Review for the following manuscript:
Journal: BG
Title: Influence of urban infrastructure on water quality and greenhouse gas dynamics in streams
Author(s): R. M. Smith et al.
MS No.: bg-2016-380
MS Type: Research article

First, my apologies for taking so long on this review. I had a personal crisis and lost track of my work responsibilities for a bit. I also apologize for the length; please respond in writing to comments only, and not all supporting examples.

General comments:
Summary for editor: This paper examines greenhouse gas saturation and emissions in urban streams, both across outflows of different green infrastructure, and spatially, across stream orders, within two stream networks. It finds super-saturation and emission levels comparable to or above those previously found in agricultural headwaters. Spatial variation is apparent, but not clearly analyzed.

Comments: This paper makes a substantial new contribution to understanding of greenhouse gas (GHG) emissions from urban headwaters. It is not clear what proportion of global GHG emissions might come from urban headwaters, and perhaps this global climate change framing used by the authors is not the most or only significant implication of their project data anyway. That said, the paper does point to biogeochemical and infrastructure controls on those emissions in a novel way. The data and its apparent trends as shown graphically are interesting. However, the paper as currently written has severe flaws, including substantial missing pieces of methodology, a multiple comparisons problem and lack of statistical analysis of part of the data that make any statistical interpretation of the results questionable at best, and significant room for improvement in clarity of the writing. I cannot recommend that this paper be published without heavy revision. It definitely appears to contain biogeoscientific information meriting publication, but it is impossible to say for sure from the current presentation of that information.

Specific comments: Numbers preceding examples refer to page number (line number). Please do not respond in writing to every example; just responding to each comment will suffice. The comments are roughly ordered from most to least concerning.

Comment 1: This paper appears to lack some methodological information, some of which is important and makes it difficult to assess what you did. For example:

- 4(22-24) and Table 1: You may want to explain why you decided to treat these watersheds as four categories of two replicates each, rather than eight watersheds varying continuously along a few axes (impervious surface cover, development age, etc.). I think the reason of different discrete stormwater infrastructure design types going with developments built at different times makes sense; you just might want to state it a little more explicitly.
- 4(26-28): Over what time period (i.e. year(s), season(s)/month(s)?, times of day?) Actually, you should probably give much of this this information earlier than this section, and I don't think you did.
- 5(5): How did you define a study reach? Approximately how long were study reaches? This information should come up in the previous section.

- 5(8): Is this the timing for the methods described in section 2.1.2 also? If so, say so, earlier.
- 5(17) & 8(21): "Estimated using Google Earth software" sounds a bit sketchy. If you must mention Google Earth, include a citation for the program. Ditto at 8(21)), and also, what's the precision on the Google DEM, and why didn't you use the lidar one mentioned in 5(19-20); is it not more precise?
- 5(17-20): There are multiple ways to make these calculations; what actual commands or tools did you use to do this?
- 8(14, 17, & 24) & 9(1-4): What is K_{20}? You did not previously explain what GT (from K_{GT}) means in general terms, so if that explanation was supposed to translate, it does not do so effectively. Ditto with K_{SF6} and plain K; are those at ambient temperature?
- 8(20) You say you, "measure[ed] the change in elevation over a reach with a handheld GPS unit." Isn't elevation from GPS units usually rather unreliable? Describe the precision of your GPS unit.
- 12(26): Can you not distinguish (or at least venture an educated guess) between "C and N inputs and/or microbial metabolism," based on measurements/calculations of these gases individually, together with those of other gases?
- Missing: How did you analyze "longitudinal variability," or the effect of "distance from watershed outlet," on any of the response variables, i.e., the output of the method described in section 2.1.3? You make claims about the results of this survey in section 3.6 and display graphs derived from the data in Fig. 5, and then about the significance of these findings in 14(10-18). However, it's never apparent that you did more than eyeball that data to assess spatial trends. Moreover, my eyeballing does not match your eyeballing; I don't see Fig. 5 as reflecting the patterns you describe in the text.

Comment 2: In your statistical methods (section 2.4, "Statistical Analyses,") you execute a number of models (linear mixed effects, stepwise linear regression, etc., yielding all the results in Table 2 and 5) testing similar or related things. This may constitute a statistical multiple comparisons problem, i.e. increased chance of Type I error (https://xkcd.com/882). Consider either combining models (e.g. in a structural equations modeling framework or similar) or correcting for this risk of error. At the very least, try to combine your categorical and continuous variables for into a single model for each gas.

Comment 3: Some interpretations of your results, most but not all minor, don't entirely make sense, or seem incomplete. For example:

- Section 3.6 and 14(10-14):
- 12(16-17): Are you sure the "influence" is actually "indirect" on "biogeochemical processes in streams," or does the "indirect" part really only apply to GHGs? It seems like those things listed are directly related to biogeochemistry in general.
- 12(23): Plain "nitrogen" or "*inorganic* nitrogen?"
- 13(9-10): "stoichiometric conditions more favorable for denitrification" would be a DOC:nitrate ratio closer to 1:1? If that ratio is different in incoming groundwater, wouldn't the N_2O:CO_2 ratio from that groundwater be correspondingly different as well?
- 13(24-25): You've made a big jump here, from relatively high emissions in certain places to "globally significant." Consider reminding your reader ("reminding" insofar as this should go in the introduction first; currently it's all just missing) what it would take for these locally high emissions to be globally significant- what's the

relative global contribution of streams in general; how much of global streams is urban stream, etc. It might make more sense to think of the impacts of NO_2 emissions in the city in terms of local air pollution than global GHGs. You might also think about if your findings suggest anything new for general biogeochemistry, as opposed to just the GHG emission application.

- Section 3.5 and Fig. 4b: Why do you think the slope directions of the lines in Fig. 4b so variable? Address this in discussion.
- 14(10-18): See comment after "missing," in Comment 1; it is unclear if you did a statistical analysis to support these claims.
- 15(17-18): "Variation in nonpoint sources and flowpaths" is not really an independent variable you tested; you don't know what in the watershed, but outside the stream, is driving anything, beyond a bit of inference about groundwater.
- Table 5: You never interpret your K_{20} results in the discussion.
- To put your results in context a bit better, see Gallo et al. 2014 ("Physical and biological controls on trace gas fluxes in semi-arid urban ephemeral waterways" in Biogeochemistry 121(1) pp.189-207). They did related measurements in ephemeral streams in urbanized deserts, with similar results. For just nitrous oxide emissions from urban streams, there are several more relevant papers; try searching "nitrous oxide urban stream," in Web of Science if you can. (No, I am not Gallo et al.)

Comment 4: You refer several times to a gradient or continuum of stormwater infrastructure, but you never elucidate the relationships between or ordering of the infrastructure types that makes them constitute a gradient or continuum. Explain, up front and early. For example:

- 2(29): Is the "along the urban watershed continuum" significant? Does something change along this gradient about the effect of the wetlands, or do you just mean "in urban watersheds?"
- 1(16): It is not immediately clear how these seemingly discrete categories constitute a "a gradient of stormwater and sanitary infrastructure"- gradient along what axis, what variable?
- 3(20-21): "Urban watershed continuum" again- is that just a way to refer to the stretch from the infrastructure in the headwater downstream a bit, or are the different kinds of infrastructure arranged along a continuum, or what?
- 5(22): This is the closest thing to an explanation you've made so far, and it still doesn't really make sense.

Comment 5: You could improve this paper by reducing vague and occasionally careless diction. Sometimes this problem makes your meaning somewhat unclear. For example:

- 1(22): "These variables" refers to the "drivers of GHG dynamics," "infrastructure categories," or both? If it's the former, I guess this line just verifies that "nitrogen stoichiometry" etc. *are* in fact "drivers of GHG dynamics" in this context (as expected); if "these variables" are the "infrastructure categories," then it's a much more novel finding.
- 2(16-17): When you talk about GI here, are you proposing that all GI will have the same effects, at least in terms of direction of change in GHGs, or might effects differ depending on GI type?

- 2(20): "Source of uncertainty" for what? Do you just mean "uncertain," or do you mean that this role could change our understanding of global fluxes from rivers, or what?
- 3(5-7): Reconsider word choice of "control;" option 2 doesn't seem to be an instance of control per se. "Determine?" Here is a spot where you could probably get away with one of those less specific verbs.
- 3(10): Specify *anaerobic* nitrification; this is unclear until 12(29). With plain "nitrification," it at first seems like N_2O must be a typo for NO_2^-. You also need a source here for the description of nitrification; I don't think Taylor and Townsend 2010 suffices.
- 3(18): "GHG emissions"- what about them? "Increased GHG emissions?"
- 3(28): Go ahead and be more specific than "water chemistry" if you can do so concisely.
- 4(8): "Reflects" what? I think you mean the timing of development. Maybe rephrase: "…developed in the 2000s *with* more infiltration-based designs..."
- 4(18): Maybe "…exists in various forms*, including* gravity sewers and septic systems*,* as well as a gradient…" or "…exists *as both* gravity sewers and septic systems *along* a gradient…"rather than the current, more ambiguous, "…exists in varying forms (gravity sewers and septic systems) as well as a gradient…."
- 11(28): "Consistent along the drainage network for Red Run and Dead Run": do you mean looking intra-Red Run drainage network and intra-Dead Run drainage network, or are you looking at both together as part of a larger drainage network? I think you mean the former, but your phrasing is unclear?
- 12(25): Instead of "Varying forms," just "form."
- 12(27) & 15(13): Provide a citation for "'hot spots'" if you're going to put it in quotes, so we can verify which definition of "hot spot" you mean. Also, decide if you're going to say, "'hot spot'" or just "hotspot;" be consistent.
- 12(30): "The source," or just "the primary source," or "a source?"
- 15(1): By "variations" you mean "differences?"
- 15(6): "Methodology" or "assumptions" (or "methodological assumptions")?
- 15(20): "Ecological?" What does that mean here?
- 15(23): "Role" or "influence?"

Sometimes your point could be stronger if you provided concrete numbers to back up your assertions. For example:

- 2(3-4): Consider fleshing out "globally significant" with some actual numbers? Also, if you have space, it might not hurt to explain very briefly how this impact of rivers and streams on GHGs was determined. It is unclear here whether the figures you cite include urban streams or not, and why. In other words, could knowing about urban stream GHGs make these fluxes more or less "globally significant?" Without this piece of information, it is unclear if all of the potentially contributing factors to urban stream GHG emissions that you describe in the rest of the paragraph are already accounted for in the currently accepted stream GHG numbers and you're just partitioning sources, or if you might revise the numbers on stream GHG fluxes as a result of this study.
- 2(13): What does "substantially" mean? Can you provide numbers as to the relative contributions of nonpoint and point sources?
- 3(22-24): How is human population relevant? Also, please contextualize "fastest form of land use change;" that statement alone isn't really enough to ascertain significance. Is the magnitude of the change (i.e. first derivative of land use rather

than second derivative) large? Is urban land use large, relative to other uses? Or do you think urban watersheds contribute disproportionately much to GHGs for their size, and so are significant globally even if small?

- 12(6): Which were the "three high-flow sampling dates?"

Sometimes you waste valuable space by not going ahead and saying what you actually mean. For example:

- 1(27-29): Your concluding sentence is rather vague; for a start, "influenced" could mean almost anything. Could you be a bit more specific about what the "influence" was and what the "implications" are?
- 2(9): Again, on "implications," try to be less vague if you can do so concisely. "Increase or decrease" or "change the magnitude of?" "Alter seasonality of?" Etc.
- 14(5): By "relative proportion of different gases," do you actually mean "methane production?"
- 15(1): By "typologies" you mean "types?"

Comment 6: Remember to maintain coherence and clarity of the paper through clear transitions, linking similar ideas, defining terms the first time you mention them, etc. For example:

- Abstract: You don't describe your "longitudinal" results here (the ones along stream length).
- 2(21-23): How do these numbers/methods for calculating global fluxes that you cite here compare to the ones in 2(2-3)?
- 2(24-25): Consider "Some key differences *between the watershed types that might affect this relationship* include," for clarity. Alternatively, "…may differ substantially *between* urban and agricultural watersheds *due to contrasting biogeochemistry and hydrology*. Some key differences…"
- 2(25-26): For clarity, consider something like, "*In urban watersheds, these factors likely vary with* stormwater and sanitary sewer…"
- 3(5): Consider ending this sentence with an "as well," or similar to tie back to previous sentence.
- 3(29)-4(2): The final sentence in this paragraph seems out of place. Maybe shift it to the start of the next paragraph and end with, ", which facilitated site selection," or something? If you don't move the sentence, at least go ahead and explain why this information store matters. I mean, I can guess, but I shouldn't have to do so, or to wait until you bring it up again later. Maybe just collapse the first two paragraphs into one?
- 4(5-6): Clarify timing. Everything was put in place in the 1950s-1970s, and the aging and cracking is now (or rather, when this study was conducted)? Also, "between" or "from?"
- 4(13): Remind us *which* eight streams- "…the eight streams *studied* drained…?"
- 4(14-20): Some of this description of what types of infrastructure were built when might go better in the introduction. Or at least, you might want to introduce the concept of change in design through time in the introduction.
- 4(12-16): This sentence has a bit of a run-on feel; consider breaking down. Also, does "stormwater infrastructure… encompass older designs" *and* the newer GI ones? The way the sentence breaks doesn't suggest so. You could say, "We define stormwater infrastructure broadly to encompass older designs such as stormwater drainage networks and newer forms of 'green' stormwater infrastructure (GI)," and then define each in a sentence (or so) each.

- 5(20): Unclear how GIS calculations in previous sentence are used; abrupt transition back to "these surveys" is hard to follow.
- 5(25): "Relative contributions of inflow" *to groundwater*?
- 12(30)-13(1): Consider referencing figures here (and more elsewhere in the discussion) to make it easy for readers to look back at the ratios etc. that you mention.
- 13(27)-14(9) & 15(5-9): Most of this information should go in the introduction. You can refer back to it here insofar as your findings update or add to it, but it's unclear that they do. It does not seem entirely relevant here.
- 14(16): "Detailed information" is not in itself a "step;" you need a verb, e.g. "*Finding* detailed information."
- 14(3): You could use "however" or another transition word before "these."
- 14(31-32): You do not make it clear how this information about plants is relevant. Are you saying that some other type of plant within the waters you surveyed might be releasing methane in this way, but you didn't measure it? There are no transitions into or out of this part about the plants, either.
- 15(9-11): This sentence goes with the end of the last paragraph.
- 15(26-27): It is unclear how exactly this part about wastewater relates to your results. Either make your transitions more clear, or move this sentence to a different section.
- 15(28): You have not brought up the concept of mitigation before, and it isn't immediately obvious if mitigation per se is the goal, or how your results translate to doing mitigation. Elaborate.

Technical corrections: Again, numbers preceding comments refer to page number (line number). Please do not feel obligated to respond to all of these; just make sure you have them the way you want them in the final version.

- 1(30): "Infrastructure" misspelled. Also, consistent capitalization of keywords?
- 3(9-10): Instead of, "nitrification is a chemoautotrophic process that produces," you could just say, "nitrification chemoautotrophically produces," (and then switch ", and consumes" to "and consuming") for brevity.
- 3(27), 5(20), & 7(22-23): Is just sticking a web link in here appropriate? For 5(20) and 7(22-23) especially, I think you need proper citations.
- 3(28): ", which" would be more grammatically appropriate than "that."
- 4(7): "In-line?" Repeats throughout document- just make sure you want "in-line" and not "inline" or "in line."
- 4(11-12): Maybe "and" instead of "that are;" the phrasing of this sentence is a bit awkward. Also, I think you could avoid the passive tense of "are located" ("exist?").
- 4(26): "First-order streams" instead of "first order streams," yes?
- 4(27-28): I'm not sure why you repeat all the categories when you just said them and even *said* that you just said them. Also, here you capitalized the categories and put apostrophes around them, whereas you didn't in the last sentence; pick a format, and be consistent.
- 4(32): "Septa" or "septum?"
- 5(3), 7(16), 10(11), & 13(26): Remove tab for consistent paragraph formatting.
- 5(3-4): Consider rephrasing for clarity and brevity, e.g.: "A single stream water sample was collected in a 250 mL high-density polyethylene bottle at each site. One sample duplication rotated site each sampling date."
- 5(10): Unnecessary "to."

- 5(15-16): Can shorten slightly by removing passive tense, i.e. "USGS provided discharge data." Also, consider providing a citation for the USGS data here.
- 6(9): "To *the* University?"
- 6(12): "Underestimates" or *underestimations*? Also, what "it" refers to is a bit unclear.
- 6(13 & 24), 10(3), 11(23), & 13(7): "*Via*" and "*vs.*" need not be italicized.
- 6(16 & 19): Move "(DOM)" up to first use.
- 6(19-20 & 27-28): You essentially describe what molecular weight characterizes which source twice in a row, and do it better the second time; condense.
- 7(4): "Eq.'s?" Maybe just write it out.
- 7(4): "Rations" or "ratios?" (Pretty sure you mean "ratios.")
- 7(5): If you must put a comma before "(μmol L^{-1}), I think you need one after too.
- 7(11) & Table 1: Combine things in parentheses in "(Eq. 3) (Stumm and Morgan 1981)." Similar change needed at end of caption for Table 1.
- 7(19): "-" may be unnecessary.
- 8(4): "In" or "at?"
- 8(7): "From" or "by?"
- 8(8): "Were," not "where."
- 8(8-9): "Would be indicative of" can be shortened to "would indicate" or even "indicates." You could also remove, "other CO_2 sources, namely."
- 8(26): "P= " or "p=?"
- 8(27): Provide units again for "±0.058."
- 9(13): Escaped ")."
- 9(19-20): Lost sentence fragment.
- 11(9): Second comma unnecessary. Also, why "may be," and only in second alternative explanation?
- 12(16): "Typologies however," should probably be, "typologies, however."
- 12(22): You can shorten, "were present across all four infrastructure typologies (Fig. 4c), which suggests," to "present across all four infrastructure typologies (Fig. 4c) suggest."
- 12(30): "Concentrations suggest that" should be, "concentrations, suggesting that."
- 13(24): "Warrants," not "warrant."
- 14(23): "With DOC:NO^{3-} while other" could use a comma in the middle (i.e. "with DOC:NO^{3-}, while other."
- 15(1-2): Isn't there just the one negative relationship? ("The negative relationship" instead of "negative relationships.")
- Table 1: Header word spacing is awkward.
- Table 4: In caption, "* Indicate" should be something like, "A '*' indicates," based on comparable sentences elsewhere.
- Table 5: You may be missing some commas towards the end of the list in the caption.
- Figure 1: "Sampling sites and black dots signify" should have a comma after "sites."
- Figure 2: "Points signify data points," in the caption is a bit confusing; consider removing the second "points."
- Figure 3c: I know it will mess with the clarity of your outliers, but consider some kind of log scale here; the differences between the actual boxes and whiskers are almost completely unapparent.

- Figure 3: In caption, “box and whiskers signify the median, first and third quartiles,” is unclear phrasing. At minimum, I think “box” needs to be plural.
- Figure 5: Consider combining identical keys for panels (e) and (f), and perhaps some of the identical axes across panels as well. Unpunctuated letters representing figure panels within the caption text, e.g. “in panels a through d signify a saturation,” are confusing; “a” is also a word. Also, more specific date here?
- 15(16): “Of aquatic ecosystems” is in the middle of a list which relates to it (either end would make more sense), and the “as well as” and “significantly alter” seem unnecessary; commas would do.
- 15(25): “Include” not “includes.”