned}$$

- 730 Where MP_j = milk production (L/head/day)
 731 L_j = intake relative to that needed for maintenance
 732 Z_j = relative size
 733 LWG_j = liveweight gain (kg/day). Default values applied under Method 1
 734 1.03 = conversion factor for milk in litres to kg

735 Where daily milk production data is collected in quantities of milk solids rather than litres of
 736 milk, refer to Chapter 3 Section 3.3.1 for converting milk solids to litres.

- 737 (7) In equation (6) intake relative to maintenance L_j is calculated as:

$$738 \quad L_j = \frac{I_j}{(1.185 + 0.00454 \times W_j - 0.0000026 \times W_j^2)^2 \times MR_j + MI_j}$$

- 739 Where MR_j = increase in metabolic rate when producing milk (kgDM/head/day)
 740 MI_j = additional intake required for milk production, as calculated in Chapter 3
 741 Section 3.3.1 (kgDM/head/day)

742

- 743 (8) In equation (6) The relative size Z_j is calculated as;

$$744 \quad Z_j = \frac{W_j}{WR_j}$$

- 745 Where WR_j = reference weight (kg)

746

747 4.3.1.4 METHOD 2 — MANURE DIRECT N2O DAIRY

748 Method 2 is the same as Method 1 except that under equations 4.3.1.3 (5), and (7) feed
 749 intake I_j is estimated as per section 3.2.1.2 and farm specific data is required for the
 750 selected time-period (i.e. seasonal, monthly or other) for W_j (Eq 4.3.1.3 (4), (7) and (8)),
 751 LWG_j (Eq 4.3.1.3 (6)) and may be applied for CP_j (Eq 4.2.1.3 (5)).

752

753 4.3.1.5 METHOD 1 — MANURE ATMOSPHERIC DEPOSITION DAIRY

- 754 (1) Annual atmospheric deposition emissions from MMS $E_{N2O,MMS,ad}$ is calculated as:

$$755 \quad E_{N2O,MMS,ad} = MN_{ATMOS} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

756 Where MN_{ATMOS} = mass of N volatilised from MMS (kg N)
 757 EF_{N_2O} = nitrous oxide emission factor for atmospheric deposition (kg N₂O-
 758 N/kg N)

759

760 (2) In equation (1) total of nitrogen volatilised from MMS MN_{ATMOS} (kg N) is calculated
 761 as:

$$762 \quad MN_{ATMOS} = \sum_j \sum_m (MN_{jm} \times FracGASM_m)$$

763 Where $FracGASM_m$ = fraction of N volatilised from MMS (fraction)

764

765 4.3.1.6 METHOD 1 — MANURE LEACHING AND RUNOFF N₂O DAIRY

766 (1) Annual emissions from leaching and run off from each MMS $E_{N_2O,leach}$ (t N₂O) is
 767 calculated as:

$$768 \quad E_{N_2O,leach} = \sum_j \sum_{m=1-13} (MNLeach_{jm} \times EF_{leach} \times C_{N_2O}) \times 10^{-3}$$

769 Where $MNLeach_{jm}$ = mass of N lost through leaching and runoff from each MMS (kg
 770 N)

771 EF_{leach} = nitrous oxide emission factor for leaching and runoff (kg N₂O-N/kg N)

772

773 $MNLeach_m$ is assumed to be zero for anaerobic lagoons (m=1), and for daily spread
 774 treatments (sump and dispersal m=3a, and drains to paddock m=3b) is nitrogen is
 775 transferred directly to manure applied to soils (see section 4.3.1.8 Manure applied to Soil)

776 Emissions from leaching and run off are only estimated for the solid storage MMS (m=4).
 777 This simplifies the equation to:

$$778 \quad E_{N_2O,leach} = MNLeach_{jm=4} \times EF_{leach} \times C_{N_2O} \times 10^{-3}$$

779 (2) In equation (1) the mass of nitrogen lost to leaching and runoff from solid storage
 780 systems $MNLeach_{jm=4}$ (kg N) is calculated as:

$$781 \quad MNLeach_{jm=4} = MN_{jm=4} \times FracWET_i \times FracLEACH_{MS}$$

782 Where $FracWET_i$ = fraction of N available for leaching and runoff

783 $FracLEACH_{MS}$ = fraction of N lost through leaching and runoff

784 4.3.1.7 METHOD 2 — MANURE LEACHING AND RUNOFF N₂O DAIRY

785 There is no Method 2 quantification option for this emission source

786 4.3.1.8 MANURE APPLIED TO SOILS

787 It is assumed that all manure managed through an MMS (m=1-13) will eventually be applied
788 to soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value
789 is transferred to Chapter 5 Section 5.1 to estimate emissions associated with the application
790 of manure to soils as organic fertilisers, including associated atmospheric deposition and
791 leaching and run-off emissions.

792 The manure may be applied to soils within the boundary of the farm or may be sent off-site
793 and applied to another farming enterprise. Where manure is applied to soils within the
794 boundary of the farming enterprise $MNSoil_{scope1}$, the emissions from shall be estimated and
795 reported as Scope 1 emissions. Where the manure is used on other farming enterprises
796 $MNSoil_{scope3}$, the emissions from shall be estimated and reported as Scope 3 emissions
797 under Scope 3 Category 5 – waste generated in operations (see Chapter 7 Section 7.10).

798 (1) The mass of nitrogen from manure that is applied to soils for scope 1 emissions
799 $MNSoil_{scope1}$ (kg N) is calculated as:

$$800 \quad MNSoil_{scope1} = \sum_j \sum_m (MN_{jm=1-13} \times (1 - EF_{m=1-13} - FracGASM_{m=1-13}) - MNLeach_{jM})$$

$$801 \quad \times PF$$

802 Where PF_{scope} = fraction of manure applied to soil within the farm boundary

803 $EF_{m=1-13}$ = Emission factor for nitrous oxide emissions per MMS (kg N₂O-N/kg
804 N)

805

806 (2) The mass of nitrogen from manure that is applied to soils for scope 3 $MNSoil_{scope3}$
807 (kg N) is calculated as:

$$808 \quad MNSoil_{scope3} = \sum_j \sum_m (MN_{jm=1-13} \times (1 - EF_{m=1-13} - FracGASM_{m=1-13}) - MNLeach_{jM})$$

$$809 \quad \times (1 - PF)$$

810

811 4.3.1.9 METHOD 1 — SOIL DIRECT N₂O DAIRY

812 (1) Direct nitrous oxide emissions $E_{N2O,dir}$ (t N₂O) on to pasture are calculated as:

$$813 \quad E_{N2O,dir} = \sum_j (MN_{jm=14} \times EF_{PRP} \times C_{N2O}) \times 10^{-3}$$

814 Where $MN_{jm=14}$ = mass of nitrogen excreted on pasture, range, and paddock for
815 each dairy cattle class (kg N)

816 EF_{PRP} = emission factor for nitrous oxide emissions for urine and dung
817 deposited on PRP (kg N₂O-N/kg N deposited)

818

819 4.3.1.10 METHOD 1 — SOIL ATMOSPHERIC DEPOSITION N2O DAIRY

820 (1) Atmospheric deposition emissions from urine and dung deposited on pasture $E_{N2O,ad}$
821 (t N₂O) are calculated as:

$$822 \quad E_{N2O,ad} = M_{vol,m=14} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

823 Where $M_{vol,m=14}$ = mass of nitrogen volatilised from urine and faeces deposited on
824 pasture (kg N)

825 EF_{N2O} = nitrous oxide emission factor for atmospheric deposition (kg N₂O-
826 N/kg N)

827

828 (2) In equation (1) the mass of nitrogen volatilised $M_{vol,PRP}$ (kg N) is calculated as:

$$829 \quad M_{vol,m=14} = \sum_j (MN_{jm=14} \times FracGASMsoil)$$

830 Where $FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces
831 deposited on pasture ((kg NH₃-N + NO_x-N)/kg N)

832

833 4.3.1.11 METHOD 2 — SOIL ATMOSPHERIC DEPOSITION N2O DAIRY

834 There is no Method 2 quantification option for this emission source

835 4.3.1.12 METHOD 1 — SOIL LEACHING AND RUNOFF N2O DAIRY

836 (1) Leaching and runoff emissions from urine and dung deposited on pasture $ES_{N2O,leach}$
837 (t N₂O) are calculated as:

$$838 \quad E_{N2O,leach} = M_{leach,m=14} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

839 Where $M_{leach,m=14}$ = mass of nitrogen lost to leaching and runoff from urine and
840 faeces deposited on pasture (kg N)

841

842 (2) In equation (1) the mass of nitrogen lost to leaching and runoff $M_{leach,m=14}$ is
843 calculated as:

$$844 \quad M_{leach,m=14} = \sum_j (MN_{jm=14} \times FracWet \times FracLEACH)$$

845

846 4.3.1.13 METHOD 2 — SOIL LEACHING AND RUNOFF N2O DAIRY

847 There is no Method 2 quantification option for this emission source

848

849 **4.3.2 Data/Parameters**850 **4.3.2.1 INPUT DATA (REQUIRED)**

Data / Parameter	N_j
Data unit	head
Description	Number of dairy cattle in each class j
Data source	Farm stock records and herd flow model see Chapter 1 Section 1.9 Noting that the number of heifer and bull calves should be reported separately to weaned stock less than 12 months in age to capture emissions from calves sold at weaning.
Quality assurance / quality control considerations	The number of heifer and bull calves should be reported separately to weaned stock less than 12 months in age to capture emissions from calves sold at weaning. Number of cattle reported may be cross checked with average stocking density for farm size and system (if known). The class of animals on farm align may be checked against expected enterprise on farm: for example, self-replacing systems vs purchased breeder or trading systems.

851

Data / Parameter	MP_j
Data unit	L/head/day
Description	Daily milk production per milking cow
Data source	Farm milk sales records and number of milking cows. The average amount of milk sold per day (in litres) may be divided by the average number of milking cows on the farm to calculate the daily milk production per milking cow. If milk production records are in terms of milk solids rather than litres of milk, refer to Chapter 3, section 3.3.1 for converting milk solids (MS _j) into litres (MP _j).
Quality assurance / quality control considerations	Farm source data may be compared to National Inventory Report state-based values to check for possible data entry errors. State-based values can be found in Appendix Table A.1.3.9. Milk production data may be reviewed through milking parlour software and corroborated via milk collection receipts.

852

853

Data / Parameter	PF
Data unit	fraction
Description	Fraction of manure from MMS applied to soil within the farm boundary
Data source	Farmer records of manure sales or transport weights compared to total manure treated on farm. When all manure treated in MMS is applied within the farm boundary and none is sold off-site to be used in a different enterprise, then PF = 1.
Quality assurance / quality control considerations	Any quantities of manure sent off-site and outside the entity / farm boundary to other entities should be recorded and tracked. If it is not known what proportion of manure is sent offsite to other entities, assume all manure is applied within the entity boundary until better data can be collected.

854

855

4.3.2.2 DATA (METHOD 1 AND 2 OPTIONS)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each dairy cattle input class
Method 1 data source	National Inventory Report Volume 1 [1]
Method 1 value	For all manure stock ($j = 1,2,4$) $D_j = 365$ For pre-weaned young stock ($j=3,5$) $D_j = 84$ For weaned stock <1 year ($j = 3,5$) $D_j = 281$
Method 2 data source	Farm stock records; system type records or purchase and sales may be evaluated to determine average duration of each cattle input class (see Chapter 1 Section 1.9 for more details on herd flow modelling).
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 is used consider if input classes of animals are on the farm all year round (and if so the duration of stay is 365 days) and that if animals are only born part way through the reporting period their duration of stay reflect this. Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values.

856

Data / Parameter	MMS _m
Data unit	Fraction
Description	Fraction of waste voided to each manure management system m
Method 1 data source	<p>Annual fraction of time spent on pasture, in the milking shed or on a feedpad is based on the assumptions underlying the defaults for MMS_{jm} used in the National Greenhouse Gas Inventory MMS calculations.</p> <p>User-defined data for fraction of waste from the milking shed and feedpad that goes to each MMS may be based on farm records of MMS quantities (where available), or estimates based on experience and observations made throughout the year.</p>
Method 1 value	<p>MMS_{jm} is determined based on the fraction of time dairy cows or heifers spend on pasture, in the milking shed, or on feedpad.</p> <p>The user shall select which feeding system is most representative of the dairy operation, to then determine the fraction of time the cows spend in each area.</p> <p>The fraction of volatile solids voided to pasture (MMS_{jm=14}) is equal to the annual fraction of time spent on pasture in the provided table.</p> <p>The annual fraction of time spent in the milking shed and on the feedpad are used to allocate manure to different MMS.</p> <p>The user shall indicate what percentage of waste is allocated to each MMS that is used to manage waste from the feedpad and from the milking shed respectively. The following MMS options are available:</p> <ul style="list-style-type: none"> • Anerobic lagoon (m = 1) • Sump and dispersal system (m = 3a) • Drains to paddocks (m = 3b) • Solid storage (m = 4) <p>MMS_{jm} is calculated as the percentage of waste allocated to the MMS from that area multiplied by the time spent in that area.</p> <p>For example, for a grazing-only system (MMS_{jm=14} = 0.89) where 50% of the waste from the milking shed is drained to paddocks and the remaining 50% is spread a through sump and dispersal system:</p> <p>MMS_{jm=3a} = 0.11*0.50 = 0.055</p> <p>MMS_{jm=3b} = 0.11*0.50 =0.055</p>
Method 2 data source	<p>If the time spent between pasture, milking shed and feedpad is different to the systems 1-4 offered in the Method 1 option, then the annual fraction of time spent in each area may be estimated from farm records for time split between paddock and housed for each livestock class. Alternatively, the ADCC tool provides a questionnaire-based approach to these calculations, which may be utilised to calculate MMS_{jm} [10].</p>
Quality assurance / quality control considerations	<p>The sum of all MMS_{jm} values should equal one</p> <p>Ensure MMS and time spent in each system align with dairy system recorded on farm, i.e., housed or pasture-based system.</p> <p>If Method 1 is used ensure the most recent estimate for annual fraction of time spent per area is used.</p>

Data / Parameter	SS _j
Data unit	Fraction
Description	Fraction of waste separated by pre-treatment of manure
Method 1 data source	National Inventory Report Volume 2 [4]
Method 1 value	If solid separation occurs SS _j = 0.20 If solid separation does not occur SS _j = 0
Method 2 data source	User specified input as to what fraction of waste is screened before flowing in to primary MMS.
Quality assurance / quality control considerations	Ensure solid separation system aligns with dairy system recorded on farm, i.e., housed or pasture-based system.

858

Data / Parameter	CP _j
Data unit	fraction
Description	Crude protein content of feed intake
Method 1 data source	Table 5.5.1.4, National Inventory Report, Volume 2 [4]
Method 1 value	0.20
Method 2 data source	Farm records or feed receipt stating crude protein of TMR (total mixed ration) for different livestock classes. The ADCC, 2025 [10] provides support on how to calculate CP from feed sources. For any stock classes where farm records of feed sources and quality are not available, the National Inventory Report default shall be applied.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 is used, farm source data may be cross checked against Method 1 default values. The ADCC, 2025 [10] provides ranges of CP for different forage of non-forage supplements which may alternatively be used to review entered data.

859

Data / Parameter	W _j
Data unit	kg
Description	Liveweight of each class of stock.
Method 1 data source	See Appendix Table A.1.3.1 and Table A.1.3.2
Method 1 value	Select the appropriate live weight based on breed and animal class.
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used. If Method 2 is used, farm source data may be cross checked against Method 1 default values.

Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may also be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.

860

Data / Parameter	LWG _j
Data unit	kg/head/day
Description	Liveweight gain of each class of stock.
Method 1 data source	See Appendix Table A.1.3.3
Method 1 value	Select the appropriate live weight gain based on breed and animal class.
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	<p>If Method 1 is used ensure the most recently available published data is used.</p> <p>If Method 2 is used, farm source data may be reviewed against Method 1 default values. Additional checks of farm source data are within expected ranges. Typical liveweight gain for heifers of various milking breeds are (ADCC, 2025):</p> <ul style="list-style-type: none"> • smaller breeds, such as Jerseys, approximately 0.45 to 0.5 kg/head/day; • medium breeds, such as Friesians, approximately 0.60 to 0.65 kg/head/day • larger breed, such as Holstein Friesians, approximately 0.7 to 0.75 kg/head/day. <p>Checking purchase and sale weight records against entered values may be used for data assurance and control.</p>

861

Data / Parameter	MCF _{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.3.6
Method 1 value	Choose default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	<p>Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1.</p> <p>See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.</p>
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.3.6 and A.1.8.1 for data source information).

862

863

4.3.2.3 CONSTANTS

Data / Parameter	MPW _{manure,j=3,5}
Data unit	kg CH ₄ /head/day
Description	Methane production from manure of pre-weaned heifer and bull calves
Data source	See Appendix Table A.1.3.8

Value	Select appropriate default values based on animal class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

864

Data / Parameter	B_0
Data unit	$m^3 CH_4/kg VS$
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	0.24
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

865

Data / Parameter	ρ
Data unit	kg/m^3
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

866

Data / Parameter	A
Data unit	fraction
Description	Ash content of manure
Data source	National Inventory Report, Volume 1 [1]
Value	0.08
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

867

Data / Parameter	$VS_{j=3,5}$
Data unit	$kg/head/day$
Description	Volatile solids production for pre-weaned calves
Data source	See Appendix Table A.1.3.5
Value	Select appropriate default values based on animal class. Default values for are only provided for pre-weaned calves. For all other

	classes volatile solids shall be calculated as described in Section 4.3.1.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

868

Data / Parameter	C _{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

869

Data / Parameter	NPW _{j=3,5}
Data unit	kg/head/day
Description	Nitrogen excreted by pre-weaned calves
Data source	See Appendix Table A.1.3.5
Value	Select appropriate default value based on animal class. Default values for are only provided for pre-weaned calves. For all other classes nitrogen excreted in faeces shall be calculated as described in Section 4.3.1.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

870

Data / Parameter	MR _j
Data unit	kg DM/head/day
Description	Increase in metabolic rate when producing milk
Data source	See Appendix Table A.1.3.9
Value	Select appropriate value based on livestock class
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

871

872

Data / Parameter	WR _j
Data unit	kg
Description	Reference weight
Data source	See Appendix Table A.1.3.4
Value	Select appropriate value based on animal class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

873

Data / Parameter	EF _{PRP}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for nitrous oxide emissions per amount of urine and dung deposited
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.1 [8]
Value	Select the appropriate EF _{PRP} specific to the climate zone. Please see Appendix Table A.2.2.2. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

874

Data / Parameter	FracGASMsoil
Data unit	(kg NH ₃ -N + NO _x -N)/kg N
Description	Fraction of nitrogen volatilized from urine and faeces deposited on pasture.
Data source	National Inventory Report, Volume 1 [1]
Value	0.21
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

875

876

877

Data / Parameter	EF _{leach}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for leaching and runoff
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.011
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

878

Data / Parameter	FracWET
Data unit	fraction
Description	Fraction of nitrogen available for leaching and run-off
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

879

Data / Parameter	FracLEACH
Data unit	fraction
Description	Default fraction of N that is lost through leaching and runoff when manure is excreted to pasture, range and paddock (m=14).
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.24
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

880

881

Data / Parameter	EF _m
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for nitrous oxide emissions per MMS
Data source	See Appendix Table A.1.3.7
Value	Select the appropriate emission factor based on the MMS in place
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

882

Data / Parameter	EF _{N₂O}
Data unit	kg N ₂ O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	<p>This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers.</p> <p>Select the value based on the production system which most accurately describes the land the dairy cattle are grazing for the majority of the year or calculate a weighted average if the number of days on each grazing system is known. If animals are housed most of the time select the system best describes the land which surrounds the housed area.</p> <p>For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the rainfall zone the enterprise is located in</p>
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is used in alignment with the Australian National Inventory Report.

883

Data / Parameter	FracGASM _m
Data unit	(kg NH ₃ -N + NO _x -N)/kg N
Description	Fraction of N volatilised from each MMS
Data source	See Appendix Table A.1.3.7
Value	Select the appropriate value based on the MMS in place.
Quality assurance / quality control considerations	Ensure the most recently available published data is used.

884

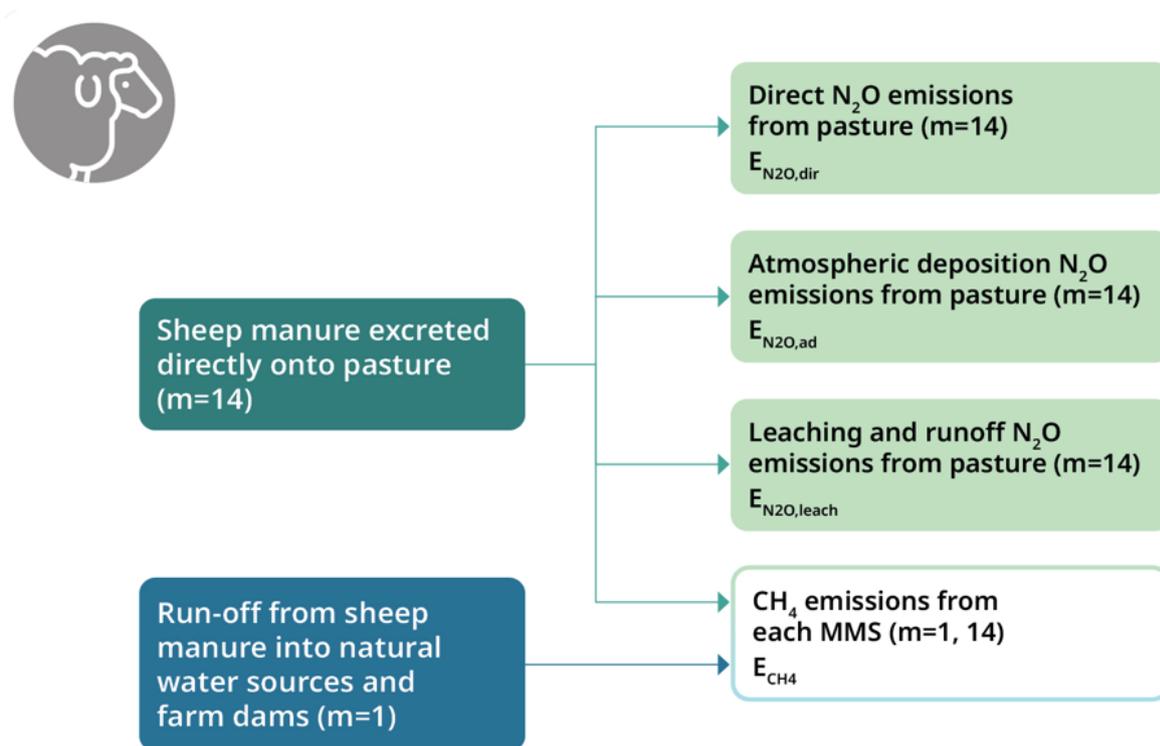
885

Data / Parameter	Fra _{CLEACH_MS}
Data unit	fraction
Description	Fraction of nitrogen lost through leaching and runoff for solid storage MMS only
Data source	National Inventory Report Vol 1 [9]
Value	0.02
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

886

887 4.4 Sheep

888 This module covers the estimation of methane and nitrous oxide that result from sheep
 889 manure management. Figure 4.6 summarises the emission sources from the manure of
 890 sheep. There are two components to methane emission estimates –manure excreted directly
 891 onto pasture, rangeland and paddock (PRP), and manure that runs-off into natural water
 892 sources and farm dams. There are no nitrous oxide emissions from manure management for
 893 manure excreted to PRP, however emissions from the soil occur from the metabolism of the
 894 deposited urine and faeces, and indirectly through atmospheric deposition and leaching and
 895 runoff.



896 Figure 4.6: Emissions that result from sheep manure
 897

898

899 The following subscripts are used in this module:

Subscript	Meaning
<i>i</i>	Temperature zone
<i>j</i>	time-period
<i>k</i>	Sheep Class
<i>m</i>	Manure management system (MMS)

900

901 Emissions are estimated based on age and sex classes of sheep, time of the year and
 902 manure management system. The temperature zone will affect the selection of appropriate

903 emissions factors. The emissions are summed across each class, manure management
904 system and time-period spent on farm during the reporting period.

905 The classes of sheep on the farm ('sheep input class') will depend on the diversity of the
906 farming operation. These classes need to be mapped back to default categories ('sheep
907 class k') to allow the use of default inventory values under Method 1

908 The time-period selected will depend on availability of stock numbers and liveweight and
909 liveweight gain data (see Herd Flow modelling guidance in Section 1.3.7).

Sheep Class <i>k</i>	Possible Sheep Input Class
1 = Rams	Rams
2 = Wethers	Wethers
3 = Maiden ewes	Maiden ewes (1-2 years) intended for breeding
4 = Breeding ewes	Breeding ewes
5 = Other ewes	Other ewes
6 = Lambs and hoggets	Ewe lambs (<1 year)
	Wether lambs (<1 year)
	Ram lambs (<1 year)

910

911 The only relevant manure management systems (*m*) for grazing beef are PRP (*m*=14) and
912 anaerobic lagoons (*m*=1). Where farmers have unfenced natural water sources and farm
913 dams, anaerobic lagoons are used as a proxy to estimate the runoff of manure into these
914 water sources.

915

916

917 **4.4.1 Estimation methodology**918 **4.4.1.1 METHOD 1 — MANURE METHANE SHEEP**

919

920 (1) Total annual methane production from manure management for sheep E_{CH_4}
 921 (kgCH₄) is calculated as:

$$922 \quad E_{CH_4} = \sum_j \sum_k \sum_m (N_{jk} \times M_{jkm} \times D_j) \times 10^{-3}$$

923 Where N_{jk} = number of sheep in each time-period and input class (head)

924 M_{jkm} = daily methane produced from the manure in each time-period, sheep
 925 class and MMS (kgCH₄/head/day)

926 D_j = number of days in each time-period (days). This is 91.25 days under
 927 Method 1 as the default time-period is a season

928 (2) In equation (1) methane produced from the manure of sheep M_{jk} (kgCH₄/head/day)
 929 is calculated as:

$$930 \quad M_{jkm} = VS_{jk} \times B_o \times MMS_m \times MCF_{im} \times \rho$$

931 Where VS_{jk} = volatile solid production in each time-period and class(kg/head/day)

932 B_o = emissions potential (m³ CH₄/kgVS)

933 MMS_m = fraction of waste in each manure management system

934 MCF_{im} = methane conversion factor for temperature zone and MMS. Under
 935 Method 1, the default state temperature zone is applied

936 ρ = density of methane (kg/m³)

937 The primary manure management system (MMS) for sheep is pasture range and paddock
 938 (m=14). Where natural water sources, such as farm dams, are present the anaerobic lagoon
 939 (m=1) MMS is used to estimate the run-off of manure into these water sources. Where
 940 farmers can demonstrate animals are on bore or reticulated water systems, where water is
 941 provided in troughs (i.e., no unfenced natural water sources), then the only relevant MMS to
 942 be considered shall be pasture range and paddock (m=14).

943 (3) In equation (2) volatile solid production from sheep VS_{jk} (kg/head/day) is calculated
 944 as:

$$945 \quad VS_{jk} = \left(I_{jk} \times \left((1 - DMD_{jk}) + (0.04 \times I_{jk}) \right) \right) \times (1 - A)$$

946 Where I_{ijk} = dry matter intake as calculated in Chapter 3 Section 3.4.1
 947 (kgDM/head/day)

948 DMD_{ijk} = dry matter digestibility expressed as a fraction. Default values
 949 applied under Method 1

950 A = ash content of feed intake

951 4.4.1.2 METHOD 2 — MANURE METHANE SHEEP

952 Method 2 is the same as Method 1 except that under equations 4.4.1.1 (3) feed intake I_{jkl} is
 953 estimated as per section 3.4.1.2 for the selected time-period (i.e. seasonal, monthly or other)
 954 and farm specific data is required for MCF_{im} . Farm specific data is may also be applied for
 955 DMD_{jk} .

956 Under Method 2 the selected time-period and associated L_j used in equation 4.4.1.1 (1) may
 957 be a season ($L_j = 91.25$ days), month ($L_j = 28-31$ day depending on month) or a specific
 958 number of days in a month or season if the entry and exit from farm of a specific cohort of
 959 animals is being estimated

960 4.4.1.3 METHOD 1 — SOIL DIRECT N₂O SHEEP

961 (1) Total annual direct nitrous oxide emissions from agricultural soils from deposition of
 962 urine and dung $E_{N_2O,dir}$ (t N₂O) are calculated as:

$$963 \quad E_{N_2O,dir} = AE \times EF_{PRP} \times C_{N_2O} \times 10^{-3}$$

964 Where AE = total mass of nitrogen excreted on PRP by sheep (kg N)

965 EF_{PRP} = emission factor for nitrous oxide from urine and dung deposited to soil
 966 (kg N₂O-N/kg N deposited)

967 C_{N_2O} = factor to convert elemental mass of nitrous oxide to molecular mass

968 (2) In equation (1) total nitrogen excreted to pasture, range, and paddock AE (kg N) is
 969 calculated as:

$$970 \quad AE = \sum_j \sum_k (N_{jk} \times NE_{jk} \times D_j)$$

971 Where N_{jk} = number of sheep in each time-period and input class (head)

972 NE_{jk} = nitrogen excreted in each time-period and by each class (kg
 973 N/head/day)

974 D_j = number of days in each time-period (days). This is 91.25 days under
 975 Method 1 as the default time-period is a season

976

977 (3) In equation (1) nitrogen excreted NE_{jk} (kg N/head/day) is calculated as:

$$978 \quad NE_{jk} = (CPI_{jk} \div 6.25) - NR_{jk}$$

979 Where CPI_{jk} = crude protein intake (kg/head/day)

980 NR_{jk} = amount of nitrogen retained by the body (kg N/head/day)

981

982 (4) In equation (3) Crude protein intake CPI_{ijk} (kg/head/day) of sheep is calculated as:

$$983 \quad CPI_{jk} = (I_{jk} \times CP_{jk}) + (0.045 \times MC_{jk=6})$$

984 Where CP_{jk} = crude protein content of feed intake expressed as a fraction. Under

985 Method 1, default values are applied

986

987 (5) In equation (4) milk intake for sheep $MC_{jk=6}$ (kg/head/day) is calculated as:

988
$$MC_{jk=6} = 1.6 \times PL_{jk=6}$$

989 Where 1.6 = milk production for time-period lambs are born (kg/head/day).

990 $PL_{jk=6}$ = proportion of lambs born in the time-period

991

992 (6) In equation (3) the amount of nitrogen retained by the body NR_{jk} (kg N/head/day) is
993 calculated as:

994
$$NR_{ijk} = \left\{ (0.045 \times MP_{jk=3,4}) + (WP_k \times 0.84) + \left\{ EBG_{jk} \times \left[\left(212 - 4 \times \left(\frac{EBG_{jk} \times 1000}{4 \times SRW_k^{0.75}} - 1 \right) \right) - \right. \right. \right.$$

995
$$\left. \left. \left. \frac{\left(140 - 4 \times \left(\frac{EBG_{jk} \times 1000}{4 \times SRW_k^{0.75}} - 1 \right) \right) \right]}{1 + e^{-6(Z_{jk} - 0.4)}} \right] \right\} \times 10^{-3} \right\} \div 6.25$$

996 Where $MP_{jk=3,4}$ = milk production (kg/head/day)

997 WP_k = clean wool production (kg/head/day)

998 EBG_{jk} = empty body gain (kg)

999 SRW_k = standard reference weight (kg)

1000 Z_{jk} = relative size

1001

1002 (7) In equation (6) milk production of sheep $MP_{jk=3,4}$ (kg/head/day) is calculated as:

1003
$$MP_{jk=3,4} = LE_{jk=3,4} \times 1.6$$

1004 Where $LE_{jk=3,4}$ = proportion of ewes lactating each season or time period as
1005 calculated in Chapter 3 Section 3.4.1

1006 1.6 = milk production for the season the lambs are born in (kg/head/day)

1007 For sheep classes other than breeding ewes and maidens, milk production should be set to
1008 zero, i.e., $MP_{jk=1,2,5,6} = 0$ and in non-breeding seasons milk production should be set to zero
1009 for all sheep classes.

1010 (8) In equation (6) clean wool production WP_k (kg/head/day) is calculated as:

1011
$$WP_k = \frac{GW_k \times Y_k}{365}$$

1012 Where GW_k = greasy wool production per sheep class (kg/head)

1013 Y_k = average clean wool yield per sheep class (fraction)

1014 365 = number of days in a year

1015

1016 (9) In equation (6) The empty body gain EBG_{jk} (kg) is calculated as:

$$1017 \quad EBG_{jk} = LWG_{jk} \times 0.92$$

1018 Where LWG_{jk} = liveweight gain (kg). Under Method 1, default values are applied.

1019

1020 (10) In equation (6) the relative size of the sheep Z_{jk} is calculated as:

$$1021 \quad Z_{jk} = \frac{W_{jk}}{SRW_k}$$

1022 Where W_{jk} = liveweight (kg). Under Method 1, default values are applied.

1023

1024 4.4.1.4 METHOD 2 — SOIL DIRECT N₂O SHEEP

1025 Method 2 is the same as Method 1 except that under equation 4.4.1.3 (4) feed intake I_{jkl} is

1026 estimated as per section 3.2.1.2 and farm specific data is required for the selected time-

1027 period (i.e. seasonal, monthly or other) for W_{jk} (Eq 4.4.1.3 (10)), LWG_{jk} (Eq 4.4.1.3 (9)).

1028 Farm specific data may also be applied for CP_{jk} (Eq 4.4.1.3 (4)).

1029 Under Method 2 the selected time-period and associated L_j used in equation 4.4.1.3 (2) may

1030 be a season ($D_j = 91.25$ days), month ($D_j = 28-31$ day depending on month) or a specific

1031 number of days in a month or season if the entry and exit from farm of a specific cohort of

1032 animals is being estimated

1033

1034 4.4.1.5 METHOD 1 — SOIL ATMOSPHERIC DEPOSITION N₂O SHEEP

1035 (1) Annual atmospheric deposition emissions from urine and dung deposited on pasture
1036 $ES_{N_2O,ad}$ (t N₂O) is calculated as:

1037
$$E_{N_2O,ad} = M_{vol} \times EF_{N_2O} \times C_{N_2O} \times 10^{-3}$$

1038 Where M_{vol} = mass of nitrogen volatilised from urine and faeces deposited on
1039 pasture (kg N)

1040 EF_{N_2O} = nitrous oxide emission factor for atmospheric deposition (kg N₂O-
1041 N/kg N)

1042 C_{N_2O} = factor to convert elemental mass of nitrous oxide to molecular mass

1043

1044 (2) In equation (1) the mass of nitrogen volatilised M_{vol} (kg N) is calculated as:

1045
$$M_{vol} = AE \times FracGASMsoil$$

1046 Where AE = total mass of nitrogen excreted on PRP by sheep (kg N)

1047 $FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces
1048 deposited on pasture ((kg NH₃-N + NO_x-N)/kg N)

1049

1050 4.4.1.6 METHOD 2 — SOIL ATMOSPHERIC DEPOSITION N₂O SHEEP

1051 There is no Method 2 quantification option for this emission source.

1052 4.4.1.7 METHOD 1 — SOIL LEACHING AND RUNOFF N₂O SHEEP

1053

1054 (1) Leaching and runoff emissions from urine and dung deposited on pasture $ES_{N_2O,leach}$
1055 (t N₂O) are calculated as:

1056
$$ES_{N_2O,leach} = M_{leach} \times EF_{leach} \times C_{N_2O} \times 10^{-3}$$

1057 Where M_{leach} = mass of nitrogen lost to leaching and runoff (kg N)

1058 EF_{leach} = emission factor for leaching and run off (kg N₂O-N/kg N)

1059 C_{N_2O} = factor to convert elemental mass of nitrous oxide to molecular mass

1060 (2) In equation (1) the mass of nitrogen lost to leaching and runoff M_{leach} (kg N) is
1061 calculated as:

1062
$$M_{leach} = AE \times FracWet \times FracLEACH$$

1063 Where AE = total mass of nitrogen excreted on PRP by sheep (kg N)

1064 $FracWet$ = fraction of N that is available for leaching and runoff

1065 $FracLEACH$ = fraction of all N that is lost through leaching and runoff

1066 4.4.1.8 METHOD 2 — SOIL LEACHING AND RUNOFF N₂O SHEEP

1067 There is no Method 2 quantification option for this emission source.

1068

1069 **4.4.2 Data/Parameters**1070 **4.4.2.1 INPUT DATA (REQUIRED)**

Data / Parameter	N_{jk}
Data unit	head
Description	Number of sheep in each time-period and class
Data source	Farm records and see herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	Number of sheep reported may be cross checked with average stocking density for farm size and system (if known). The animal class proportions may be cross checked with those expected in the farm's type of operation For example, self-replacing systems vs purchased breeder or trading systems.

1071

Data / Parameter	GW_k
Data unit	kg/head
Description	Average greasy wool fleece weight for each sheep class
Data source	Farm source data – based on average wool fleece weight for each class. If not known this can be calculated from the total greasy weight sold divided by the number of head in each class shorn. .
Quality assurance / quality control considerations	Invoices from wool sales may be used to cross check the weight of wool sold in the reporting period. The average fleece weight may be considered in the context of the farming operation and breed of sheep farmed. Industry averages may be used to sense check average fleece weights for different breeds and age classes.

1072

Data / Parameter	Y_k
Data unit	fraction
Description	Average clean wool yield for each sheep class
Data source	<p>Farm source data – based on wool testing results at point of sale for the clean wool percentage for each class.</p> <p>If only total greasy and total clean weights are known the fraction of clean may be calculated as:</p> $Y = \frac{\text{cleanweight}}{\text{greasyweight}}$ <p>For more accurate estimation, it is recommended this value is calculated for ewes and lambs separately and applied to each class appropriately.</p>
Quality assurance / quality control considerations	<p>Invoices from wool sales may be used to cross check the percent clean wool sold in the reporting period.</p> <p>The clean wool yield may be considered in the context of the farming operation and breed of sheep farmed. Industry averages may be used to sense check average fleece weights for different breeds and age classes.</p>

1073

1074

4.4.2.2 DATA (METHOD 1 AND 2 OPTIONS)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each sheep input class
Method 1 data source	National Inventory Report Volume 1 [1]
Method 1 value	91.25 as the default time period is seasonal.
Method 2 data source	Farm stock records; system type records or purchase and sales may be evaluated to determine average duration of each sheep input class (see Chapter 1 Section 1.9 for more details on herd flow modelling)
Quality assurance / quality control considerations	<p>Ensure that if animals are on the farm all year round the duration of stay is 365 days</p> <p>Ensure that if animals are only born part way through the reporting period their duration of stay reflect this.</p> <p>If Method 1 is used inputs should be entered seasonally throughout the calculations.</p> <p>Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values.</p> <p>Recorded stock counts may also be used for quality assurance of entered values.</p>

1075

1076

Data / Parameter	DMD _{jk}
Data unit	fraction
Description	Dry matter digestibility of feed
Method 1 data source	See Appendix Table A.1.4.2
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records - user input values for each season and class of stock. Noting that if farm specific DMD may be used for some classes or seasons if known and inventory defaults for other unknown classes of stock.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 is used farm source data may be cross checked against Method 1 default values.

1077

Data / Parameter	CP _{jk}
Data unit	fraction
Description	Crude protein content of feed
Method 1 data source	See Appendix Table A.1.4.4
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records - user input values for each season and class of stock. Noting that if farm specific CP may be used for some classes or seasons if known and inventory defaults for other unknown classes of stock.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 is used farm source data may be cross checked against Method 1 default values.

1078

1079

Data / Parameter	LWG _{jk}
Data unit	kg
Description	Liveweight gain per time period and sheep class
Method 1 data source	See Appendix Table A.1.4.5
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records and see herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	<p>Purchase and sale weight records (invoices) may be used for data assurance and control of entered values.</p> <p>Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.</p> <p>It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. that default liveweight gain reflects when stock are expected to be growing more due to feed quality and availability.</p>

1080

Data / Parameter	W _{jk}
Data unit	kg
Description	Liveweight of livestock per time period and sheep class
Method 1 data source	See Appendix Table A.1.4.1
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records and see herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	<p>Purchase and sale weight records (invoices) may be used for data assurance and control of entered values.</p> <p>Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.</p> <p>It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. if lambing in spring ensure default weights reflect this with lowest weigh value applied in spring for stock <1 year and/or that default weights reflect when stock are expected to be at the lightest and heaviest due to feed availability and quality.</p>

1081

Data / Parameter	MCF _{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.4.8
Method 1 value	Choose default based on State and MMS.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1082

1083 4.4.2.3 CONSTANTS

Data / Parameter	B ₀
Data unit	m ³ CH ₄ /kg VS
Description	Emissions potential
Data source	IPCC (2019), Chapter 10 [3]
Value	0.24
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1084

Data / Parameter	MMS _m
Data unit	fraction
Description	Fraction of waste in each MMS
Data source	See Appendix Table A.1.4.7
Value	Where a producer cannot demonstrate water bodies are stock excluded MMS _m values shall be selected based on State and MMS. If animals are on bore or reticulated water systems where water is provided in troughs (i.e. no unfenced natural water sources) then all waste should be allocated to pasture range and paddock and MMS _{m=14} = 1.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report. High resolution aerial imagery may be used to cross check that water sources are stock excluded.

1085

Data / Parameter	ρ
Data unit	kg/m ³
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1086

Data / Parameter	A
Data unit	fraction
Description	Fractional ash content of feed intake.
Data source	National Inventory Report, Volume 1 [1]
Value	0.08
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1087

Data / Parameter	C _{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1088

Data / Parameter	SRW _k
Data unit	kg
Description	Standard reference weight
Data source	See Appendix Table A.1.4.6
Value	Select appropriate default value for location of sheep and sheep class
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1089

Data / Parameter	EF _{PRP}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for urine and dung deposited on pasture, range or paddock
Data source	Please see Appendix Table A.2.2.2.
Value	The appropriate EF _{PRP} shall be selected by using the IPCC values for EF _{PRP} specific to the climate zone in which the farm is located. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1090

Data / Parameter	EF _{N₂O}
Data unit	kg N ₂ O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Apply the EF that best represent the production system In some farm systems animals may graze on crops. Apply the inorganic fertiliser EF that best representing how the sheep are grazed for the majority of the year or calculate a weighted average if the number of days on each grazing system is known. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on determining the relevant rainfall zone.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1091

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

1092

Data / Parameter	FracGASMsoil
Data unit	(kg NH ₃ -N + NO _x -N)/kg N
Description	Fraction of nitrogen volatilised from urine and faeces deposited on pasture
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [8]
Value	0.21
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1093

Data / Parameter	FracLEACH
Data unit	fraction
Description	Fraction of N that is lost through leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.24
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Greenhouse Gas Inventory.

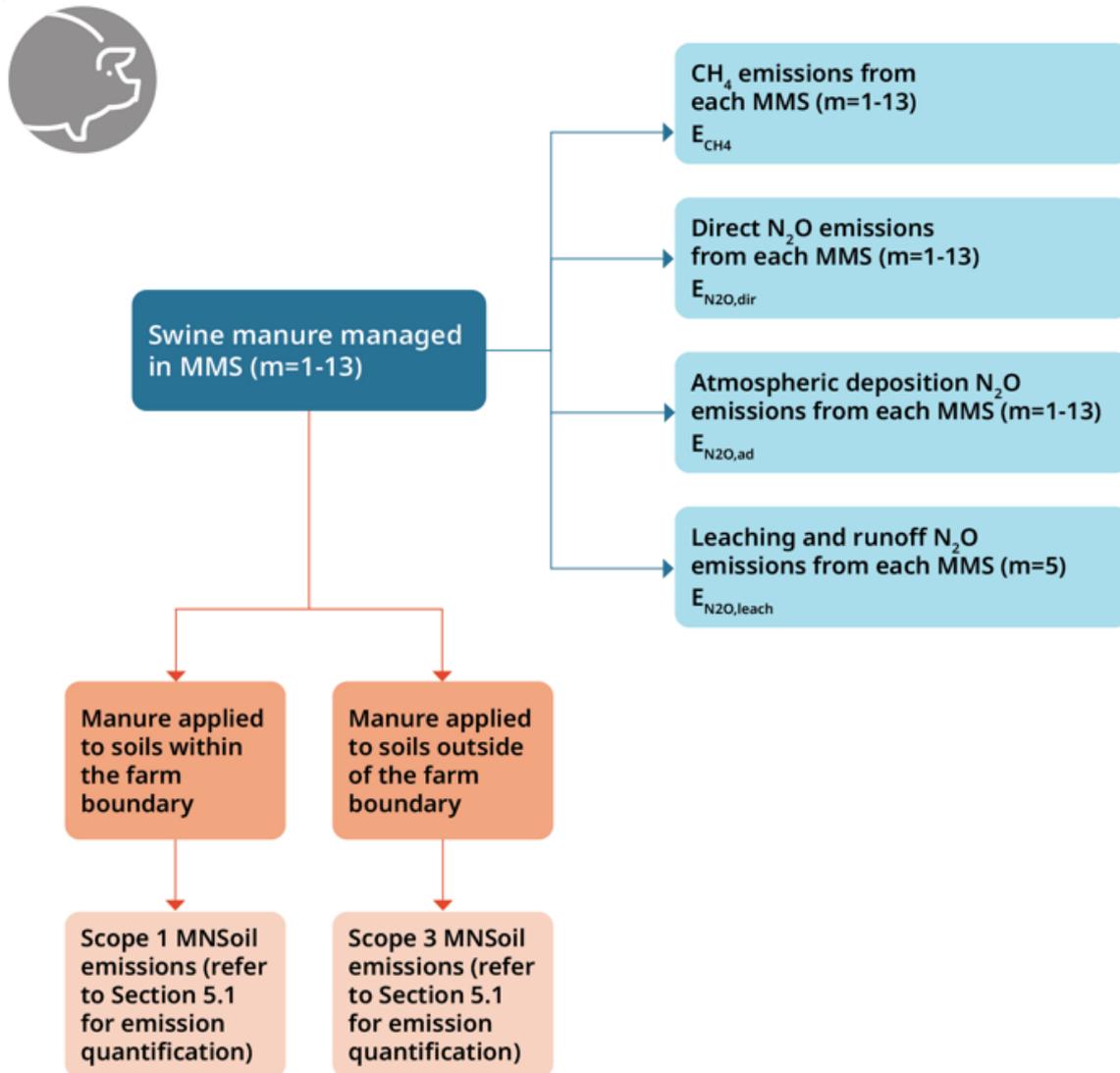
1094

Data / Parameter	EF _{leach}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.011
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1095

1096 4.5 Swine

1097 This module covers the estimation of methane and nitrous oxide that results from the
 1098 manure management of swine. Figure 4.7 summarises the emission sources associated
 1099 with the manure from swine. The allocation of waste to different manure management
 1100 system is dependent of the type of housing system (e.g. conventions, deep litter or
 1101 outdoor/free range) and whether there is a primary and secondary treatment of the manure.
 1102 Emissions associated with manure from management systems that is subsequently applied
 1103 to soils are covered in the organic fertiliser section in Chapter 5 Section 5.1 Fertiliser
 1104 module.



1105
 1106 Figure 4.7: Summary of emissions sources associated with manure management in swine
 1107 systems

1108 The following subscripts are used in this module:

Subscript	Meaning
<i>i</i>	Temperature zone

j	Swine class
m	Manure management system (MMS)
T	Treatment stage

1109

1110 Emissions will be summed across each class within the swine system during the reporting
 1111 period to enable the accounting of emissions based on age classes of swine with different
 1112 intake requirements and time spent on farm within the reporting period.

1113 The classes of pigs on the farm ('Swine input class') will depend on the diversity of the
 1114 farming operation. These input classes need to be mapped back to NGGI default categories
 1115 to allow the use of default inventory values (if required) e.g.,

1116

Swine Class j	Possible Swine Input Class
1 = Boars	Boars
2 = Sows	Sows
3 = Gilts	Gilts
4 = Others	Suckers
	Weaners
	Growers
	Slaughter pigs

1117

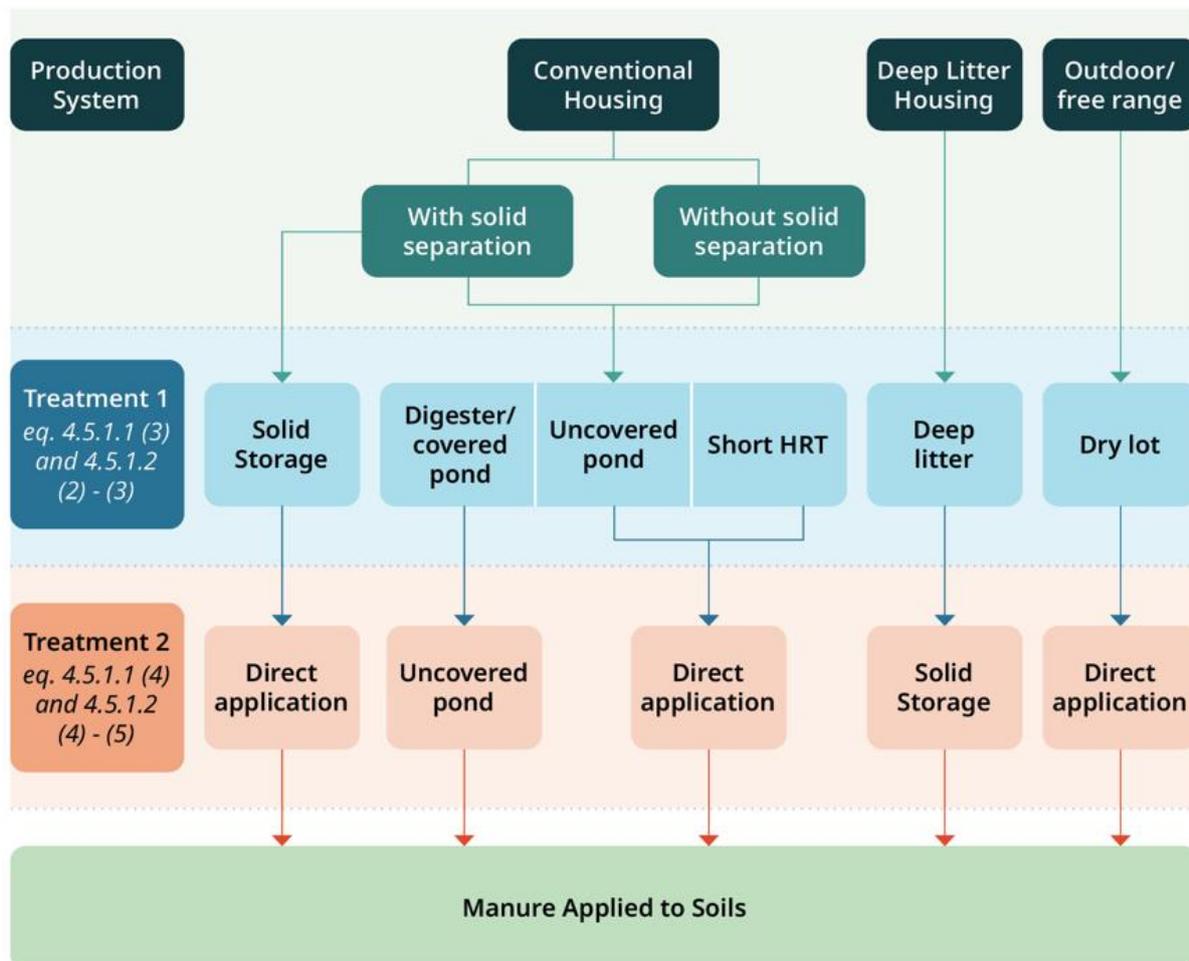
1118 In Australia most swine farming systems include housing and a manure management
 1119 system (MMS). While outdoor or free-range housing allows pigs to be outdoors at all times,
 1120 the manure deposited in outdoor systems is treated as a dry lot rather than pasture range
 1121 and paddock. The manure produced by farmed swine may pass through multiple treatment
 1122 stages. The manure management system (m) for primary treatment stage (T=1) and
 1123 secondary treatment stage (T=2) will need to be selected. In conventional housing there is
 1124 the option of separating solids before manure enters the primary system. The allocation of
 1125 waste to the different primary systems needs to be adjusted for solid separation. The
 1126 separated solids are currently assumed to be treated through solid storage. The following MMS
 1127 are currently included in the National Inventory Report:

Manure Management System (MMS) m
1 = Anaerobic lagoon
4 = Solid storage
5 = Dry lot (outdoor/free range)
7 = Digester/Covered lagoon
8 = Deep litter
9 = Pit storage (short hydraulic retention tank (HRT) < 1 month)

13 = Direct application to soil

1128

1129 Figure 4.8 outlines how swine manure is assumed to be transferred between primary and
 1130 secondary treatments in the National Inventory Report. For farm-level estimation the fraction
 1131 of manure transferred shall be allocated to relevant primary and secondary treatment stage
 1132 based on the MMSs used on farm.



1133

1134 Figure 4.8 Example of the possible different stages of manure management in different
 1135 swine production systems from the Australian National Inventory Report [1].

1136 **Question Reference 4.1.**

1137 Current guidance provides MMS options aligned with National Inventory Report and
 1138 Greenhouse Gas Accounting Framework options. Are there other MMS in use in piggeries?
 1139 For example, are separated solids treated in systems other than solid storage?

1140 **Question Reference 4.2.**

1141 Outdoor and free-range housing is treated as a dry lot in the National Inventory Report,
 1142 rather than pasture, range and paddock, due to the relatively high concentration of waste. It
 1143 is assumed that the manure is subsequently removed from the outdoor pen and is eventually
 1144 applied to soils (within or outside the farm boundary). Is this assumption correct or does this
 1145 waste remain in the outdoor pen?

1146 **4.5.1 Estimation methodology**1147 **4.5.1.1 METHOD 1 – MANURE METHANE SWINE**1148 (1) Total annual methane emissions from manure management E_{CH_4} (t CH₄) is calculated as:

1149
$$E_{CH_4} = \sum_j \sum_m \sum_T (D_{jmT} \times M_{jmT} \times N_{jmT}) \times 10^{-3}$$

1150 Where D_j = length of stay of each class of swine (days)1151 M_j = methane production from manure in each swine class, MMS, and
1152 treatment stage (kg CH₄/head/day)1153 N_j = numbers of swine in each class (head)

1154

1155 **Pre-treatment and Treatment stage 1 (primary system)**1156 (2) In equation (1) production of methane in treatment stage 1 MMS $M_{jmT=1}$ (kg
1157 CH₄/head/day) is calculated as:

1158
$$M_{jmT=1} = VS_j \times FVS_{jmT=1} \times MCF_{im} \times B_O \times \rho$$

1159 Where VS_j = volatile solid production from swine in each class (kg VS/head/day).
1160 Under Method 1 default values are applied1161 $FVS_{jmT=1}$ = the fraction of volatile solids in each primary system,1162 MCF_{im} = methane conversion factor for temperate zone and system. Under
1163 Method 1, the default State temperate zone is applied1164 B_O = emissions potential (m³ CH₄/kg VS)1165 ρ = density of methane (kg/m³)1166 (3) In equation (2) the fraction of volatile solids in each primary system $FVS_{jmT=1}$ other
1167 than solid storage (m=4) is calculated as:

1168
$$FVS_{jmT=1} = MMS_{jmT=1} \times (1 - SS_m)$$

1169 Where SS_m = fraction of volatile solids separated to solid storage for each MMS1170 $MMS_{jmT=1}$ = fraction of manure to each primary MMS for each class prior to
1171 solid separation

1172

1173 (4) In equation (3) the fraction of volatile solids in solid storage, $MMS_{jm=4T=1}$ is calculated
1174 as:

1175
$$FVS_{jm=4T=1} = MMS_{jm=4T=1} + (MMS_{jm=1,7,9T=1} \times SS_m)$$

1176 Note: Where solid separation systems are applied, the separated solids are currently
1177 assumed to treated through solid storage.

1178 Note: Where manure is treated in a series of uncovered anaerobic ponds (commonly two or
 1179 three ponds used in a series) these may be treated as a single primary system. If different
 1180 systems are used, such as a covered anaerobic primary pond followed by an uncovered
 1181 secondary pond, the secondary system emissions shall be estimated.

1182 Treatment stage 2 (secondary system)

1183 (5) In equation (1) production of methane in each treatment stage 2 MMS $M_{ijmT=2}$ (kg
 1184 CH₄/head/day) is calculated as:

$$1185 \quad M_{ijmT=2} = VST_j \times B_0 \times MMS_{jmT=2} \times MCF_{im} \times \rho$$

1186 Where $MMS_{jmT=2}$ = fraction of manure in each secondary system

1187 $VST_{jmT=2}$ = volatile solids transferred from the primary system (kg
 1188 VS/head/day)

1189 (6) In equation (5) volatile solids transferred to treatment stage 2 MMS $VST_{jmT=2}$ (kg
 1190 VS/head/day) is calculated as:

$$1191 \quad VST_{jmT=2} = VS_j \times FVS_{jmT=1} \times (1 - VSL_{mT=1})$$

1192 Where $VSL_{mT=1}$ = fraction of volatile solids lost during storage in the primary system.

1193

1194 4.5.1.2 METHOD 2 – MANURE METHANE SWINE

1195 Method 2 is the same as Method 1 except that under equations 4.5.1.1 (3) – (7) farm specific
 1196 data for VS_j , SS_j and the temperature zone for $MCF_{im=1}$. is required.

1197

1198 4.5.1.3 METHOD 1 – MANURE DIRECT N₂O SWINE

1199 (1) The total annual direct nitrous oxide emissions from manure management systems
 1200 $E_{N_2O,dir}$ (t N₂O) is calculated as:

$$1201 \quad E_{N_2O,dir} = \sum_j \sum_m \sum_T (MN_{jmT} \times EF_{jm} \times C_{N_2O}) \times 10^{-3}$$

1202 Where MN_{jmT} = nitrogen per swine class, MMS and treatment stage (kg N₂O)

1203 EF_{jm} = nitrous oxide emission factor for MMS (kg N₂O-N/kg N)

1204 C_{N_2O} = factor to convert elemental mass of nitrous oxide to molecular mass

1205 Pre-treatment and Treatment stage 1 (primary system)

1206 (2) In equation (1) nitrogen in the treatment stage 1 MMS $MN_{jmT=1}$ (kg N₂O) is
 1207 calculated as:

$$1208 \quad MN_{jmT=1} = AE_j \times FN_{jmT=1}$$

1209 Where AE_j = total nitrogen excreted by each swine class (kg N)

1210 FN_j = fraction of nitrogen in each primary MMS system (kg N)

1211

1212 (3) In equation (2) the fraction of nitrogen in each primary system $FN_{jm\ T=1}$ other than
1213 solid storage (m=4) is calculated as:

1214
$$FN_{jm\ T=1} = MMS_{jm\ T=1} \times (1 - SN_m)$$

1215 Where SN_m = fraction of nitrogen separated to solid storage for each MMS

1216

1217 (4) In equation (2) the fraction of nitrogen in solid storage, $FN_{jm=4\ T=1}$ is calculated as:

1218
$$FN_{jm=4\ T=1} = MMS_{jm=4\ T=1} + (MMS_{jm=1,7,9\ T=1} \times SN_m)$$

1219

1220 (5) In equation (1) annual nitrogen excretion AE_j (kg N) from each swine group is
1221 calculated as:

1222
$$AE_j = N_j \times NW_j \times D_j$$

1223 Where NW_j = nitrogen produced in swine manure and waste feed in each
1224 class (kg N/head/day).

1225 Under Method 1 default values for NW_j are used

1226

1227 **Treatment stage 2 (secondary system)**

1228 (6) In equation (1) nitrogen in each treatment stage 2 MMS $MN_{jm\ T=2}$ (kg N₂O) is
1229 calculated as:

1230
$$MN_{jm\ T=2} = NT_{jm\ T=2} \times MMS_{jm\ T=2}$$

1231 Where $NT_{jm\ T=2}$ = nitrogen transferred to secondary treatment MMS (kg N)

1232 Note: if direct application to soil occurs at treatment stage 2 ($MN_{jm=13\ T=2}$) the nitrogen
1233 moves directly to MN_{soil} calculation (equation 4.5.1.5 (1)) and is not included in direct
1234 nitrous oxide from manure management equation (Equation 4.5.1.3 (1)).

1235

1236 (7) In equation (8) nitrogen transferred to treatment stage 2 MMS $NT_{jm\ T=2}$ (kg N) is
1237 calculated as:

1238
$$NT_{jm\ T=2} = \left(MN_{jm\ T=1} \times (1 - FracGASM_{m\ T=1} - EF_{m\ T=1}) \right)$$

1239 Where $FracGASM_{m\ T=1}$ = fraction of N volatilised from MMS treatment at stage 1

1240 $EF_{m\ T=1}$ = Nitrous oxide emission factor for MMS treatment at stage 1

1241

1242 4.5.1.4 METHOD 2 – MANURE DIRECT N2O SWINE

1243 Method 2 is the same as Method 1 except that under equation 4.5.1.3 (3) farm specific data
1244 for NW_j is required and farm specific and SN_j are required for equation 4.5.1.3 (2) if relevant
1245 to the production system.

1246

1247 4.5.1.1 METHOD 1 – MANURE ATMOSPHERIC DEPOSITION SWINE

1248 (1) Total annual atmospheric deposition emissions from manure management $E_{N2O,ad}$ (t
1249 N_2O) is calculated as:

$$1250 \quad E_{N2O,ad} = (MMS_{ATMOS} \times EF_{N2O} \times C_{N2O}) \times 10^{-3}$$

1251 Where MMS_{ATMOS} = mass of N volatilised from MMS (kg N)

1252 EF_{N2O} = Nitrous oxide emission factors for atmospheric deposition (kg N_2O -
1253 N/kg N)

1254

1255 (2) In equation (1) volatilised nitrogen from MMS MMS_{ATMOS} (kg N) is calculated as:

$$1256 \quad MMS_{ATMOS} = \sum_j \sum_m \sum_T MN_{jmT} \times FracGASM_{mT}$$

1257 Where $FracGASM_{mT}$ = fraction of N volatilised in each MMS ((kg NH_3-N +
1258 NO_x-N)/kg N)

1259 Note: in the case of direct application at treatment stage 2 ($MN_{jm=13T=2}$) the nitrogen moves
1260 directly to MN_{soil} calculation (equation 4.5.1.5 (1)) and is not included in the atmospheric
1261 deposition from manure management calculation.

1262 4.5.1.2 METHOD 2 – MANURE ATMOSPHERIC DEPOSITION SWINE

1263 There is no Method 2 quantification option for this emission source

1264

1265 4.5.1.3 METHOD 1 – MANURE LEACHING AND RUNOFF N2O SWINE

1266 (1) Annual emissions from leaching and run off from each MMS $E_{N2O,leach}$ (t N_2O) is
1267 calculated as:

$$1268 \quad E_{N2O,leach} = \sum_j \sum_{m=1-13} (MNLeach_{jm} \times EF_{leach} \times C_{N2O}) \times 10^{-3}$$

1269 Where $MNLeach_{jm}$ = mass of N lost through leaching and runoff from each MMS (kg
1270 N)

1271 EF_{leach} = Emission factor for leaching and runoff (kg N_2O-N /kg N)

1272

1273 Due to strict environmental controls, $MNLeach_m$ is assumed to be 0 for all MMS other than
 1274 outdoor piggeries. Therefore, emissions from leaching and run off are only estimated for
 1275 drylots MMS ($m=5$). This simplifies the equation to:

$$1276 \quad E_{N2O,leach} = MNLeach_{jm=5} \times EF_{leach} \times C_g \times 10^{-3}$$

1277 This assumption may need to be reconsidered if other MMS are incorporated based on
 1278 stakeholder feedback.

1279

1280 (2) In equation (1) the mass of nitrogen lost to leaching and runoff from solid storage
 1281 systems $MNLeach_{jm=5}$ (kg N) is calculated as:

$$1282 \quad MNLeach_{jm=5} = MN_{jm=5T=1} \times FracWET \times FracLEACH_{MS}$$

1283 Where $FracWET$ = fraction of N available for leaching and runoff.

1284 $FracLEACH_{MS}$ = fraction of N lost through leaching and runoff

1285

1286 4.5.1.4 METHOD 2 – MANURE LEACHING AND RUNOFF N₂O SWINE

1287 There is no Method 2 quantification option for this emission source

1288 4.5.1.5 MANURE APPLIED TO SOILS

1289 It is assumed that all manure managed through MMS ($m=1-13$) will eventually be applied to
 1290 soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value is
 1291 transferred to Chapter 5 Section 5.2 to estimate emissions associated with the application of
 1292 organic fertilisers, including the associated atmospheric deposition, and leaching and run-off
 1293 emissions.

1294 This manure may be applied to soils within the boundary of the piggery or may be sent off-
 1295 site and applied to another farming system or enterprise. Where manure is applied to soils
 1296 within the boundary of the farming enterprise $MNSoil_{scope1}$, the emissions from shall be
 1297 estimated and reported as Scope 1 emissions. Where the manure is used outside the direct
 1298 emissions boundary the emissions from shall be estimated and reported as Scope 3
 1299 emissions, $MNSoil_{scope3}$, under Scope 3 Category 5 – waste generated in operations (see
 1300 Chapter 13).

1301 (1) The mass of nitrogen applied to soils for scope 1 emissions $MNSoil_{scope1}$ (kg N) is
 1302 calculated as:

$$1303 \quad MNSoil_{scope1} = \sum_j \sum_m (MN_{jmT=2} \times (1 - EF_{mT=2} - FracGASM_{mT=2}) \\ 1304 \quad - MNLeach_{jm=5}) \times PF$$

1305 Where $EF_{mT=2}$ = nitrous oxide emission factor for each MMS at treatment
 1306 stage 2 (kg N₂O-N/kg N)

1307 PF = fraction of manure applied to soil within the piggery boundary

1308 Note: where direct application occurs at treatment stage 2 ($MN_{jm=13T=2}$), $EF_{jm=13T=2}$ and
 1309 $FracGASM_{jm=13T=2}$ are set to zero.

1310 (2) The mass of nitrogen applied to soils for scope 3 emissions $MNSoil_{scope3}$ (kg N) is
 1311 calculated as:

$$1312 \quad MNSoil_{scope3} = \sum_j \sum_m (MN_{jmT=2} \times (1 - EF_{mT=2} - FracGASM_{mT=2}) - MNLeach_{jm=5})$$

$$1313 \quad \times (1 - PF)$$

1314 The current approach assumes that the manure used off-site within a different farm
 1315 enterprise, *if not sold*, is considered a residue from the farm, rather than a co-product. The
 1316 CRF definitions and guidance for product allocation are still under review and this approach
 1317 will be updated to align with the final CRF definitions and guidance. Please refer to Section
 1318 10 of CRF for more guidance on allocation and to provide feedback on allocation
 1319 approaches.

1320

1321 **4.5.2 Data/Parameters**1322 **4.5.2.1 INPUT DATA (REQUIRED)**

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each swine class within the annual period assessed
Data source	Farm stock records; system type records or purchase and sales records and National Vendor Declarations or NLID transfer records may be evaluated to determine average length of stay of each class. Breeding stock that are kept year-round shall be assumed to be on the farm for 365 days.
Quality assurance / quality control considerations	For those classes with stays of less than 365 days purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values. Recorded stock counts may also be used for quality assurance of entered values. The class of swine on farm align can be cross checked with reported products from farm.

1323

Data / Parameter	N_j
Data unit	head
Description	Number of swine in each class
Data source	Farm stock records; system type records, purchase and sales records and National Vendor Declarations or NLID transfer records may be evaluated to determine average length of stay of each class. Breeding stock that are kept year-round shall be assumed to be on the farm for 365 days.
Quality assurance / quality control considerations	Number of swine reported may be cross checked with stocking density allowances for system size (if known). The class of swine on farm may be cross checked against reported production system (breeder vs trader) and products from farm.

1324

1325 **Question Reference 4.3.**

1326 If there is more than one MMS per feedlot will the farmer need support in calculating the
 1327 percent manure distributed to each system? Is PigBal the best tool to support this?

Data / Parameter	$MMS_{jmT=1}$
Data unit	Fraction
Description	Fraction of manure in each primary MMS
Data source	<p>Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). This fraction should be based consistently on either weight or volume of manure. If treatment is different for different swine groups this may also be recorded per swine group.</p> <p>For each production system there are different primary MMS options. The options estimated in the National Inventory Report are:</p> <p>Conventional housing:</p> <ul style="list-style-type: none"> • Uncovered pond (m=1) • Digester/covered pond (m=7) • Short HRT (m=9) • Solid storage (m=4) – associated with solid separation <p>Deep litter housing:</p> <ul style="list-style-type: none"> • Deep litter (m=8) <p>Outdoor/free range:</p> <ul style="list-style-type: none"> • Drylot (m=5) <p>If a different MMS is applied which is not listed for swine the most closely aligned MMS should be identified.</p>
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=1}$ values should equal one. If only one primary MMS is used to treat manure, then $MMS_{jmT=1}$ should equal 1.

1328

1329

Data / Parameter	$MMS_{jmT=2}$
Data unit	Fraction
Description	Fraction of manure from primary system in each secondary manure management system
Data source	<p>Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). This fraction should be based on either weight or volume of manure. If treatment is different for different swine groups this may also be recorded per swine group.</p> <p>The options estimated in the National Inventory Report are:</p> <ul style="list-style-type: none"> • Solid storage • Direct application • Uncovered pond <p>If a different MMS is applied which is not listed for swine the most closely aligned MMS should be identified.</p>
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=2}$ values should equal one. If there is only one available secondary MMS then $MMS_{jmT=2}$ should be equal to 1.

1330

Data / Parameter	PF
Data unit	fraction
Description	Fraction of manure applied to soil within the farm boundary
Data source	<p>Farmer records of manure sales or transport weights compared to total manure treated on farm.</p> <p>When all manure treated in MMS is applied within the entity boundary and none is sold off-site to be used in a different enterprise, then $PF = 1$.</p>
Quality assurance / quality control considerations	If all of manure is not applied to soil within the farm boundary ensure it is appropriately tracked what proportion is sold to other entities. If it is not known what proportion is sold to other entities assume all manure is applied within in the farm boundary until better data can be collected.

1331

1332 4.5.2.2 DATA (METHOD 1 AND 2 OPTIONS)

Data / Parameter	SS _j
Data unit	Fraction
Description	Fraction of volatile solids separated by pre-treatment of manure
Method 1 data source	National Inventory Report Volume 2 [4]
Method 1 value	If solid separation occurs SS _j = 0.25 If solid separation does not occur SS _j = 0
Method 2 data source	User specified input as to what fraction of volatile solids is screened before flowing in to primary MMS. PigBal [11] may be used to support the estimation of this fraction based on the options effluent pre-treatment.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data is used Table 10 in the PigBal [11] manual may be used to check the typical percentages of solids and nutrients removed from raw piggery effluent by a range of pre-treatment systems. The value entered and type of pre-treatment specified may be compared to the values in the PigBal manual.

1333

Data / Parameter	VS _j
Data unit	kg/head/day
Description	Volatile solids produced in swine manure and waste feed in each class
Method 1 data source	See Appendix Table A.1.6.1
Method 1 value	Select the appropriate value based on animal class and year.
Method 2 data source	PigBal [11] may be used to calculate daily production of volatile solids per swine class by entering animal characteristics, feed intakes, diet composition and wastage rates.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 is used farm source data may be cross checked against Method 1 default values.

1334

Data / Parameter	MCF _{im}
Data unit	fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.6.4
Method 1 value	Choose default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.6.4 and A.1.8.1 for data source information).

1335

Data / Parameter	SN _j
Data unit	Fraction
Description	Fraction of nitrogen separated by pre-treatment of manure
Method 1 data source	National Inventory Report Volume 2 [4]
Method 1 value	If solid separation occurs SN _j = 0.25 If solid separation does not occur SN _j = 0
Method 2 data source	User specified input as to what fraction of nitrogen is screened before flowing in to primary MMS. PigBal [11] may be used to support the estimation of this fraction based on the options effluent pre-treatment.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data is used Table 10 in the PigBal manual [11] may be used to check the typical percentages of solids and nutrients removed from raw piggery effluent by a range of pre-treatment systems. The value entered and type of pre-treatment specified may be compared to the values in the PigBal manual.

1336

1337

1338

Data / Parameter	NW _j
Data unit	kgN/head/day
Description	Nitrogen waste production per pig and swine class per day including both animal waste and feed waste
Method 1 data source	See Appendix Table A.1.6.1
Method 1 value	Select the appropriate value based on animal class and year,
Method 2 data source	PigBal [11] may be used to calculate the nitrogen waste produced per swine class per head per day This is calculated by mass balance, as the difference between the amount in the ingested feed and the amount retained by the animal as live weight gain and the nitrogen in the waste feed.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 is used farm source data may be cross checked against Method 1 default values.

1339

1340

4.5.2.3 CONSTANT

Data / Parameter	VSL _{mT=2}
Data unit	Fraction
Description	Fraction of volatile solids lost during storage in the primary system.
Data source	National Inventory Report Volume 2 [4]
Value	There are only two production systems where losses are assumed when manure is transferred from a primary system to a secondary system and these each transfer a different fraction of manure. Conventional housing: <ul style="list-style-type: none"> VSL = 0.75 from digester/covered pond (m= 7) Deep litter housing: <ul style="list-style-type: none"> VSL = 0.05 from deep litter (m=8) In all other cases VSL = 0
Quality assurance / quality control considerations	N/A.

1341

1342

Data / Parameter	B_0
Data unit	$m^3 CH_4/kg VS$
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	0.19
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1343

Data / Parameter	ρ
Data unit	kg/m^3
Description	Density of methane.
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1344

Data / Parameter	C_{N_2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1345

Data / Parameter	EF_{mT}
Data unit	kgN_2O-N/kgN
Description	Nitrous oxide emission factor for each MMS.
Data source	See Appendix Table A.1.6.3
Value	Select appropriate default values based on manure management system.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1346

Data / Parameter	FracGASM _{mT}
Data unit	(kg NH ₃ -N + NO _x -N)/kgN
Description	Fraction of N volatilized in each MMS.
Data source	See Appendix Table A.1.6.2
Value	Select appropriate default values based on manure management system.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1347

Data / Parameter	EF _{N₂O}
Data unit	kgN ₂ O-N/kgN
Description	Nitrous oxide emission factors for atmospheric deposition
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Select the value based on the production system which most accurately described the land surrounding the piggery. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the rainfall zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is used in alignment with the Australian National Inventory Report.

1348

Data / Parameter	EF _{leach}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for leaching and runoff
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.011
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1349

1350

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define temperature zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

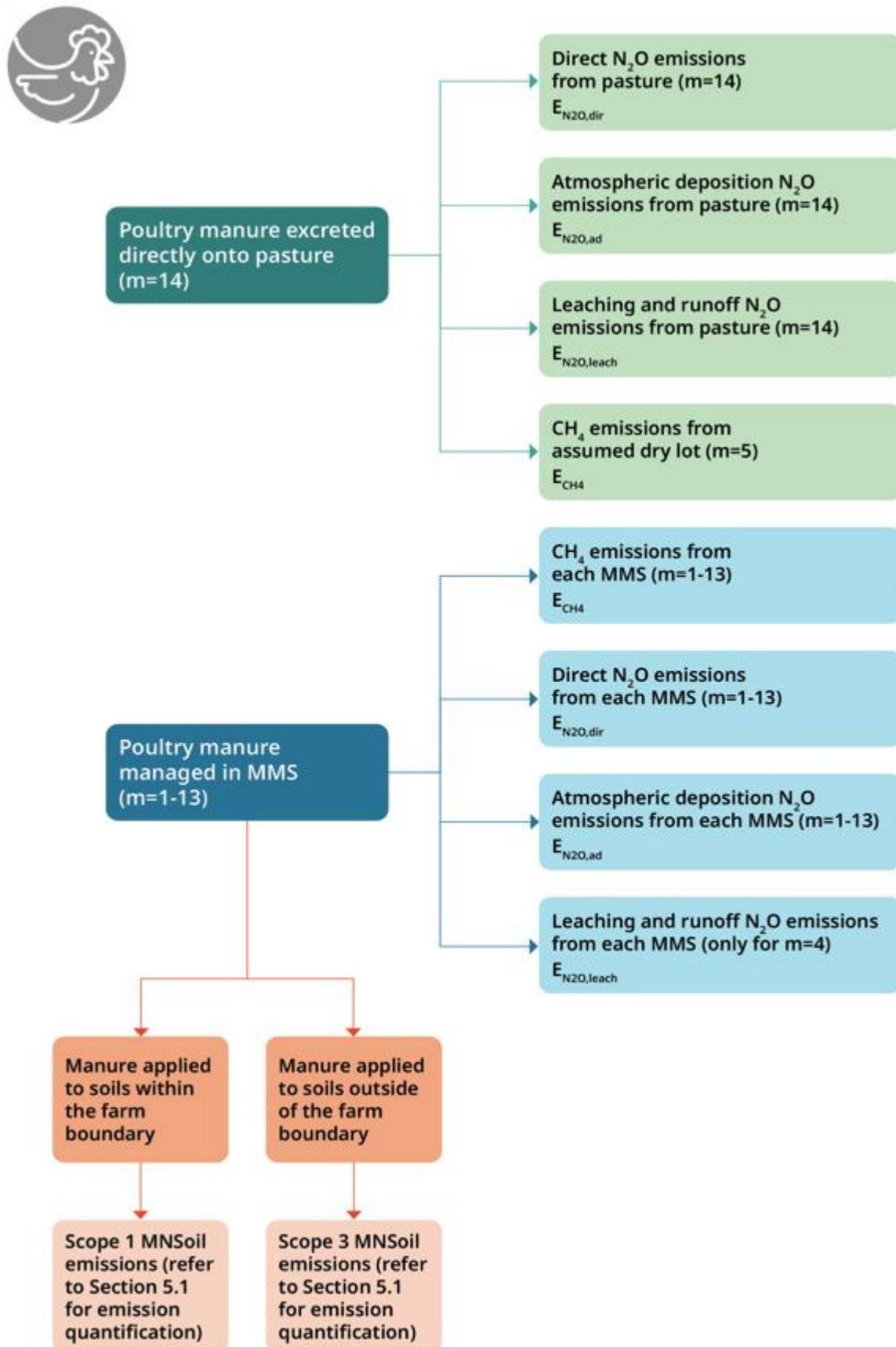
1351

Data / Parameter	FracLEACH _{MS}
Data unit	fraction
Description	Fraction of nitrogen lost through leaching and runoff for solid storage MMS only
Data source	National Inventory Report Vol 1 [1]
Value	0.02
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1352

1353 4.6 Poultry

1354 This module covers the quantification of greenhouse gas emission that results from manure
1355 management of poultry. Figure 4.9 summarises the resultant emissions from the manure
1356 management of poultry. The fraction of waste allocated to different manure management
1357 system is dependent of the type of housing system (e.g. housing with or without
1358 litter/bedding or free range) and whether there is primary and secondary treatment of the
1359 manure. Emissions associated with manure from management systems that is subsequently
1360 applied to soils as a secondary treatment are covered in the organic fertiliser section in
1361 Chapter 5 Section 5.1 Fertiliser module.



1362
1363 Figure 4.9: Emissions that result from manure management of poultry

1364 The following subscripts are used in this module:

Subscript	Meaning
<i>i</i>	Temperature Zone
<i>j</i>	Poultry Class
<i>k</i>	Poultry Subclass
<i>m</i>	Manure management system
<i>T</i>	Treatment stage

1365

1366 Emissions are estimated based on the class of poultry and the manure management system.
 1367 The emissions are summed across each poultry class and subclass within the farming
 1368 operation during the reporting period. These classes and subclasses may be broken down
 1369 further into different input classes to facilitate tracking of different lengths of stay, housing, or
 1370 management approaches. Input classes may be labelled as numbers e.g. Group 1, Group 2,
 1371 Group 3 or given relevant names based on housing or management approach or age for
 1372 data entry purposes.

1373 These input classes need to be mapped back to the default categories to allow the use of
 1374 default inventory values (if required) e.g.,

Poultry Class (j)	Poultry Subclass (k)	Possible Input Classes
1 = Layer	1 = Layer	Cage
		Barn
		Free Range
2 = Meat	2a = Meat Chicken Growers	Group 1 depletion 50%
		Group 1 depletion 100%
		Group 2 depletion 50%
		Group 2 depletion 100%
	2b = Meat Chicken Breeders	Breeders
	2c = Other	Other

1375

1376 Manure from poultry farms may pass through multiple manure management systems (m).
 1377 Free range systems will include both a shelter and an outdoor range component. The
 1378 outdoor range component is assumed to have similar methane emissions to a dry lot.
 1379 Additionally, the temperature zone (i) the poultry farm is operating in is needed to inform the
 1380 methane conversion factor applied. The following are common MMS used for poultry:

1381

1382

1383

Manure Management System (MMS) m
Primary Systems (T=1)
10 = Poultry manure with litter
11a = Poultry manure without litter with belt manure removal
11b = Poultry manure without litter with manure stored in house
14 = Pasture range and paddock
Secondary Systems (T=2)
4 = Solid Storage
6 = Composting (passive windrow)
7 = Digester/Covered Lagoon
8 = Deep Litter
12 = Direct processing into pelletized fertilizer
13 = Direct application to soils

1384

1385

Question Reference 4.4.

1386

Current guidance provides MMS options aligned with National Inventory Report and Greenhouse Gas Accounting Framework options. What other MMS are in use in poultry houses in both primary and secondary treatment stages?

1387

1388

1389

1390

1391

1392 **4.6.1 Estimation methodology**1393 **4.6.1.1 METHOD 1 – MANURE METHANE POULTRY**

1394 (1) Total annual methane emissions from manure management E_{CH_4} (t CH₄) is
 1395 calculated as:

$$1396 \quad E_{CH_4} = \sum_j \sum_k \sum_m \sum_T (D_{jk} \times M_{jkmT} \times N_{jk}) \times 10^{-3}$$

1397 Where D_{jk} = duration of stay of each class and subclass of poultry (days)

1398 M_{jk} = methane production from manure per class, subclass, MMS, and
 1399 treatment stage (kg CH₄/bird/day)

1400 N_{jk} = numbers of poultry in each class and subclass (bird)

1401

1402 **Treatment stage 1 (primary system)**

1403 (2) In equation (1) production of methane in treatment stage 1 MMS $M_{ijmT=1}$ (kg
 1404 CH₄/bird/day) is calculated as:

$$1405 \quad M_{jkmT=1} = VS_{jk} \times B_{oj} \times MMS_{jmT=1} \times MCF_{im} \times \rho$$

1406 Where VS_{jk} = volatile solid production poultry classes (kg VS/bird/day)

1407 B_{oj} = emissions potential per class (m³ CH₄/kg VS)

1408 $MMS_{jmT=1}$ = the fraction of manure in each primary system

1409 MCF_{im} = methane conversion factor for temperature zone and MMS. Under
 1410 Method 1, the default state temperature zone is applied.

1411 ρ = density of methane (kg/m³)

1412

1413 **Treatment stage 2 (secondary system)**

1414 (3) In equation (1) production of methane in each treatment stage 2 MMS $M_{ijmT=2}$ (kg
1415 CH₄/bird/day) is calculated as:

$$1416 \quad M_{jkmT=2} = VST_{jk} \times B_0 \times MMS_{jmT=2} \times MCF_{im} \times \rho$$

1417 Where VST_{jm} = fraction of volatile solids transferred to treatment stage 2 MMS (kg
1418 VS/bird/day)

1419 $MMS_{jmT=2}$ = the fraction of manure in each secondary system

1420 MCF_{im} = methane conversion factor for temperature zone and MMS. Under
1421 Method 1, the default state temperature zone is applied

1422 Note: there is no secondary system for manure on pasture, range and paddock (M=14)

1423

1424 (4) In equation (3) volatile solids transferred to treatment stage 2 MMS $VST_{jmT=2}$ (kg
1425 VS/bird/day) is calculated as:

$$1426 \quad VST_{ijmT=2} = VS_{jk} \times MMS_{jmT=1} \times (1 - VSL_{mT=1})$$

1427 Where $VSL_{mT=1}$ = fraction of volatile solids lost during storage in the primary system.

1428

1429 (5) In equation (4) volatile solid production VS_j (kg/bird/day) is calculated as:

$$1430 \quad VS_{jk} = I_{jk} \times (1 - DMD_{jk}) \times (1 - A_j)$$

1431 Where I_{jk} = dry matter intake for each class and subclass (kg DM/bird/day).

1432 DMD_{jk} = dry matter digestibility for each class and subclass (fraction).

1433 A_j = ash content of manure for each class and subclass (fraction)

1434 Under Method 1, default I_{jk} and DMD_{jk} values are applied.

1435

1436 **Question Reference 4.5.**

1437 It is understood that mortalities and/or spent hens may be managed through manure
1438 management systems. The addition of spent hens and/or mortalities to manure management
1439 systems will increase the VS within the system. Are there known values for VS of mortalities
1440 and/or spent hens? Or MCF appropriate for the decomposition of this material? How else
1441 could this be quantified other than the National Greenhouse Accounts Factors waste factors
1442 in Chapter 13?

1443

1444 4.6.1.2 METHOD 2 – MANURE METHANE POULTRY

1445 Method 2 is the same as Method 1 except that under equations 4.6.1.1 (3) – (5) farm specific
1446 data I_{jk} and DMD_{jk} are required and for temperature zone is required for MCF_{tm} .

1447 **Question Reference 4.6.**

1448 Current guidance provides default options for intake and dry matter digestibility (DMD)
1449 aligned with National Inventory Report. However, as emissions estimates are sensitive to
1450 these variables should farm-specific intake and DMD be required data for Method 1?
1451 Alternatively, should intake be required while defaults are provided for DMD?

1452

1453 4.6.1.3 METHOD 1 – MANURE DIRECT N₂O POULTRY

1454 (1) The total annual direct nitrous oxide emissions from manure management systems
1455 $E_{N_{2O},dir}$ (t N₂O) is calculated as:

$$1456 \quad E_{N_{2O},dir} = \sum_j \sum_k \sum_m \sum_T (MN_{jkmT} \times EF_{jm} \times C_{N_{2O}}) \times 10^{-3}$$

1457 Where MN_{jkmT} = nitrogen per poultry class, subclass, MMS and treatment stage (kg
1458 N₂O)

1459 EF_{jm} = nitrous oxide emission factor for MMS (kg N₂O-N/kg N)

1460 $C_{N_{2O}}$ = factor to convert elemental mass of nitrous oxide to molecular mass

1461 **Treatment stage 1 (primary system)**

1462 (2) In equation (1) nitrogen in the treatment stage 1 MMS $MN_{jkmT=1}$ (kg N₂O) is
1463 calculated as:

$$1464 \quad MN_{jkmT=1} = AE_{jk} \times MMS_{jmT=1}$$

1465 Where AE_{jk} = total nitrogen excreted by each poultry class and subclass (kg N)

1466 **Question Reference 4.7.**

1467 It is understood that mortalities and/or spent hens may be managed through manure
1468 management systems. The addition of mortalities to manure management systems will
1469 increase the N content within the system. Are there known values for N content of mortalities
1470 and/or spent hens? How else could the decomposition of this material be quantified other
1471 than the National Greenhouse Account Factors waste factors in Chapter 13?

1472

1473 (3) In equation (2) annual nitrogen excretion AE_{jk} (kg N) from is calculated as:

$$1474 \quad AE_{jk} = N_{jk} \times NE_{jk} \times D_{jk}$$

1475 Where NE_{jk} = nitrogen excretion (kg N/bird/day)

1476

1477 (4) In equation (3) nitrogen excretion NE_j (kg/bird/day) is calculated by:

$$1478 \quad NE_{jk} = NI_{jk} \times (1 - NR_{jk})$$

1479 Where NI_{jk} = nitrogen intake (kg/bird/day)

1480 NR_{jk} = nitrogen retention expressed as a fraction of intake (per cent).

1481 Under Method 1, default NR_{jk} values are applied.

1482

1483 (5) In equation (4) nitrogen intake NI_j (kg/bird/day) of poultry is calculated by:

$$1484 \quad NI_{jk} = I_{jk} \times CP_{jk} \div 6.25$$

1485 Where CP_j = crude protein content of feed (fraction).

1486 6.25 = factor for converting crude protein into nitrogen

1487 Under Method 1, default I_{jk} , and CP_{jk} values are applied.

1488

1489 **Treatment stage 2 (secondary system)**

1490 (6) In equation (1) nitrogen in each treatment stage 2 MMS $MN_{jkmT=2}$ (kg N₂O) is
1491 calculated as:

$$1492 \quad MN_{jkmT=2} = NT_{jkmT=2} \times MMS_{mT=2}$$

1493 Where $NT_{jkmT=2}$ = nitrogen transferred to secondary treatment MMS (kg N)

1494 Note: if direct application occurs at treatment stage 2 ($MN_{jkm=13T=2}$) the nitrogen moves
1495 directly to MN_{soil} calculation (equation 4.6.1.9 (1)) and is not included in direct nitrous oxide
1496 from manure management equation (equation 4.6.1.3 (1)).

1497 (7) In equation (6) nitrogen transferred to treatment stage 2 MMS $NT_{jkmT=2}$ (kg N) is
1498 calculated as:

$$1499 \quad NT_{jkmT=2} = \left(MN_{jkmT=1} \times (1 - FracGASM_{mT=1} - EF_{mT=1}) \right)$$

1500 Where $MN_{jkmT=1}$ = nitrogen in MMS treatment stage 1 (kg N)

1501 $FracGASM_{mT=1}$ = fraction of N volatilised from MMS treatment at stage 1

1502 $EF_{mT=1}$ = Nitrous oxide emission factor for MMS treatment at stage 1

1503

1504 4.6.1.4 METHOD 2 – MANURE DIRECT N₂O POULTRY

1505 Method 2 is the same as Method 1 except that under equation 4.6.1.3 (4) - (5) farm specific
1506 data for I_j , and CP_j is required.

1507 **Question Reference 4.8.**

1508 Current guidance provides default options for intake and crude protein (CP) aligned with
1509 National Inventory Report. However, as emissions estimates are sensitive to these variables
1510 should farm-specific intake and CP be required data for Method 1? Alternatively, should
1511 intake be required while defaults are provided for CP?

1512

1513 4.6.1.5 METHOD 1 – MANURE ATMOSPHERIC DEPOSITION POULTRY

1514 (1) Total annual atmospheric deposition emissions from manure management $E_{N_2O,ad}$ (t
1515 N₂O) is calculated as:

$$1516 E_{N_2O,ad} = (MMS_{ATMOS} \times EF_{N_2O} \times C_{N_2O}) \times 10^{-3}$$

1517 Where MMS_{ATMOS} = mass of N volatilised from MMS (kg N)

1518 EF_{N_2O} = Nitrous oxide emission factors for atmospheric deposition (kg N₂O-
1519 N/kg N)

1520

1521 (2) In equation (1) volatilised nitrogen from MMS MMS_{ATMOS} (kg N) is calculated as:

$$1522 MMS_{ATMOS} = \sum_j \sum_k \sum_m \sum_T MN_{jkmT} \times FracGASM_{mT}$$

1523 Where MN_{jkmT} = nitrogen in each treatment stage MMS (kg N) (excluding
1524 $MN_{ijm=13T=2}$)

1525 $FracGASM_{mT}$ = fraction of N volatilised in each MMS ((kg NH₃-N + NO_x-N)/kg
1526 N)

1527 Note: in the case of direct application at treatment stage 2 the nitrogen ($MN_{jkm=13T=2}$) moves
1528 directly to MN_{soil} calculation (equation 4.5.1.5 (1)) and is not included in the atmospheric
1529 deposition from manure management calculation.

1530

1531 4.6.1.6 METHOD 2 – MANURE ATMOSPHERIC DEPOSITION POULTRY

1532 There is no Method 2 quantification option for this emission source

1533

1534 4.6.1.7 METHOD 1 – MANURE LEACHING AND RUNOFF N₂O POULTRY

1535 (1) Annual emissions from leaching and run off from each MMS $E_{N_2O,leach}$ (t N₂O) is
1536 calculated as:

$$1537 E_{N_2O,leach} = \sum_j \sum_k \sum_{m=1-13} (MNLeach_{jkm} \times EF_{leach} \times C_{N_2O}) \times 10^{-3}$$

1538 Where $MNLeach_{jkm}$ = mass of N lost through leaching and runoff from each MMS
 1539 (kg N)

1540 EF_{leach} = Emission factor for leaching and runoff (kg N₂O-N/kg N)

1541

1542 $MNLeach_m$ is assumed to be 0 for all MMS except free range operations manure excreted on
 1543 pasture in free range operations and manure and manure stockpiles. Leaching from
 1544 emissions from the pasture component (m=14) is estimated in the manure applied to soils
 1545 equations (Section 4.6.1.10 - 4.6.1.15). Therefore, emissions from leaching and run off are
 1546 only estimated for solid storage stockpiles MMS (m=4). This simplifies the equation to:

$$1547 \quad E_{N_{2O},leach} = MNLeach_{jkm=4} \times EF_{leach} \times C_{N_{2O}} \times 10^{-3}$$

1548 **Question Reference 4.9.**

1549 Current guidance assuming leaching and runoff can only occur from poultry manure
 1550 excreted on pasture, range and paddock or from solid storage stockpiles. Is there any
 1551 existing research indicating leaching and run off could occur from other secondary treatment
 1552 such as composting systems?

1553 (2) In equation (1) the mass of nitrogen lost to leaching and runoff from solid storage
 1554 systems $MNLeach_{jm=5}$ (kg N) is calculated as:

$$1555 \quad MNLeach_{jm=4} = MN_{jkm=4T=1} \times FracWET \times FracLEACH_{MS}$$

1556 Where $FracWET$ = fraction of N available for leaching and runoff.

1557 $FracLEACH_{MS}$ = fraction of N lost through leaching and runoff

1558

1559 4.6.1.8 METHOD 2 - MANURE LEACHING AND RUNOFF N₂O POULTRY

1560 There is no Method 2 quantification option for this emission source

1561 4.6.1.9 MANURE APPLIED TO SOILS

1562 It is assumed that all manure managed through an MMS (m=1-13) will eventually be applied
 1563 to soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value
 1564 is transferred to Chapter 5 Section 5.2 to estimate emissions associated with the application
 1565 of organic fertilisers, including the associated atmospheric deposition, and leaching and run-
 1566 off emissions.

1567 This manure may be applied to soils within the boundary of the poultry farm or may be sold
 1568 and applied to another enterprise. Where manure is applied to soils within the boundary of
 1569 the farming enterprise $MNSoil_{scope1}$, the emissions shall be estimated and reported as
 1570 Scope 1 emissions. Where the manure is used with in the direct emissions boundary of other
 1571 entities the emissions from shall be estimated and reported as Scope 3 emissions
 1572 $MNSoil_{scope3}$, under Scope 3 Category 5 – waste generated in operations (see Chapter 13).

- 1573 (1) The mass of nitrogen applied to soils for scope 1 emissions $MNSoil_{scope1}$ (kg N) is
1574 calculated as:

$$1575 \quad MNSoil_{scope1} = \sum_j \sum_m (MN_{jmT=2} \times (1 - EF_{jm=1-13} - FracGASM_{jm=1-13}) - M_{leach,MMS})$$

$$1576 \quad \times PF$$

1577 Where $MN_{jmT=2}$ = mass of N in secondary treatment stage as calculated for manure
1578 management (kg N)

1579 $EF_{mT=2}$ = nitrous oxide emission factor for each MMS (kg N₂O-N/kg N)

1580 $FracGASM_{mT=2}$ = fraction of animal waste N volatilised in each MMS ((kg
1581 NH₃-N + NO_x-N)/kg N)

1582 PF = fraction of manure applied to soil within the farm boundary

- 1583 (2) The mass of nitrogen applied to soils for scope 3 emissions $MNSoil_{scope3}$ (kg N) is
1584 calculated as:

$$1585 \quad MNSoil_{scope3} = \sum_j \sum_m \sum_T MN_{jmT=2} \times (1 - EF_{mT=2} - FracGASM_{mT=2}) \times (1 - PF)$$

1586 The current approach assumes that the manure used off-site within a different farm
1587 enterprise, *if not sold*, is considered residue product from the farm, rather than a co-product.
1588 The CRF definitions and guidance for product allocation are still under review and this
1589 approach will be updated to align with the final CRF definitions and guidance. For more
1590 guidance on allocation and to provide feedback on allocation approaches including poultry
1591 industry standards for co-products and allocation please refer to Section 10 of the CRF.

1592 4.6.1.10 METHOD 1 – SOIL DIRECT N₂O POULTRY

- 1593 (1) Direct nitrous oxide emissions $E_{N2O,PRP,dir}$ from poultry manure deposited directly on
1594 to pasture at the primary treatment stage are calculated as:

$$1595 \quad EM_{N2O,PRP,dir} = \sum_j \sum_k (MN_{jkm=14T=1} \times EF_{PRP} \times C_{N2O}) \times 10^{-3}$$

1596 Where $MN_{jkm=14T=1}$ = mass of nitrogen excreted directly on pasture by poultry class
1597 and subclass (kgN)

1598 EF_{PRP} = nitrous oxide emissions emission factor for manure deposited on
1599 pasture (kgN₂O-N/kgN deposited)

1600

1601 4.6.1.11 METHOD 2 – SOIL DIRECT N₂O POULTRY

1602 There is no Method 2 quantification option for this emission source

1603

1604 4.6.1.12 METHOD 1 – SOIL ATMOSPHERIC DEPOSITION N₂O POULTRY

- 1605 (1) Atmospheric deposition emissions from poultry manure deposited on pasture $E_{N2O,ad}$
1606 (t N₂O) are calculated as:

1607
$$E_{N2O,ad} = M_{vol,m=14} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

1608 Where $M_{vol,m=14}$ = mass of nitrogen volatilised from manure deposited on pasture
1609 (kg N)

1610 EF_{N2O} = emission factor for atmospheric deposition (kg N₂O-N/kg N)

1611 (2) In equation (1) the mass of nitrogen volatilised $M_{vol,PRP}$ (kg N) is calculated as:

1612
$$M_{vol,m=14} = \sum_j \sum_k MN_{jkm=14T=1} \times FracGASMsoil$$

1613 Where $FracGASMsoil$ = fraction of nitrogen volatilised from manure deposited on
1614 pasture ((kg NH₃-N + NO_x-N)/kg N)

1615

1616 4.6.1.13 METHOD 2 – SOIL ATMOSPHERIC DEPOSITION N2O POULTRY

1617 There is no Method 2 quantification option for this emission source.

1618

1619 4.6.1.14 METHOD 1 – SOIL LEACHING AND RUNOFF N2O POULTRY

1620 (1) Leaching and runoff emissions from urine and dung deposited on pasture $ES_{N2O,leach}$
1621 (t N₂O) are calculated as:

1622
$$E_{N2O,leach} = M_{leach,m=14} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

1623 Where $M_{leach,m=14}$ = mass of nitrogen lost to leaching and runoff from urine and
1624 faeces deposited on pasture (kg N)

1625 EF_{leach} = emission factor for leaching and runoff (kg N₂O-N/kg N)

1626

1627 (2) In equation (1) the mass of nitrogen lost to leaching and runoff $M_{leach,PRP}$ is
1628 calculated as:

1629
$$M_{leach,m=14} = \sum_j \sum_k MN_{jkm=14T=1} \times FracWet \times FracLEACH_{MS}$$

1630 Where $FracWet$ = fraction of N available for leaching and runoff.

1631 $FracLEACH_{MS}$ = fraction of N that is lost through leaching and runoff

1632

1633 4.6.1.15 METHOD 2 – SOIL LEACHING AND RUNOFF N2O POULTRY

1634 There is no Method 2 quantification option for this emission source

1635

1636 **4.6.2 Data/Parameters**1637 **4.6.2.1 INPUT DATA (REQUIRED)**

Data / Parameter	N_{jk}
Data unit	birds
Description	Number of poultry in each class j and subclass k
Data source	Farm flock records
Quality assurance / quality control considerations	Number of poultry reported may be cross checked with expected flock numbers for system size and production, if known. The numbers reported with in each input class of animals may be crossed checked with expected enterprise values, if known: for example, number of laying hens vs meat chickens vs breeder.

1638

Data / Parameter	D_{jk}
Data unit	days
Description	Duration of stay for each class and subclass of poultry
Data source	Farm flock records, housing/system records and placement and dispatch documentation may be used to determine average duration of stay for each poultry class and subclass. For broiler chickens records of depletions, or “flock thinning” may be used to ascertain length of stay within each class and subclass of poultry.
Quality assurance / quality control considerations	Ensure average length of stay aligns with duration of stay expected for poultry type, class and subclass. Layers would be expected to be on farm on average for 365 days while broiler chickens will vary depending on production system and when depletions occur.

1639

1640 **Question Reference 4.10.**

1641 If there is more than one MMS per treatment stage will the farmer need support in
1642 calculating the fraction of manure distributed to each system for the MMS input values? Are
1643 there existing calculations or tools that should be referenced to support this?

1644

Data / Parameter	$MMS_{jmT=1}$
Data unit	Fraction
Description	Fraction of manure in each primary MMS
Data source	<p>Farmer records as to what fraction each system is used to treat manure based on the available MMS options (m). If treatment is different for different poultry groups this may also be recorded per poultry group.</p> <p>Free range systems will include both a shed and range component. Unless other data is available it shall be assumed that 0.8 of manure in free range system is allocated to the shed (with or without litter) and 0.2 to a drylot MMS system as a pasture substitute [12], [13].</p> <p>Available primary MMS options include:</p> <ul style="list-style-type: none"> • Poultry manure with litter • Poultry manure without litter - stored in house • Poultry manure without litter – belt removal • Pasture, range and paddock <p>If a different MMS is applied which is not listed for poultry the most closely aligned MMS should be identified.</p> <div style="border: 1px solid black; padding: 5px;"> <p>Please see consultation Question Reference 4.4 if you know of systems in use which are not captured in the available options</p> </div>
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=1}$ values should equal one. If only one primary MMS is used to treat manure, then $MMS_{jmT=1}$ should equal 1.

1645

Data / Parameter	$MMS_{jmT=2}$
Data unit	Fraction
Description	Fraction of waste from primary system transferring to each secondary manure management system i.e. what fraction of manure goes to what MMS once it has been removed from the house.
Data source	<p>Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). If treatment is different for different poultry groups this may also be recorded per poultry group.</p> <p>If a different MMS is applied which is not listed for poultry the most closely aligned MMS should be identified.</p> <div style="border: 1px solid black; padding: 5px;"> <p>Please see consultation Question Reference 4.4 if you know of systems in use which are not captured in the available options</p> </div>
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=2}$ values should equal one. If there is only one available secondary MMS then $MMS_{jmT=2}$ should be equal to 1.

1646

Data / Parameter	PF
Data unit	Fraction
Description	Fraction of manure from MMS applied to soil within the farm boundary
Data source	Farmer records of manure sales or transport weights compared to total manure treated on farm. When all manure treated in MMS is applied within the entity boundary and none is sold off-site to be used in a different enterprise, then PF = 1.
Quality assurance / quality control considerations	If all manure is not applied to soil within the entity boundary, ensure it is appropriately tracked what proportion is sold to other entities. If it is not known what proportion is sold to other entities assume all manure is applied within the entity boundary until better data can be collected.

1647

1648 4.6.2.2 DATA (METHOD 1 AND 2 OPTIONS)1649 **Question Reference 4.11.**

1650 Are there existing tools or equations you would want included to support the calculation of
 1651 intake? The Australia Eggs tool has been referenced below but calculation of intake is not
 1652 visible to users.

Data / Parameter	I_{jk}
Data unit	kg DM/bird/day
Description	Dry matter intake for each class and subclass
Method 1 data source	See Appendix Table A.1.7.1
Method 1 value	Select appropriate value based on animal class.
Method 2 data source	Farm records relating to daily feed intake for each class or subclass. For rearers and layers the Australian Egg Tool [14] provides a calculation of intake based on total feed delivered to rearers or subclass of layer (cage, barn, free range) and diet characteristics, if known.
Quality assurance / quality control considerations	Intake may be compared to Method 1 defaults for the relevant poultry class. If significantly higher or lower than inventory defaults check farm records to ensure correct data entry.

1653

1654

Data / Parameter	DMD _{jk}
Data unit	fraction
Description	Dry matter digestibility
Method 1 data source	See Appendix Table A.1.7.1
Method 1 value	Select appropriate value based on animal class.
Method 2 data source	If average DMD for the reporting period of different poultry classes is known based on farm records of feed sources and quality, a farm specific DMD value may be used. For any poultry classes where farm records of feed sources and quality are not available, the National Inventory Report default shall be applied.
Quality assurance / quality control considerations	Compare to inventory defaults, if values are significantly higher or lower data entry error is possible. Where Method 2 data is used conduct checks of farm source data are within expected ranges.

1655

Data / Parameter	CP _j
Data unit	fraction
Description	Crude protein content of feed intake
Method 1 data source	See Appendix Table A.1.7.1
Method 1 value	Select appropriate value based on animal class.
Method 2 data source	Farm records or feed delivery receipt stating crude protein of complete feed for different poultry classes. For any poultry classes where farm records of feed sources and quality are not available, the National Inventory Report default shall be applied.
Quality assurance / quality control considerations	Compare to defaults, if values are significantly higher or lower data entry error is possible. Where Method 2 data is used conduct checks of farm source data are within expected ranges.

1656

1657

1658

Data / Parameter	MCF _{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.7.4
Method 1 value	Choose default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	Select relevant MCF for MMS and temperature zone from Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.7.4 and A.1.8.1 for data source information).

1659

1660 4.6.2.3 CONSTANT

Data / Parameter	B ₀
Data unit	m ³ CH ₄ /kg VS
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	Layers = 0.39 Meat Chickens = 0.36
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report..

1661

Data / Parameter	ρ
Data unit	kg/m ³
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1662

1663

Data / Parameter	VSL _{mT=1}
Data unit	fraction
Description	Fraction of volatile solids lost in the primary system
Data source	National Inventory Report, Volume 2 [4]
Value	Poultry manure with litter = 0.15 Poultry manure without litter - stored in house = 0.2 Poultry manure without litter – belt removal = 0
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1664

Data / Parameter	A
Data unit	fraction
Description	Ash content of manure
Data source	See Appendix Table A.1.7.1
Value	Select appropriate value based on animal class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1665

Data / Parameter	EF _{jm}
Data unit	kgN ₂ O-N/kgN
Description	Nitrous oxide emission factor for each MMS.
Data source	See Appendix Table A.1.7.3
Value	Select appropriate value based on manure management system.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1666

Data / Parameter	C _{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1667

Data / Parameter	NR_{jk}
Data unit	per cent
Description	Nitrogen retention expressed as a per cent of intake
Data source	See Appendix Table A.1.7.1
Value	Select appropriate value based on animal class.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1668

Data / Parameter	$FracGASM_{mT}$
Data unit	(kg NH_3-N + NO_x-N)/kgN
Description	Fraction of N volatilized in each MMS.
Data source	See Appendix Table A.1.7.2
Value	Apply the FracGASM that best represents the MMS in each treatment stage.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report..
Data / Parameter	EF_{N_2O}
Data unit	kg N_2O-N /kgN
Description	Nitrous oxide emission factors for atmospheric deposition
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Select the value based on the production system which most accurately describes the land surrounding the housing area. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the rainfall zone the enterprise is located in
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is selected in alignment with the production system-based emissions factors reported in the Australian National Inventory Report.

1669

Data / Parameter	EF_{leach}
Data unit	kg N_2O-N /kg N
Description	Emission factor for leaching and runoff
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.011

1670

Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report..
Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

1671

Data / Parameter	FracLEACH _{MS}
Data unit	fraction
Description	Fraction of N that is lost through leaching and runoff
Data source	National Inventory Report, Volume 1 [1]
Value	0.02
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Greenhouse Gas Inventory.

1672

1673 4.7 Other Livestock

1674 This module covers the estimation of methane and nitrous oxide that result from other
 1675 livestock manure management. Other livestock are assumed to be range-kept livestock with
 1676 manure deposition occurring in a dispersed fashion on pasture, range or paddock (PRP).

1677 The following subscripts are used in this module:

Subscript	Meaning
<i>i</i>	Temperature Zone
<i>j</i>	Other livestock type

1678

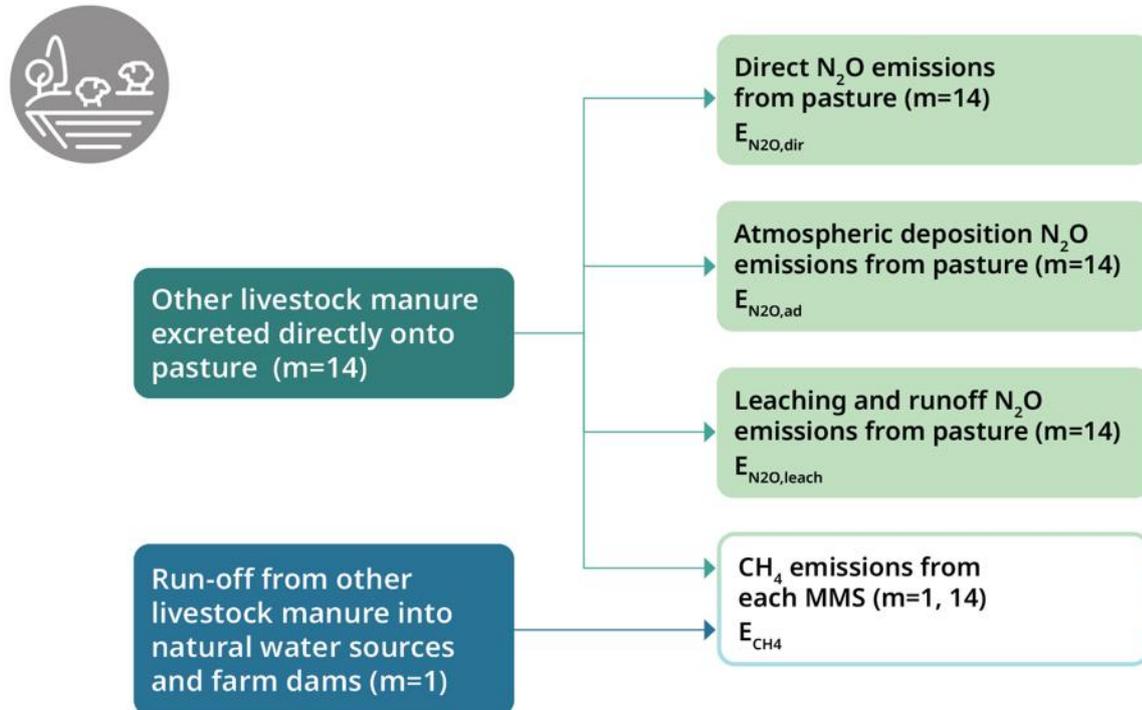
1679 Emissions are estimated based on type of animal and the manure management system. The
 1680 temperature zone will affect the selection of appropriate emissions factors. The emissions
 1681 are summed across manure management systems.

1682 The other livestock types on the farm will depend on the diversity of the farming operation.
 1683 The classes of different other livestock types need to be mapped back to default categories
 1684 ('Other Livestock Types (j)') to allow the use of default values under Method 1.

Other livestock types j	Possible input classes
1 = Buffalo	Bulls
	Cows
	Steers
	Calves
2 = Goats	Bucks/Billy
	Wethers
	Maiden breeding does/nannies
	Breeding does/nannies
	Other
	Kids
3 = Deer	Bucks
	Breeding Does
	Other Does
	Fawn
4 = Camels	Camels
5 = Alpacas	Alpacas
6 = Horses	Horses
7 = Mules/asses	Mules/asses
8 = Emus/ostriches	Emus/Ostriches

1685

1686 The only relevant manure management systems (m) for other livestock are PRP (m=14)
 1687 and anaerobic lagoons (m=1). Where farms have unfenced natural water sources and farm
 1688 dams, anaerobic lagoons are used as a proxy to estimate the runoff of manure into these
 1689 water sources. Figure 4.10 summarises the emission sources associated with the manure
 1690 of other livestock.



1691
 1692 Figure 4.10: Emissions that result from manure of other livestock on pasture, rangeland and
 1693 paddock

1694

1695 **4.7.1 Estimation methodology**1696 **4.7.1.1 METHOD 1 – MANURE METHANE OTHER LIVESTOCK**

1697 (1) Total annual methane production from manure management of other livestock E_{CH_4} (t
1698 CH_4) is calculated as:

$$1699 \quad E_{CH_4} = \sum_j \sum_m (N_j \times M_{jm} \times 365) \times 10^{-3}$$

1700 Where N_j = average annual of livestock per livestock type j (head)

1701 M_{jm} = annual methane production (kg CH_4 /head/day)

1702 (2) In equation (1) annual methane production from manure management M_{jm} (kg
1703 CH_4 /head/day) is calculated as:

$$1704 \quad M_{jm} = VS_j \times B_o \times MMS_m \times MCF_{im} \times \rho$$

1705 Where VS_j = volatile solid production (kg/head/day)

1706 B_o = emissions potential (m^3 CH_4 /kgVS)

1707 MMS_m = fraction of waste in each manure management system

1708 MCF_{im} = methane conversion factor for temperature zone and MMS. Under
1709 Method 1, the default state temperature zone is applied.

1710 ρ = density of methane (kg/m^3)

1711 The primary manure management system (MMS) for other livestock is pasture range and
1712 paddock (m=14). Where natural water sources, such as farm dams, are present the
1713 anaerobic lagoon (m=1) MMS is used to estimate the run-off of manure into these water
1714 sources. Where farmers can demonstrate animals are on bore or reticulated water systems,
1715 where water is provided in troughs (i.e., no unfenced natural water sources), then the only
1716 relevant MMS to be considered shall be pasture range and paddock (m=14).

1717 The assumption regarding run-off into farm dams is under review and may change in future.
1718 Until new assumption confirmed by DCCEEW the allocation to MMS for unfenced water
1719 sources is aligned with the current National Inventory Report approach. A new method for
1720 estimating VS production will be implement in the next National Inventory Report and has
1721 been reflected here.

1722

1723 **4.7.1.2 METHOD 2 – MANURE METHANE OTHER LIVESTOCK**

1724 Method 2 is the same as Method 1, except a temperature zone specific value for MCF_{im} is
1725 applied in equation 4.7.1.1 (2).

1726

1727 **4.7.1.3 METHOD 1 – SOIL DIRECT N₂O OTHER LIVESTOCK**

1728 (1) Total annual direct nitrous oxide emissions from agricultural soils from deposition of
1729 urine and dung to pasture $E_{N_2O,dir}$ (t N_2O) is calculated as:

1730
$$E_{N2O,dir} = AE \times EF_{PRP} \times C_{N2O} \times 10^{-3}$$

1731 Where AE = annual nitrogen excreted by each livestock type (kg N/year)

1732 EF_{PRP} = emission factor for nitrous oxide from urine and dung deposited to soil
1733 (kg N₂O-N/kg N deposited)

1734 C_{N2O} = factor to convert elemental mass of nitrous oxide to molecular mass

1735

1736 (2) In equation (1) total nitrogen excreted to pasture, range and paddock AE (kg N/year)
1737 is calculated as:

1738
$$AE = \sum_j (N_j \times NE_j \times 365)$$

1739 Where NE_j = Nitrogen excreted by each livestock type (kg N/head/day)

1740

1741 4.7.1.4 METHOD 2 – SOIL DIRECT N₂O OTHER LIVESTOCK

1742 There is no Method 2 quantification option for this emissions source.

1743

1744 4.7.1.5 METHOD 1 – SOIL ATMOSPHERIC DEPOSITION N₂O OTHER LIVESTOCK

1745 (1) Atmospheric deposition emissions from urine and dung deposited on pasture $E_{N2O,ad}$
1746 (t N₂O) are calculated as:

1747
$$E_{N2O,ad} = M_{vol} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

1748 Where M_{vol} = mass of nitrogen volatilised from urine and faeces deposited on
1749 pasture (kg N)

1750 EF_{N2O} = emission factor for atmospheric deposition (kg N₂O-N/kg N)

1751

1752 (2) In equation (1) the mass of nitrogen volatilised M_{vol} (kg N) is calculated as:

1753
$$M_{vol} = AE \times FracGASMsoil$$

1754 Where $FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces
1755 deposited on pasture ((kg NH₃-N + NO_x-N)/kg N)

1756

1757 4.7.1.6 METHOD 2 – SOIL ATMOSPHERIC DEPOSITION N₂O OTHER LIVESTOCK

1758 There is no Method 2 quantification option for this emission source

1759 4.7.1.7 METHOD 1 – SOIL LEACHING AND RUNOFF N₂O OTHER LIVESTOCK

1760 (1) Leaching and runoff emissions from urine and dung deposited on pasture $E_{N_{2O},leach}$
 1761 (t N₂O) are calculated as:

1762
$$E_{N_{2O},leach} = M_{leach} \times EF_{leach} \times C_{N_{2O}} \times 10^{-3}$$

1763 Where M_{leach} = mass of nitrogen lost to leaching and runoff (kg N)

1764 EF_{leach} = emission factor for leaching and runoff (kg N₂O-N/kg N)

1765

1766 (2) In equation (1) the mass of nitrogen lost to leaching and runoff M_{leach} is calculated
 1767 as:

1768
$$M_{leach} = AE \times FracWet \times FracLEACH$$

1769 Where $FracWet$ = fraction of N available for leaching and runoff.

1770 $FracLEACH$ = fraction of all N that is lost through leaching and runoff

1771

1772 4.7.1.8 METHOD 2 – SOIL LEACHING AND RUNOFF N₂O OTHER LIVESTOCK

1773 There is no Method 2 quantification option for this emission source

1774

1775 **4.7.2 Data/Parameters**1776 **4.7.2.1 INPUT DATA (REQUIRED)**

Data / Parameter	N_j
Data unit	head
Description	Average annual numbers of other livestock per other livestock type j
Data source	Farm stock records – Method assumes animals are on farm for 365 days. If there are changes in livestock numbers throughout the year an average annual number should be calculated based on animal movements i.e. for systems with multiple subclasses where numbers of animals on farm varies between these subclasses throughout the year purchase/birth and sales/deaths records may be used to estimate an annual average number of livestock over a month or season. These numbers may then be averaged to estimate the annual average number of livestock on the farm.
Quality assurance / quality control considerations	All animals purchased or sold in the reporting period are assumed to be reported. Number of other livestock reported may be cross checked with stocking density allowances for system size. The type of animals on farm may be crossed check against reported products from farm.

1777

1778 4.7.2.2 DATA (METHOD 1 AND 2 OPTIONS)

1779

Data / Parameter	MCF _{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.5.6
Method 1 value	Choose default based on State and MMS.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1780

1781

1782 4.7.2.3 CONSTANTS

Data / Parameter	VS _j
Data unit	kg VS/head/year
Description	Volatile solids produced for other livestock type j
Data source	See Appendix Table A.1.5.2
Value	Select the appropriate livestock type.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1783 DCCEEW is investigating the provision of more granular spatial mapping of MMS for method
1784 2 option.

Data / Parameter	MMS _m
Data unit	fraction
Description	Fraction of waste in each MMS
Data source	National Inventory Report, Volume 1 [1]
Value	Where a producer cannot demonstrate water bodies are stock excluded MMS _m values shall be selected based on State, Region and MMS. If animals are on bore or reticulated water systems where water is provided in troughs (i.e. no unfenced natural water sources) then all waste should be allocated to pasture range and paddock and MMS _{m=14} = 1.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report. High resolution aerial imagery may be used to cross check that water sources are stock excluded.

1785

Data / Parameter	C _{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1786

1787

Data / Parameter	ρ
Data unit	kg/m ³
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1788

Data / Parameter	EF _{PRP}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for urine and dung deposited on pasture, range or paddock
Data source	See Appendix Table A.2.2.2.
Value	The appropriate EF _{PRP} may be selected by using the IPCC values for EF _{PRP} specific to the climate zone in which the farm is located. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1789

Data / Parameter	NE _j
Data unit	kg N ₂ O/head/year
Description	Nitrogen excreted per livestock type
Data source	See Appendix Table A.1.5.3
Value	Select the appropriate livestock type.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1790

Data / Parameter	EF _{N₂O}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Apply the EF that best represent the production system

	<p>In some farm systems animals may graze on crops. Apply the inorganic fertiliser EF that best representing how the animals are grazed for the majority of the year or calculate a weighted average if the number of days on each grazing system is known.</p> <p>For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8 for guidance on determining the relevant rainfall zone.</p>
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report

1791

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	<p>To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8 on how to determine whether the enterprise is located in a leaching zone.</p> <p>Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0</p>
Quality assurance / quality control considerations	<p>Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct.</p> <p>Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.</p>

1792

1793

Data / Parameter	FracGASMsoil
Data unit	(kg NH ₃ -N + NO _x -N)/kg N
Description	Fraction of nitrogen volatilised from urine and faeces deposited on pasture
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [8]
Value	0.21
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1794

1795

Data / Parameter	FracLEACH
Data unit	fraction
Description	Fraction of N that is lost through leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [1]
Value	0.24
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Greenhouse Gas Inventory.

1796

Data / Parameter	EF_{leach}
Data unit	kg N ₂ O-N/kg N
Description	Emission factor for leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [1]
Value	0.011
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

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