January 14th, 2022

VIA EMAIL
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Subject: Bishop Tube Public Comment

The Pennsylvania Department of Environmental Protection (PADEP) has failed to fulfill its regulatory, statutory, and constitutional obligations with its remedial action proposal for the Bishop Tube Site.

PADEP released this remediation proposal prematurely, seemingly in response to the fact that PADEP is the subject of a legal challenge, rather than having a fully composed and understood remediation plan that complies with the law and is appropriate for public review and comment.

Contamination concentrations in the surface and groundwater at and near the site represent a threat to human health and the environment. The proposed Analysis of Alternatives and Remedial Response (AOA) fails to address known contamination at, and leaving, the site; the AOA is fraught with misinformation that prevents formation of an informed plan that will effectively and completely address contamination at the site and ensure compliance with the law and protection of human health and the environment.

The AOA Fails to Fulfill Requirements of Law.

Pursuant to Article 1, § 27 of the Pennsylvania Constitution:

> The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.

Pursuant to Hazardous Sites Cleanup Act (HSCA):

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> Where there is a release or substantial threat of release of a contaminant which presents a substantial danger to the public health or safety or the environment or where there is a release or threat of a release of a hazardous substance, the department shall investigate and, if further response action is deemed appropriate, the department shall notify the owner, operator or any other responsible person of such release or threat of a release if such persons are known and may allow such person or persons to investigate and undertake an appropriate response, or may undertake any further investigation, interim response or remedial response relating to the contaminant or hazardous substance which the department deems necessary or appropriate to protect the public health, safety or welfare or the environment.

35 P.S. § 6020.501(a).

> The department *shall* undertake or cause to be undertaken by the owner, operator or any other responsible person as permitted under subsection (a), investigations, monitoring, surveys, testing and other similar activities necessary or appropriate to identify the existence and extent of the release or threat of release, the source and nature of the hazardous substances or contaminants and the extent of danger to the public health or welfare or the environment.

35 P.S. § 6020.501(d) (emphasis added).

> Final remedial responses under this act *shall* meet all standards, requirements, criteria or limitations which are legally applicable or relevant and appropriate under the circumstances presented by the release or threatened release of the hazardous substance or contaminant and shall be cost effective.

35 P.S. § 6020.504(a) (emphasis added).

PADEP must base its response action on an administrative record. 35 P.S. § 6020.505(a). In preparing the administrative record, PADEP is required to have a public comment period and hold a public hearing. 35 P.S. § 6020.506(c), (d).

> At the close of the public comment period, the department shall file a statement of the basis and purpose for its decision. The statement shall include findings of fact, an analysis of the alternatives considered and the reasons for selecting the proposed response action. It shall include an explanation of any major changes in the response action from that described in the notice. The department shall also file a response to each of the significant comments, criticisms and new data submitted in oral or written presentations during the public comment period.

35 P.S. § 6020.506(e).

The Department issued an Analysis of Alternatives and Remedial Response report on or about August 17, 2021. The AOA divides the site into three operable units ("OU").

- OU1 - soil contamination at the site
- OU2 groundwater at the site
- OU3 - drinking water impacts

The AOA identifies the following five (5) alternatives for OU1 (soil):

- Alternative 1 - No Action
- Alternative 2 - Engineering Controls, Coupled with ICs
- Alternative 3 - Excavation with Offsite Treatment and/or Disposal
- Alternative 4 - Excavation with Onsite Treatment
- Alternative 5 - In Situ Chemical Oxidation/In Situ Chemical Reduction ("ISCO/ISCR"), Coupled with Soil Mixing

The AOA identifies the following five (5) alternatives for OU2 (groundwater):

- Alternative 1 – No Action
- Alternative 2 – Monitored Natural Attenuation (MNA)
- Alternative 3 – In Situ Injection (ISCO/ISCR/Bioremediation)
- Alternative 4 – In Situ Thermal Treatment ("ISTT")
- Alternative 5 – Hydraulic Control ("HC")

The AOA proposes Alternative 5 for OU1 (Soil), and Alternative 3 for OU2 (Groundwater).

The AOA is based largely on the Remedial Investigation Report (RIR) and Feasibility Study (FS) conducted by Roux Associates, Inc. on behalf of former site operators. Initially, the FS considered seven (7) groundwater remediation alternatives:

1. No action
2. Monitored natural attenuation
3. In situ chemical reduction that includes involving the injection of chemical amendments to treat organic contaminants
4. In situ chemical oxidation that includes involving the injection of chemical amendments to treat organic contaminants
5. Enhanced reductive chlorination that includes involving the injection of chemical amendments to treat organic contaminants
6. Two-part in-situ chemical oxidation that includes involving the injection of chemical amendments to treat organic contaminants
7. Hydraulic control

An eighth alternative was considered in an addendum document that combined soil and in situ chemical reduction but reduced the number of areas to be treated. The options for OU1 and OU2 proposed by PADEP in the AOA are largely the same as FS Alternative 8.

PADEP's chosen options would leave substantial TCE in place by failing to treat a number of known areas of contamination and by failing to fully treat/remove TCE in the locations that are treated. Leaving TCE on site ensures that there will continue to be ongoing contamination, and fails to provide the remediation or protection required by law or needed by the community and our environment. In addition, this proposal includes the injection of as-of-yet unknown chemicals that could themselves become problematic or react with contamination on site that will result in additional releases of contamination.

Removal of contaminated soil from the site for treatment is an essential component of an effective solution, but was rejected by PADEP at the behest of the responsible parties rather than because it wasn't the right proposal for human health and the environment.

The Remediation Plan Fails to Meet Anti-Degradation Protections Required for Little Valley Creek and Associated Wetlands.

The Little Valley Creek is classified as an exceptional value stream. *See* 25 Pa. Code § 93.9f. Pursuant to regulation, its associated wetlands are also given this same exceptional value designation and associated protections. 25 Pa. Code § 105.17(1)(iii). As a result of this special protection waters designation, the Little Valley Creek and Associated wetlands are the subject of heightened antidegradation protections and standards.

In Pennsylvania, "[t]he water quality of Exceptional Value Waters shall be maintained and protected." 25 Pa. Code § 93.4a(d). Any:

> person proposing a new, additional or increased discharge to . . . Exceptional Value Waters shall evaluate nondischarge alternatives to the proposed discharge and use an alternative that is environmentally sound and cost-effective . . .. If a nondischarge alternative is not environmentally sound and cost-effective, a new, additional or increased discharge shall use the best available combination of cost-effective treatment, land disposal, pollution prevention and wastewater reuse technologies.

25 Pa. Code § 93.4c(b)(1)(i)(A). Further, PADEP is prohibited from issuing a general NPDES permit for any point source that discharges to a surface water classified as an Exceptional Value Water under Chapter 93. 25 Pa. Code § 92a.54(8).

Rather than consider these antidegradation protections as mandatory ARARs, PADEP treated these standards and this EV protection as something simply "To Be Considered." As a result, PADEP neither mandated nor recommended a plan that will achieve the appropriate exceptional value regulatory standards applicable to Little Valley Creek and its wetlands. *See* 35 P.S. § 6020.504(a); Applicable or Relevant and Appropriate Requirements (ARARs) for Cleanup Response and Remedial Actions in Pennsylvania, 262-4500-606, 13-14 (2013).

The Remediation Proposal Fails to Protect for Residential Development of the Site.

The site has been rezoned to accommodate a residential use, a residential development of approximately 90 homes is proposed for this site, and a residential site preliminary plan has been approved by the Township. It is clear that the proposed future use of this site, against the wishes of the community, is a residential development. Therefore, remediation of the site must meet the highest standards available for residential use.

The RIR and FS on which the AOA is based, however, expressly states that the analysis is based on the assumption that present and future use of the Site will be non-residential only. Feasibility Study Report - Former Bishop Tube Property, at 2 (Jan. 13, 2021) ("As agreed with [PA]DEP, both this FS Report and the 2021 RIR assume that present and future use of the Property will be non-residential only."). The failure by PADEP to address a residential end use of the site while investigating the feasibility of various remedial alternatives is a fundamental failing. This is especially true where, as here, Statewide Health Standards are being utilized as part of the cleanup standards for the remediation. Statewide Health Standards vary based on

whether the end use is residential or nonresidential. Thus, a cleanup plan selected based on its ability to achieve Statewide Health Standards for a nonresidential end use will not meet the standards required for a residential end use.

While the community is 100% opposed to any development of this site and is demanding that all government officials work to ensure its protection as natural open space, in perpetuity, for the benefit of the community, currently the proposed-approved-use is residential. Therefore, the evaluation process must be initiated with an understanding that the end goal of the remediation plan is a residential use. Instead, however, PADEP based its AOA on multiple reports that assumed the site as a non-residential development.

The Proposed Remedial Response is Undermined by Misinformation, Missing Information, Misrepresentations, and Misinterpretations.

To highlight a few of the ways (but by no means a comprehensive or complete list) in which the Remedial Response is factually deficient:

- While the plan assumes a clear boundary for the pollution plume, there is a lack of monitoring wells to support this assertion/assumption.
- Mapping fails to clearly articulate the differences in the pollution plume between the overburden soils and the bedrock aquifers.
- The site is a likely source of PFOS/PFAS contamination. The failure to test for, and address, this contamination is a constitutional, legal, and moral failing of PADEP's proposal.
- The reports relied upon to create the plan use a modeling approach that is not adequate to evaluate the movement of TCE and therefore cannot be used to inform or support the plan put forth by PADEP for consideration.

As a result of the proposed plan and supporting analyses being fraught with many areas of misinformation, data gaps, misrepresentations or misinterpretations of science, data, modeling, and/or facts, the proposed remedial action plan is not final and cannot be said to fulfill the requirements of law.

The AOA itself recognizes the fundamental failings in terms of the inaccuracy of its information. The AOA repeatedly calls for additional data and study in order to determine the extent of the contamination and steps that need to be taken. *See, e.g.*, AOA at p.12 fn. 3, p. 14, p. 15, p. 16, p. 22. As a result of the misinformation and missing information, it cannot be determined nor demonstrated that the Remedial Response could or would address the site contamination to the degree required by law. In addition, absent this information, this is not a proposal that experts or community members can fully understand and comment upon. This proposal more closely resembles a draft interim set of ideas than a remedial action plan intended to comply with the requirements of the law.

Underlying modeling, amongst other things, fails to account for variation in quantities and timings of TCE releases and thereby invalidates the methodology used for estimating TCE decay half-lives. It also assumes no continuing source of TCE present at the site, despite acknowledging the presence of DNAPL in deep bedrock, thereby invalidating the effects of the predicted future plume behavior so that the modeling applied is inaccurate. The model itself is contradicted by the earlier, more complex model used at the site.

In evaluating the growing and future pollution plume, PADEP conveniently fails to evaluate VOCs other than TCE, even though they are present and have different subsurface transport behaviors. Amongst our many concerns in this regard, is the failure to consider vinyl chloride, a confirmed, and potent, cause of cancer in humans and other animals that may be carried by groundwater four times faster than TCE.

An option for OU2 proposed by PADEP involves the injection of chemicals, yet it is not clear what chemicals would be used, nor was there the needed consideration of the discharge of new/additional contaminants that could result from this approach, and how the chemicals break down and/or react with other contaminants. AOA at p. 31. The environmental ramifications of this have not been assessed as part of the proposed remedial action plan. In addition, the additives that will be used to treat saturated and unsaturated soils are as-of-yet unknown, so it is impossible for PADEP, let alone the public, to comment or assess the ramifications of this proposed remediation.

The AOA reports limited human health risk assessments involving vapor inhalation and exposure to surface water, but fails to evaluate the potential effects of future modeled concentrations throughout the whole plume. Because the AOA, and the documents on which it is based (i.e., the Roux RIR and FS) fail to model future concentrations of all contaminants, or any contaminants at all in the Little Valley Creek, the AOA could not undertake this necessary evaluation. Also missing are assessments of risk from other potential offsite uses of groundwater, such as irrigation, or commercial and industrial uses. There are downstream business operations such as Uhler seed, for whom this evaluation is important.

It is notable that concentrations of hexavalent chromium in Little Valley Creek were found to have exceeded the PADEP Fish and Aquatic Life criteria in 2018 when it was measured under low flow conditions, yet the Ecological Risk Assessment fails to consider hexavalent chromium. Additional data should have been collected and ecological risk assessment evaluations undertaken. The failure to pursue this threat based on a lack of existing data cannot be legally justified.

The Reports Relied Upon by PADEP for its Proposed Remediation Plan are Fundamentally Flawed.

There are numerous bodies of misinformation, incorrect assumptions, and misrepresentations of fact and science that prevent PADEP from putting forth an analysis or remediation proposal that fulfills its legal and constitutional obligations.

The reports relied upon: are based on the assumption that soil on the site will be removed when that is not in fact being proposed; fail to consider other potentially hazardous VOCs that are known to be present in the pollution plume and of environmental and human health concern, and; the assumption that present and future use of the site will be non-residential only.

The RIR and FS assume that contaminated unsaturated soils above the water table will be removed, thereby removing one of the contaminant sources that will leach into the groundwater long term. This assumption, which directly impacts the entire analysis and remediation proposal, is fundamentally incorrect because the proposal for soils remediation would leave substantial COCs in the soil. Additionally, there are significant sources of TCE in the bedrock on the site which dissolve and desorb from fractures into the groundwater that will not be addressed by the proposal.

Much of the site will have trenches excavated to install utilities. Some of this excavation will be 20 feet deep and more in proximity to known contamination. If the remediation is not adequate, this material will be excavated and there is no requirement or guidance on the approved land development plans of how to protect workers and the public, or keep potentially contaminated materials contained on site.

The AOA Fails to Address a Significant Proportion of the Contamination and, as a Result, Leaves in Place an Ongoing Source of Contamination to Groundwater, Little Valley Creek, and the Community.

The TCE plume exceeds 3,000 feet in length and has been found to be greater than 400 feet deep into the earth, including in bedrock. Yet, the remediation plan focuses only on shallow groundwater contamination, less than 120 feet deep. In fact, most of the source contamination is in the bedrock and deeper soils. That means there will continue to be TCE source material that will feed into the environment, completely undermining any proposed remediation. The failure to address the full breadth of the contamination is legally, constitutionally, and morally unacceptable.

The failure of PADEP to consider a combination of alternatives is an obvious failing of the analysis and proposal. For example,

- for groundwater cleanup and protection there should be consideration of the environmental benefits of combining AOA Alternatives 3 and 5, with an emphasis on Alternative 3. By themselves, neither of these approaches is sufficient to address contamination. Alternative 3 is the only alternative that could, if properly implemented, affect deep bedrock and the DNAPL that is present. Complimenting this approach with hydraulic control in the overburden and shallow bedrock aquifer to prevent constituents from reaching Little Valley Creek would be beneficial.
- for the soils, PADEP should have considered combining Alternative 5, a rapid development of a vegetation cover to limit infiltration, and doing it while hydraulic control in the groundwater on the property (not mentioned in any of the proposed alternatives) is working to capture any released constituent or treatment chemicals before they reach Little Valley Creek.

There is not enough monitoring in the area northeast of the site in the bedrock. While PADEP acknowledges a substantial amount of TCE in the overburden and shallow bedrock groundwater, it has relatively few wells in the intermediate and deep bedrock. MW-44C has quite high concentrations of TCE in deep bedrock. As a result, TCE in bedrock is not adequately characterized. If there is a substantial amount of TCE there, additional groundwater alternatives could be necessary. At present PADEP plans to use MNA in that area regardless of the choice for clean-up at the site. Doing nothing but monitoring is not an acceptable solution given the high degree of contamination, impact, and the years communities and the natural environment have been harmed by site contamination. Active treatment is essential to address all contamination at, and emanating from, this site.

PADEP Failed to Provide a Public Process that Adequately Allowed Community Members to Meaningfully Engage with the Dense Technical Materials Involved.

While PADEP relented to public pressure and extended the opportunity for written comment until the end of January, as opposed to the original date just after the year-end holidays; it continued to advance a hearing process that failed to provide a meaningful opportunity to comment. The November date was too early after release of the extensive and highly technical materials to provide the public the opportunity to fully digest and assess the proposal in order to provide meaningful comment. Further, PADEP's use of a Zoom platform where disembodied voices got to speak to a faceless set of agency representatives was not conducive nor supportive to hearing the concerns, input, and questions of a community that has been deeply and profoundly impacted by the Bishop Tube contamination for decades.

Additional comments from Delaware Riverkeeper Network consultants on the AOA, and the RIR and FS on which it is based, are attached hereto and incorporated herein by reference. In addition, we incorporate by reference comments submitted by Caroline Armstrong, Sarah Caspar, Kathleen and Larry Stauffer, Deb Mobile, Bill Coneghan, Trout Unlimited, and other impacted neighboring and downstream residents and businesses.

Based on the foregoing, it is clear that the AOA, including the Remedial Response, is completely inadequate and PADEP has failed to meet its statutory and Constitutional obligations. It has failed to undertake or cause to be undertaken investigations, monitoring, surveys, testing and other activities necessary or appropriate to identify the existence and extent of the release or threat of release, the source and nature of the hazardous substances or contaminants and the extent of danger to the public health or welfare or the environment, as required by 35 P.S. § 6020.501(d). It has failed to propose remedial responses that meet all standards, requirements, criteria or limitations which are legally applicable or relevant and appropriate under the circumstances presented by the release of the hazardous substances or contaminants. 35 P.S. § 6020.504(a). And, it has failed in its duty as a trustee of the Commonwealth's public natural resources, to conserve and maintain them for the benefit of all the people.

Respectfully submitted,

Maya K. van Rossum
the Delaware Riverkeeper

Enclosures

Cc:
East Whiteland Board of Supervisors
East Whiteland Environmental Advisory Council
Regional Administrator Adam Ortiz, EPA Region 3
Senator Carolyn T. Comitta
Representative Kristine Howard
Regional Director Patrick Patterson, PADEP Southeast Region
Chester County Commissioners
Chester County Planning Commission

Comments on the Bishop Tube Site 8/17/2021
Analysis of Alternatives and Proposed Response

Edmund A.C. Crouch, Ph.D.

January 13, 2022

The following are comments on the 8/17/2021 *Analysis of Alternatives and Proposed Response* (the "AOA") for the Bishop Tube Property, East Whiteland Township, Chester County (the "Site"[1]) from the Hazardous Sites Cleanup Program of the Commonwealth of Pennsylvania, Department of Environmental Protection (the "Department").

Per the Department, its AOA "presents the decision-making process and description of the proposed response for the Bishop Tube Site." The Department further explains that it:

> … proposes to address contaminant source areas within unsaturated and saturated soils through addition of treatment reagents, coupled with in situ mixing; groundwater and surface water through in situ injection of reagent designed to chemically or biologically treat Site-related COCs, coupled with monitored natural attenuation, engineering controls, and institutional controls ("ICs"); and an impacted residential water supply through the connection to the existing public water supply waterline, combined with restrictions on the use of groundwater. This action is taken to protect human health, safety, and the environment.

Unfortunately, the AOA for this Site is deficient. Accordingly, the proposed response is not likely to adequately protect human health or the environment. The deficiencies include at least the following.

1. In its AOA, the Department relies on prior reports that are substantially flawed.
The AOA relies primarily on a series of reports by Roux Associates, Inc. ("Roux") and Groundwater & Environmental Services, Inc. ("GES"). However, these reports are inadequate to evaluate the effects of contaminants from the Site, since, fundamentally, they:

i. are based on an incorrect assumption that the soil on the site will be removed,
ii. use a modeling approach that is not adequate to evaluate the movement of the potentially hazardous chemical, trichloroethylene (TCE), and
iii. do not evaluate the movement of other, potentially hazardous, volatile organic compounds (VOCs) known, or reasonably expected, to be present in the plume.

[1] "Site" refers herein to the Bishop Tube property combined with the area of off-property contamination emanating from the property.

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For additional detail, please refer to my comments (in the memorandum attached herewith) on the June 2019 version of Roux's Remedial Investigation Report (RIR) and Feasibility Study (FS), which comments apply to the subsequently slightly modified January 2021 RIR and FS cited in the Administrative Record.

2. The anti-degradation requirement is an ARAR, and not just a TBC (To Be Considered).
The AOA mentions (on page 17) that:

> As noted, above, LVC is classified as an Exceptional Value stream by DEP. This designation subjects LVC to special protections, including anti-degradation requirements discussed in Section V, below.

However, there is no discussion of anti-degradation requirements in Section V, and no special protections are mentioned there or elsewhere in the AOA. Indeed, "anti-degradation" occurs twice (page 17, as noted above, and page 30, where it is referred to as an ARAR), while "antidegradation" occurs 8 times at pages 22, 23, 28, 32, 33, 35 in Section VI, and twice in Appendix B; none of these locations provides any discussion of the requirements. In the discussions of Section VI, where alternatives are rejected the antidegradation requirements are cited as though they are ARARs, whereas for acceptable alternatives it is always wording such as "progress toward achieving antidegradation requirements" that apparently makes the alternative acceptable, rather than the compliance *demanded* of other ARARs.

Moreover, the sole reference given in Appendix B as an "authority" for listing anti-degradation requirements as TBC (To Be Considered) status is a *Water Quality Antidegradation Implementation Guidance*, November 29, 2003. This despite references to "antidegradation *requirements* of Chapter 93" (or equivalent wording) throughout the AOC (pages 22, 23, 28). Indeed, 25 Pa. code 93.4a(d) states "*Protection for Exceptional Value Waters*—The water quality of Exceptional Value Waters shall be maintained and protected."

The AOA appears to be compounding the error in the (2021) FS on pp63-64, in which preliminary remediation goals are discussed by comparison with human health, fish and aquatic life criteria, and by a Human Health Risk Assessment and Ecological Risk Assessment. Those are irrelevant in view of the requirement to *maintain* and *protect* the water quality of Exceptional Value Waters – there is no exception that holds that water quality may be degraded to match any of the criteria or approaches discussed in the FS.

3. On-site soil (OU1)

a. Alternatives 1 (No Action) and 2 (Engineering and Institutional Controls).

As discussed in the AOA, these alternatives are inadequate and unacceptable through failure to meet ARARs, including anti-degradation requirements for LVC, and would also fail to meld with any of the proposed groundwater alternatives because the soil may act as a continuing source to groundwater.

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b. The Department's proposed Alternative 5 (ISCO/ISCR, with soil mixing).

The AOA claims that "some varieties of ISCR amendments …" and "[i]n some circumstances …" this alternative might provide desirable results. However, no actual evidence is provided that that with any "variety" of amendment, or in the particular "circumstances" of the Site, these desirable results could in fact be achieved. It is all left to "pre-design investigation to maximize effectiveness and minimize negative effects such as impacts to LVC." Thus the outcome is uncertain even as to effectiveness of this proposed alternative. And there is no guarantee of meeting ARARs, or of meeting the anti-degradation requirements for LVC, indeed the AOA only mentions the possibility to "maximize effectiveness" and "minimize negative effects" on LVC, with no certainty of being able to do both simultaneously.

Even if the "pre-design investigation" is successful, application of this alternative will still be incomplete — there will be contaminated sub-surface locations that are missed, even with soil mixing (e.g. due to the unevenness of bedrock preventing mixing all the way to bedrock everywhere; locations between the proposed mixing "cells" due to the geometry of the cells and the shape of the mixers; misalignment of the mixers with the hypothetical "cells").

Also not mentioned is the time required for initial soil testing, for effectiveness testing (with the also unmentioned but necessary aging tests that should be required for the inorganic COCs[2] hopefully stabilized by the treatment but not actually removed or reduced in concentration), and for the post-treatment testing to ensure the treatment behaves in the field as in the effectiveness testing. Nor is there any mention of the interaction of this alternative with the current, already approved, plans to develop the site.

Complete implementation would require more complete soil testing – for example soil testing on a grid across the site – to ensure location of all contaminated areas, since current soil testing has been limited primarily to previously suspect areas, without consideration that there may be unsuspected contaminated areas.

Finally, the injection of soil amendments might *exacerbate* the contamination of LVC by liberating or adding contamination to the LVC. A pre-requisite for any evaluation of effects on the LVC and planning protection efforts is an adequate 3-D groundwater model for surface soils and upper bedrock on the property and to the east under LVC.

The *effectiveness* of the proposed alternative is currently uncertain and would depend on the outcome of future unspecified testing; the protectiveness of future health would rely on future testing and the application of an institutional control; and the protectiveness of LVC from degradation is entirely uncertain without modification of the alternative to incorporate protections.

[2] Such aging tests might be accelerated by adjustment of physical parameters (e.g. temperature); but they would also have to account for potential biological effects such as microbial action, which are less susceptible to such accelerations.

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c. Alternative 3 (Excavation with offsite treatment/disposal)

This alternative is the only one evaluated that could, if implemented properly, achieve compliance with ARARs, could be implemented rapidly, and would not require any post-compliance institutional controls connected with soil. Adequate implementation requires more detailed soil testing to ensure finding all elevated soil concentrations that need to be addressed. Excavation and removal or treatment of the soil would ensure eventual compliance with the anti-degradation requirement for LVC, from on-property soil sources, and in particular for the metals/fluoride contamination. Choice of replacement soil, and adequate attention to methods of emplacement need to be determined for DEP to evaluate this plan.

To be effective, treatment and disposal of extracted water would be required for treatment of soil below groundwater. What is not mentioned in the AOA is that further on-site controls (beyond stormwater and fugitive emissions management) would likely be necessary to ensure compliance with anti-degradation requirements for LVC. Extracting groundwater might compromise groundwater flow to LVC, and some method of mitigation might be required (e.g. upgradient clean groundwater extraction with re-injection along and adjacent to LVC, possibly reversing flow of contaminated water back towards the excavation while maintaining groundwater levels near LVC). Planning of such mitigation would require adequate 3-D modeling of groundwater flow in the surface soil and upper bedrock on the property and to the east under LVC.

d. Alternative 4 (Excavation with onsite treatment)

Alternative 4 is similar to Alternative 3, except that soil treatment and disposal would be on site (with "disposal" back into excavated areas). In this Alternative, the treatment for non-volatile COCs would have to be evaluated using aging tests to ensure continued compliance with ARARS and the anti-degradation requirements. And institutional controls on soil would be required similar to those for Alternative 5.

4. Groundwater (OU2)

a. Alternatives 1 and 2 (no action, and monitored natural attenuation)

The AOA correctly dismisses these alternatives as failing to meet ARARs, including anti-degradation requirements. There is no difference in what happens to the contamination under these two Alternatives.

b. The Department's proposed Alternative 3 (In Situ Injection — ISCO/ISC/Bioremediation)

Alternative 3 would be unlikely to have any effect on any deep bedrock sources of the off-property plume, and any effect on the plume or on off-property discharges to LVC would be slow (if there is any effect at all). Attempts to evaluate any effect or timing of differing options in application of this Alternative on the plume or discharge to LVC would require an adequate 3-D groundwater model on- and off-property, both currently lacking (as described above); without such a model, any such attempt would provide meaningless results, so option selection

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would be arbitrary. Indeed, any estimates of timing in the AOA are pure speculation at this point, insofar as they are based on the "degradation rate" claimed in the RI, since that was estimated by a procedure that cannot be accurate (as shown in the accompanying memorandum). The 30-year lifespan mentioned in the AOA for active period plus post-remedial care can thus be regarded as completely speculative — for example, Figure 10 of the accompanying memorandum shows that 50 years after a complete cleanup of the source (which cannot be achieved), the concentration at 3000 feet and further from the property could be practically unaffected.

The AOA mentions that "[i]n situ injection may not be viable for hot spot areas (i.e., acid rinse spill area) in close proximity to LVC because of potential negative impacts to surface water." What it fails to mention is that any type of use of the proposed methods in Alternative 3 could impact LVC, and that evaluation of such potential impacts cannot be attempted without a suitable 3-D groundwater model for the groundwater on the property in soils and shallow bedrock. Without such a modeling effort, application of these methods will be blind, and effects on LVC will only be determined in retrospect and only if they are actively sought. The idealized approach "anticipated" in the AOA that is a "closely monitored, phased implementation to maximize effectiveness and avoid negatives outcomes, such as negative impacts to LVC or to the ongoing natural attenuation processes" is reactive only — by the time the "close monitoring" detects any effect, it may well be too late to do anything about it (and it cannot be determined ahead of time whether it is too late, nor even to determine how to "closely monitor" without such a model).

c. Alternative 4 (In Situ Thermal Treatment — ISTT)

This alternative has all the disadvantages of Alternative 3 and more. It could not affect deep bedrock sources. Any effect on the off-property plume is even less likely since treatment would extend only to 80 ft depth rather than 120 ft (or more if the treating chemicals were to sink deeper).

d. Alternative 5 (Hydraulic control)

Alternative 5 is considered in the AOA as a stand-alone system, but as described there it would actually be designed to affect off-property migration to downgradient areas and to the LVC, not to clean up contamination on the property, except indirectly through capture as those contaminants migrate off-site. It is the only Alternative considered that would plausibly have a noticeable effect on the off-property plume, with an effect that propagates from the property into the plume over time. Mention is made in the AOA of the requirement for hydraulic modeling in the "[p]re-design investigations", but what is needed for complete design and evaluation of the effectiveness of this Alternative is an accurate 3-D groundwater model. Such a model also would allow determination of the rate of propagation into the plume of the effect of implementation. As mentioned above, and demonstrated in the accompanying memorandum, the effect will be negligible beyond the propagation front, and the front could easily move as slowly as 60 ft/yr (3000 ft in 50 yrs).

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5. The Department's lack of consideration of combinations of alternatives

The AOA treats the Alternatives individually, and inexplicably fails to consider the possibility of using two (or more) together, or elements of one with elements of another. In particular, Groundwater Alternative 5 is the only Alternative examined with any plausible effect on the off-site plume, while Soil Alternatives 3 or 4 may be the most effective for on-site remediation. And Soil Alternatives 3 or 4 (or other) may be improved by using a version of hydraulic control to ensure no further degradation of LVC and possibly to start to clean up LVC to its natural state (and hence maintain and protect its Exceptional Quality).

*****

Please see the attached memorandum for additional details.

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ATTACHMENT

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Memorandum

To: *Delaware Riverkeeper Network*

Edmund Crouch

From: *Edmund A.C. Crouch, Ph.D.*
Date: *January 26, 2020*
Subject: *Comments on the Bishop Tube 2019 Remedial Investigation Report and Feasibility Study Report*

Introduction and Summary

I write to provide comments on the *Remedial Investigation Report* (RIR) and *Feasibility Study Report* (FSR) regarding the Former Bishop Tube Property, East Whiteland Township, Chester County, Pennsylvania, authored by Roux Associates, Inc. (2019a and 2019b). As you will read, I find that the analyses presented in the RIR are deficient in several respects; and I offer suggestions for improving upon these analyses. Because the FSR is based on the RIR, it too is unreliable.

The technical issues detailed below, are:

- The history of the site provided in the RIR omits salient facts that would assist evaluation of the current and future site conditions; in particular, there are no estimates of the quantities and timings of releases of trichloroethylene (TCE) (and other volatile organic compounds, VOCs) that might (i) bound the quantities currently present in the plume and/or in dense non-aqueous phase liquid (DNAPL; that is, undissolved TCE) in the deep bedrock, and (ii) assist the evaluation of decay half-lives of contaminants. The RIR fails to present any estimates of these quantities, ignoring an earlier report (Baker, 2003) that had indicated a total of 3.7 tons down to 10 to 20 ft depth in the hot spots on site; moreover the RIR plume delineation in Figure 45 implies a plausible range of from 6.5 to 56 tons (omitting any DNAPL), although both these estimates use implausible assumptions such as assigning the maximum measured concentration in any well or boring throughout the entire depth range considered.
- The methodology used in the RIR to evaluate the half-life of decay of TCE in groundwater is deficient in many ways, and cannot provide a reliable estimate of that half-life on this site. It is (i) theoretically incorrect, (ii) biased to low values, (iii) not consistently applied, and (iv) omits multiple measurements meeting its own inclusion criteria. The methodology also

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assumes the same value everywhere in the plume, an assumption which is provably incorrect.

- At least some of the contaminant measurements in groundwater made at the site have been omitted from the summary tables.
- The RIR modeling takes no account of potential variations in the quantities and timings of TCE releases, and assumes that there is no continuing source of TCE present, despite acknowledging, correctly but inconsistently, the presence of DNAPL in deep bedrock. The first (failing to account for variation in quantities and timings of TCE releases) affects the interpretation of time-series of concentrations in wells, and entirely invalidates the methodology used for estimating TCE decay half-lives. The second (assuming no continued source) affects the predicted future plume behavior, so that the modeling applied is inaccurate.
- The modeling performed by the RIR fails to build on previous extensive and more comprehensive modeling of contaminant behavior in groundwater at this site (Baker, 2004). The model used is needlessly simplistic, and results in unjustified conclusions.
- Indeed, a straightforward calculation of the flow velocity of TCE according to the parameters used in the model used in the RIR shows that it could not possibly account for the extent of the current plume. The earliest that TCE could have been used at the site is the early 1950s, approximately 70 years ago. With the RIR modeling, TCE could only have travelled about 1,100 feet in that time, compared with a plume that actually extends some 3,500 feet (and the additional distance to the plume front due to dispersivity cannot account for the difference). The RIR authors should have made, but apparently did not make, this simple check on their work.
- The RIR modeling also includes unrealistic assumptions about the boundary of the plume, both currently and in the future. Previous (more comprehensive) modeling showed that the plume potentially could, at some depth, (i) extend beneath Little Valley Creek to the north, in areas where the RIR model deliberately prevents that possibility; and (ii) extend into the Northwest corner of General Warren Village, another possibility that the modeling apparently deliberately omits.
- While the modeling implies contaminated discharges to Little Valley Creek, there is no attempt to evaluate the resulting contaminant concentrations in Little Valley Creek by evaluating the flow of groundwater and its entrained contaminants into the Creek.
- There is no evaluation of VOCs other than TCE in the future plume, although they have different subsurface transport behavior — in particular vinyl chloride (which is most worrisome, being a confirmed, and potent, cause of cancer in humans and other animals), which may be carried by groundwater about four times faster than TCE.
- While some limited assessments of risks to public health and the environment are performed for the current situation, there is no attempt to evaluate risks from future plume configurations, neither in the RIR nor the FSR. The FSR requires such evaluations to adequately compare the potential health and environmental effects of various clean-up schemes.

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- The FSR is inadequate in that it relies on incomplete and incorrect evaluations in the RIR. In particular, the evaluation of monitored natural attenuation is incorrect, in that it is based on the incorrect evaluation of future plume behavior in the RIR.

The RIR clearly requires amendment to adequately evaluate future plume behavior, in particular delineation of the extent of, and concentrations in, the future plume, not only for TCE but also for other contaminants. The FSR subsequently must be modified to account for such corrections.

1. Timing and mass of trichloroethylene (TCE) released to groundwater

The RIR provides a summary history of the site that, unfortunately, omits salient facts that might assist in bounding the mass of TCE that was released to groundwater, and the timing of such release, which information is necessary (or must be inferred) in modeling of plume extent and persistence. For example, Section 5.1 of the RIR mentions only that "During certain periods of time, chlorinated solvents were used for degreasing at the Property." Evaluation, even if only approximate, of total receipts (and specification as to identity of each such solvent, if more than just TCE had been used), for example, would serve to place an upper bound on the quantity of these solvents. The total potential time frame runs from approximately 1951 (when the building was built; RIR Section 5.1) through approximately 1991. TCE was stored for some of this time in a 4,000 gallon aboveground storage tank (which, when full, would contain approx. 24 tons of the solvent), installed in 1975 (RIR Section 5.2), that was removed in 1992 (Armstrong, 2018, Exhibit 43). All releases should have ceased prior to 1991 (Marcegagalia USA, Inc letter, DEP 000055090–55091, and RIR Section 5.1), although earlier documentation assumed TCE release to have ceased by 1983, based solely on assumed implementation/enforcement of federal RCRA regulations (Baker, 2004, pp84–85).

The combined mass of TCE present in (i) the shallow soil down to approximately 10.7 ft depth below the vapor degreaser area in building 8, (ii) 8 ft depth below the vapor degreaser area in building 5, and (iii) 20.7 ft depth below the former drum storage area was estimated by Baker (2003, Tables 8.1–8.3 and Appendix D) as approximately 3.7 tons. This is likely an overestimate, in that maximum concentrations in each borehole evaluated were assumed to apply through the entire soil column. The estimated plume provided as Figure 45 of the RIR corresponds to approximately 56 tons of TCE in the groundwater and adsorbed to soil (omitting any non-aqueous phase TCE), assuming an average groundwater thickness of 440 ft, porosity of 0.05, retardation coefficient of 9 (all from RI, Appendix S). Approximately half of that mass is within the 100,000 μg/L contour. This probably represents an upper bound on the mass of TCE; a lower bound (for the groundwater as modeled in the RIR) can be obtained by assuming no adsorption to soil (e.g. no organic carbon in the soil[3]), which gives approximately 6.5 tons dissolved in groundwater in the plume. Both of these estimates are likely overestimates, since

[3] There appear to have been no measurements of soil organic carbon over the entire history of the site, though some should have been made.

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the assumption is made in the RIR that the maximum concentration measured at any depth in a well applies throughout that entire groundwater thickness.

2. Methodology for estimating the half-life of TCE in groundwater

The methodology used in the RIR (Roux, 2019a, Appendix S) for estimating the half-life of TCE in groundwater is incorrect, undefined, and/or inconsistently followed.

First, and most important, the methodology is theoretically incorrect, and cannot under any circumstances (except by chance) give an accurate estimate of half-life. For the methodology to be accurate, the groundwater concentration of TCE at every point evaluated would have to be decreasing at the same first-order rate, implying that the spatial variation (factoring out this exponential term) was constant. That is, the TCE plume would have to have exactly the same shape and location throughout time, and simply be everywhere (or at least at all measured points) decreasing at the same rate. This conclusion is model independent, but can also be inferred from the solute transport model used in the RIR. Moreover, such a plume would be physically impossible in advecting groundwater — in order to maintain the same plume shape and location, concentrations would have to rise sufficiently in downgradient directions so that dispersion could cancel the effect of advection (which moves the location of the plume). The appendix to this report demonstrates this physical impossibility analytically for a 1-dimensional simplification of the model used in the RIR. The actual rate of change of concentration at any point in a plume depends on the time, advection velocity, and the time course of the source term of the plume, as illustrated below by simplified examples in this case.

Second, the methodology was specified as, "Monitoring wells considered for this calculation required: 1) at least 4 data points over an extended period of time (i.e., at least 4 years); and 2) evidence of attenuating TCE concentrations (i.e., declining concentrations with time)." This approach is problematic for several reasons, including:

a. The second specification arbitrarily omits any wells without such a declining concentration, so will necessarily bias any estimate of "decay rate."[4]
b. The second specification is also undefined; no operational definition of "declining concentrations with time" is provided. The natural interpretation would be that the value of λ, the "decay rate" defined on page 11 of Appendix S of the RIR, is positive. However, examination of the data in Appendix B-1 shows that this cannot have been the operational definition, since multiple wells meeting the first specification (4 or more data points over 4 or more years) and with positive λ are in fact not included in Table 2 of Appendix S (e.g. MW-06, MW-14, MW-19, MW-20). Indeed, there are

[4] Since the methodology cannot evaluate the degradation half-life of TCE in the plume, the only quantities estimated are time-variations in particular wells over particular time periods; I distinguish these quantities from the decay rate and half-life associated with TCE degradation by quoting the terms "decay rate" and "half-life."

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51 monitoring wells (MW-XX) listed in Table B-1 of the RIR that meet the first criterion, 44 of which have a positive λ, but only 30 are included in Table 2 of Appendix S. No explanation for omission of data from these wells is offered.

c. It is difficult to conceive of any consistent specification that would include MW-23 but exclude MW-06, as is done in the RIR (see Figure 1).

d. The methodology adopted in the RIR was to average the "half-lives" calculated by linear regression over all available measurements in Table B-1 for the wells in Table 2 of Appendix S. This methodology is incorrect, however, for at least two reasons. First, if such averaging over wells were appropriate, then the correct methodology requires averaging over all "decay rates" (both positive and negative), not averaging over "half-lives" (essentially the inverse of "decay rates"). Second, performing such averaging assumes that the average has some physical meaning — that the "decay rate" measurements in individual wells are all (imperfect) measures of the same quantity applicable to the whole site — but in this case, examination of the distribution of "decay rates" shows that the measurements are in fact not of the same quantity. Figure 2 shows a normal probability plot of the "decay rate" (λ) for all 51 monitoring wells satisfying the first criterion ($\geq$ 4 points, $\geq$ 4 years). This distribution is indistinguishable from normal,[5] and clearly the measurements are not all consistent with a single mean value. A formal likelihood ratio test confirms this — maximum likelihood estimates of mean and standard deviation of a normal distribution are 0.00029 per day and 0.00024 per day respectively, taking account of all the individual uncertainties, and the standard deviation estimate is non-zero (p = 1e–97).

The implication of the non-zero standard deviation is that the "half-life" varies in different places on the site. This variation (if the methodology used to derive the value had any meaning; but see above and below) would need to be taken into account in any modeling. Indeed, approximately one third or more of the "half-life" measurements are consistent *with no "decay" at all* that those locations (see Figure 2). This conclusion is not surprising, given the results shown below, since the concentration at any particular well can be increasing, decreasing, or constant, dependent on multiple factors of which TCE degradation is only one. And in view of the microcosm tests (Baker, 2009, Appendix A; Roux, 2015a, Appendix B), such a finding for actual TCE degradation rates would also not be surprising; and such degradation rates remain to be measured, particularly any variation of half-life with depth and/or location.

[5] There are no standard tests that can incorporate the uncertainties in individual measurements, but application of the Shapiro-Wilk test to the point estimates, omitting the most negative which clearly is so uncertain as to provide only negligible information on the distribution shape, shows a p-value of 0.67, indicating the distribution is indistinguishable from normal.

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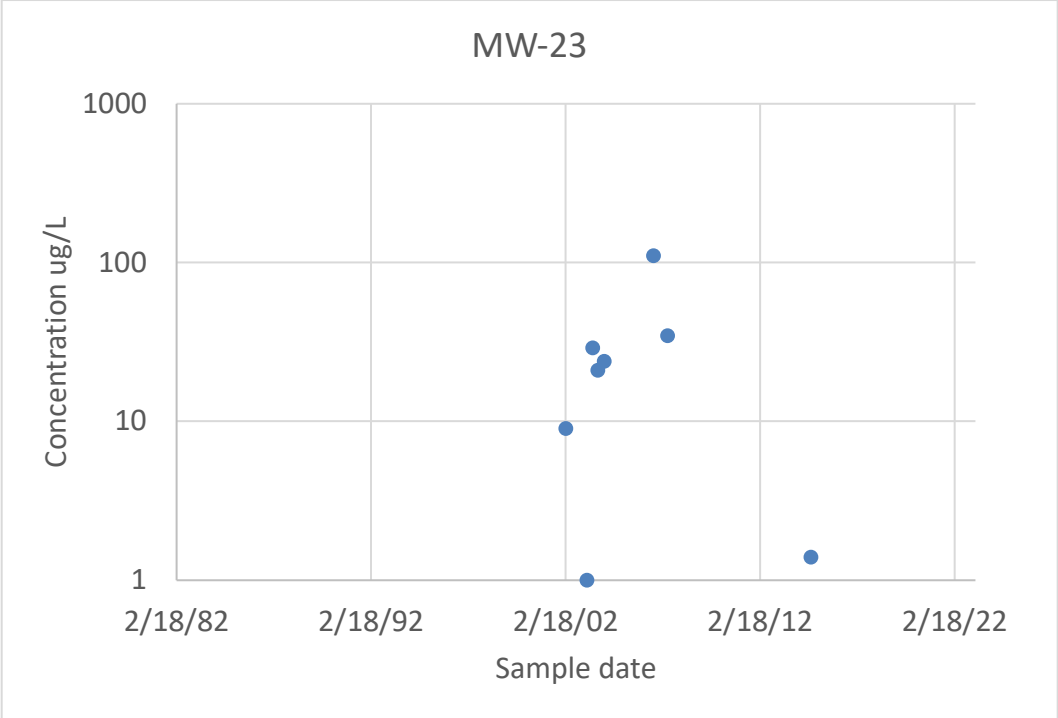

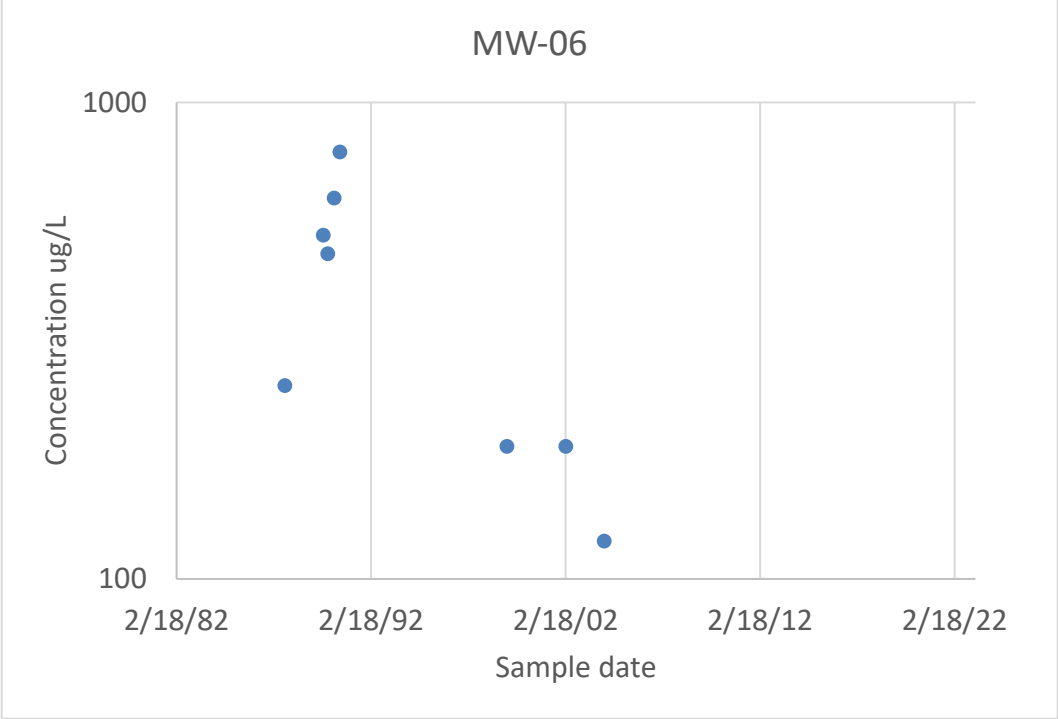

Figure 1 Comparison of sampling in MW-23 and MW-06

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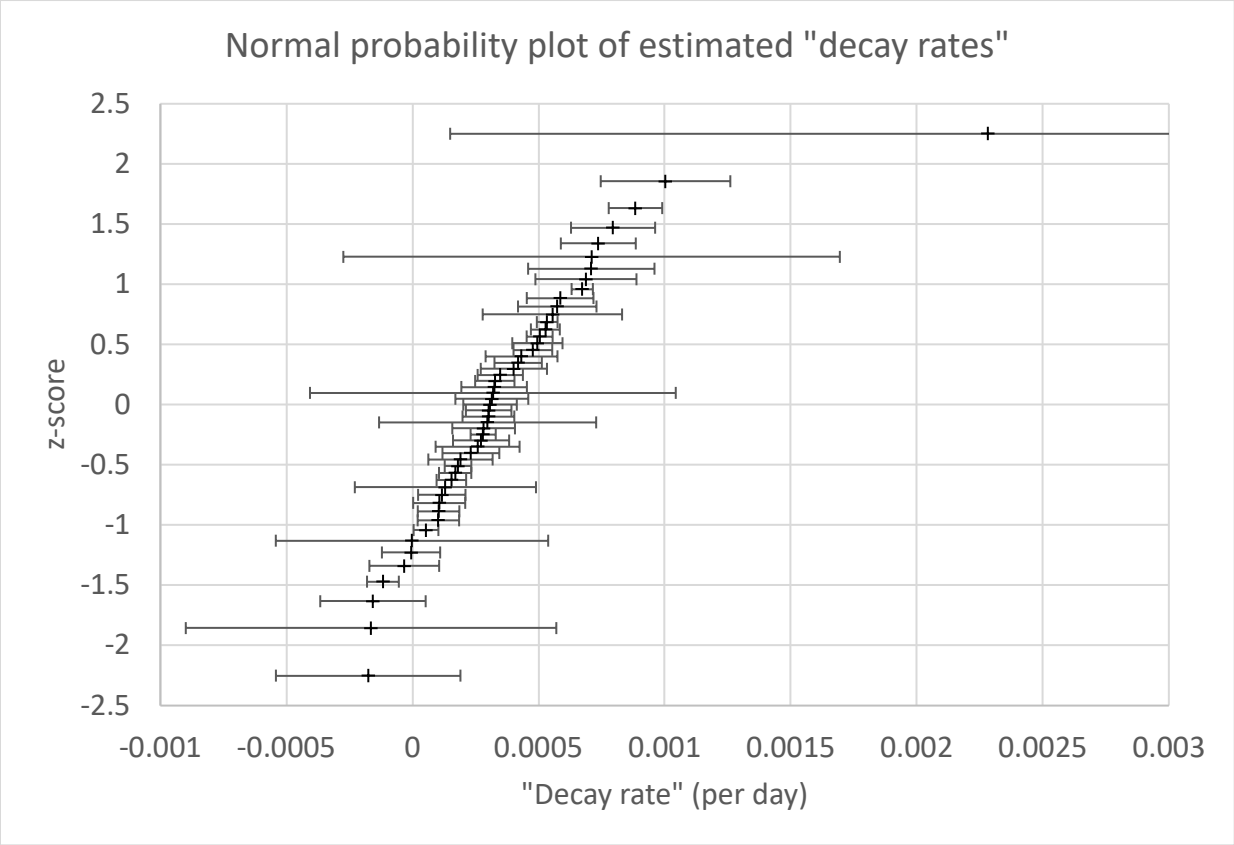

Figure 2 Normal probability plot of "decay rates" in the 51 monitoring wells, with standard errors

3. Missing data from time series

Some of the groundwater measurements have been excluded from the RIR. Specifically, the measurements documented in the microcosm study of Appendix B of the 2015 Treatability Study (Roux, 2015a) in MW-08, MW-25C, MW-26A, VDA8-1, VDA8-3, and VDA8-4 (from 10/10/11) and MW-25C (from 10/11/11) are not included in the summary data in Appendix B of the RIR; although apparently the sample (possibly a split sample) taken in 8/23/06 from MW-02 and used in the earlier microcosm study (Baker, 2009, Appendix A) is included.

4. Failure to account for source variation

The RIR makes the factually incorrect assumption that there is no continuing source present — only the TCE present in groundwater and adsorbed to soil/rock (with no non-aqueous phase TCE). It also implicitly assumes the lack of any source prior to the start of the modeling timeframe, through the methodology used to evaluate "half-life" of TCE in the various wells. Suppose instead that there was a source at some time in the past (which is obviously true), and this source varied in strength with time. Then variations in concentration can be expected to occur at the source location; and these variations in concentration would propagate into the plume, so that variations in concentration at each well will occur due to such variations in

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source strength. Moreover, the variations in concentrations in wells will represent variations in source strength at earlier times. Thus any analysis of concentrations in wells that attempts to estimate true decay (degradation) rates must account for variations in source strength at those earlier times, and must untangle such variations from any decay that is occurring. No such attempt was made in the RIR.

There are some wells in which variations in source strength are much more likely than decay to account for a major part of some concentration variations. Several wells have a very substantial decrease in concentration between measurements made prior to the mid 1990s and those made subsequent to that time. Particular examples in which decay as the only determinant of substantial reductions occurring between the 1980 to early 1990s and early 2000s seems unlikely are MW-15 (Figure 3) and MW-03 (Figure 4), with less obvious examples being MW-02 (Figure 5), MW-06 (Figure 6), and MW-08 (Figure 7), although such an effect cannot be ruled out in *any* well without adequate analysis that takes account of the propagation time and dispersion occurring between source and well. The example wells mentioned here are close to the putative source(s) of the TCE, so would reflect changes in source terms relatively soon after such source changes, and the changes would not be substantially extended in time by dispersion. The effect of source changes in wells further downgradient would occur later and be slower. Since the source term probably ceased sometime in the 1980s or as late as 1991, abrupt changes in nearby wells between the 1980s and late 1990s may quite plausibly be due to source changes.

Figure 3 (MW-15) also illustrates the disconnect between measured concentrations and the RIR modeling, for this well at least. The initial peak in the modeling is due to a higher concentration part of the plume passing by MW-15, and the faster drop-off in concentration at large times (compared with the decay rate, illustrated by the dashed black line) is due to the reducing concentration behind that higher concentration part of the plume (MW-15 is situated so that, in the modeling, a kink in the assumed 10,000 μg/L contour will sweep across it as the whole plume migrates down-gradient; see Figure 46 of the RIR).

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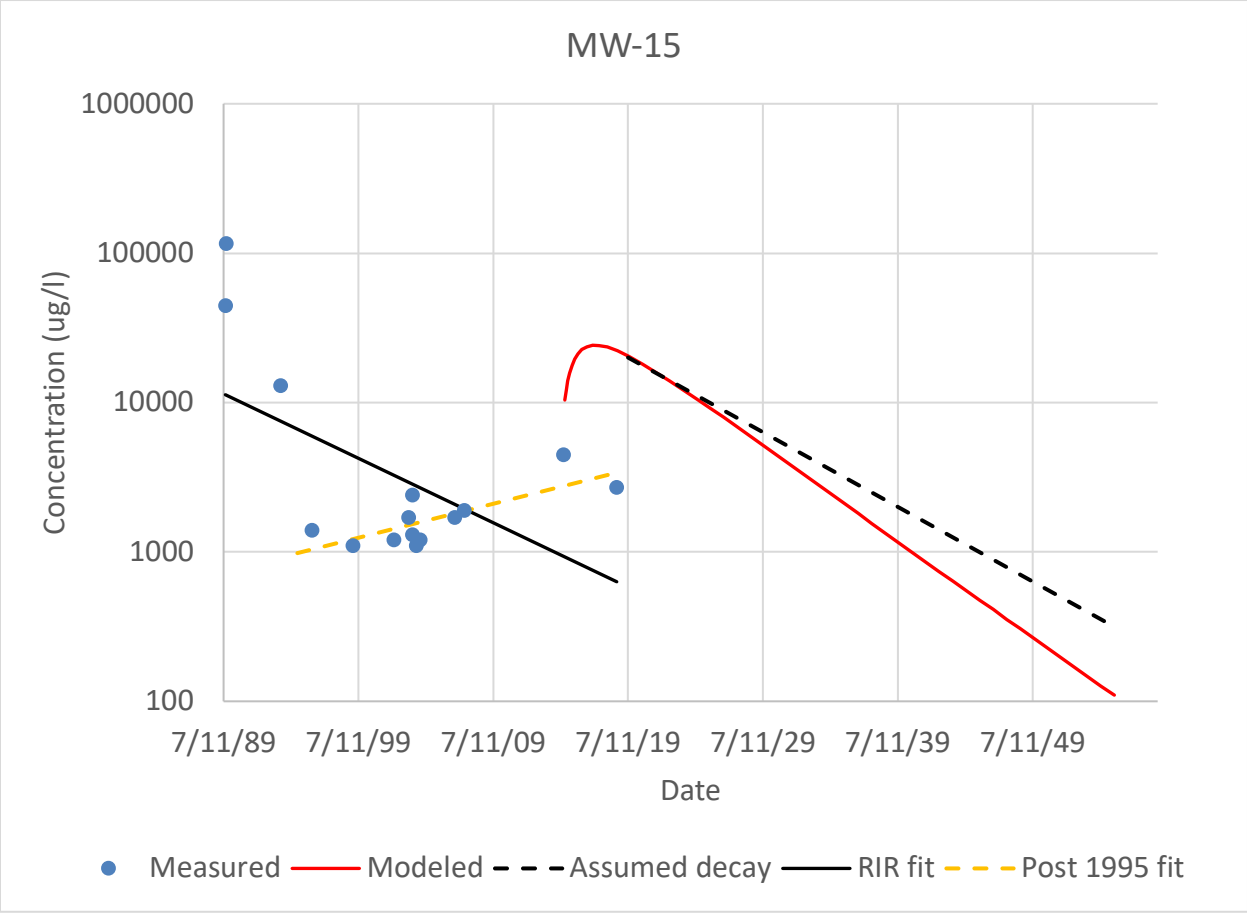

Figure 3 Measured concentrations, the RIR "fit" to those concentrations, and a fit to those after 1995, and the modeled concentration in MW-15, with a line showing the assumed decay rate.

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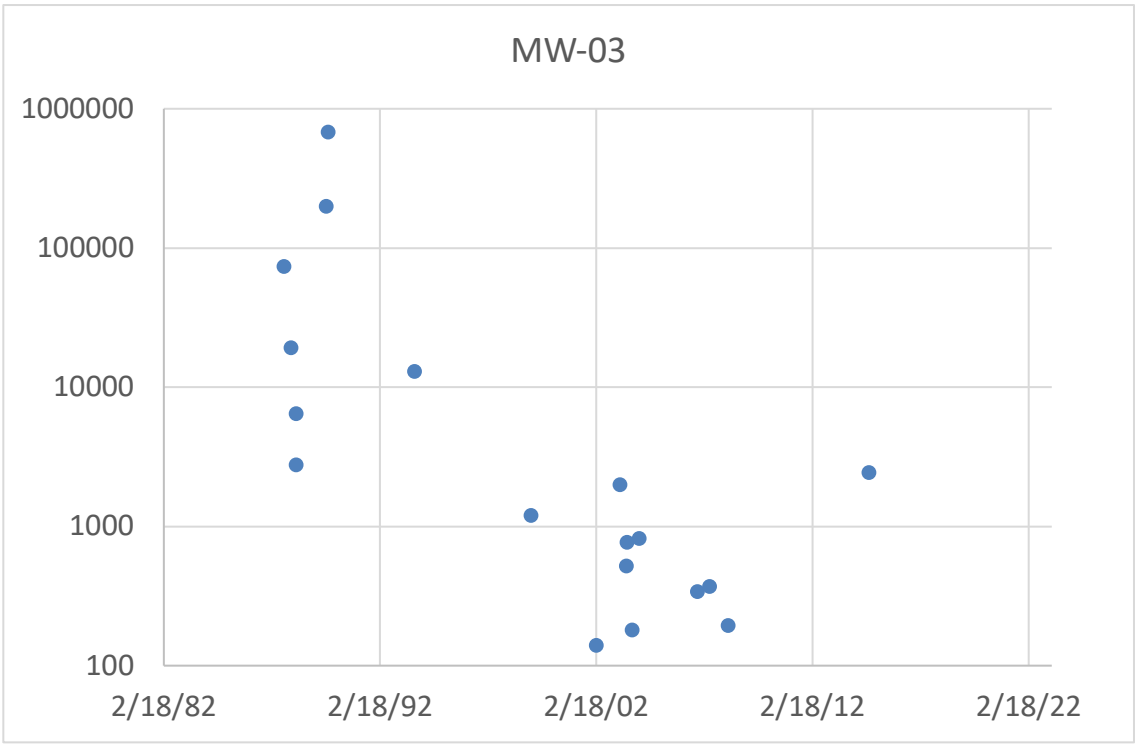

Figure 4 Concentrations measured in MW-03, showing a substantial drop in the mid 1990s

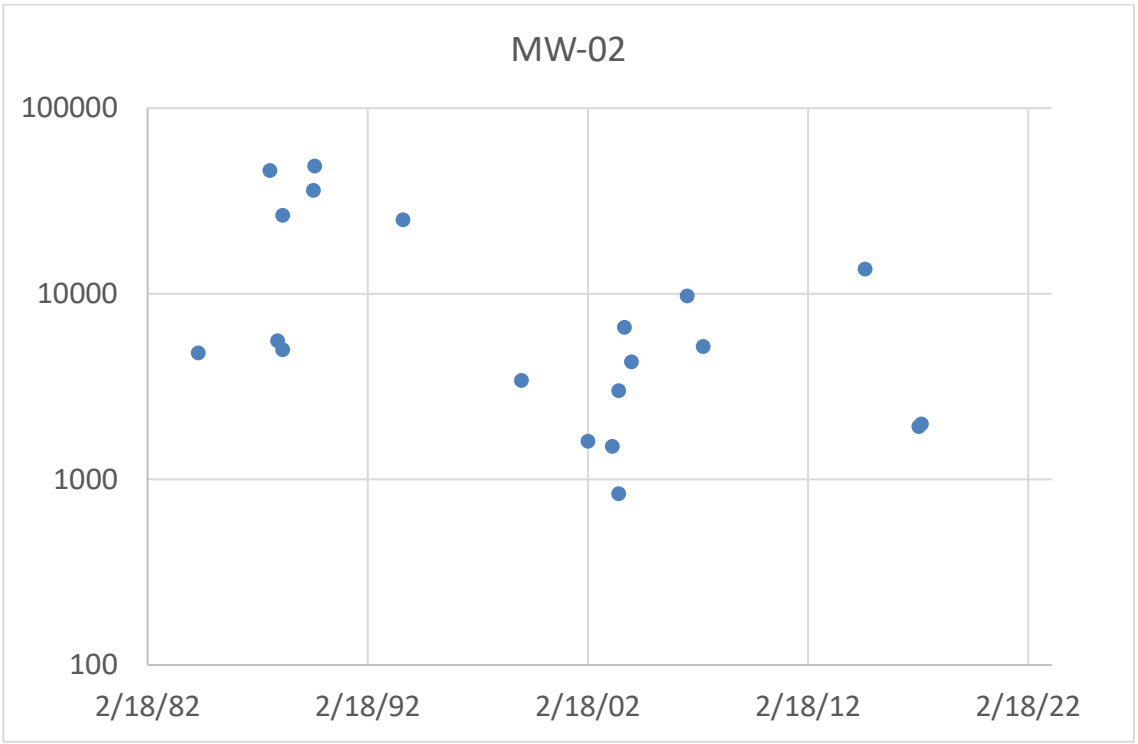

Figure 5 Concentrations measured in MW-02

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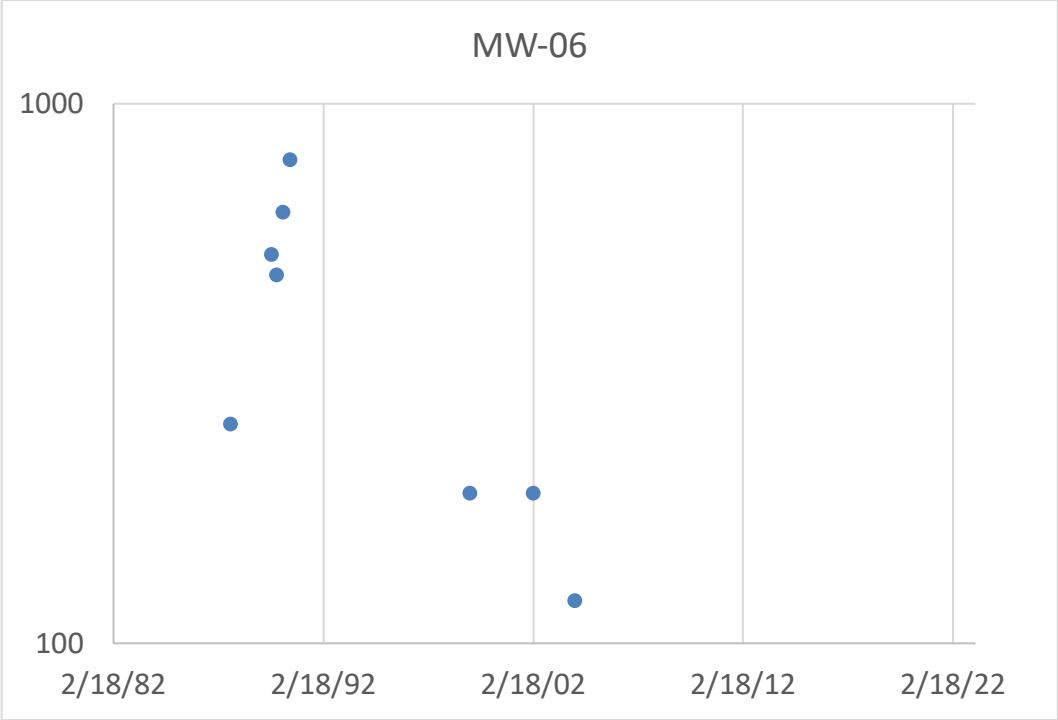

Figure 6 Concentrations measured in MW-06

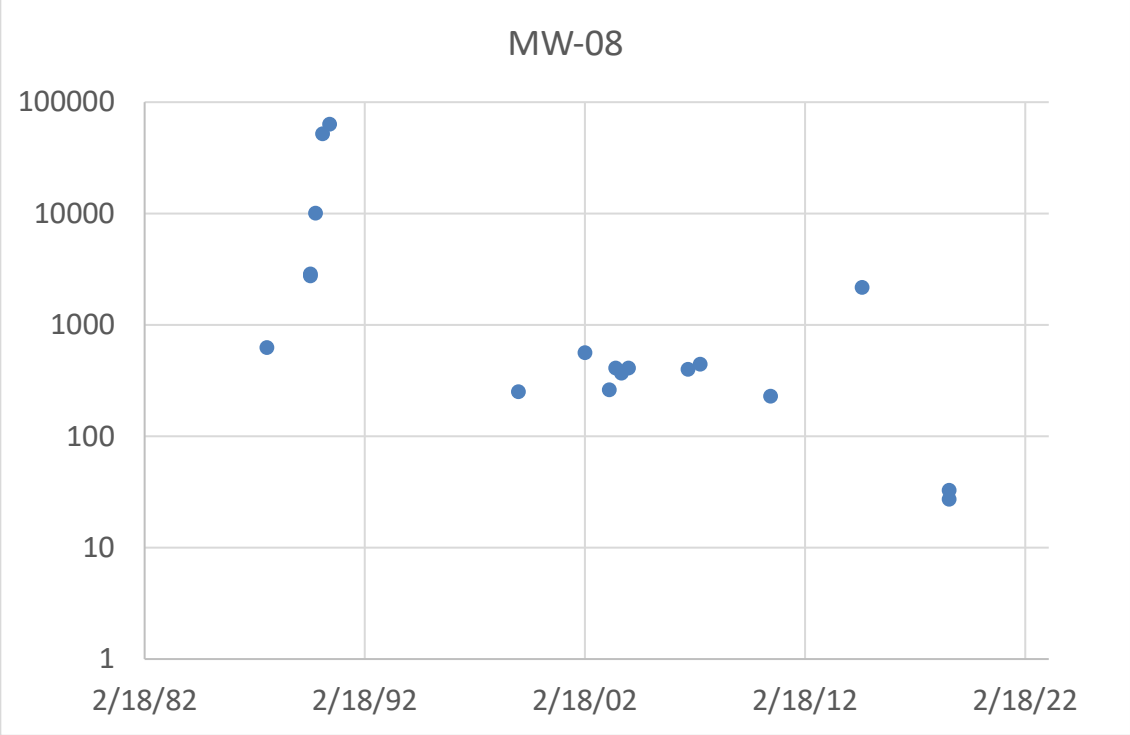

Figure 7 Concentrations measured in MW-08

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5. Failure to cite, evaluate, and build on previous analyses

While a previous extensive groundwater characterization report (Baker, 2004) is mentioned, none of its findings or analyses are cited within the RIR, and the model used in the RIR takes nothing from that previous modeling. As explained below, this failure to build upon prior work is inappropriate, and should be remedied.

Baker (2004) presented a groundwater model that better characterized the site than the model adopted by the RIR, by (i) using the MODFLOW/MODPATH/RT3D model system, (ii) using four depth layers, and (iii) accounting for the different hydrogeologic units in the modeling domain (Baker, 2004, Tables 29 and 30), building on the previous hydraulic modeling by Sloto (1990). This approach allowed taking account of the variation of hydraulic conductivity with depth (acknowledged in the RIR, p121) and hydrogeologic unit, which variation is not included in the RIR model. Critically, many of the formations and depth ranges have hydraulic conductivity substantially higher than the 1.1 ft/day assumed to apply uniformly by the RIR (Appendix S).

The substantial improvement (a reduction in residual statistics by a factor of about 2) of the Baker (2004) model over the model adopted in the RIR can be inferred from the fit to measured hydraulic heads over a near-site hydraulic head range of 90–100 feet (Table 1).

Residual statistic	2019 RIR	Baker (2004)	Unit
Mean	0.899	-0.091	feet
Mean absolute value	6.883	3.793	feet
Root mean square	9.004	4.789	feet
Number of wells	14	~33	(count)

Table 1 Statistics of residuals of modeled versus observed hydraulic heads near the site (RIR: Attachment B to Appendix S, table and figure; Baker, 2004, Figure 28)

6. Impossibility of the RIR modeling to account for TCE plume extension

The essential need to account for variation in hydraulic conductivity in modeling the plume behavior, and in particular for including paths with higher hydraulic conductivity, may be illuminated by some simple calculations. The RIR modeling assumed a constant hydraulic gradient of 0.019, a constant hydraulic conductivity of 1.1 ft/day, a constant porosity of 0.05 (RIR, Appendix S, Table 1), and a retardation coefficient of 9 for TCE. These assumptions imply a linear velocity for a TCE plume (ignoring longitudinal dispersion), or approximately of the center of a plume front (including longitudinal dispersion) of ($1.1\times 0.019/(0.05 \times 9) = 0.0464$ ft/day. After a modeling time of 41 years (2014 to 2055; RIR, Appendix S, Attachment C, Table C1) the distance traveled by a plume front would be approximately 700 feet, which is only about 1/5 the length of the current plume. The model is thus *incapable* of explaining the current plume, which extends at least 3,500 feet after at most 69 years (1951 to 2020),

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corresponding to 1171 feet using the RIR model parameters, so cannot be expected to evaluate the extension of the plume, which was, of course, the claimed purpose of this modeling.

In contrast to the RIR modeling, Baker (2004, Table 30) estimates the hydraulic conductivity in the top 100 feet of the Ordovician Conestoga Formation (in which most of the RIR modeling grid presumably[6] lies) at 10.4 ft/day, decreasing to 1.2 ft/day only in the 300–400 foot depth range.

In the modeling sensitivity analysis, the RIR notes that increasing the hydraulic conductivity by a factor of just 5 would result in the plume extending beyond the modeling domain, but claims that, "The value chosen in the calibrated model is based on Site-specific data (slug tests) for the shallow bedrock zone and represents the highest Site-specific K value of all bedrock aquifer zones at the Site." The slug tests (Roux, 2015b, Table 43) however, show that hydraulic conductivity decreases with depth; and for the first 100 ft depth (center of screen; including both overburden and bedrock), the average value[7] measured in the slug tests is 2.6 ft/day (and the screen-length-weighted average is 2.84 ft/day), with individual values up to 22 ft/day (in a bedrock measurement with screen 46–63 feet, MW-22). Thus, a calibrated model value as high as 10.4 ft/day is quite plausible, and a value at higher than the RIR value of 1.1 ft/day is necessary to explain the current plume size (see below).

An alternative possibility not considered in the RIR is that most groundwater flow is through fractures, with little involvement of the bulk of the soil or rock. Flow through fractures only requires equilibrium with the surfaces of those fractures, not the surrounding rock/soil, so that adsorption to rock and soil would be negligible compared with an assumption of equilibrium with the entire rock/soil mass.[8] In such circumstances, the retardation factor for VOCs could be substantially lower than estimated; and ultimately a retardation factor close to unity is likely. The sensitivity analysis performed for the modeling fails to account for this quite likely scenario.

To further explore the adequacy of the RIR modeling even for evaluation of plume extension, I examined a one-dimensional simplification (see appendix) to overestimate the center-line concentration of the plume. This simplification provides an overestimate because it omits

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[6] The RIR does not provide a diagram of the location of the modeling grid, nor its dimensions, and does not provide any other method of identifying its exact location except by obtaining the model input file and a copy of the model.

[7] For flow through multiple layers driven by the same hydraulic gradient, the total flow per unit width is the sum over layers of the product of layer hydraulic conductivity and layer thickness, so that the average hydraulic conductivity is the layer-thickness-weighted average of layer hydraulic conductivities; in the absence of information on layer thicknesses (and not too extreme differences) the best estimate is the straight arithmetic average.

[8] Diffusion into the rock surrounding fractures would occur, but the time-scale for such diffusion is likely to be long enough to result in negligible effect. A fracture-transport model would take such effects into account.

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dispersion to the sides; however, I expect that the results provided could be reproduced in the two-dimensional case with slight adjustment to the parameters. The simplest possible example, and an absolute worst case, assumes that the source has been maintained at a concentration equal to the solubility limit of TCE, approximately 1,100,000 μg/L (e.g. Baker, 2004, Tables 1–18) from the initial possible time of 1951 through 2013, the mid-point of the times used in the RIR to construct the contours shown in Figure 46 of the RIR, and continues forever. Figure 8 shows the result, which demonstrates that even in this worst-case scenario, the model adopted by the RIR (with the parameter values in the RIR, Appendix S, Table 1) cannot account for the distance to the 10 μg/L plume contour (nor the predicted 5 μg/L contour).

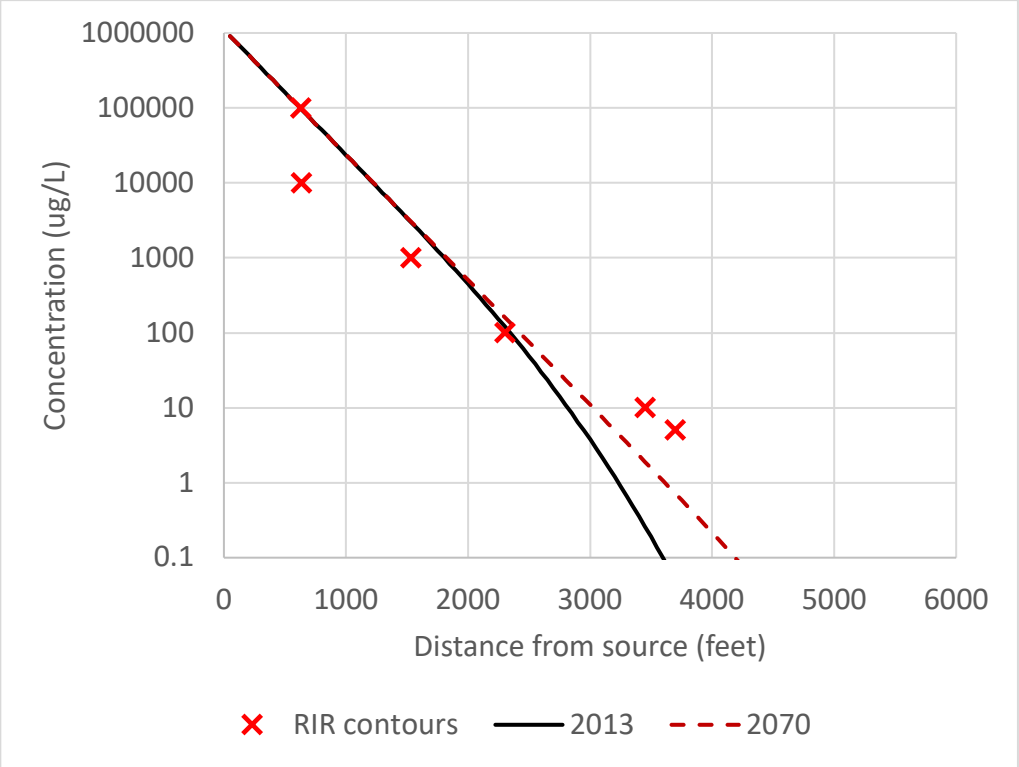

Figure 8 The absolute worst-case estimate of plume centerline concentration using the RIR model.

Clearly, with the parameter values used in the RIR, this worst-case plume would be in steady state out to 2,000 feet in 2013, and out to beyond 4,000 ft by 2070, and the 5 μg/L contour would never extend beyond about 3,200 feet.

It is, however, not difficult to find parameter estimates within the range discussed in the RIR or in previous modeling (Baker, 2004), that allow matching the plume estimates of RIR Figure 46, at least beyond the 100,000 μg/L contour. I consider that contour to simply reflect the anisotropy of the subsurface, with insufficient distance from the source(s) for the averaging effect of dispersion to have had sufficient effect for any smooth model to match it. For

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example, simply increasing the estimated hydraulic conductivity to 2.129 ft/day and reducing the assumed (constant forever after 1951) source term gives Figure 9, which shows a plume in practical equilibrium to about 2,500 ft by 2013, and beyond 5,000 feet in 2070.

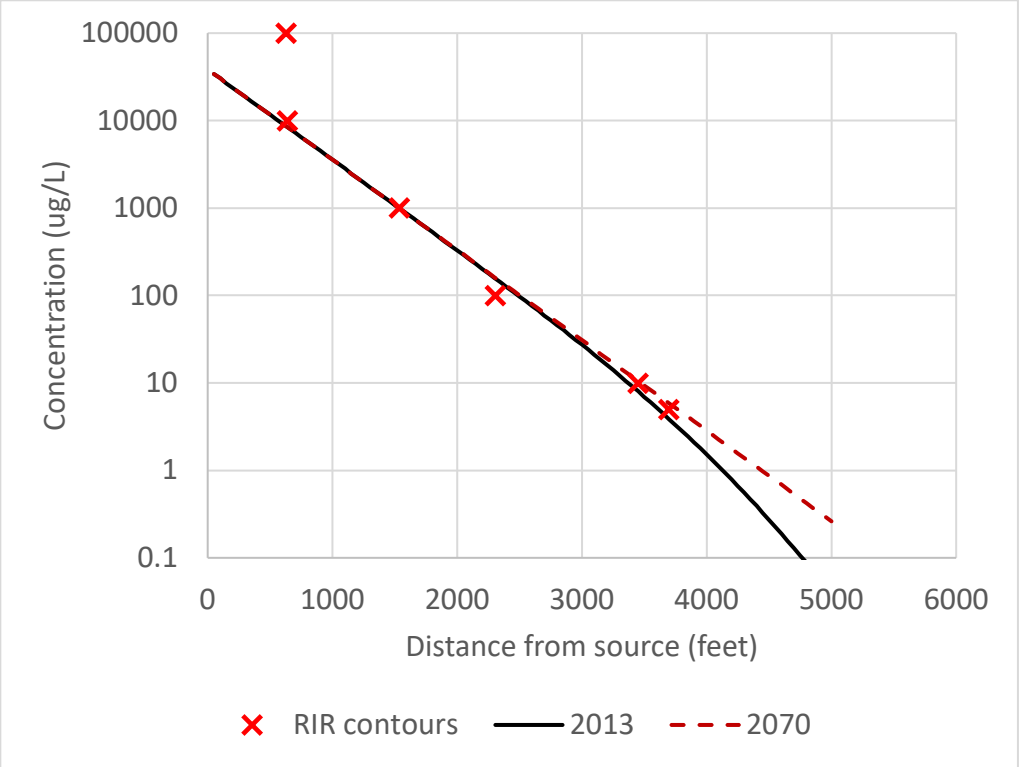

Figure 9 Showing that a constant source can match the RIR results with just a change in hydraulic conductivity.

However, while it is possible to find combinations of parameters agreeing with the RIR conclusions, it is also possible to find combinations that disagree substantially. Thus Figure 10 shows an example with variable source term that matches the RIR estimated plume in 2013, but demonstrates that the plume might extend considerably further by 2070 (indeed, in this case, the 5 μg/L contour would extend to approximately 4,500 ft by about 2100). This particular solution corresponds to a hydraulic conductivity of 1.776 ft/day and a degradation half-life of 3,506 days,[9] which are fully as plausible as the values used in the RIR and are "calibrated" to the observed plume in 2013.[10]

[9] Combined with a source term that varies from 1,100,000 μg/L starting in 1954, dropping to 3,000 μg/L in 1954.25, increasing to 103,907 μg/L in 1988, then decreasing to 31,172 μg/L in 1991.

[10] The source term dates were chosen (not quite arbitrarily) and then the other parameters obtained by a constrained optimization. The fit to the 2013 RIR plume contours (omitting 100,000 μg/L or higher) is well within any uncertainties in the contour locations.

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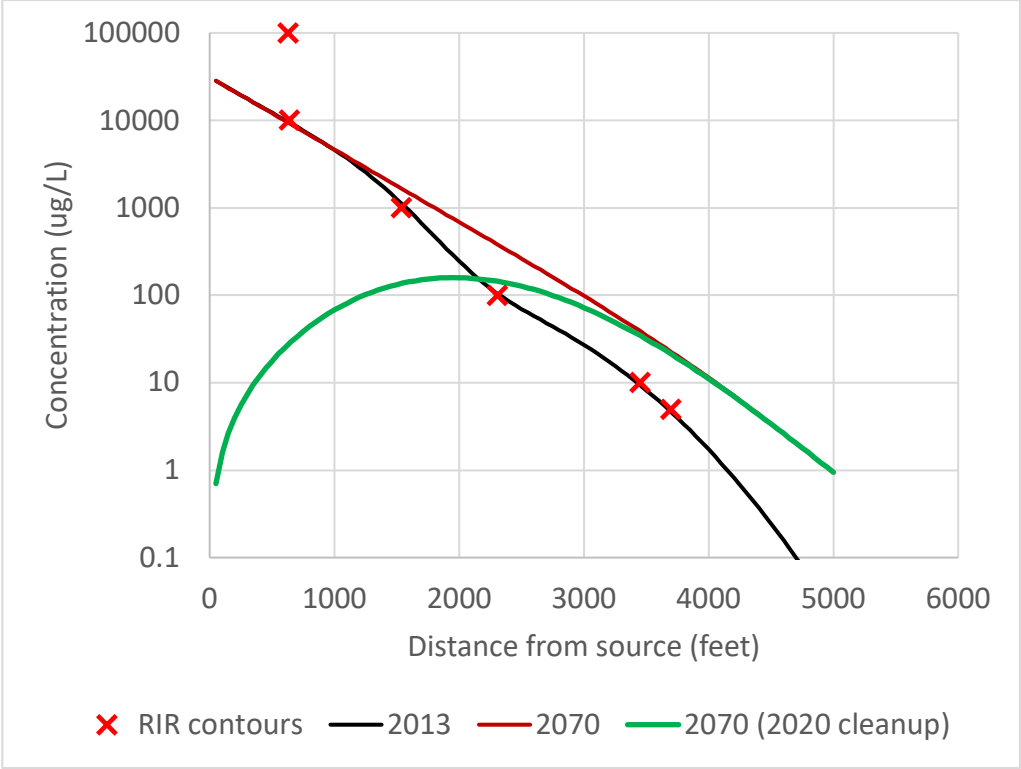

Figure 10 An example showing that the RIR might have substantially underestimated potential plume extent; and the effect of an immediate source term cleanup.

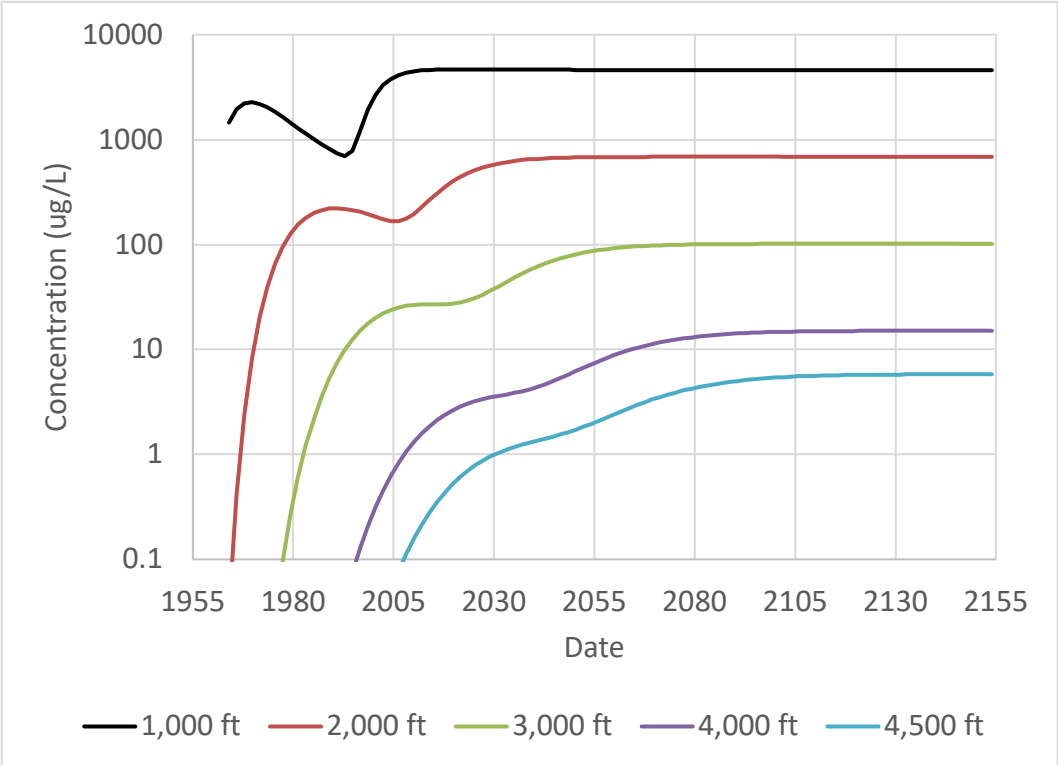

Figure 11 Concentration versus time at various distances for the example in Figure 10

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Concentration versus date curves at various down-gradient distances for the example shown in Figure 10 are shown in Figure 11. Noteworthy features include:

- Periods of decreasing concentration have nothing to do with TCE degradation. They are controlled by variations in source terms.
- The "decay rates" estimated from such periods would certainly vary by location, and probably by time frame.
- Ultimately, all concentrations tend to a constant value (this occurs because of the assumption of a continuing source).
- The time to reach the ultimate value can extend well beyond the modeling time-frame of the RIR (which was limited to 2055).

This example is probably not entirely compatible with all the measurements in individual wells at the site, although short term fluctuations in source term (not included here) could provide better correlations with such measurements while retaining the overall average effect. It is included to illustrate the potential effect of variations in source term. An adequate RIR would investigate the inverse problem of estimating the source terms from the well measurements, and obtain a consistent solution that would allow accurate estimates of the future plume.

Also shown on Figure 10 is the effect of stopping the entire source completely in 2020, to illustrate the importance of immediate action. The hypothetical source term was selected so that, in 1991, 70% of the source at that time was removed in an effort to illustrate the potential effect of stopping TCE releases at the site at that time. Any DNAPL TCE in the bedrock at that time would sink to deeper levels, with some presumably remaining trapped in blind pockets throughout the rock column. Gradual dissolution of both sources would probably provide a substantially reduced source strength compared with DNAPL TCE still flowing through the rock column. However, TCE present as DNAPL in or adsorbed to soil above the rock column would not be so affected by such a change — that would still be available for leaching into groundwater. Unfortunately, the RIR makes no attempt to evaluate the relative sizes of these sources, but merely assumes that both vanish entirely — the TCE in the rock column by implicit omission, and the TCE in the soil by simply assuming it away. Figure 10 arbitrarily assumes that the rock column is a negligible source after 1991, and that leaching from the soil could amount to 30% of the total at that time (and could continue forever). Removing the soil in 2020 would then correspond to the green curve, showing a substantial reduction in concentrations over the first 3,000 ft of plume by 2070.[11]

[11] Nothing done at the site can have any effect beyond about 3,000 ft (for the combination of hydraulic conductivity and half-life simulated) by 2070, since there is insufficient time for any effect to propagate that far in that time

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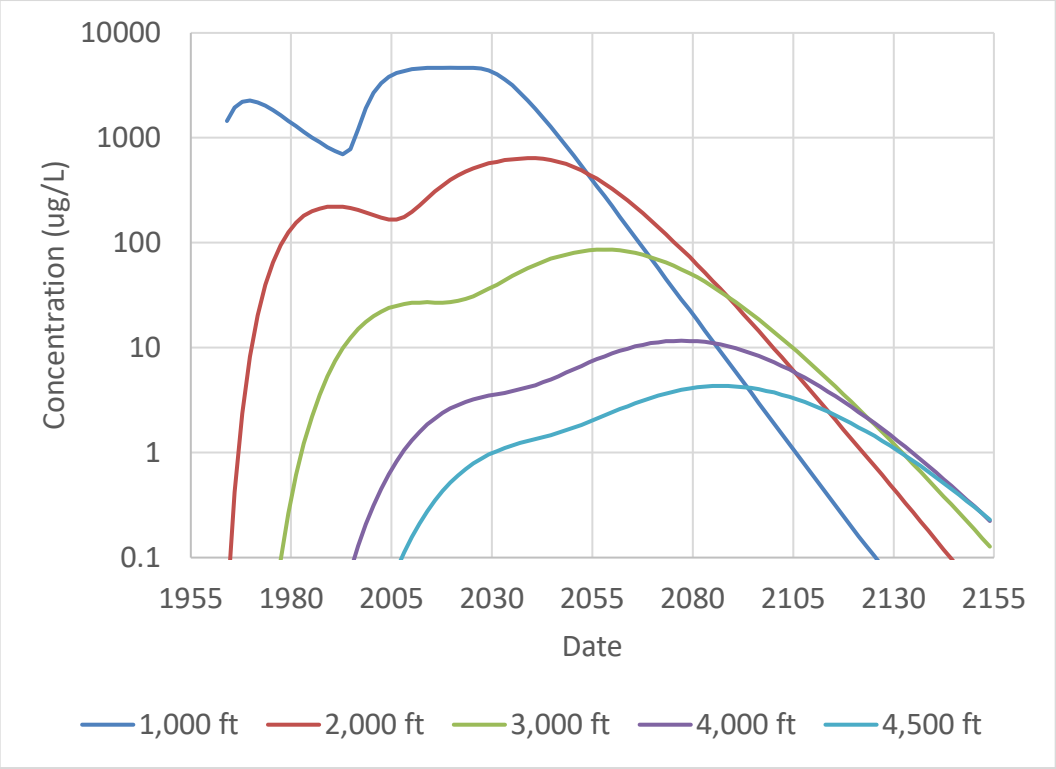

Figure 12 Concentration versus date curves at various distances for the clean-up scenario in Figure 10

The concentration versus date curves corresponding to the cleanup scenario of Figure 10 are shown in Figure 12. Further noteworthy (and generic) features (compared with Figure 11) are:

- After a time delay corresponding to the propagation time from the source, the concentrations start to decline almost exponentially with time.
- Despite the appearance on Figure 12 that the declining curves could be parallel and straight, the exponential declines are different at different times and distances, and none of them correspond to the TCE degradation half-life (they are more rapid).

7. Inadequate boundary conditions on the modeling

The RIR model imposes a line sink boundary condition at the Little Valley Creek (LVC) in the part of the modeling domain where the LVC was measured as gaining. This condition, however, is artificial, since it implies (in the model) that no TCE can be advected under the location of the LVC. However, the more complex and realistic MODFLOW/MODPATH/RT3D modeling by Baker (2004) demonstrated such flow beneath the LVC (Figures 41–44). Examination of a cross-section of the valley (Baker, 2004, Figure 15) illustrates why the LVC would not be expected to act as a groundwater boundary, except in shallow groundwater, with the continued decrease in surface elevation down to Valley Creek.

The initial contour shape in the vicinity of the Northwestern corner of General Warren Village appears unlikely, and there are no wells in that corner of the Village to confirm or deny the

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prior modeling (Baker, 2004, Figures 41–52) that projected contamination beneath that corner. The RIR also lacks any figures showing future modeled contours, except for the interpretation of the plume extent, so prevents evaluation of the modeling in that area.

8. Undetermined effect on the Little Valley Creek (LVC)

The LVC, treated as a line sink, was specified as gaining 75 gallons per minute along a 2,500 foot length (RIR, Appendix S, p7), despite the substantially higher measurements. These inflows along the northern boundary of the site imply influxes of TCE carried by those inflows. However, there is no accounting for the effect on concentrations in the LVC from those flows, so the RIR has failed to document the potential degradation of this stream, which is classified as being of exceptional value.

9. Undetermined evaluation of other volatile organic compound (VOC) contaminants

The RIR documents measurements of multiple volatile organic compounds (VOCs), but then models only the TCE plume. Other VOCs may have different plume characteristics because of their different transport and decay characteristics, and in any event should be explicitly evaluated. Of particular concern is the potent, established, human carcinogen, vinyl chloride (VC), which has a soil-water partition coefficient approximately 1/9 that of TCE, hence a retardation factor of about 2, so would move through the subsurface approximately 4 times faster than TCE. Actual concentrations would also depend on decay rates that differ for different VOCs. And since VC is a microbial degradation product of TCE, evaluation of plume characteristics requires a model such as the reactive multi-species transport in 3-dimensional groundwater systems model (RT3D) designed to account for degradation of contaminants.

10. Incomplete assessments of impacts to public health and the environment

The RIR performs limited human health risk assessments involving vapor inhalation and exposure to surface water based on recently measured concentrations at individual wells and in individual buildings (and implicitly for groundwater ingestion), but fails to evaluate the potential effects of future modeled concentrations throughout the whole plume. Indeed, it could not do so, in that it failed to model future concentrations of all contaminants, or any contaminants at all in the LVC. There are also no assessments of risk from other potential uses of groundwater, such as irrigation, or commercial and industrial uses.

Potential ecological effects were claimed to be evaluated in the tributary of the LVC near the Bishop Tube site, but the effect on the LVC of future potential concentrations was not evaluated (and, again, could not be evaluated through lack of evaluation of such concentrations). It is notable that the concentrations of hexavalent chromium in the tributary exceeded the PADEP Fish and Aquatic Life criteria (RIR Table 20) on the single occasion (in 2018) on which it was measured under low flow conditions; yet the Ecological Risk Assessment (RIR, Appendix R) passes over hexavalent chromium because “hexavalent chromium, thallium and vanadium did not have TRVs that could be located in the published literature commonly used to conduct ecological risk assessments, therefore the potential for ecological risk to benthic invertebrates ***cannot be estimated***” (emphasis added). Clearly, however, what can be

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"estimated" is that the current conditions exceed PADEP criteria. Moreover, it appears that hexavalent chromium has never been measured any further downstream than SW-5, despite the exceedance of criteria at SW-5. Clearly again, therefore "the potential for ecological risk to benthic invertebrates cannot be estimated" any further downstream into the LVC.

11. Inadequacy of the Feasibility Study Report (FSR)

The Feasibility Study Report necessarily relies upon the RIR for site evaluation, and in particular must account for the future condition of the site under various alternative scenarios. As documented above, however, the RIR fails to adequately evaluate future site conditions in the plume. The Feasibility Study Report is thus necessarily inadequate, since evaluation of future changes due to potential remedial technologies necessarily require an accurate baseline. This is particularly true for "Monitored Natural Attenuation" (MNA), since the only clean-up mechanisms in such circumstances are decay, dilution, and containment (if the latter two can be considered "clean-up"). The RIR, however, provides an inaccurate estimate of decay rate and dilution for TCE only, since it uses a methodology that fails to account for multiple effects. Production, decay, and dilution of the other VOCs is, inappropriately, ignored entirely.

In addition, the FSR considers that the DNAPL phase of TCE in deep bedrock is "a) below the water table, b) contained in rock, and c) at depth," so that "there is no direct exposure pathway from DNAPL in bedrock" (FSR, p6). However, this is an argument made without any apparent analysis whatsoever. The RIR assumes the absence of DNAPL and fails to evaluate multiple depth ranges separately, so cannot examine whether there is a "direct exposure pathway." Such a pathway is certainly plausible, since the deep DNAPL will certainly act as a source to groundwater, and that groundwater may be directly tapped, or may flow into surface water. The current RIR does not (and could not) evaluate either possibility; clearly, it should.

Concluding remarks

Overall, then, the analyses presented in the 2019 Remedial Investigation Report and Feasibility Study Report for this site are inadequate, particularly with respect to evaluation of the future plume conditions and associated risks: these reports could and should be improved. Such improvements should include full acknowledgement and use of previous analyses. The substantial quantities of TCE, other volatile organic compounds, and inorganic contaminants apparently remaining in soils at the site create a potentially significant risk to public health and the environment, due to exposures via soil, ambient air, surface water, and groundwater. It appears that prevention of continuing contamination of the LVC tributary, if not the LVC itself, above PADEP criteria requires removal (or other mitigation) of the site soil sources. And further downgradient contamination with TCE and other VOCs would also likely be substantially ameliorated by removal (or other mitigation) of site soil sources; and given the likely higher cost and requirement for off-site action to achieve the same amelioration later, the sooner the better.

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Acknowledgements
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Appendix: The one-dimensional advection-dispersion groundwater solute transport model

1. **Analytic solution for specific boundary conditions**

The one-dimensional version of the advection-dispersion groundwater solute transport model of the Aquifer^{Win32} model (ESI 2011) as used in the RIR is a solution of the differential equation:

$$D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} = \varphi R\frac{\partial C}{\partial t} + \lambda\varphi RC$$

where the terms are:

$C = C(x,t)$	the solute concentration at distance x, time t,
$V = -iK$	the Darcy velocity of the groundwater, the product of hydraulic gradient i and hydraulic conductivity K,
$D = \alpha V$	the dispersion coefficient, the product of the dispersivity α and the Darcy velocity V (ignoring molecular diffusivity, which is small enough to ignore in this context),
φ	the porosity of the soil or rock,
R	the retardation coefficient of the solute, and
λ	the first-order decay coefficient of the solute.

This formulation assumes that all the terms except C are constant in time and space (as assumed in the RIR), and for this analysis the required solution has boundary conditions of a zero concentration everywhere prior to $t = 0$, with a constant concentration C_0 for all $t > 0$ at $x = 0$ (maintained, for example, by dissolving DNAPL), and with $C(x,t) \to 0$ as $x \to \infty$ for all t.

The unique analytical solution satisfying the differential equation with these boundary conditions is:

$$C(x,t) = \frac{C_0}{2}\exp(-\lambda t - [X - B]^2)\{\mathrm{M}(X + \gamma) + \mathrm{M}(X - \gamma)\}$$

where:

$$a = {}^{D}/_{\varphi R};\ b = {}^{V}/_{\varphi R};\ d = 2\sqrt{at};\ X = {}^{x}/_{d};\ B = {}^{bt}/_{d};\ \gamma = \sqrt{\lambda t + B^2};\ \text{and}$$

$$\mathrm{M}(z) = \exp(z^2)\mathrm{erfc}(z) \text{ for arbitrary } z \text{ is a modified Mills ratio}$$

This solution was used in the text to produce the curves shown. The linearity in concentration of the differential equation shows that the effect of multiple sources can be obtained independently and added to obtain the effect of all sources combined; and negative sources at later times can be used to obtain the effect of arbitrary step function sources.

2. Unique unphysical solution for similar exponential decay at all locations and times.

If it is assumed, as in the RIR, that the concentration at all locations falls exponentially with the same decay rate λ at all times, then the right hand side of the defining equation above

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vanishes, and the solution factorizes into a product of a term exp(–λt) and an x-dependent term $H(x)$, which is the solution of the equation

$$D\frac{d^2H}{dx^2} - V\frac{dH}{dx} = 0$$

which has the general solution

$$H = K_1 + K_2 \exp\left({}^{Vx}/_{D}\right)$$

where K_1, K_2 are constants, corresponding to a concentration everywhere constant or exponentially increasing with x everywhere, which is physically impossible.

Appendix Reference

ESI, 2011. Guide to Using Aquifer^{Win32} Version 4. Environmental Simulations, Inc., 300 Mountain top Rd., Reinholds, PA 17569. [Note: the RIR used Aquifer^{Win32} Version 5, but correspondence with ESI shows the Version 4 manual applies to Version 5]

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Technical Memorandum

January 13, 2022

Subject: Bishop Tube 2021 Remedial Investigation Report, Feasibility Study, and Selection of Alternative

Prepared for: Delaware Riverkeeper Network

Summary

Roux Associates (Roux) completed a Remedial Investigation Report (RIR) and Feasibility Study (FS) for the Bishop Tube (BT) site in 2021[1], which were updates to 2019 versions. The FS identifies potential remedial activities, as identified by Roux. A FS Addendum supplemented the FS report. In August 2021, the Pennsylvania Department of Environmental Protection (DEP) issued its Analysis of Alternatives and Proposed Response (AOA) in which it chooses its remediation plans for the BT site. The memorandum reviews that choice and DEP's reasoning.

DEP chose an alternative that mixes soil recovery (OU1), groundwater remediation (OU2) and drinking water (OU3) into one decision in the AOA.

For soils, DEP chose to use an in-situ injection alternative which could inject either reductive or oxidizing compounds into a mixed surface soil. The soil in the targeted areas would be mixed down to the saturated zone. DEP's choice for soils is not acceptable because it will leave TCE in place at areas that will not be treated and will not treat all the TCE at the treated locations. For groundwater, DEP combined all FS injection alternatives into a simple in-situ injection alternative combined with the soil injection choice. It only directly treats two areas, the building vapor degreaser and the drum storage area with chemical amendments that still have to be chosen. By not choosing which chemical addendums to use, DEP essentially admits it does not understand enough about the groundwater chemistry of the site. Treating just two areas would leave substantial TCE mass in place in the bedrock and groundwater. By not treating offsite areas, the plume would be allowed to naturally attenuate, a process DEP rejected as an

[1] Roux Associates, Inc., Remedial Investigation Report (Volume 1 of 2), Former Bishop Tube Property, January 13, 2021. Roux Associates, Inc., Remedial Investigation Report (Volume 2 of 2), Former Bishop Tube Property, January 13, 2021. (hereinafter RIR). Roux Associates, Inc., Feasibility Study Report, Former Bishop Tube Property, January 13, 2021. (hereinafter FS). Roux Associates, Inc. Former Bishop Tube Site Feasibility Study Addendum, Remedial Alternative #8 – Basis of Design Memorandum, December 20, 2020 (hereinafter FS Addendum).

alternative because it would take decades, during which time it will continue to impact on-site and off-site areas.

In choosing its remediation plan, DEP relied heavily on Roux RIR and FS reports. Roux assumed the property would be developed for nonresidential uses but, the property has since been rezoned for residential use. The RIR assumes that the soils, meaning unsaturated materials above the water table in the overburden, will be removed, so that analysis assumes there is no contaminant source leaching into the groundwater long term. These assumptions bias all analyses of groundwater quality and remediation strategies presented in the FS, making the strategies seem to remediate the area faster than they otherwise would if the surface soils are not removed or otherwise adequately treated.

There are at least three identifiable aquifers on the site. On the surface, there is overburden, which is saturated soil on top of the bedrock. Second is shallow bedrock which is substantially fractured bedrock with relatively high conductivity. Deep bedrock where fractures become smaller and denser is a third aquifer. Roux treats overburden and shallow bedrock as one aquifer, but this is inappropriate because the bedrock has a northeasterly fracture trace so that groundwater tends to flow in that direction, but the overburden does not. Deep bedrock also trends northeast.

Trichloroethene (TCE) concentrations vary substantially with both location around the area and with time at all levels. A plume map shows the site has affected groundwater north of Lancaster Ave to at least Conestoga Blvd. The TCE contour map as presented in the RIR has errors and uncertainties as represented by the rapid fluctuation of TCE concentrations in various wells and the lack of a single consistent date for sampling events. A steep gradient in the concentration contours on the east side is not supported by the data due to a lack of monitor wells in the General Warren Village east of Bishop Tube.

TCE concentration varies with depth and between the overburden and bedrock such that a single map does not adequately represent the plume. Showing TCE contours for the entire site is a gross simplification and does not demonstrate the actual conditions at the site.

TCE concentration at some wells varies substantially, probably due to recharge events. There are very high concentrations in the overburden very near several sources on the BT site. The two areas with highest known concentrations are the Building 8 vapor degreaser site and the drum storage area east of Building 5. There are also very high TCE concentrations in the deep bedrock under the site. Northeast of the site between Lancaster Ave and Conestoga Blvd, the highest known concentrations are in the shallow bedrock, not the overburden. There are also

very high TCE concentrations in the shallow bedrock just northeast of the site which may be a fracture flow zone to the northeast.

Groundwater at the Bishop Tube site eventually discharges to surface water, specifically the Little Valley Creek (LVC) tributary just east and north of the site. Surface water quality data shows the TCE concentrations increase along the stream reach from nondetect upstream of BT to levels that substantially exceed standards at the northeast corner of the site. TCE is detectable surface water as far as a site beyond Conestoga Ave. By considering just concentration instead of load, the RIR does not provide a good description of TCE interaction between the groundwater and surface water. TCE concentrations have decreased since 2003, but the data is not controlled for flow which could cause the concentrations to fluctuate due to the amount of dilution.

TCE and other contaminant concentrations in surface and groundwater at and near the site continue to represent a threat to human health and the environment. The FS provides seven alternatives for remediation, including no action (1), monitored natural attenuation (MNA, 2), in-situ chemical reduction (ICR, 3), in-situ chemical oxidation (4), enhanced reductive chlorination (5), two-part in-situ chemical oxidation (6), and hydraulic control (HC, 7). MNA is basically just monitoring the on-going natural attenuation and would require decades or longer for the site to be remediated. Alternatives 3 through 6 all involve injection of chemical amendments that would treat the organic contaminants. The FS does not identify the amendments which would be determined once the strategy is selected. Because it does not specify the amendments, the FS is incomplete and cannot be considered a decision document; a reviewer does not have a full picture of what is being proposed. The FS Addendum added an eighth alternative which combined soil and alternative 3 ICR treatment but reduced the number of areas to be treated. It would leave much more TCE in the groundwater as compared to alternatives 3 through 6, assuming an appropriate amendment was chosen.

Alternative 7, HC, involves creating a line of low water level or potentiometric surface levels which would create a capture zone for groundwater flowing from the site. It would likely be effective only in alluvium because pumping from fractured rock would remove water mostly from the larger fractures. TCE would remain in the smaller fractures and adsorbed to the aquifer media. HC could deplete stream flow or dry groundwater dependent wetlands which would be an unacceptable effect.

The FS did not consider an alternative that mixes injection with HC. A line of wells downgradient of the injection sites could intercept any contaminants created by injection, including toxic breakdown products, the targeted contaminants that had been adsorbed to the soils, or the chemical amendments.

As noted above, DEP chose a slimmed-down alternative that mixes soil recovery, groundwater remediation and drinking water into one decision. It would leave contaminants in the soils and fail to treat major groundwater contaminationareas. Contaminants would continue to leach into Little Valley Creek.

Throughout the FS, revised FS and DEP's decision document, there is a failure to consider the actions that have worked at similar sites. Roux and DEP failed to complete a detailed literature review of the remediation of other TCE sites or compare them to Bishop Tube. DEP is making decisions for Bishop Tube without learning from similar sites. The memorandum below details many issues regarding trend in contaminants at the site including temporal and spatial trends. There is detailed discussion of the fate and transport model developed in the RIR and relied on for developing the FS and AOA.

Introduction

The Pennsylvania Department of Environmental Protection (DEP) issued its Analysis of Alternatives and Proposed Response (AOA) in August 2021 in which it chooses its remediation plans for the Bishop Tube (BT) site. The memorandum reviews that choice and DEP's reasoning. In preparation for the AOA, Roux Associates (Roux) completed a Remedial Investigation Report (RIR) and Feasibility Study (FS) for the BT site in 2021, which were updates to 2019 versions. The RIR supplemented earlier reports completed in 2015 and 2010 (RIR, p 1). RIR Appendix A presents raw soil contaminant concentrations and Appendix B presents a time series of groundwater concentrations for all monitoring wells. RIR Appendix S partially documents a groundwater fate and transport model used to develop the plume map. The FS identifies potential remedial activities, as identified by Roux. This memorandum reviews aspects of the RIR and FS, concentrating on the 2021 versions that provide the basis for DEP's choice in the AOA.

Analysis of Site Hydrogeologic Conditions

There are at least three identifiable aquifers on the site. On the surface, there is overburden, which is saturated soil on top of the bedrock. Second is shallow bedrock which is substantially fractured bedrock with relatively high conductivity. Deep bedrock where fractures become smaller and denser is a third aquifer. Roux treats overburden and shallow bedrock as one aquifer, but this is inappropriate because the bedrock has a northeasterly fracture trace so that groundwater tends to flow in that direction, but the overburden does not. Deep bedrock also trends northeast.

The RIR does not quantitatively describe the hydrogeologic properties of the site, which should be the first step to developing a site conceptual model. The 2015 RIR provided a cursory description of slug-test results but left out significant important information. The RIR essentially sets conductivity equal to 1.1 ft/d for the entire aquifer consisting of both overburden and fractured bedrock, the geometric mean of a few slug tests discussed in the 2015 RIR (conductivity is specified only in RIR Appendix S). A mid-range estimate such as the mean ignores the high and low values which control most flow. Reported values (in the 2015 RIR) are as much as an order of magnitude higher than the geometric mean which would indicate there are preferential flow zones at the site. Flow and contaminant transport through such a zone occur much faster than expected from the (unweighted geometric) average values. Contaminants could flow much faster and have a higher load than expected using averages.

The geometric mean conductivity also provides no information regarding anisotropy, the tendency for conductivity to be greater in one direction over another so that more flow occurs in that direction. As will be discussed, flow at this site is at an angle to the primary gradient, south to north, which means there are preferential flow zones in the bedrock that controls the flow direction.

Contaminants in groundwater at the site (chlorinated volatile organic compounds (CVOCs)) discharge to local tributaries of Little Valley Creek (LVC). Stream trichloroethene (TCE) concentrations have decreased for six consecutive sampling events, but those events may not be comparable, because they were collected during differing wet or dry periods, when flow rates were not similar. Surface runoff dilutes the stream concentrations because the contaminants are not lying on the ground surface where they can be washed into runoff. Roux's analysis of trend mixes observations from different flow regimes and therefore is not evidence of a decreasing TCE load in the stream.

There has been no data collected or tests performed to obtain evidence describing groundwater flow, dissolved contaminant transport, dense non-aqueous phase liquids (DNAPL, undissolved TCE and other COCs,) or flow among aquifer levels, although it clearly occurs. This would be important to understand how fast contaminants settle into the aquifer and from how deep they could discharge to LVC. Without this information, it is not possible to estimate how the various remediation scenarios in the FS would respond.

Soil Concentrations

RIR Appendix A compiles soil contaminant masses from 1988 through 2018, but Roux does not analyze soils contaminant concentrations or consider them as a source. It presents figures of concentration in soils of TCE and other contaminants including heavy metals; the figures color

code wells by contamination categories. Soil samples have identified CVOCs including TCE, 1,1,1-trichloroethane (TCA), cis-1,2-dichloroethene (cDCE), and tetrachloroethene (PCE) (Id.). An earlier figure presented by Baker includes contours of TCE (Figure 1). Contaminants occur in at least three hot spots, but there is no evidence of how they vary with time. Neither the RIR figures nor Appendix A present data that can be analyzed for trend because samples are spot measures, not monitoring points, meaning they extract soil at distinct locations rather than measure concentrations in place.

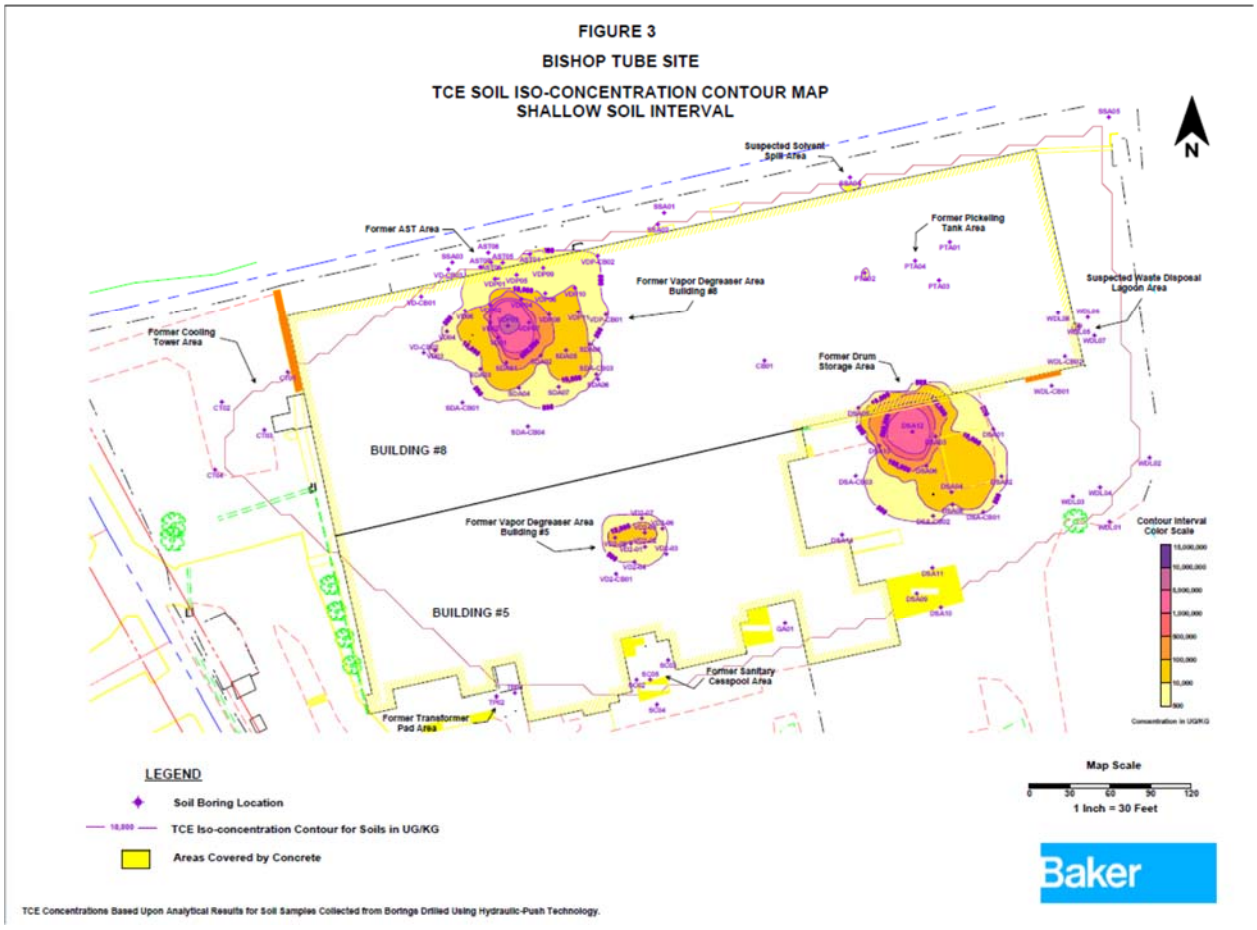

Figure 1: Concentration map for TCE prepared by Baker 2003).

Roux collected additional data from known hotspots and PADEP investigated reports of other potential hot spots, with Roux analyzing split samples, but did not find any. There does not appear to have been a systematic sampling of soil beneath the site. Without sampling on a grid, it is impossible to rule out the existence of other soil surface hot spots.

Without time series plots of the mass of contaminants including TCE and the various breakdown products, it is not possible to assess whether the mass in soils is decreasing, as might be expected as precipitation leaches mass from the original sources.

The groundwater analysis erroneously assumes that the soils, meaning unsaturated materials above the water table in the overburden, will be removed. This means the analysis assumes there is no contaminant source in the unsaturated zone leaching into the groundwater long term. Assuming total removal of the source renders predictions of the evolution of the plume inaccurate if removal does not actually occur and renders the use of the model, discussed below, to assess remediation useless.

Groundwater TCE Concentrations by Well

RIR Figure 30A and B shows most recent TCE concentrations for monitoring wells in the overburden, shallow, intermediate, and deep bedrock groundwater, respectively. Because the observation dates vary from 2014 to 2018, with a few being even earlier, the maps are not a snapshot in time. However, discussions throughout the RIR alleging concentrations are steady state or falling imply these figures are somehow a maximum observation.

The TCE concentrations by depth in RIR Figure 30 tell a story of the TCE sources and migration. In the overburden, the highest concentrations occur under one portion of Building 8; the remaining overburden wells throughout the area of the building show detectable but lower concentrations. Northeast of the source in Building 8, concentrations are higher in shallow bedrock than in the overburden. This is at an angle to the flow path expected based on groundwater gradient which suggests regional flow and contaminant advection should be due north. However, Figure 30 shows that in the overburden (MW-49A and MW-60) and the shallow bedrock (MW-7, MW-14D, MW-49B and MW-50A, B), little TCE moves in that direction and TCE is almost nondetect north of Lancaster Blvd.

Overburden wells north of Lancaster Ave and east of LVC, northeast of the site, have relatively higher TCE concentrations than found in the overburden on the northeast portion of the property away from the sources. Shallow bedrock wells there have higher TCE than occurs in the overburden. TCE at depth north of Lancaster could be from vertical movement because of limited horizontal conductivity and even connectivity in the fractures at depth. Transport to those wells appears to be through shallow bedrock and a preferential pathway in deeper bedrock. MW-51 (all levels) and MW-79A show very high TCE concentrations in an area offsite near Lancaster Ave between the site and the area north of Lancaster Ave. Well MW-26B shows high concentrations in the northeast of the site. The high TCE concentrations at these wells could reflect transport and measurements along a specific fracture that is not monitored either

further up- or down-gradient. This pathway should be better delineated to identify targets for treatment.

TCE concentrations on the site around Building 8 are higher at depth than in the overburden or shallow bedrock due to the tendency for TCE to disperse vertically downward because it is denser than water. Only at the source is the concentration at Building 8 high in shallow aquifers. MW-78 demonstrates the short-term variability of TCE concentrations in shallow bedrock and that the AOC continues to be a source that leaches during recharge events. This well is located near the center of the AOC in NW Building 8 and has screens in bedrock from 85 to 110 (A), 262 to 287 (B) and 340 to 400 (C) ft below ground surface (bgs), respectively. In just two years, the shallow well decreased from 10,000 ug/l to non-detect and then increased back to 15,600 ug/l; this demonstrates a slug of TCE transported through the aquifer layers, likely with a significant downward gradient. MW-78B fluctuated between 21,500 and 93,600 ug/l and MW-78C between 147,000 and 233,000 ug/l. The proportional fluctuations at depth are likely less than higher up because the K at depth is lower so groundwater and TCE moves slower and thereby accumulates. Recharge events cause this temporal variability, but the RIR does a poor job in considering these variable sources. Unless treatment removes these sources, high TCE concentrations at depth will continue for a very long time.

DNAPL is likely the source of very high TCE in wells under the northwest and northeastern portions of Building 8 (RIR Figure 30B). It is likely bound in the bedrock and slowly dissolving into the groundwater. The slow movement of groundwater at depth allows the concentration to become very high. There is insufficient well density, however, to know whether preferential flow causes some TCE to move far from the source, however it could be part of the fracture trace discussed above. For example, MW-44C had TCE equal to 694 and 646 ug/ in 2017, but it appears to be downgradient of MW-43C which had TCE equal to 27 ug/l; this suggests there could be very narrow pathways for TCE to move from DNAPL sources downgradient. The paucity of sampling also allows many areas that could be substantial sources to have been missed or remain unknown for these studies. Remediation plans will miss the DNAPL sites due to poor sampling.

DNAPL resident in bedrock will be a long-term source of TCE to bedrock groundwater at the site if it is not properly remediated. For this reason, an accurate map of wells that potentially have DNAPL is necessary. RIR Figure 47 is grossly insufficient because it is not a systematic assessment of DNAPL. There has not been a systematic drilling program to various depths to identify DNAPL. Areas on the map without wells with potential DNAPL will be inappropriately assumed to be free of DNAPL and not receive the remediation treatment they require.

In summary, TCE concentration maps show two trends for TCE emanating from the source in Building 8. After dissolving into overburden and shallow groundwater, it flows northeast to the area north of Lancaster Ave likely through a preferential flow zone. This should be identified and be a target for treatment. Some TCE disperses to deeper bedrock. At the site, DNAPL has settled into deep bedrock which causes very high TCE concentrations at depth. These areas must be treated or they will be a long-term source of TCE to the groundwater that will spread downgradient.

Groundwater TCE Concentration Contour Mapping and Errors

The RIR presents TCE concentration contours in two figures, Figures 45 and 46, developed in the groundwater model discussion presented in RIR Appendix S (the model is reviewed below). Roux hand-contoured contours from 10 to 100,000 ug/l (logarithmic spacing) based on 2012 to 2014 groundwater quality data for both figures. The figures claim they used the maximum concentration from that period (which means the concentrations used for the mapping differ from those presented in Figure 30 and discussed in the previous section), therefore the figures do not represent a point in time. The description of the contours indicates the contouring was for just shallow bedrock (RIR, App S, p 11), although the figures show both overburden and bedrock wells. For nested bedrock wells, Roux used the highest concentration regardless of depth, so the plume map cannot be said to represent a given level in the bedrock. Some wells have higher TCE at depth, so the map would be representing deep bedrock at those wells. The 5 ug/l contour, developed in part using the groundwater model, is the only difference between Figure 46 and Figure 45.

Concentrations in overburden wells SMP-2 through SMP-5, adjacent to the LVC tributary east of the site, far exceed the mapped contours. For example, TCE concentrations at SMP-2 is 245 ug/l although it is outside of the 5 ug/l contour[2]. The concentration at SMP-1 on the same date is 802 ug/l although it is between the 5 and 10 ug/l contour. The SMP wells are shallow, with screens from 5 to 10 or 6 to 11 ft bgs. These observations show the TCE has certainly expanded further east toward General Warren Village in the overburden than Roux estimates in the bedrock, although the basis for the 5 ug/l contour is unclear since Roux does not present any contoured model outputs, and these results contradict earlier multi-level modeling (Baker, 2004). There are insufficient wells east of LVC in the General Warren Village to accurately identify the extent that TCE has reached within the subdivision.

TCE concentrations vary substantially with both location around the area and with time at all levels. Therefore, the TCE contour maps as presented in the RIR has errors and uncertainties as

[2] Table B-1 presents a time series of concentrations for all wells

represented by the rapid fluctuation of TCE concentrations in various wells and the lack of a single consistent date for a sampling event. Continuing recharge of TCE is one cause of short-term variability.

TCE extends far from the original site, as demonstrated by the plume shown in the RIR and by the changes in the mapping suggested here and represents a potential threat to human health and the environment.

Groundwater TCE Trends and Roux's Half-Life Analysis

The trend of TCE is quite variable as described above due to the sources being intermittent and controlled by recharge events. Recharge and rising/falling water tables also affect the rate of flow through the aquifers. The RIR indicates there is a general decreasing trend in TCE and other VOC concentrations at the site and it near offsite wells, but time series graphs in Appendix B show the trend is not consistent across the site. The RIR concluded that the general decrease in TCE at the site can be described as having a half life of 2200 days (6 years). This implies the average TCE concentration decreases by half every six years. So many gross assumptions go into this estimate that it is useless.

Half-lives as calculated by Roux display a significant bias. First, the half-life estimate is an average of half-life estimates at approximately 30 wells on the site that have at least 4 data points over at least 4 years with evidence of attenuating TCE concentrations (RIR p 70). Roux only considered wells that show TCE concentrations are decreasing. This biased the analysis by not considering wells with steady or not decreasing concentrations. Other biases come from mixing wells that may have little in common, as the following paragraphs describe.

Wells from different levels or aquifers have different TCE sources. Shallow groundwater TCE is likely sourced from TCE deposits in the unsaturated zone or deep groundwater TCE from DNAPL deposits in the bedrock. Differing transport and dissolution rates in the different media would cause different rates of change. Additionally, the distance from the source affects the concentration trends. Even if the source were decreasing, concentrations at a distance could be increasing while those near the source are decreasing.

Simple averaging of the values determined from such variable monitoring well is improper. In statistical terms, the data has been drawn from wells that are not part of the same data set. Some are bedrock, some are overburden. Some are increasing or decreasing due to distance from the source. They should not be treated as representative of one source.

In summary, the soil source continues to leach sufficient TCE to keep TCE concentrations in wells under the site high. There are insufficient monitoring wells to fully identify the plume or its trend with time along the preferential pathway. Many factors affect the concentration and its changes with time. At depth, DNAPL bound in bedrock continues to dissolve causing very high TCE concentrations at the site that are a continuing source for transport downgradient. It is not possible to define a decay rate for TCE that applies across the site.

Surface Water Trends

Groundwater at the Bishop Tube site eventually discharges to surface water. Shallow groundwater discharges to and supports the LVC tributary just east of the site and to a ditch that bounds the north side of the site and flows east. RIR Figure 40 shows 2014 TCE concentrations in the stream and springs. The highest surface water TCE concentrations are near the BT site, specifically at the northeast corner of the site, but are detectable as far as a site beyond Conestoga Ave (SW-11). The decrease in concentrations going downstream is not evidence that TCE does not discharge into the stream beyond Conestoga Ave. The RIR claims incorrectly that "absence of a marked increase in CVOC concentrations in this stream segment supports the conclusion that CVOC contributions from groundwater … are largely limited to … the northeast corner of the Property" (RIR, p 139). Stream concentrations would decrease due to a groundwater inflow with concentrations lower than that in the stream even if the additional load is substantial. The TCE mass could have increased if there are TCE discharges into the stream below the site. The RIR analysis is not evidence that TCE does not enter the stream downstream of the northeast corner of the property.

In the data relied on by Roux, concentrations at SW-4 and SW-5 have decreased between 2003 and 2018. However, the data is not controlled for flow which could cause the concentrations to fluctuate due to the amount of dilution. The most recent dry season value, September 2018, is the lowest compared to previous samples (the November 2018 value is a wet period and therefore more diluted). Separating the data into wet/dry conditions based on precipitation in the previous couple days is not sufficient because groundwater discharge varies based on groundwater levels which depend on a much longer period of antecedent moisture conditions. Any analysis of trend is in error because it does not consider load.

Tables showing average statistics for groundwater or surface water concentration are useless. This is because the inherent assumption is the data is stationary. Statistics of data that could be trending and which differs depending on antecedent conditions is meaningless.

REMEDIATION

The FS considers various remediation strategies which form the basis for the choice made by DEP. Many sections repeat information provided in the RIR and are not further reviewed here. This section considers aspects of the FS that are new and necessary for understanding and selecting a remediation scheme.

Functional Areas

The FS distinguishes functional areas (FA) for groundwater, surface water and DNAPL. Soil is not considered because the FS does not consider soil remediation. The FS designates DNAPL as technologically infeasible to remediate, so the area is not considered here. Figure 2 shows the functional areas.

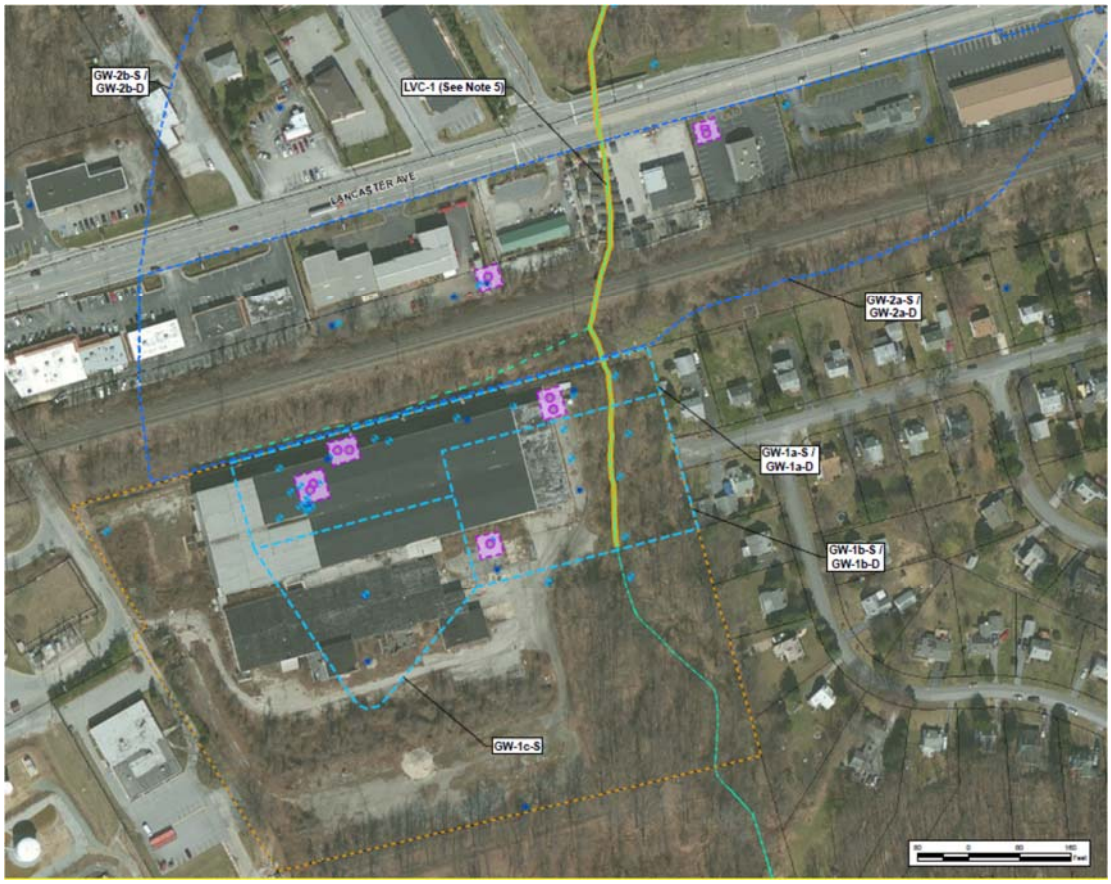

Figure 2: Snapshot of part of FS Figure 17 showing functional areas as identified for remediation of organic contaminants. There are three onsite areas, GW-1a, b, and c, and two offsite areas, GW-2a and b, and LVC and tributary east of the site. The purple areas are DNAPL FAs. Each groundwater FA has a shallow (overburden and shallow bedrock) and deep (intermediate and deep bedrock) layer. GW-1d is an area of inorganic contaminants that includes most of the three onsite areas (not shown).

The surface water FA is the LVC reach with average TCE greater than 2.5 µg/l. The three onsite groundwater areas link to the three main TCE source areas and include shallow and deep divisions; the shallow groundwater is overburden and shallow bedrock and deep groundwater is intermediate and deep bedrock (shallow, intermediate and deep correspond to various maps of TCE concentrations in the RIR). There is also a groundwater FA for inorganics (not shown on Figure 2) that covers most of the three areas set aside for organics.

The offsite areas include too little area. The GW-2a area is area between the northern property boundary and the south side of Lancaster Ave. There is no hydrogeologic or TCE concentration evidence that supports Lancaster Ave as a boundary. There are numerous wells with substantial TCE concentrations extending northeast from the site under Lancaster Ave that should be included for remediation with higher concentrations south of Lancaster Blvd. The northern boundary of GW-2b area is LVC. This implies that the stream is a sink boundary into which groundwater flows rather than extending north. There is no evidence supporting this, even if the stream is gaining. There are no monitoring wells at any level near but north of LVC (RIR Figure 30), therefore there is no evidence that groundwater does not flow to the north beneath LVC.

The calculation of volume of media requires the determination of thickness of layer. FS Table 2 shows the bottom of bedrock is 420 and 240 feet for areas GW-1a-D and GW-2a-D, respectively. The FS fails to explain the choice of depth. The choice appears to coincide with the depth of wells, but it is not reasonable to assume there is no TCE below these depths; this is especially true considering the DNAPL is heavier than water and has settled to a depth that has not been identified.

Because the site is abandoned and not being used, the analysis identifies “no current unacceptable human health or ecological risk” (FS p 5). The FS then implies that remedial actions could make the site worse (Id.) which allows Roux to imply current conditions are better than conditions that could occur due to remedial actions. There are numerous actions and mitigations that would prevent these problems if implemented. The FS highlighting of the problem without considering a solution instills a bias in the reader or decision maker.

DNAPL has been designated as technically impractical to remove due to its depth in fractured bedrock (FS p 6). Specifically, its high specific gravity (it is heavier than water, so it sinks), the reduction in fracture frequency and connectivity, decreasing fracture transmissivity, and matrix diffusion limits the vertical movement of DNAPL (Id.). The DNAPL has entered the pore spaces of the rock including the bulk media, from which it could diffuse into groundwater for as long as it remains. Because it is below the water table, in rock and at depth, the analysis assumes there is no direct exposure pathway for DNAPL from bedrock. There has been no risk analysis

performed regarding the risks of leaving it in place. For example, all groundwater eventually discharges to surface water, but Roux does not consider the ultimate destination for TCE-laden groundwater in deep bedrock.

Roux assumes the property would be developed for nonresidential uses only (RIR p 3, FS p 2), even though it has been rezoned for residential use and current development plans are for residential development (FS p 10). The analysis uses the nonresidential use assumption to claim that "current exposure pathways" (FS p 4) do not cause a risk to "any existing receptors or the LVC tributary" (Id.). The no residential use standard therefore allows the analysis to consider less remediation. The RIR therefore fails to describe the extent of the needed remediation and the FS fails to identify strategies based on the actual site requirements.

The only pathway discussed for future residential development is vapor intrusion, for which there is an assumption that "pathway elimination measures" will protect the residents (FS 39); there is no analysis of these practices, and no analysis of the proposed residential plans to determine whether they incorporate any such measures.

Remediation Alternatives

The FS considers seven alternatives for remediation, including no action (1), monitored natural attenuation (MNA, 2), in-situ chemical reduction (ICR, 3), in-situ chemical oxidation (4), enhanced reductive chlorination (5), two-part in-situ chemical oxidation (6), and hydraulic control (HC, 7). Except for HC, the five action alternatives result in the use of natural or enhanced breakdown of PCE and TCE. PCE breaks down to TCE. Breakdown products of TCE include 1,1-DCA, 1,1-DCE, cDCE, and VC (RIR, p 69). Vinyl chloride (VC) is potentially more toxic than TCE and its presence as part of remediation is important.

MNA is basically just monitoring the on-going natural attenuation. It assumes there will be a continuing decrease of TCE concentrations. It also relies on the source decreasing or being eliminated. Roux predicts it would require more than 30 years, although the FS does not provide details used for the prediction. DEP estimates it could take decades even if the soil source is removed. The time for natural attenuation clearly depends on what happens to the sources in the soils and the location of DNAPL which is dissolving into the groundwater. The FS fails to consider this and therefore does not provide a reasonable assessment of the period required for MNA to occur. The FS also fails to consider the breakdown product and the period over which they will remain in the groundwater or whether they may be more damaging. As noted, VC is potentially more toxic than TCE.Alternatives 3 through 6 involve injection of various chemicals to cause the TCE and other contaminants to degrade or decay more than they would if natural attenuation is the only strategy used. These include:

- Alt 3: in-situ chemical reduction (ISCR) using zero-valent iron (ZVI) components to reduce the organics and the metals in GW-1D
- Alt 4: in-situ chemical oxidation (ISCO) using alkaline activated sodium persulfate for organics and the ISCR agent to reduce the metals in GW-1D
- Alt 5: enhanced reductive dichlorination using molasses and biological amendments for the organics and the ISCR agent to reduce the metals in GW-1D
- Alt 6: a two-part ISCO method with sodium permangate followed by liquified activated carbon and the ISCR agent to reduce the metals in GW-1D

Figures 3 and 4 show the locations proposed in the FS.

The FS relies on yet-to-be-done studies to identify which chemical additives would be most effective. As noted for MNA, the fate and type of breakdown products resulting from the enhanced reactivity, the concentrations of which could increase more quickly due to injection, have not been considered. Part of the needed study is a determination of the relative toxicity of the breakdown products and their transport properties. If a breakdown product moves more quickly through the groundwater, it could create a plume that covers a larger area if it moves faster than TCE and/or does not further degrade. These studies should provide parameters that would allow the calculation of the required for complete remediation. The FS fails as a decision document because there are no estimates of the effectiveness of various chemicals or the time for them to work.

None of the injection points would be in deep bedrock. The FS claims highly fractured bedrock as found in the deeper layers is too difficult to target with injection. Because the groundwater flow is so slow, the TCE and other contaminants will mostly remain in the deep groundwater onsite until they naturally attenuate (use of MNA for deep bedrock since monitoring will continue). Because DNAPL occurs at depth, as determined in the RIR, deep bedrock groundwater onsite will likely remain contaminated for a very long period and eventually contaminate downgradient unidentified surface water. Institutional controls (ICs), primarily a prohibition on developing onsite groundwater, are not a substitute for treatment.

The location of injection sites is the same for the four injection alternatives. Both onsite and offsite, the injection locations include the DNAPL locations and groundwater directly beneath the surface sources. DNAPL locations are areas where TCE concentrations exceed 1% of its solubility (about 14,720 µg/l) or where there were signs of DNAPL in the wells or observed during well construction.

The injected chemicals are more viscous than water. Therefore, they will remain close to the injection point rather than moving quickly with groundwater flow. Especially in the shallow

bedrock, the injection solutions would flow through the more pervious fractures. Because the solutions would probably be heavier than water, they would sink deeper into the fractures rather than move as part of the groundwater flow. There would be a chance for the amendments to flow into lower permeability fractures, through diffusion and dispersion, just as groundwater otherwise moves into those fractures. Because of the high viscosity and being heavier than water, the treatments would be effective only near the point of injection. The FS does not analyze the radius over which it could be effective as it must do before DEP can select a density of injection locations. The FS also does not consider injecting chemicals directly into deep bedrock, even into obvious hot spots under or just northeast of the site. This is a failure that would allow a substantial amount of TCE go untreated and remain as a source in deep bedrock.

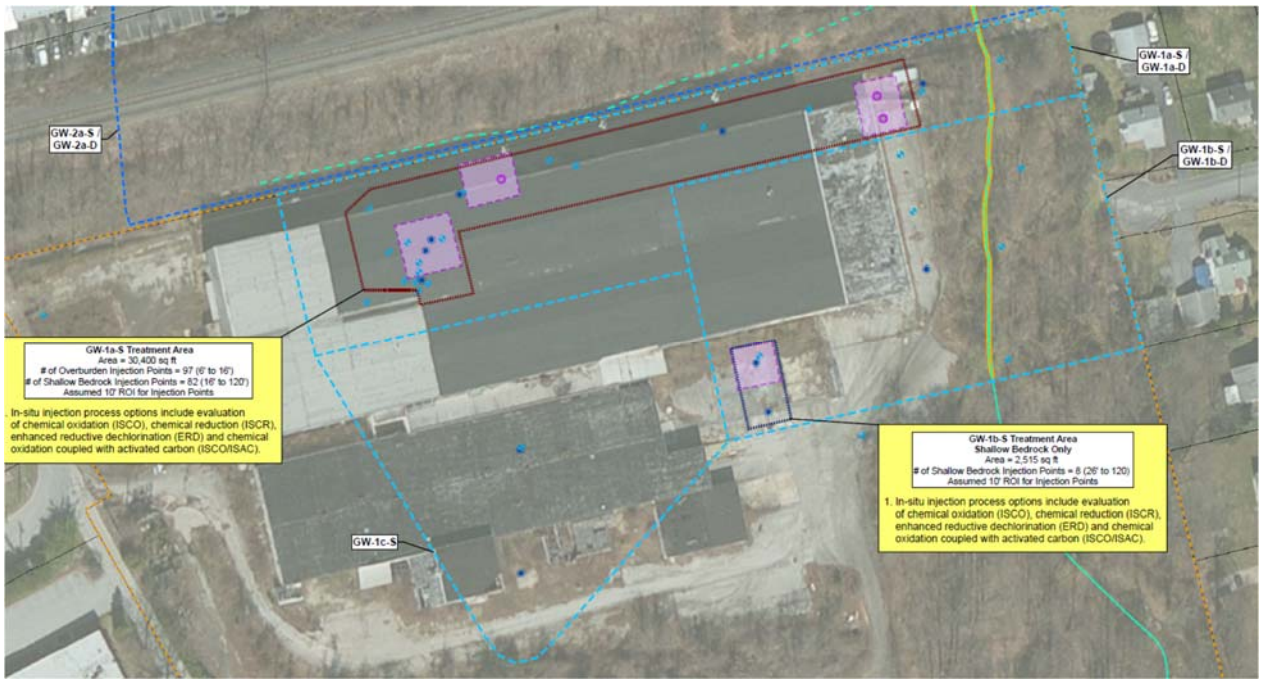

Figure 3: Snapshot of FS Figure 19b showing the onsite areas for injection in alternatives 3 through 6 in FS GW-1a-S and GW-1b-S. The outlined injection sites would include points located based on 10 ft radii of influence with wells in both the overburden and shallow bedrock layers. There would be no injection into GW-1c or into deep bedrock.

Figure 4: Snapshot of FS Figure 20b showing the areas for offsite injection in alternatives 3 through 6 in FS GW-2a-S. The outlined injection sites would include injection points located on 10 ft radii of influence in the overburden and shallow bedrock layers.

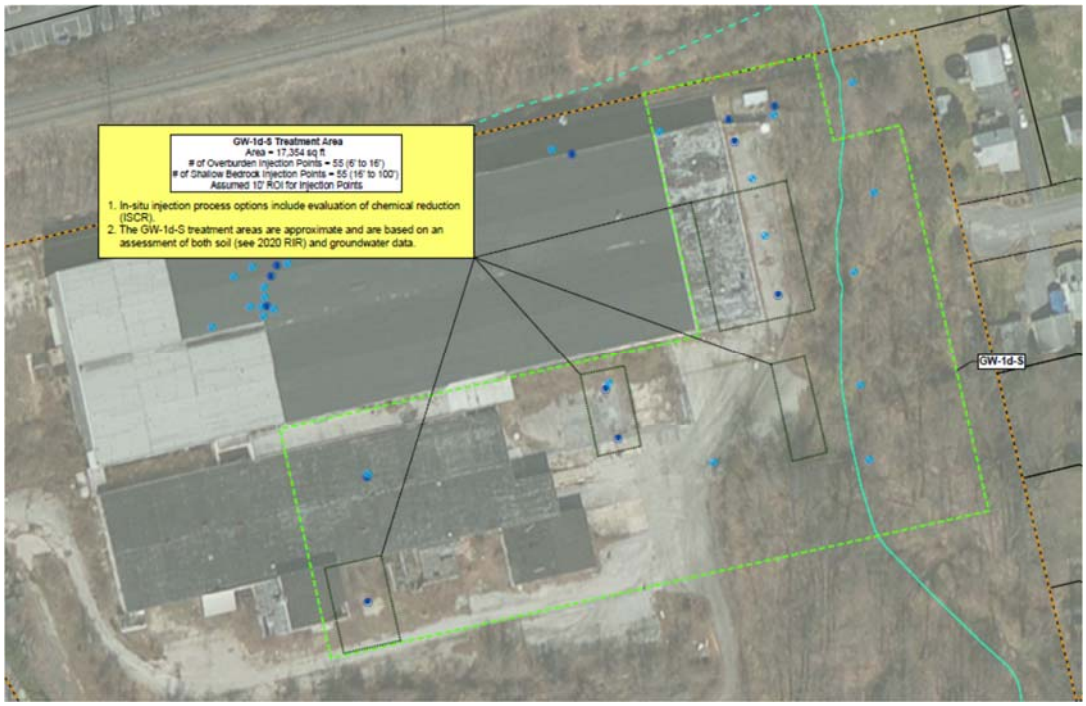

Figure 5: Snapshot of FS Figure 21b showing the areas for injection in alternatives 3 through 6 to treat metals in FS G-1d-S. The outlined injection sites would include injection points located on 10 ft radii of influence with wells in the overburden and shallow bedrock layers.

The FS raises the same implementability issues for all injection alternatives. The RIR repeats the following section in several footnotes to describe issues with these alternatives. These concerns are also raised individually for each alternative:

> Potential deleterious effects exist for this in-situ injection RA. Injecting in-situ amendments in fractured bedrock is complex and injecting large quantities of amendments in immediate proximity to the LVC tributary also poses significant implementability concerns (e.g., human health and/or ecological risks that do not currently exist). Implementation concerns include a) dissolution of adsorbed-phase COCs and a consequent increase in the rate of discharge or migration of these COCs, b) discharge of the amendments themselves into the adjacent stream, c) injection measures could modify the groundwater flow and COC transport conditions which could cause undesirable conditions such as creation of VI exposure routes that do not currently exist, d) injection measures/amendments could be incompatible with observed natural attenuation mechanisms active at the Site, e) injection measures could cause COCs or the amendments themselves to discharge at land surface (i.e., "day-lighting") and potentially produce adverse effects on human health and the environment, f) ineffective delivery of the amendment to the desired treatment intervals, g) loss of amendment to less-impacted but more transmissive bedrock fractures (i.e., not the desired fracture network where high CVOCs are located), h) loss of amendment to subsurface infrastructure (e.g., the abandoned AS/SVE piping network), i) rebound effects after treatment including anticipated matrix back diffusion, and j) amendments to treat inorganic COCs in groundwater will not treat fluoride. (FS, p 100, footnote 106)

These implementability issues are theoretically legitimate from a hydrogeologic perspective but were poorly considered in the FS and are relatively easy to counter in practice. Tests could show if the amendments would dissolve adsorbed COCs but leaving them in place simply allows them to remain a source until they naturally desorb and move. The concern that the amendments, desorbed COCs or breakdown products could reach LVC is also legitimate, but mitigation could include changing the point or rate of injection, the use of cutoff barriers or hydraulic control to prevent them reaching LVC or otherwise daylighting onto the ground surface. (See the discussion below on combining injection with HC.) The FS does not present an analysis, theoretical or experimental, of interactions between chemicals and natural attenuation. The concern with creating VI exposure routes is fallacious since the studies have minimized the idea such routes existing near the site and future development would be required to prevent such routes. Concerns about ineffective delivery or loss of amendment to transmissive fractures can be overcome with proper design, including close spacing of injection

sites, and with adaptive management; monitoring so that adjustments in product placement could be made are necessary. As for rebound effects, if the treatment shows significant decreases for each application, it is simply a matter of continuing the treatment until rebound effects cease.

Alternative 7, hydraulic control (HC), differs from the other alternatives by pumping and treating contaminated water. Contrary to the in-situ injection methods, it treats the water above ground and reinjects it to the groundwater. Figure 6 shows that a zone of pumping wells would line zone GW-1a on the east and northeast, the direction of likely flow through shallow groundwater to the northeast.

HC does not target onsite sources, so it does not quickly remove large amount of contaminant mass. This alternative would require substantial time to remove substantial mass of TCE or other contaminants. A huge problem with HC is that HC would pull water through the fractures more rapidly than groundwater flows naturally. There would be a significant tendency for the majority to pass through the larger fractures. As the gradient increases, the amount of flow from the larger fractures would increase more rapidly than from the small fractures. Much contaminated groundwater would be missed. Additionally, drawing overburden water could intercept groundwater flowing to LVC thereby decreasing stream baseflow and potentially drying groundwater dependent wetlands. Pumping at lower rates would decrease the effects on the LVC but would also make the alternative less effective.

Offsite HC would focus on pumping near the DNAPL source areas (Figure 7). The northeastern most extraction area is near the very high TCE MW-79 and MW-51. The westerly extraction site is at the high concentration site MW-28. However, extraction would be from shallow bedrock and the high TCE concentrations are in the deep bedrock. The alternative would not pump from near the source but would simply remove mostly clean water above the source. The FS does not consider the value of capturing groundwater near the source in deep bedrock.

Figure 6: Snapshot from FS Figure 19a showing location of extraction and reinjection zones for alternative 7.

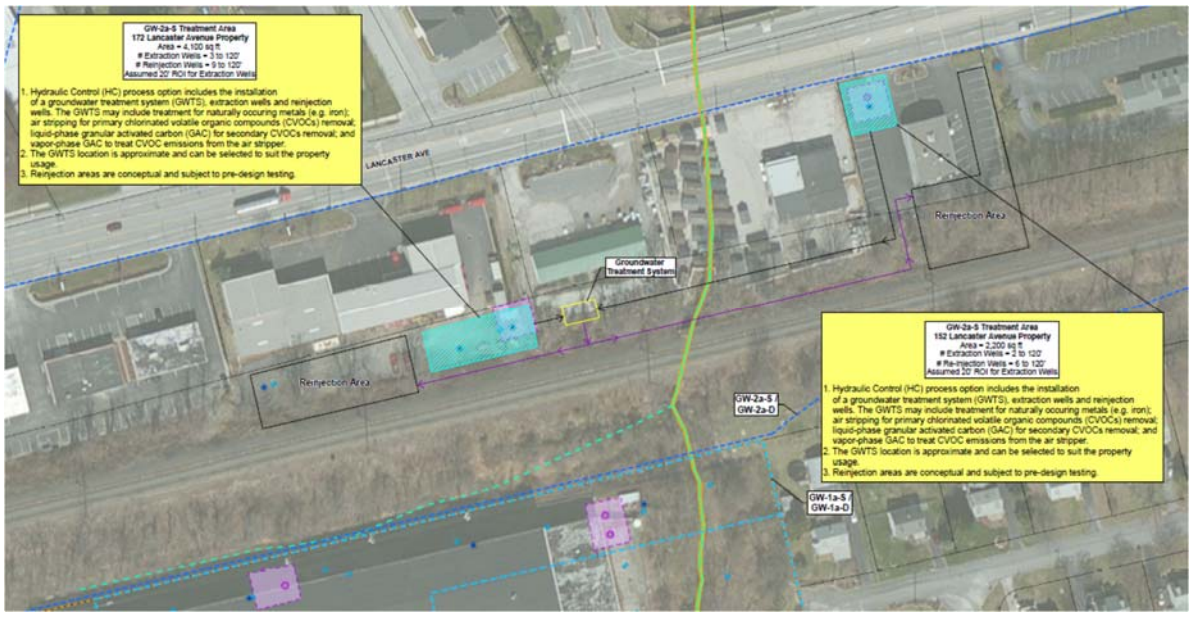

Figure 7: Snapshot from FS Figure 20a showing location of extraction and reinjection zones for offsite areas for alternative 7

The FS did not consider an additional alternative that would combine an injection alternative with an HC alternative to overcome some of the implementability issues with the injection

alternative A line of collection wells downgradient and between the injection wells and LVC could prevent the unwanted products of injection from reaching the streams or daylighting into wetlands if properly designed. HC would only be necessary if monitoring detected transport of COCs to the creek. The FS failed therefore to analyze what could be the most promising alternative.

Best Management Practices

Alternatives 2 through 7 use BMPs to address effects of the alternatives on surface water, specifically LVC (FS, p 98).

Proposed BMPs include methods designed to prevent contaminated surface water from reaching LVC and to intercept contaminated groundwater before it discharges to LVC. Roux claims the primary BMP for LVC is MNA (FS Appendix D, p 1). However, Roux does not estimate the time required for the stream to naturally recover to occur. Because LVC receives groundwater discharge from the entire site, recovery of the entire site would be necessary for the ongoing degradation of LVC to cease. Natural recovery would depend on the portion of the site that takes the longest, meaning that MNA alone would take as long as the longest natural attenuation period on the site – an unacceptable fate for LVC.

The first BMP proposed is that the six primary source regions, three for CVOCs and three for metals (Figure 8), be capped with an impervious layer. There is no consideration of how this would work with future development of the site. There is no consideration of the need for an impervious cap if the source within the soil is completely removed. There is also no consideration of a water balance barrier which would use most of the infiltration for plant growth and limit infiltration of CVOCs substantially.

Stormwater runoff will reach the LVC tributary if the site is developed. FS Appendix D suggests the use of bioretention areas adjacent to the west side of the LVC tributary to cause runoff to infiltrate. Bioretention areas would be a mixture of sand, soil and organic matter into which runoff would percolate. The runoff would then percolate into groundwater before reaching LVC. However, the bioretention area would only remove sediment, not dissolved CVOCs that could reach the creek. The RIR does not provide any samples of surface runoff, so there is no evidence regarding the quality of storm runoff from the current site.

The FS does not provide calculations as to the size of the bioretention area, but merely states it would need 4200 square feet (FS Appendix D, p 2). The FS failed to consider the volume of runoff that would have to be captured (dependent on the return interval of storm from which sheet flow runoff would be infiltrated) and calculate the needed site of bioretention area. The

FS failed to consider the infiltration rate, the rate of seepage into surrounding groundwater, and the water volume that could be held.

The third BMP is the use of rows of poplar trees as a “phyto technology” area to intercept groundwater flowing to LVC. Supposedly, each tree would take up and transpire 10 to 25 gallons of groundwater per day thereby sequestering contaminants dissolved in the water (FS Appendix D, p 2). This would decrease groundwater inflow to the creek. There is no evidence presented that a plan such as this could work or references to sites where this as worked. The plan also fails to consider the period during which the trees are becoming established. It also does not consider the effect on baseflow in the stream.

The FS failed to consider the use a line of shallow wells between LVC and the site as a BMP. The wells could be pumped whenever monitoring indicates that COCs are moving toward the creek. The water could be treated either on or offsite and reinjected at optimally located points so that the pumping does not affect the flow in LVC.

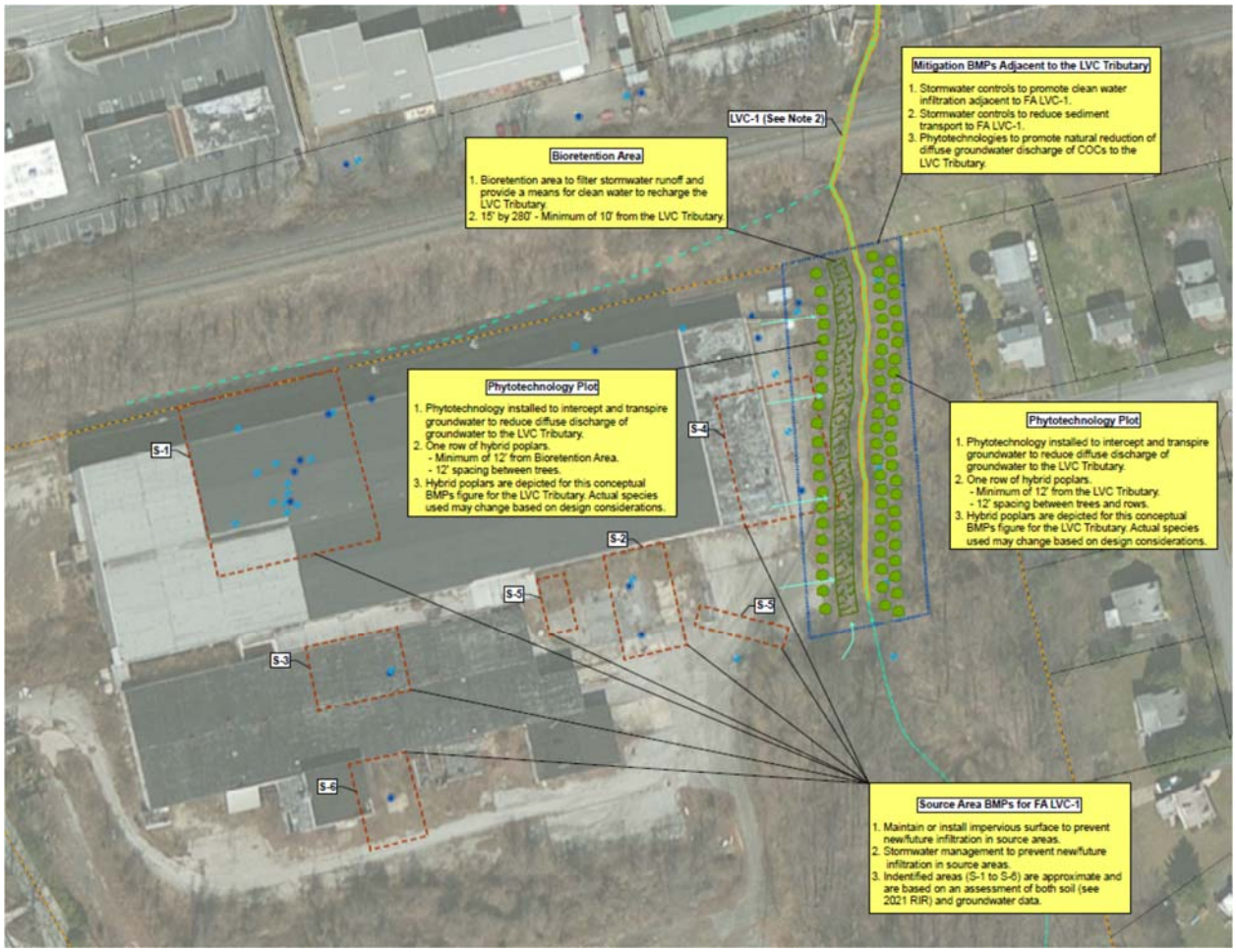

Figure 8: Snapshot of FS Figure 22 showing the conceptual design of best management practices to protect LVC.

FS Addendum

Roux prepared an addendum to the FS report after DEP reviewed the seven alternatives reviewed above. The FS Addendum identified an eighth alternative, which is essentially a combination of alternative 2, MNA, part of alternative 3, ISCR, and a soils remediation alternative.

The soils remediation would involve using ISCR to treat in place the unsaturated soil at two locations (Figure 9), AOC 1 (Building 8 vapor degreaser area) and AOC 9 (Drum storage area near Building 5). The soil would also be mixed in place to enhance the placement of the ISCR amendments. Groundwater alternative 3 would be reduced to utilize ISCR at just two much smaller onsite locations (Figure 9) rather than the areas shown in Figures 3, 4 and 5. There would be no treatment of offsite areas north of the site.

This new alternative 8 leaves substantial TCE in the groundwater and is even less effective than other FS injection alternatives. This alternative leaves many areas, especially the high TCE concentration in the preferential flow zone offsite north of the northeast corner of the site.

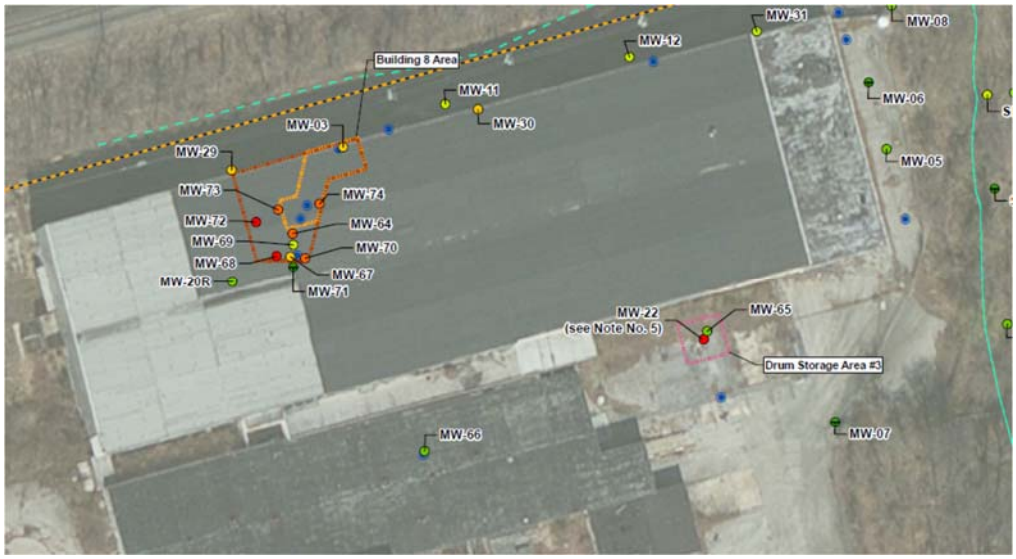

Figure 9: Snapshot from FS Addendum Figure 1 showing the location of the two areas to receive active soils and groundwater treatment.

Choice of PA DEP

DEP chose an alternative that mixes soil recovery (OU1), groundwater remediation (OU2) and drinking water (OU3) into one decision in the AOA.

For soils, DEP chose to use an in-situ injection alternative which could use either reductive or oxidizing compounds into a mixed surface soil. The soil in the targeted areas would be mixed down to the saturated zone. The targeted areas would be as shown in Figure 9.

DEP's choice for soils is not acceptable because it will leave TCE in place at areas that will not be treated and will not treat all the TCE at the treated locations. Excavation can be much more effective. If sampling is performed to identify the highest mass loading of TCE, the excavation can be very focused. Dewatering the saturated soil would not be as significant a problem as DEP claims. If the excavations are limited as could happen with detailed sampling on a grid, the volume of groundwater removed near the excavations, lowering the water table at most a few feet for a short period should be manageable. The water could be trucked from the site for treatment and discharge elsewhere or reinjected into groundwater far upgradient from the LVC.

For groundwater, DEP combined FS alternatives 3, 4, 5, and 6 into a simple in-situ injection alternative but combines with the soil injection choice and only directly treats the two areas identified in the FS Addendum, the Building vapor degreaser and the drum storage area. It differs from the FS Addendum alternative 8 by allowing a full complement of injection amendments, leaving the final decision to future study. By not choosing which chemical addendums to use, DEP essentially admits it does not understand enough about the groundwater chemistry of the site. As noted above in the discussion of FS Addendum, treating just two areas would leave substantial TCE mass in place in the groundwater at the sites it does not treat. By not treating the offsite area GW-2a-S, the extent of the plume would not be contained nearly as fast as it could have been.

Throughout the FS, revised FS and DEP's decision document, there is a failure to consider the actions that have worked at similar sites. Roux or DEP failed to complete a detailed literature review of the remediation of other TCE sites or compare them to Bishop Tube. Decisions are being made at Bishop Tube without learning from similar sites.

FATE AND TRANSPORT MODEL

Roux describes Fate and Transport in Chapter 10 of the RIR. There are various conceptual problems with this analysis, most importantly the reliance on a two-dimensional approach to flow and transport simulation for what is inherently a three-dimensional problem. The modeling is not even close to accurate enough to use for predictions of the fate of plume as various remediation scenarios are applied to it. The following section comments in detail on the modeling mostly described in the RIR Chapter 11 and Appendix S.

Groundwater Fate and Transport Model

Roux completed a simple, two-dimensional groundwater flow and transport model to generally fill in the 5 ug/l contour in the plume mapping; the discussion is included in RIR Appendix S. The description is incomplete, and assumptions are necessary to understand how the modeling was completed. The page references in this section are to the model report in Appendix S unless otherwise stated.

Roux used the WinFlow/WinTran code to simulate a two-dimensional model of the shallow groundwater. The flow model WinFlow is analytic which means it relies on solutions of the differential equations so can accommodate only very simplified representations of the domain. WinFlow describes a flow field based on a grid over the domain. The model outputs water level and flow rates for any chosen point in the flow field.

The flow field is steady state which means that seasonal changes in the water level due to recharge events cannot be considered. Wet and dry season discharges to the streams cannot be considered.

The transport model uses a finite element solution based on the steady state flow solution on the grid. The transport model is transient for contaminant but cannot consider temporal changes in recharge rates. Roux's modeling only considers the movement of a plume described with initial conditions through the domain. No sources can be incorporated.

Roux calibrated the model to the 2014 observed TCE concentrations and simulated four years to 2018 for verification. Roux claims the verification shows that simulated concentrations match observed concentrations, but there is little evidence of this in the report. The concentration contour mapping is the exact same for initial and calibrated simulations.

Roux hypothesized a model thickness to be 500 feet (p 6) but the actual simulated thickness is less than that (and very poorly described). The model top and bottom were set equal to 500 and -100 feet (Table 1), but the constant head boundary at the upgradient end was set equal to 390 feet (p 8). At this boundary, the thickness would be 490 feet. Water level at the downgradient end is not specified, but the report sets a gradient equal to 0.019 ft/ft (p 8m Table 1), so with an aquifer length of 6000 feet, the groundwater level would be 276 feet, so the thickness reduces to 376 feet, assuming the aquifer bottom elevations are constant throughout the domain. The reducing thickness means the transmissivity decreases with length along the flow paths, but the flow velocity may not change because groundwater would discharge to the line sink boundary on the north of the domain.

The model assumes the aquifer is homogeneous, so the same parameters describe its entire thickness, which is as much as 390 feet. Roux provides substantial evidence that this is poor conceptual modeling but does it regardless. Specifically, the pores and permeability decrease with depth in bedrock, so conductivity also decreases with depth as noted (p 3). The parameters were based on shallow bedrock, so at depth the parameters describe media that is more permeable than reality which causes the model to simulate too much flow at depth. Second, Roux correctly notes that high TCE concentrations at depth do not represent a flow path because the fractures are discontinuous and do not represent a long-range flow path (p 3). There is "no expectation that the deep bedrock interval will produce higher groundwater velocities or a longer CVOC plume when compared with the shallow interval" (p 3, 4).

Roux claims it is conservative to treat the entire aquifer thickness with the parameters as described for shallow bedrock:

> Therefore, the fate and transport analysis focuses (sic) on the shallow bedrock conditions, thereby presenting a conservative/protective evaluation for all depth intervals. The entire vertical thickness of the affected bedrock aquifer was assigned the characteristics of the shallow bedrock interval as a conservative measure regarding TCE fate and transport analysis. (p 4)

This is not conservative and is indeed quite wrong, because, being 2-d, the model assumes that concentration is the same throughout the layer thickness. As contaminants enter a section of the domain, the model assumes that the concentration is spread evenly through the layer. TCE load that would otherwise be near the surface would be simulated at depth. The monitoring wells with multiple sampling portals show substantial variation with depth. In some areas, TCE is higher in the overburden and other areas the higher concentrations occur at depth, so the model is an oversimplification. Roux's explanation, as follows is meaningless:

> This conceptual modeling approach is validated through the existing groundwater quality data, whereby slight exceedances of groundwater MSCs are confirmed only in the two most downgradient shallow bedrock wells MW-81 and MW-82A (screened at depths extending to 26 feet and 85 feet below ground surface ["bgs"], respectively)7. Therefore, considering the above-stated modeling objectives, the shallow interval of the bedrock hydrostratigraphic unit represents the only zone for which calculation of a simulated downgradient plume boundary is necessary and is the pathway where the longest potential plume dimension is anticipated. (FS Appendix D, p 4)

That TCE has low concentrations in the two most downgradient shallow bedrock wells has little to do with modeling a thick aquifer, regardless of the objectives. Rather it justifies modeling just the upper 120 feet and somehow accounting for the TCE that settles into deeper bedrock. In fact, simulating the aquifer as thick as it proposes would cause more transport at depth. TCE is high onsite and without effectively isolating it, the model would simulate flow from deep below the site downgradient; higher flow velocities modeled at depth would allow the model to move contaminant load away from the project domain faster than occurs in reality. Predictions would be for faster attenuation as a result.

Roux cites the Sloto (1990) analysis as justification for a 2-d analysis. There are two problems with this. First, Sloto's analysis occurred in 1990 when the ability for models to simulate two or more layers was much less than it is currently because of the lesser computer power. Second, and more important, Sloto described a regional model where the details of local flow were less important. Sloto's model was for flow only and the effect of vertical gradients on transport was unimportant. Furthermore, there was already available a model for the site using multiple layers (Baker, 2004) that Roux could readily have adapted.

Vertical gradients are ignored in a one-layer model. Roux dismisses this by stating that vertical gradients are local (p 3), but this is exactly the point. The model cannot simulate the variable vertical flow which would affect the distribution of contaminants. This assumption is most problematic near the stream where there is evidence for upward gradients and flow into the stream. This could cause the model to underestimate discharge of contaminants into the stream. Only a three-dimensional flow/transport model could accommodate the issues regarding homogeneity and the lack of vertical flow. Many of the wells have multiple ports that could be used to calibrate a 3-d model.

The model ignores recharge that occurs across the site by assuming all flow enters at the constant head boundary (p 7). The model does not consider that recharge equaling about 15 in/y enters the top of the domain and therefore ignores a source of dilution. Rather than making the model conservative, the failure to consider recharge causes the calibration to adjust other parameters to match the observed conditions. Without considering recharge, the model cannot consider changes in transport due to changing loads and due to BMPs affecting recharge.

Boundaries provide flow sources and sinks to the model and partially control the groundwater level, but Roux describes them poorly. At the upgradient end, the boundary is a constant head set at 390 feet. Roux states the 390 feet is at a point, but a CH boundary is along the edge of the model domain so it is actually a line source.

The other described boundary is a line sink for LVC and its tributaries, which Roux describes as representing "a portion of LVC and its tributaries that has gaining conditions between Conestoga Road and Morehall Road" (p 7). This indicates that the model does not simulate discharge to the LVC tributary on the east side of the site or the gaining reaches upstream of Conestoga Road. It fails to simulate the concentrating effect of having TCE-laden groundwater converge on the creek.

A line-sink boundary simply accepts groundwater discharge from the domain. The boundary would have an elevation which would control the downgradient elevation and hence the gradient through the model. Roux claims that LVC and tributaries are simulated with line-sink boundaries and Figure S-1 shows the stream and tributaries which could receive groundwater discharge, the description appears to allow only discharge downgradient of Conestoga Road (p 7). With the constant head boundary at the upgradient end, the boundaries impose a simplistic control on the flow through the aquifer, preventing flow from converging to the streams within the domain, such as the tributary just east of the site. This may prevent the stream from simulating hot spots of TCE concentration.

LVC has reaches from which water discharges into the groundwater, so a boundary that can act only as a sink is not appropriate. The proper boundary for this simulation would be one that both receives and provides groundwater and contaminants to the aquifer.

Also, Roux considers it "conservative" to simulate the line-sink as receiving "discharge from shallow bedrock to LVC and its tributaries of approximately 75 gallons per minute over a length of approximately 2,500 feet" as compared to measured 237 and 171 gpm during previous surveys (p 7). Since this is the only outflow from the model domain, it causes flow and advection to occur slower, but it also allows more TCE to decay before it reaches downgradient portions of the domain. It would cause the model to simulate less TCE transmission off the site and constrain simulated future TCE contours.

Transmissivity changes through the model domain as the saturated thickness decreases. Because the line sink boundary borders the northern portion of the domain, the decreasing transmissivity would direct groundwater toward the boundary. However, decreasing the transmissivity must also increase the gradient to allow groundwater to flow through the domain cross-section. This means the Darcy flow velocity (flow rate over the entire cross-sectional area) must increase. This would increase the rate that contaminants transport by advection through the domain and from the model.

The model simulates flow that cuts across the regional potentiometric surface contours, which run generally east-west and show a north-south gradient of 0.05 to 0.04 ft/ft. Roux shifted the grid 32 degrees north of east to align with the flow/transport axis surmised from the TCE contour maps, and create a gradient of about 0.023 ft/ft, later calibrated to 0.019 ft/ft based on matching groundwater levels at various wells. That groundwater flow does not follow the steeper regional gradient demonstrates the control exhibited by fractured rock. The horizontal conductivity is highly anisotropic, which means the conductivity along the flow path (at a 0.019 ft/ft gradient) is much higher than the conductivity in another direction. This is a major reason that the simplifying assumptions used in this model are inappropriate.

Many of the simplifications critiqued above led to a poor calibration for the model. Roux used just 14 monitoring wells for calibration (p 9) and the statistics show the fit is very poor. The standard deviations and sum of squares are very high for a domain with such a small elevation range. The maximum absolute residual is about 28% of the total potentiometric head difference, a very high number (p 10). Although there is no "standard" for an acceptable model, 10% is often considered a decent fit. Roux dismisses concern with the high maximum absolute residual by noting the mean error is close to zero. Mean error being zero effectively means the residuals are scattered around zero and provides no information about the magnitude of those residuals. The high scatter of residuals is due to the model effectively trying to fit a flat surface

(a plane based on one parameter set) through a curvilinear surface (the reality of a nonhomogeneous aquifer).

The model simulates concentration in three ways. It starts with an initial concentration, which is the observed concentrations from the 2012-14 contour mapping. Contaminants flow with the steady state groundwater flow and undergo dispersion, degradation, and retardation.

The model does not simulate TCE sources to the model domain. The mass initially present (as initial concentrations) is the only mass simulated as flowing through the system. It is effectively a slug of contaminant present throughout the aquifer at a given initial time. The model then advects and disperses contaminants through the aquifer and removes contaminants either by degradation processes or by discharging them into a boundary sink. For any future predictions, the model assumption is that sources in the unsaturated soils have been removed, and no leaching occurs from TCE adsorbed to soil or from non-aqueous phase TCE. The simulated graphs of monitoring well concentration show the movement of a slug of TCE passing through the system rather than a source providing TCE to the system.

TCE mass is removed from the domain in two ways. One is discharge into the line sinks that simulate LVC and its tributaries. Roux should report the amount that leaves the domain through the boundaries so it can be compared to measured values for calibration. Most of the TCE likely does not discharge in this way and therefore remains within the domain after adsorbing or disappears after decaying, the second way TCE is removed from the domain.

A half-life controls the rate that TCE decays within the domain. This means that half of the mass disappears in that period (the model does not consider its fate, so “disappears” is the proper descriptor). Even without advective transport removing mass from the domain, the simulated concentrations would decrease by half over that period. Roux used a decay half-life of 2200 days based on decay rate constants of 30 site monitoring wells. As described above, this decay value is meaningless.

Retardation is the process that the contaminant moves much slower than it would if controlled simply by advection, or transport with the flow of groundwater. Dispersion through pore spaces and adsorption to aquifer particles contributes to retardation (Fetter 1999). Retardation varies with depth at Bishop Tube because in fractured rock retardation increases in areas with lower fracture density (p 14). Adsorption and the process of a contaminant being bound in fractures would also contribute to estimated decay. Roux calibrated the model by adjusting the retardation coefficient and comparing the evolution of concentration with time. Degradation affects the observed concentrations, so calibration also causes the model to double count

retardation. Roux's model double counts the effects of retardation; it withdraws mass from the plume inappropriately fast.

Roux calibrates the transport parameters by adjusting parameters so that simulated concentrations approximate the observed concentrations yields parameters based on there being no source of TCE to the groundwater, which is simply incorrect. Observed TCE concentration graphs show temporally variable values that reflect recharge events contributing TCE to the groundwater. Simulated concentrations often rise and fall in a steady pattern, but observed concentrations appear mostly random in comparison. The sources continue to leach TCE which affects the observed TCE concentrations; observed TCE increases rapidly in response to TCE recharge events. Without simulating the sources leaching contaminant into the groundwater, the calibrated parameters are meaningless.

The graphs of simulated concentration at various monitoring wells and hypothetical monitoring points demonstrate that the model simply advects TCE from the domain into the boundaries. For example, TCE at MW-51, which lies about 500 feet northeast of Building 8, starts at near 100,000 ug/l, which is about 70% of the actual observed value, decreases rapidly to about 12,000 ug/l by 2025 and approaches zero by 2035. Considering that this monitoring well has had high values for a couple decades, Figure S-3 demonstrates what would occur only if the sources are removed. A similar trend occurs for MW-15, which lies about 150 feet north of Building 8; a difference is that TCE increases in the simulation for the first few years from its initial (currently observed) values. Advection of the higher concentrations under the building causes the initial increase; after the mass passes, TCE concentration decreases rapidly because there is no source adding TCE to the system. Inadvertently, the model demonstrates the value in removing all TCE sources to the groundwater.

In conclusion, the groundwater flow and transport model is insufficient for predicting future conditions due to any remediation strategy proposed at Bishop Tube. The preceding the paragraphs outline the primary problems, but they include (1) treating the aquifer as two-dimensional flow, (2) not considering heterogeneity in the aquifer properties, (3) ignoring the change in properties with depth, (4) ignoring preferential flow, (5) not considering natural recharge, (6) not simulating contaminant sources (assuming all sources in the soils are removed), (7) improper boundary conditions, (8) reliance on a faulty half life analysis, (9) poor calibration, and (10) not consideration of transient loading.

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LEGEND

EXISTING		PROPOSED
	MANHOLE	
	INLET	
	CONCRETE HEADWALL	
	FLARED END SECTION	
	UTILITY POLE	
	FIRE HYDRANT	
	SIGN	
	EDGE OF WOODS	
S	SANITARY SEWER	S
ST	STORM DRAIN	ST
W	WATER MAIN	W
SL	SANITARY LATERAL	SL
RD	ROOF DRAIN	RD
WL	WATER SERVICE	WL
T	TELEPHONE LINE	T
E	ELECTRIC LINE	E
G	GAS LINE	G
BV	GATE VALVE	BV
	TEE	
	PLUG(CAP)	
00	CONTOUR LINE	00
00X00	GRADE	00X00
N/A	MEET EXISTING GRADE	(00X00)
K38.50	TOP OF CURB ELEVATION	K38.50
G38.00	GUTTER ELEVATION	G38.00
H	HANDICAP RAMP	H
	CONCRETE CURB	
	EDGE OF PAVEMENT	
N/A	CONCRETE	
N/A	POROUS PAVERS	

REVISION No. 3: REVISED PER 9-14-2020 ARRO, 9-14-2020 MoM
REVISION No. 2: REVISED PER 6-4-2019 ARRO, 4-5-2019 ZONIN

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FOR THE DELAWARE
RIVERKEEPER NETWORK

12/07/2021

LEGEND

- CONTAMINATED SOIL, TO BE REMEDIATED
- PROPOSED DEP SOIL SAMPLING AREAS
- TEMPORARY SOIL STOCKPILE AREA
- EXISTING BUILDING, TO BE DEMOLISHED
- PROPOSED STORM SEWER
- PROPOSED SANITARY LINE
- PROPOSED WATER LINE
- +/- 0.0' PROPOSED EXCAVATION DEPTH BELOW EXISTING GROUND SURFACE