DRAFT1 JCPH OWTS Nitrate Loading Model

Jefferson County, Colorado	September 14, 2021
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Onsite Wastewater Standards for the Indian Hills / Parmalee Gulch Area

Onsite Wastewater Nitrate Loading Model (OW-NLM)

Jefferson County Public Health (JCPH), with citizen input, developed a simple mathematical model to evaluate nitrate loading from onsite wastewater treatment system (OWTS) to groundwater. The JCPH nitrate loading model uses a water budget and mass balance approach and the following input parameters:

- *(A)* Kilograms of nitrate per person per year that reaches the groundwater table
- *(B)* Percent of nitrogen remaining after treatment
- *(C)* Percent of nitrogen remaining after attenuation / removal through the soil treatment zone
- *(D)* The average annual precipitation in inches per year
- *(E)* The percent of precipitation available to the nitrate mixing zone
- *(F)* The concentration of nitrate from OWTS in groundwater goal in milligrams per liter
- *(G)* Units conversion factor

Given the above input parameters, the model uses the following equation to calculate the acres of land per person (H) required to meet the nitrate concentration in groundwater goal:

$$H = ABCDEF x\ G$$

The values for the model input parameters presented in the following section were derived from several sources.

(A) Kilograms of nitrate per person per year that reaches the groundwater table

The Buzzards Bay Project [Costa, 1999] adopted a per capita annual nitrogen load to groundwater of 2.7 kg from onsite septic systems. For comparison, Costa provides the following reference:

> *"Reviews of septic system and household sewage discharges by EPA (1980, 1992) showed that per capita nitrogen load from human urine and feces and household graywater (excluding garbage disposal systems) ranged from 2.2-6.2 kg y-1."*

Looking at 2.7 kg of nitrogen per capita from OWTS reaching groundwater in terms of milligrams per liter and assuming a per person water use of 50 gallons of water per day, the concentration of nitrogen in wastewater that reaches the groundwater would be 39 milligrams per liter as follows:

2,700,000 milligrams / 50 gallons per day / 3.78 liters per gallon / 365 days per year =

39 milligrams per liter

Compared to the total nitrogen found in Treatment Level 1 effluent of 60 to 80 milligrams per liter, the 39 milligrams per liter figure represents a 35% (39/60) to 51% (39/80) reduction in total nitrogen.

JCPH selects 2.7 kilograms of nitrate as the per person annual load of nitrate to the groundwater system.

(B) Percent of nitrogen remaining after treatment

The values for the percent of nitrogen remaining after treatment (B) are derived from Colorado Department of Public Health and Environment Regulation 43 Onsite Wastewater Treatment System Regulation and presented in the Jefferson County Onsite Wastewater Regulation Table 12-2.

TABLE 12-2 TREATMENT LEVELS

Treatment level	BOD5 *	CBOD5[1] *	TSS *	Total Nitrogen *
TL1[2]	180	-	80	60-80
TL2	-	25	30	NA[3]
TL2N	-	25	30	>50% reduction[4]
TL3	-	10	10	NA[3]
TL3N	-	10	10	20

* in milligrams per liter (mg/l)

(Gray shading indicates higher level treatment)

Table 12-2 provides the total nitrogen remaining after various levels of treatment. Treatment Level 1 (TL1) represents the treatment of typical domestic wastewater through a properly designed two-compartment septic tank. The total nitrogen concentrations for TL1, 60 to 80 milligrams per liter, are typical values for the concentration of total nitrogen in domestic wastewater septic tank effluent. A Treatment Level 2 system with nitrogen reduction (TL2N) reduces the total nitrogen concentration by approximately 50% over a TL1 system. This equates to total nitrogen concentrations of 30 to 40 milligrams per liter discharged from a TL2N system. The concentration of total nitrogen discharged from a Treatment Level 3 system with nitrogen reduction (TL3N) is approximately 20 milligrams per liter. As such, the total nitrogen concentration discharged from a TL3N system represents a 67% to 75% (midpoint = 71%) total nitrogen reduction compared to the total nitrogen discharged from a TL1 system.

Given the above total nitrogen concentrations for various treatment levels, the nitrate loading model uses the following input values for total nitrogen remaining after treatment:

Treatment Level	Percent of Total Nitrogen Remaining After Treatment
TL1	100%
TL2N	50%
TL3N	29%

(C) Percent of nitrogen remaining after attenuation / removal through the soil treatment zone

The removal of nitrogen in the soil zone is highly variable and difficult to predict. Many factors affect the uptake and/or removal of the nitrogen in the soil zone. The Buzzards Bay Study suggests that after the removal of nitrate in the soil zone by the various mechanisms, 2.7 kilograms of nitrate per person per year makes its way to the groundwater system. As such, the Buzzards Bay Study value of 2.7 kilograms of nitrate per person per year to groundwater represents the amount of nitrate after the attenuation and/or removal of nitrate in the soil zone.

The removal of nitrogen in a subsurface wastewater infiltration system (SWIS) was estimated at 15% in sandy soils and 25% in other soils (loam, clay loam, clay), see the excerpt below from the 2002 US EPA OWTS Manual.

Nitrogen contributions from onsite systems

The San Lorenzo River basin in California is served primarily by onsite wastewater treatment systems. Since 1985 the Santa Cruz County Environmental Health Service has been working with local stakeholders to develop a program for inspecting all onsite systems, assessing pollutant loads from those systems, and correcting identified problems. Studies conducted through this initiative included calculations of nutrient inputs to the river from onsite systems. According to the analyses performed by the county and its contractors, 55 to 60 percent of the nitrate load in the San Lorenzo River during the summer months came from onsite system effluent. Assumptions incorporated into the calculations included an average septic tank effluent total nitrogen concentration of 50 mg/L, per capita wastewater generation of 70 gallons per day, and an average house occupancy of 2.8 persons. Nitrogen removal was estimated at 15 percent for SWISs in sandy soils and 25 percent for SWISs in other soils.

Source: Ricker et al., 1994.

Note, in the excerpt above, the per person nitrogen load is calculated to be 4.8 kilograms per year as follows:

(50 milligrams/liter) x (70 gallons/day) x (3.78 Liters/gallon) x (365 days/year) x (1 kilogram/1,000,000 milligrams) =

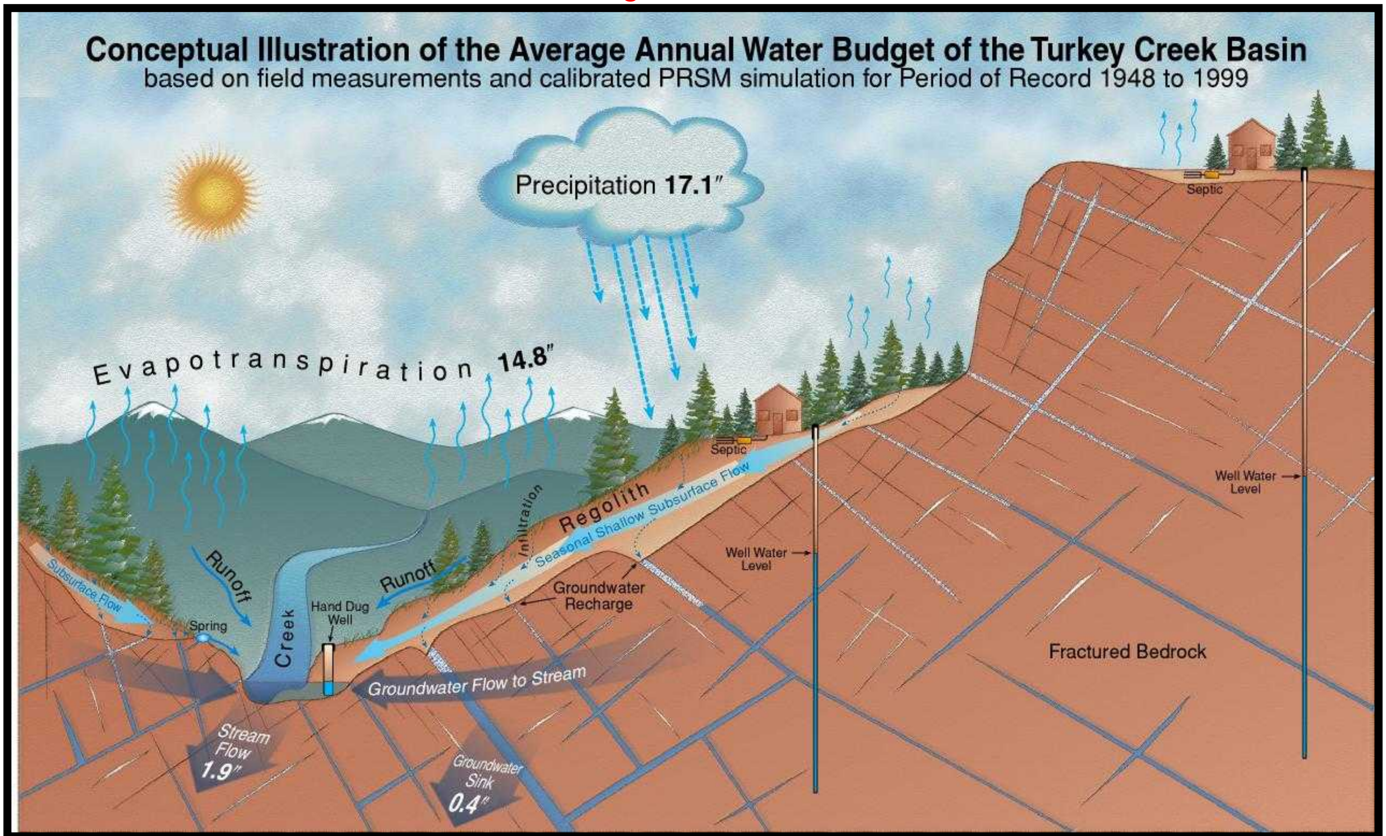
4.8 kilograms of nitrogen per person per year

The annual per person nitrogen load of 2.7 kilograms used in the model for variable A, compared to the 4.8 kilograms of nitrogen per person per year calculated above, represents a 43% decrease in the nitrogen load. As previously mentioned, the 2.7-kilogram figure represents the amount of nitrogen that makes it way to the groundwater table by accounting for the nitrogen that is removed and/or attenuated as the septic tank effluent passes through the soil zone. The 4.8-kilogram figure represents the per person nitrogen load found in septic tank effluent and does not consider attenuation and/or removal of nitrogen as the OWTS effluent passes through the soil zone to the groundwater table. Based on the above, JCPH selects 100% (of 2.7 kilograms) as the value for variable (C) in the nitrate loading model.

***(D)* The average annual precipitation in inches per year**

The annual precipitation in Jefferson County is variable. The measured precipitation in and near the Turkey Creek Basin reported in the Table 14 [Bossong, 2003] from 1949 to 2001 ranged from a minimum of 9.47 inches per year to maximum of 23.18 inches per year with a mean value of 16.49 inches per year. The annual summary statistics for the 50-year (1949 to 1999) Precipitation-Runoff Modeling System (PRMS) simulation, yielded a mean (average) annual precipitation value of 17.13 inches per year [Bossong, 2003, Table 30]. Based on the PRMS simulation, the following conceptual illustration of the average annual water budget for the Turkey Creek Basin was developed by Jefferson County Planning and Zoning and Jefferson County Public Health.

[Continue to the next page.]



Given the above, JCPH selects 17.1 inches per year as the input parameter for the annual average precipitation (D) in the nitrate loading model.

***(E)* The percent of precipitation available to the nitrate mixing zone**

The fate of precipitation in the upper mountain counties of the South Platte Basin, which includes Jefferson County, is described and illustrated in Section 3.2.1.2 of the Camp, Dresser and McKee (CDM) report [CDM 2011]. As indicated in this report, only a portion of the precipitation is available to mix with and dilute the nitrate discharged from OWTS into the soil zone. The Site Water Budget Conceptual Model presented in CMD 2011 Figure 3.7 illustrates that evapotranspiration is supported by flow from precipitation and flow from the soil zone.

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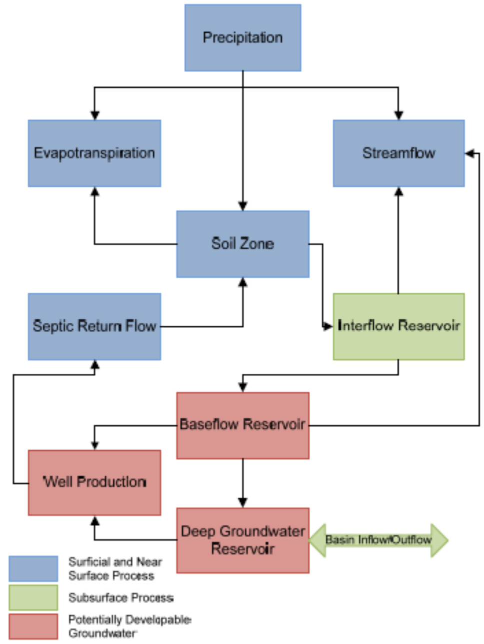

Figure 3-7 Site Water Budget Conceptual Model

CMD 2011 Figure 3.9 illustrates that 86.5% of precipitation is consumed by evapotranspiration directly from precipitation and from the infiltration of precipitation into the soil zone. Of the remaining 13.5% of precipitation that infiltrates into the soil zone, 11.5% flows to surface water via overland flow (approximately 0.5%), interflow (approximately 5%) and baseflow (approximately 6%). The remaining infiltration from precipitation, approximately 2%, flows to the deep groundwater.

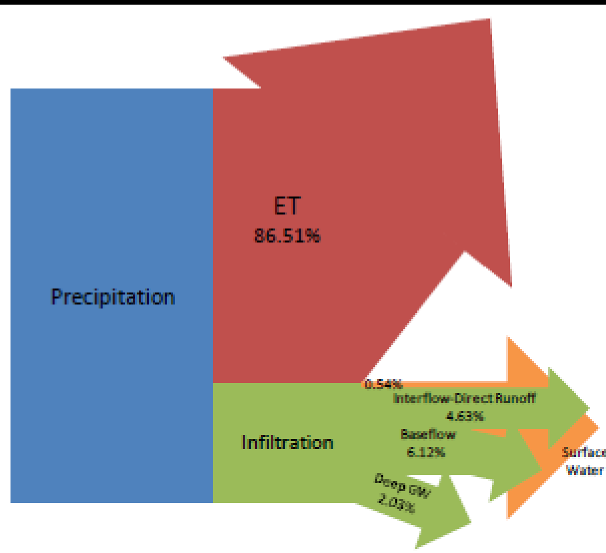

Figure 3-9 Precipitation Partitioning based on Turkey Creek Study

Given the conceptual model of the partitioning of precipitation into and through the soil zone, the amount of precipitation available to dilute the nitrogen discharged from OWTS into the soil zone is at least 13.5% plus a portion of the evapotranspiration that emanates from the soil zone. Based on the conceptual model of the fate of precipitation and our general understanding of soil zone (regolith), transpiration, and the fate of OWTS effluent in the soil zone, JCPH estimates that the amount of precipitation available to mix with and dilute the nitrate from OWTS effluent to be 20% and selects this value for variable (E) in the nitrate loading model.

_(F)_ The concentration of nitrate from OWTS in groundwater goal in milligrams per liter

The US EPA safe drinking water standard for nitrate is 10 milligrams per liter. This value was selected for the nitrate loading model as the goal for the concentration of nitrate in the groundwater system. Given the natural background concentration of nitrate in groundwater is approximately 1 to 2 milligram per liter, the additional load of nitrate load from OWTS effluent must be less than or equal to 8 milligrams per liter for the total concentration of nitrate from natural groundwater and from OWTS effluent to meet, or be less than, the 10 mg/L nitrate in groundwater goal. Therefore, JCPH selects 8 milligrams of nitrate per liter as the value for variable (F) in the nitrate loading model.

_(G)_ Units conversion factor

The unit's conversion factor is required to account for the units of the various input parameters. The unit's conversion factor = (1,000,000 milligrams per kilogram) * (12-inches/1-foot) * (1-acre/43560 square feet) * (1-cubic foot/7.48 gallons) * (1-gallon/3.78-liters) equals = 9.74 (mg-inch-acre)/(kg-liter)

DRAFT1 JCPH OWTS Nitrate Loading Model

OWTS NITRATE GROUNDWATER LOADING MODEL Version 5

The following represents an OWTS nitrate groundwater loading model run using the input parameters identified in the previous section. The model calculates the number of acres required per person to dilute and attenuate the per person nitrate load to groundwater to meet the nitrate in groundwater goal.

Input Value
Conversion Factor
Calculated Value

DESCRIPTION OF PARAMETER	VARIABLE	VALUE	COMMENT / INSTRUCTIONS / SOURCES / REFERENCES
Kilograms of nitrate per person per year that reaches the groundwater table	A	2.7	See Buzzards Bay Study for the selection of this value.
Percent of nitrogen remaining after treatment	B	29%	Per JCPH OW Regulation Table 12-2 For TL1, TL2 and TL3 use 100% For TL2N use 50% For TL3N use 29% (ranges from 25% to 33%)
Percent of nitrogen remaining after nitrogen attenuation / removal through the soil treatment	C	100%	The amount of nitrogen remaining after soil treatment can range from 10% to 100% depending nitrogen removal processes in the soil, such as, biotransformation, denitrification, plant uptake. See Siegrist, Geza, Farrell and others.
Average annual precipitation in inches	D	17.1	Precipitation data for the Turkey Creek Study (Bossong 2003) reports a precipitation range of 9.47 to 23.18 inches per year with a mean of 16.49 inches per year and a PRSM value of 17.13 inches per year.
Percent of precipitation available to the nitrate mixing zone	E	20%	Figure 3-7 and 3-9, Upper Mountain Counties Report (CDM 2011), presents conceptual models of the water budget and precipitation partitioning based on the Turkey Creek Study.
OWTS nitrate in groundwater goal in milligrams per liter	F	8	Using the EPA safe drinking water standard of 10 mg/L nitrate and a background value of 2 mg/L nitrate, the nitrate contribution from OWTS effluent must be 8 mg/L or less to keep the total nitrate concentration in groundwater at or below the EPA safe drinking water standard.
Units conversion factor	G	9.74	= (1,000,000 mg/kg)*(12-inches/1-foot)*(1-acre/43560-square feet)*(1-cubic foot/7.48-gallons)*(1-gallon/3.78-liters)
Acres required per person to dilute and attenuate the annual per person nitrogen load to groundwater to achieve the groundwater nitrogen goal	H	0.28	$H = ABCDEFx\ G$

REFERENCES

Bossong, C.R., J.S. Caine, D.I. Stannard, J.L.Flynn, M.R. Stevens, and J.S. Heiny Dash. 2003. Hydrologic Conditions and Assessment of Water Resources in the Turkey Creek Watershed, Jefferson County, Colorado, 1998–2001. USGS Water Resources Investigations Report 03-4034, Denver. http://pubs.usgs.gov/wri/wri03-4034/pdf/wri03-4034.pdf

Costa, J. E., B. L. Howes, D. Janik, D. Aubrey, E. Gunn, A. E. Giblin. 1999. Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis and evaluation of a management strategy adopted for Buzzards Bay. Buzzards Bay Project Technical Report. Draft Final. September 24, 1999.

Camp, Dresser and McKee (CMD). 2011. Upper Mountain Counties Aquifer Sustainability Project – Final Report. CWCB SWSI.

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Soil Treatment

Typical Concentration of Domestic Wastewater Contaminants

(Reference: EPA OWTS Manual 2002/625/R-00/08 and M Gross 2004)

Parameter	Units	Septic Tank Influent	Septic Tank Effluent Applied to Soil Treatment Area (STA)	% removal after percolating through ~ 4 feet of soil
Total suspended solids	Milligrams / liter	250	60	> 90 %
Biochemical oxygen demand	Milligrams / liter	250	120	> 90 %
Fecal Coliform Bacteria	Coliform forming units / 100 milliliters	10 million	1 million	➢ 99.99 % (1 thousand)
Nitrogen	Milligrams / liter	60	60	10 to 20 %
Phosphorus	Milligrams / liter	10	8.1	0 to 100 %

CONVERSION FACTORS

1 kilogram = 1,000,000 milligrams

1 foot = 12 inches

1-acre = 43,560 square feet

1-cubic foot = 7.48 gallons

1-gallon = 3.78 liters

LIST OF GROUNDWATER MODELS REVIEWED

STUMOD – Geza, McCray, Lowe et al

Hansen Allen & Luce 2016 Model

Colorado State Engineer 1985 Model

Hezog Model 2016