Staff Response to Peer Reviews

Comment No.	Reviewer(s)	Comment	Staff Response
1.00	Professor Pedro J.J. Alvarez, Ph.D., Chair	The proposed policy for low-threat UST closure is an important effort to alleviate resource allocation challenges and preserve mitigation and remediation resources for higher priority sites. The policy is based on 10 assertions, all of which are based on broadly accepted axioms and best practices such as conservative assumptions about bioattenuation and generally safe separation distances. The assertions are also consistent with existing California statutes and regulations. Overall, the document is well written, but it could be improved by providing additional information and clarification as detailed in the following comments.	General endorsement of the Policy.
1.01		The policy should explicitly recognize that biodegradation of vapors in the unsaturated zone significantly depends on moisture content. The modeling efforts seem to have ignored moisture content. Whereas the assumed bioattenuation rate coefficients (e.g., 0.79 h-1) might be appropriate for most of the state of California, they may be optimistically high for arid areas where lack of soil moisture may preclude biodegradation. What attenuation factors would be predicted by models assuming dilution/dispersion alone? Would dilution alone in arid areas support the presumed 1,000-fold attenuation factor? What do field studies show for arid areas?	Biodegradation rates could potentially be affected at soil moisture contents less than the wilting point (Guyman 1997). Vadose zone soils are seldom drier than the wilting point, however, with the exception of near surface soil layers under arid conditions (DeVaull, 1997). Although sensitivities to moisture content were not explicitly evaluated in the referenced model studies, any dependence on soil moisture is expected to be embodied in the referenced empirical analysis described by Lahvis (2011). Approximately 67% of the soil-gas samples in the Lahvis (2011) database were collected at UST sites in Utah and Australia where relatively low soil-moisture conditions are likely to have been present. The soil conditions at these sites are assumed to represent soil conditions encountered at the vast majority of relatively arid UST sites in California. **This information has been added to the Technical Document for Vapor Intrusion.** Guymon, G. L., 1994: Unsaturated Zone Hydrology. Prentice Hall, Englewood Cliffs, NJ. DeVaull, G. E., R. A. Ettinger, J.P. Salinitro, and J. B. Gustafson. 1997. Benzene, toluene, ethylbenzene, and xylenes (BTEX) degradation in vadose zone soils during vapor transport: First order rate constants, paper presented at NWWA/API Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Remediation, National Water Well Association, Houston, Texas, November 12-14 1997.
1.02		In principle, I agree that stable or shrinking plumes tend to be low risk, but there should be some minimum data requirements (e.g., number of monitoring wells and time span considered for data analysis) to reliably establish that the plumes are indeed stable or shrinking. What statistical tests or other data analysis tools will be used to ascertain that a groundwater plume has stabilized?	The demonstration of plume stability is a site-specific task. The size of the plume and physical constraints will affect the number of monitoring wells; therefore it is difficult to define a minimum requirement. Simple sites contaminated with low concentrations of BTEX will not require the same degree of monitoring as complex sites with higher concentrations and more recalcitrant types of contaminants (National Research Council, 2000). EPA (2011) provides an appendix with several statistical methods, which are useful to demonstrate plume stability. **This information has been added to the Technical Document for Groundwater.** Guidance Documents: ASTM E 1943-98, 1998. Standard Guide for Remediation of Ground Water by Natural Attenuation at Petroleum Release Sites. ASTM International, West Conshoken, PA. National Research Council, 2001. Natural Attenuation for Groundwater Remediation. National Academy Press. Washington, D.C. U.S. EPA. 1999. The Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Office of Solid Waste and Emergency Response, Directive 9200.4-17P. U.S. EPA. 2011. An Approach for Evaluating the Progress of Natural Attenuation in Groundwater. EPA 600/R-11/204.
1.03		A clear definition of the criteria for establishing plume length, specifically what dissolved phase concentration of benzene or MTBE defines the leading edge of the plume (1 ug/L, 5 ug/L or some other value?) is needed. As the term "defined plume boundary" is used in the document (Attachment 4, p. 16 for example) a definite guideline for determining plume length should be provided.	See comment No.1.03. Site specific issues apply to plume length determination, similar to plume stability determination.
1.04		When referring to the oxygen gas concentration minimum threshold criteria, clarify what does % mean in 4%. Does this mean 40,000 ppmv? Or, recognizing that pure air has about 21% O2, is 4% 0.04×210,000 ppmv = 8,400 ppmv? Also, while very conservative, no justification (or reference to an authoritative literature source) is given for this arbitrary threshold.	4% refers to 40,000 ppmv. O2 concentrations in soil gas sufficient to support aerobic mineralization are reported to be in the range of 1 to 4 % (DeVaull, 2007) **This information has been added to Technical Document for Vapor Intrusion.**
1.05		Attachment 4, page 15 needs a transition statement to provide context for the criteria beginning on p. 16	**A transition statement has been added to the Policy.**
1.06		The technical arguments are often based on conference papers and other literature that has not been rigorously peer-reviewed. This does not imply the studies are wrong, but points to the potential need for greater scrutiny. For example, there are several figures showing probability of exceeding a given concentration as a function of distance (e.g., Attachment 6, page 12 & 17). However, no assurances are given that the correct probability distribution function was used (as opposed to using the normal distribution as a default).	Use of soil-gas data to support the development of vapor intrusion guidance for petroleum hydrocarbon site cleanup is relatively new. Consequently, the technical justification includes several references to non-peer-reviewed literature. Although the analyses are subject to change as a consequence of subsequent peer reviews, the non peer-reviewed attachments are based on sound scientific knowledge and serve to validate the model theory and development of vapor intrusion guidance.
1.07		For Appendices 1-4 in Attachment 4: Guidance for determining the soil TPH concentrations in the separation/bioattenuation zones should be provided. Language on the minimum acceptable number of soil samples that are representative of the entire depth of the separation distance is desirable. Also, to avoid confusion, guidance should be included on deriving the TPH < 100 mg/kg criteria. Is this an average, maximum, geometric mean or some other statistical descriptor based on a prescribed minimum of samples?	These are site specific determinations based upon professional judgement. The number of samples required could depend upon concentration distributions, soil types, potential land use, and other factors.
1.08		For Appendix 3 in Attachment 4: How and where should the representative dissolved phase concentration be determined? Is this concentration representative of the nearest monitoring location sampling results, is this a concentration based on multiple sampling points, if historical monitoring data exists would this be the highest dissolved phase concentration ever detected (assuming a current worst case scenario), or is this criteria to be determined by other means? Guidance on acceptable statistical analysis for developing a representative dissolved phase concentration should be provided.	See respone to comment No. 1.07.
1.09		Criteria for Groundwater (Attachment 4, page 16): Similar to the previous comments, guidance for determining dissolved phase criteria need to be clarified (e.g., 3,000 ug/L benzene). The number of representative groundwater samples, location of the samples within the plume, minimum number of sampling events (i.e., historical data) and adequate/allowable statistical methods for determining the representative dissolved phase concentration should be addressed.	See respone to comment No. 1.07.

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1.10		The document should provide criteria for qualifying a site as a Low-Threat UST site when another nearby source(s)/site(s) (not associated with the potential Low-Threat site in question) also poses risks to common receptor(s). Although the Policy as written should provide the majority of the necessary guidance, cases such as commingled plumes or risk contribution from nearby sources should be addressed. If a potential Low-Threat site cannot be considered by default as such due to the presence of other (unassociated) impacts, the Policy should include specific language addressing this potential scenario.	Agency professional judgment is required to determine if all the criteria for low-threat closure under this proposed Policy are satisfed. Commingled plumes will need to be evaluated on a site specific basis to determine if they present a unique site specific condition.
1.11		In Attachment 5, page 2, only Howard (1990) is cited to support the statement that "biodegradation/natural attenuation of petroleum hydrocarbons and MTBE occurs under aerobic and anaerobic conditions". This is not an authoritative literature source to support this statement. More literature review and discussion is needed regarding MTBE biodegradability in the saturated zone (consider for examples see, Martienssen et al., 2006; Rasa et al., 2011; Schirmer et al., 1999; Shah et al., 2005; Wilson et al., 2005). Note that there is still significant debate on the significance of the reported MTBE biodegradation rates.	Howard (1990) is an adequate source for biodegradation of BTEX compounds, but as the Peer Reviewer indicates, it is not an authoritative source for MTBE biodegradation. Rasa et al. (2011) (also cited by the Peer Reviewer) does provide support for MTBE biodegradation; this paper also provides an excellent literature review of current references that support MTBE biodegradation. U.S. EPA (2005) describes the application of Compound-Specific Stable Isotope Analysis (CSIA) to predict the extent of MTBE biodegradation in groundwater. CSIA makes it possible to unequivocally identify and measure anaerobic biodegradation of MTBE at field scale (U.S. EPA, 2005). **This information has been added to the Technical Document for Groundwater**. Rasa, E., S.W. Chapman, B.A. Bekins, G.E. Fogg, K.M. Scow, and D.M. Mackay. 2011. Role of back diffusion and biodegradation reactions in sustaining an MTBE/TBA plume in alluvial media. Journal of Contaminant Hydrology 126 (2011) 235-247. U.S. EPA. 2005. Monitored Natural Attenuation of MTBE as a Risk Management Option at Leaking Underground Storage Tank Sites. EPA/600R-04/1790.
1.12		There should be consistency in choosing the additional safety factors applied to the separation distances, or at least provide the rationale/reference explaining why different safety factors are chosen for different cases (i.e., different plume classes, vapor intrusion scenarios, or plume versus vapor intrusion). For example, explain why the additional safety factors for plume edge separation distances range between 100% and 400% (i.e., 250% for Class 1, 400% for Class 2 and 3, and 100% for Class 4 plumes), whereas for vapor intrusion the safety factors range between 0% and 100% (i.e., 50% for scenario 1 and 2, 0 to 100% for scenario 3 and 0% for scenario 4 vapor intrusion). The rationale for choosing these wide ranges of safety factors and for choosing different safety factors for plume versus vapor intrusion is not provided.	The policy is based in part upon the knowledge and experience gained from the last 25 years of investigating and remediating unauthorized releases of petroleum from USTs. Separation distances were chosen that provide for protection of public health in a variety of circumstances, were easy to understand, and easy to implement. While the commenter may desire uniform factors of safety, all of the scenarios are protective of human health, safety, and the environment.
1.13		In Attachment 5, pages 4 and 5, do the separation distances consider the cases where the MTBE plume detaches from the source? If not, justify this decision. It seems that the separation distances are theoretically based on the plume lengths where the plume lengths are estimated from the source to the edge of the plume. What would be the base of plume length estimation and separation distances for sites where the plume is detached? There is an ongoing discussion within the research community whether or not MTBE plumes detach from the sources and what may be the effect of plume detachment on their extent and associated environmental risk (for examples see, Durrant et al, 1999; Ellis, 2000; Rixey and Joshi, 2000; Weaver et al., 1999; Wilson and Kolhatkar, 2002).	The separation distances described in Attachment 5, pages 4 and 5, are based on plume lengths estimated from the source to the downgradient edge of the plume, as suggested by the Peer Reviewer. These separation distances would also apply to a detached plume, as long as the plume could be demonstrated to be stable or shrinking. The references provided by the Peer Reviewer (all references are at least 10 years old) do acknowledge the potential for detached MTBE plumes. A more recent reference, Rasa et al. (2011), cited by the Peer Reviewer earlier, describes the role of back diffusion and biodegradation in sustaining MTBE plumes; this paper explains why MTBE plumes frequently persist near the source. Partitioning of MTBE from nonaqueous phase liquid (NAPL) source soils is typically controlled by mass transfer limitations. Rixey (2000) also describes how NAPL bypassing affects long-term dissolved benzene, toluene, xylene, and MTBE concentrations. Detached plumes can occur in highly transmissive aquifers with high recharge rates; low-threat plumes are not likely to occur in these types of aquifers. However, if NAPL is depleted, contaminant concentrations will decline at the source and potentially create a detached dissolved-only plume in some environments. Rixey, W.G. 2000. Dissolution of MTBE from a Residually Trapped Gasoline Source. American Petroleum Institute Research Bulletin No. 13, September 2000.
1.14		Is vapor intrusion significant in the case of MTBE volatilization? The significance (if any) of MTBE vapor intrusion should be addressed. While the Henry's Law Constant for MTBE is approximately 10 times lower than that for benzene and MTBE should not be readily volatilized from water, MTBE has a higher vapor pressure than benzene and it may volatilize more readily from the separate product phase or residual phase (LNAPL). Therefore, while MTBE vapor intrusion from a plume may not be significant, MTBE vapor intrusion from LNAPL source could pose risks.	The Policy currently requires at least 30 feet of separation between the LNAPL source area and the building foundation. Based on the physical properties of MTBE, specifically the lower Koc and Henry's Law Constant and higher water solubility as compared to benzene, the fate and transport properties of MTBE would be expected to significantly attenuate the migration of MTBE and limit its potential for vapor intrusion. Long-term (30-yr exposure duration) chronic inhalation risks from MTBE are not expected to occur at the vast majority of UST sites because of the rapid attenuation of MTBE in source areas. This assertion is supported by results of a recent study by McHugh et al. (2012) showing MTBE concentrations have decreased in groundwater by an average of 85% from 2001 to 2011 in California. In addition, no reports of MTBE as a constituent of concern for vapor intrusion are documented in the literature even though MTBE is routinely measured as part of soil-gas sampling (TO-15 air analyses). **This information has been added to the Technical Document for Vapor Intrusion.** McHugh, T.E., Kamath, R., Kilkarni, P.R., Newell, C.J., and J.A. Connor. 2012. Remediation progress at California LUFT sites: Insights from the Geotracker database. GSI Environmental, Houston, Texas.

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1.15		Explain why MTBE is not considered for vapor intrusion (Assertions 5-7) and direct contact (Assertions 8-10). As mentioned above, MTBE volatilization could be important if LNAPL source zones are present.	Regarding the potential of MTBE vapor intrusion, please see the response to comment No. 1.15. For direct contact, the EPA Regional Screening Level for benzene in soil for residential land use is 1.1 mg/kg, which is 1,654-times lower than its soil saturation concentration. For MTBE, the residential soil RSL is 43 mg/kg, which is about 200-times lower than its soil saturation concentrations. Even though the MTBE content of gasoline may be 10- to 15-times that of benzene, potential risks from direct contact with soil will still be driven by benzene, which is about 60-times more toxic than MTBE. Currently, EPA does not evaluate MTBE as a potential human carcinogen. The State of California has developed a cancer slope factor for MTBE based on a combination of data from two animal studies, one study by the inhalation route and the other study by the oral route. Numerous uncertainties have been identified in the animal studies, including severe mortality and lack of histopathological criteria. In addition, the mechanism of MTBE carcinogenicity is not known. Given all of the uncertainties associated with MTBE carcinogenicity, benzene will be the risk driving chemical of concern associated with fuel-related hydrocarbons, especially considering that benzene is a known human carcinogen with a known mechanism of action.
2.00	Professor Elizabeth Edwards, Ph.D.	Overall I found the policy to be based on sound science where possible or extensive practical experience and field data in other cases, and is generally conservative when considering uncertainty. This policy is designed to increase overall cleanup efficiency by making sure that funds are not spent where the efforts would have minimum incremental benefit and thereby make funds available for the most threatening releases. Moreover, the general criteria (a-h) that must be satisfied to be even considered as a candidate site are very conservative with respect to ensuring that drinking water has no chance of being impacted by the proposed policy.	General endorsement of the Policy.
2.01		The three assertions for groundwater come from the justification presented in Appendix 5. The focus on three specific components, Benzene, MTBE, and TPHg as representative measures of 1) toxicity (Benzene), 2) mobility (MTBE), and 3) mobile hydrocarbon fingerprint (TPHg) is a logical choice to span the range of contaminant types and properties at these sites. Overall, Appendix 5 culminates in a valid justification for the development of plume classes, but I would recommend that this appendix be presented with a more logical structure to be more specific and to make a stronger rationale.	General endorsement of the Policy.
2.02		As currently written, the first part talks about plume length (without any heading); next there is a heading entitled “Diesel”, but is really more about analytical challenges (i.e. what constituents do you measure and how) and how they relate to defining plume length. The next section is the definitions of plume classes. A final section speaks about free-product removal. These sections are a little disjointed and could flow more logically to culminate in the proposed plume classes. I would suggest that Attachment 5 be structured first with a section on the measurement of plume concentrations and appropriate methods to delineate the plume (including analytical challenges and approaches associated with free product and other heterogeneities), then present the use of plume lengths as a site-specific, in situ measure of the rates of attenuation relative to groundwater flow, and finally the integrated view presented as rationale for defining plume classes. I elaborate on my reasons for this suggestion below. The ability to clearly and sufficiently accurately delineate a given plume, with appropriate measurement and sampling strategy, is absolutely key. Practical guidelines for establishing a sufficiently accurate Site Conceptual Model (SCM) need to be clearly referenced in this proposal. A SCM can include varying degrees of extrapolation and interpretations that may compromise the accuracy of the model. Since the groundwater plume classes are defined based on specific plume lengths and separation distances, it is imperative that more detail be provided on how to adequately practically measure these distances given the challenges related to heterogeneity and seasonal variations (e.g., such as changes water table depths and flow patterns). A set of consistent guidelines and methodology are needed to clearly define how a plume length is measured in practical terms. Often plumes are not clear ovals, and length can also be a function of depth. Determinations of plume length can be quite arbitrary and are subject to error and subjectivity. What if the source area is not known, or there are multiple source areas? How then is plume length determined? What concentration limit is used to define the edge of a plume? I think these should be clearly set and explained to minimize chance of error or misinterpretation.	**The Technical Document for Groundwater has been revised for clarity.** For a discussion of plume definition see the response to comment No. 1.02.
2.03		I agree with assertion 1. However, paragraph 6 of Attachment 5 speaks to the body of work demonstrating biodegradation and attenuation of petroleum hydrocarbons and oxygenates, but only one reference from 1990 is cited (Howard, 1990). There is indeed a tremendous body of work on this subject, many of the citations are provided, and should be cited explicitly to reflect that the statement includes work more recent than 1990. Moreover, the following statement: “the rate of biodegradation/attenuation depends on the constituent and the plume bio/geochemical conditions” is vague. While I don’t disagree with this statement, really what is needed is a measure of confidence that the attenuation rate will be always greater than zero for the chemicals of concern at sites that meet the criteria defined in this policy. The challenge is that in the literature, the reported rates of biodegradation and natural attenuation are all over the map because every single experimental system or site is different and everyone picks a different measure of rate, so what numbers do you pick? I think that perhaps one could turn the argument around to make a more compelling case for the approach proposed in the policy. Rather than using literature values of rate for rationale, (i.e., picking a conservative rate range and then running scenarios) it should be emphasized that the measurement of plume stability is in effect akin to taking a site specific approach. The plume criteria are essentially a site-specific and “in situ” measure of the overall attenuation/biodegradation rate relative to groundwater flowrate. In other words, if a plume meets the criteria to put it into one of the groundwater classes defined in the policy, then biodegradation and natural attenuation are definitively occurring at the site and most importantly are occurring fast enough to prevent contaminant migration. These criteria essentially define site conditions where rates of natural attenuation and biodegradation are clearly sufficient to protect downstream receptors. The additional advantage to presenting plume lengths and plume stability as an in situ measurement of relative attenuation rate means that site-specific conditions that are known to very much affect the rate of biodegradation, such as presence of ethanol blends are inherently considered.	General endorsement of the Policy. We agree that the measurement of plume stability is in effect akin to taking a site specific approach. The plume criteria are essentially a site-specific and “in situ” measure of the overall attenuation/biodegradation rate relative to groundwater flowrate. In other words, if a plume meets the criteria to put it into one of the groundwater classes defined in the policy, then biodegradation and natural attenuation are definitively occurring at the site and most importantly are occurring fast enough to prevent contaminant migration. These criteria essentially define site conditions where rates of natural attenuation and biodegradation are clearly sufficient to protect downstream receptors. The additional advantage to presenting plume lengths and plume stability as an in situ measurement of relative attenuation rate means that site-specific conditions that are known to very much affect the rate of biodegradation, such as presence of ethanol blends are inherently considered. **We have added this language to the Technical Document for Groundwater**. For a discussion of biodegradation and natural attenuation see the response to comment No. 1.11.

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2.04		This use of separation distances is consistent with other State and local practices regarding impacts to groundwater caused by other anthropogenic releases. Assertion 2, provides additional confidence in the approach and the feasibility to practically implement a policy based on separation distances and attenuation (because this has been done before, and is easy to understand – which is very important). Again though, as mentioned previously, the definitions of the points that define the distances (plume boundaries) are critical. These have not been specified and in my opinion aught to be.	In the proposed Policy, the criteria required to define the dissolved phase plume length is, "the contaminant plume that exceeds water quality objectives." For a discussion of site specific data requirements, see the response to comment No. 1.03.
2.05		This second part of assertion 3 is vague. I'm not sure what site specific conditions would change the assertion. Who is going to be responsible for determining that "unique site specific conditions exist". It seems like this would be a way to easily disqualify any site at the slightest uncertainty, which may be counter-productive to the goals of the policy.	A site specific assessment using professional judgment is required to determine if "unique site specific conditions exist" for each case. While this may seem vague, the Policy cannot capture every possible situation in the State and special consideration of unique site specific conditions is prudent.
2.06		Other miscellaneous comments regarding Attachment 5: Table of plume length measurements (Tables should have a title and a number). The rationale by Shih et al, 2004 for using 5 ug/L rather than 1 ug/L for plume edge is a practical one. What will be implemented in the proposed policy? Oxygenates (MTBE, TBA, DIPE, TAME , ETBE). Acronyms should be defined. Ethanol should be added to this list as it is going to be very relevant. Acronym for Silica Gel Cleanup (SGC) should be defined on first use, and it is misspelled later in the paragraph "non-SCG laboratory quantified" change to SGC. It is inconsistent that the policy attachment does not specify specific concentration measurement guidelines except for this SGC step…At some point the policy needs to state that EPA (or whatever is deemed appropriate) approved methodology for measurements and site characterization are used throughout. I'm not sure why this specific attention to Silica Gel Cleanup was necessary. Perhaps additional details on all measurement methods and sampling plans should be provided? (or reference to approved standard practices?) Low threat groundwater classes: The proposed policy needs to provide a clear definition of how safety factors are defined and implemented to come up with separation distances. For example the last sentence of the first paragraph relating to ethanol gasoline blends "… by applying separation distance safety factors of 100% to 400%." I don't find this statement clear. What are the safety factors applied to (i.e. 100% of what)? Why would these values for safety factor be adequate for ethanol blends? I recommend that different wording be used (or a figure would be good) to show what these safety factors clearly represent and what literature was used to support their use. Rather than say "a SF of 100%", it seems to be clearer to say "twice the length of the plume from the source", or "an additional distance equal to the length of the plume from the edge"? I thus suggest being more direct. Class 2: wording of sentence: "Solubility of MTBE in water in contact with unweathered gasoline" (rather than solubility of MTBE in unweathered gasoline). References: check that website accession dates are provided, and that acronyms are written out in full (e.g. SFRWQCB)	**The Technical Justification for Groundwater has been updated for clarity.** For a discussion of safety factors, see the response to comment No. 1.13.
2.07		The assertions for vapor intrusion are also based on separation distances. Just as the definition for separation distance is important in the context of a groundwater plumes, it is also very important in defining distances in the context of vapor intrusion. Given that the distances are actually quite small (as low as 5 ft), the accuracy with which these distances are defined becomes more all the more important (see comments below under Assertion 4).	Agency professional judgment is required to determine if separation distances are satisfied and if criteria have been meet. For a discussion of data requirements, see response to comment No. 1.03.
2.08		I agree that different exclusion distances are needed for the two source scenarios, because the thickness of the bioattenuation zone required to degrade hydrocarbons to below levels of concern are indeed different for low- and high concentration sources. However, in this and subsequent Assertions, exclusion distances are defined as source-to-building separation distances. And while the distances proposed seem justified in the context of a static source, they do not seem to consider complications related to changing water table elevations to the determination of these distances. Some specific clarity on this point is required, to show how the determination of the distance in a real situation (with inherent variability) is achieved. In addition I suggest that the document clearly distinguish aqueous and gas phase concentrations for compounds like benzene. In section 3.1.1, benzene gas phase concentrations are reported as "< 10 mg/L", units typically applied to liquid phase concentrations and therefore easily confused. Elsewhere, concentrations are reported in units of µg/ m3, which is probably a better way to consistently express gas-phase concentrations to avoid confusion (even though they are technically equivalent). If ambiguity is possible, always specify "in the gas phase" or "in the liquid phase". I suggest a table of aqueous and equilibrium gas phase concentrations would very much help the reader. The Henry's law constant is cited several times throughout the document in various forms. This should be consistent. For example at the bottom of Attachment 6 page 5 footnote, a Dimensionless Henry's law constant for benzene is provided (0.25). It is also provided at the bottom of page 10 with units of m3 per m3 (the units are atypical). Moreover, it is nowhere noted that this constant is a strong function of temperature, and that this value is for 25 ^{o}C (I think). Was the effect of temperature considered in the development of exclusion distances? Similarly, biodegradation constants are also a strong function of temperature. Some discussion on the effects of temperature changes on the assumptions in the model should be elaborated on. As temperature decreases, volatility decreases (good), but biodegradation rates decrease (bad), so the potential for vapor intrusion depends on the slope of the temperature dependencies of these two competing processes.	Uncertainty in the depth to groundwater is factored into the conservatism for the vertical exclusion distances proposed in this guidance. For dissolved-phase sources, the empirical analysis described by Lahvis (2011) indicates a vertical source-receptor separation distance of 0 ft is sufficient to prevent vapor intrusion from occurring in greater than 95% of cases (i.e., the water table would have to be essentially in contact with a building foundation for there to be a potential concern for vapor intrusion). The 5- and 10-ft exclusion distances proposed in the guidance are thus deemed adequate to account for uncertainties in the depth to groundwater likely to be encountered at most UST sites. For LNAPL sources, the empirical analysis of Lahvis (2011) shows that the potential for vapor intrusion is less than 5% for vertical source-receptor separation distances greater than ~13 ft (well less than the 30 ft exclusion distance proposed in the guidance). Again, the vertical exclusion criteria in the proposed guidance are more than adequate to account for uncertainties in the depth to groundwater. Alternatively, one could apply Scenario 4 where an understanding of the depth to groundwater (source) is not necessary. However, an even more conservative approach could be to use the highest known groundwater elevation determined in the site specific CSM. **The Units used in the Policy have been standardized.** For discussion on temperature see response to comment No. 1.01.
2.09		Assertion 5 is based on both modeling and field soil gas data, and both sources agree in that the attenuation of benzene above an LNAPL is significant, and thus from the data presented the assertion is valid. However, as mentioned above, there should be some analysis to show that the temperature effects would not significantly change the results. I don't think they would, but it would be important to run through the scenarios, much like different oxygen concentrations were considered. Another comment would be to consider the effect of soil moisture. Biodegradation only occurs if there is sufficient moisture in the soil. For arid sites where the LNAPL is not on the water table (i.e. as in Assertion 7), biodegradation rates may be significantly slower, and a correction or test for low moisture content should be considered. I agree that the 30-ft. exclusion distance is conservative based on both modeling results and field data analysis. However, another way to look at the modeling would be to determine what biodegradation rate you would need to achieve the desired attenuation in the given scenarios. And then show that this value is readily achieved. In Section 3.1.1 Model studies – the value of the aerobic biodegradation rate of 0.79 per hour is referred to as the mean of published rates. In fact it is the geometric mean of published rates, and should be accurately referred to as such. The geometric mean is always lower than the arithmetic mean, and is the appropriate measure here.	See respone to comment No. 1.01.

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2.10		Other minor comments -Appendix 2 of the policy, Scenario 2. I wondered what the dotted fill in the figure signifies (I don't think anything really). -In general, I do think that the figures reproduced in Attachment 6 should be properly named with the title of the figure (from the original source) and proper legends. In some cases the axes are not evident, for example the figure on page 12 from Lahvis (2011), the probability presented on the Y-axis is not defined, and forces the reader to go to the original source to understand what the probability really means. A proper legend would remedy this easily, and give the reader an easier task. -Replace all uses of ug and use proper symbol: μg (e.g. p 11) -Spelling of receptor on P. 15	**The figures have been revised for clarity.**
2.11		I agree with Assertion 6, that the rates of biodegradation of such low concentrations of benzene in the dissolved phase will be sufficient given the proposed exclusion distances. I agree with the statement that the field data indicate that the water table would have to essentially be in contact with a building foundation for there to be a potential concern for vapor intrusion at low concentration sites.	Agreement with the scientific basis of the Policy.
2.12		I am less confident in (and my ability to comment on) the predictions of the vadose-zone biodegradation from vapor sources. As mentioned before, I would be concerned about moisture content in these situations. The proximity to the water table and precipitation record would be a factor that should be considered (monitored).	Agency professional judgment is required to determine an adequate SCM. For a discussion of soil moisture content, see the response to comment No. 1.01.
3.00	Professor Mark A. Widdowson, Ph.D., P.E. Professor John C. Little, Ph.D., P.E.	Assertion 4 It is well established that naturally-occurring subsurface microorganisms are active in degrading petroleum hydrocarbon vapors in the unsaturated region above the water table (i.e., vadose zone or unsaturated zone). Microorganisms utilize petroleum hydrocarbon compounds (PHCs) as a food source (carbon/energy source) in the presence of oxygen. Under natural conditions, the composition of dissolved gas in the vadose zone is nearly identical to the earth's atmosphere which contains approximately 21% oxygen. PHCs have the propensity to volatilize from gasoline and other fuels. As a result, PHC vapors are commonly detected in soil gas at UST sites. The movement or transport of these vapors is primarily a diffusive process driven by concentration gradients where molecules of PHCs are capable of transport through interconnected pore spaces in the vadose zone. Oxygen in the vadose zone is also subject to diffusion along with advective transport driven by pressure gradients. Because conditions required for the biodegradation of PHC vapors in the vadose zone are common, it is correct to use the term "conservative" if biodegradation is not considered in any site screening methodology. Given the state-of-the-science pertaining to bioattenuation of petroleum vapors in the vadose zone, the proposed framework for evaluating vapor intrusion evaluation at UST release sites is appropriate.	Agreement with the scientific basis of the Policy.
3.01		The phenomenon of aerobic biodegradation in the vadose zone has been observed at UST sites for over 20 years including field research supported by the U.S. Environmental Protection Agency. An outcome of aerobic biodegradation of PHC vapors in soils at UST sites is the reduction in PHC vapor concentrations as the vertical distance from gasoline/fuel source increases (i.e., closer to the ground level). At sites where an adequate distance for attenuation of PHC vapors exists, naturally-occurring biodegradation can be sufficient to reduce concentrations to a level that will prevent harmful intrusion of vapors into buildings. Therefore, the notion of using an exclusion distance as a means for a site-screening methodology for PHC vapor intrusion is scientifically sound.	Agreement with the scientific basis of the Policy.
3.02		The two source scenarios described in Assertion 4 represent the two most commonly encountered conditions at UST sites: low-concentration source (i.e., dissolved phase plumes) and high-concentration source (i.e, light non-aqueous-phase-liquids [LNAPLs]). The latter describes the condition where gasoline/fuel is present in a free-phase either floating on the water table or trapped in pore spaces above or below the water table. In PHC plumes present in groundwater at UST sites, the dissolved phase concentration of contaminants of concern such as benzene are controlled by solubility limits and the composition of the fuel. These values are unique for each compound and result in equilibrium concentrations in both aqueous (liquid) and vapor (gas) phases. Therefore, the maximum expected concentration of a volatile compound such as benzene at either high- or low-concentration sources can be predicted with confidence. Given the range of possible source concentrations based on these two common scenarios, it is reasonable to relate the required extent of an exclusion distance to the strength of the source.	Agreement with the scientific basis of the Policy.
3.03		General comments on the "Technical Justification for Vapor Intrusion Media-Specific Criteria" (Attachment 6) The literature cited in Attachment 6 is pertinent to the question of petroleum vapor intrusion into buildings and is derived from reputable peer-review journals. The scientific evidence cited as justification for the proposed Policy relies on model simulation and field investigations. Model simulations are useful to visualize the spatial distribution of PHC vapor and oxygen concentrations with depth relative to the foundation of buildings and the location of low- and high-concentration sources. The simulation results are based on representative values of soil properties, biodegradation rates and building/foundation characteristics. While the results shown from the literature are not meant to represent the exact outcome at every UST site, these simulation studies are useful to determine the minimum required separation distance for these representative conditions.	Agreement with the scientific basis of the Policy.
3.04		The field studies provide supporting data that show the range of soil-gas concentrations for benzene, an expected risk driver for vapor intrusion at UST sites, with distance above the source. Site data are presented for both low- and high-concentration sources. This type of data analysis has been employed in the remediation field for other questions related to the efficacy of natural attenuation in soil and groundwater and has proven to be useful to understanding the bigger picture. However, the impact of site-specific parameters that could influence results is not always captured in this type of study.	Agreement with the scientific basis of the Policy. and recognizes that site specific factors are important.
3.05		The conceptual model for a generic UST site can incorporate a range of assumptions from relatively simple to overly complex. Assumptions are needed to fill in the details to allow calculations but should be meaningful for applicability to the real world. The conceptual model associated with the modeling investigation (i.e., Abreu et al. 2009) includes several assumptions that are known to vary among sites and may potentially impact on results. These include the assumptions of 1) a static water table, 2) no barriers to the replenishment of oxygen from the atmosphere to soil, and 3) a homogeneous sandy soil. The exact impact of these assumptions on the proposed Policy is unknown, but the following are raised as potential concerns in relation to Assertions 5 through 7.	See response to comment No. 2.08, 3.07 and 3.08.

Comment No.	Reviewer(s)	Comment	Staff Response
3.06		Static water table – The elevation of a local water table is subject to increases with rainfall and decreases with drought. The extent to which a water table rises or falls over time is site specific depending on the intensity and duration of recharge events, land cover, and soil properties. At UST sites historical data from monitoring reports would provide data for determining temporal variation in the water table elevation. Some consideration for a site-specific evaluation of the temporal variability in the depth to the water table is recommended to properly implement the proposed Policy.	See response to comment No. 2.08.
3.07		Barriers to oxygen exchange at the land surface – As noted previous, diffusive and advective transport of oxygen from the atmosphere is known to replenish soil-gas oxygen at UST sites. In the model simulations cited from the literature there is no substantial barrier to oxygen exchange at the land surface. It is known that the porosity4 of asphalt and concrete is relatively low and will inhibit, but not completely prevent, the flow of gases or liquids. The presence of impervious land cover around a building will result in less oxygen replenishment and the potential trapping of PHC vapors. In addition, a 10 m × 10 m building footprint was used in the model simulations. For larger buildings, the peak concentration of PHC vapors and extent of oxygen depletion in soil gas would be greater than that depicted in the simulation results. Sites with barriers to oxygen exchange at the land surface should be identified as part of the screening process and given consideration in implementation of the proposed Policy.	Potential effects of building foundations on O2 ingress at land surface are factored in the empirical analysis of Lahvis (2011). In particular, 17% of soil-gas samples contained in the databases were collected from locations below building foundations (i.e., sub-slab) commonly encountered at UST sites. Although not explicitly stated, the exclusion distances were found to be relatively insensitive to the presence/absence of a building foundation at land surface. Additional characterization may still be warranted for unique site specific conditions. These conditions could include sites with excessively large building foundations associated with industrial/commercial buildings or apartment complexes.
3.08		Soil properties – Data analysis provided by Lahvis (2011) from numerous UST site provides a wealth of information on attenuation of PHC vapors due to aerobic biodegradation. It is noted that for less permeable soils (i.e., silt and silty clay), the mean rate of aerobic biodegradation for benzene decreased by as much as two orders of magnitude relative to UST sites with a sandy soil type. While this site condition suggests less attenuation potential, it is noted that soil porosity and moisture content in less permeable soils favors attenuation and is less conducive for transport of PHC vapors. Therefore, the lack of consideration of soil properties is a conservative approach in site screening.	Agreement with the scientific basis of the Policy.
3.09		Assertion 5 The field data provided by Lahvis (2011) for NAPL sites provides a compelling argument for the 30-ft source-receptor separation distance. Model simulation results provide meaningful justification for the observed data. Based on these findings, we agree that the vertical distance of 30 ft is conservative, and that the lateral exclusion distance of 30 ft is very conservative. Identifying the presence and location of LNAPL can be problematic at UST sites. However, the requirement that the TPH (total petroleum hydrocarbons) concentration in soils must be less than 100 mg/kg throughout the entire depth of the bioattenuation zone (as defined in Appendix 1 and 2 of the Policy) is a conservative approach. It is recommended to include technical guidance on evaluating TPH at sites (e.g., sufficient number of samples) and on determining LNAPL presence. In addition, the concerns listed above, particularly #1 (site-specific analysis of the temporal variability in water table elevation), are applicable to Assertion 5.	Agreement with the scientific basis of the Policy. For a discussion of data sampling requirements, see response to comment No. 1.02.
3.10		Assertion 6 Studies citing data collected at various UST sites (Davis, 2010; Lahvis, 2011) for dissolved-phase sites (i.e., source derived from contaminant plume) provides ample data to suggest that i) and ii) are appropriate standards. For the case indicated by iii) the notion that benzene bioattenuation is associated with sites where soil gas oxygen concentrations are ≥4% is consistent with theory and observations at some UST sites. However, as noted in Lahvis (2011), oxygen concentration in soil gas is not necessarily a good predictor of benzene concentrations in the unsaturated zone. It is recommended to incorporate technical guidance on the measurement of soil gas oxygen concentration in relation to the 4% threshold (e.g., number of samples and location of sampling locations) and on methods to verify benzene bioattenuation. Again, the concerns listed above, both #1 and #2, are applicable to Assertion 6.	Agreement with the scientific basis of the Policy. For a discussion of data sampling requirements, see response to comment No. 1.02.
3.11		Assertion 7 In our opinion, Davis (2010) presents the most thorough study on the magnitude of attenuation factors (AF) at UST sites, which is based on soil gas data collected for over 400 sampling events. On p. 13, Davis (2010) provides three reasons for “insignificant” attenuation factors (<100-fold contaminant reduction): 1) no clean soil overlying the source; 2) low source strengths (e.g., low-concentration dissolved plume); and 3) rapid attenuation at the source. It is noted that over half of the events fell into this category. The majority of the remaining sampling events show 1,000-fold contaminant reduction (i.e., 1000x or greater). It is not clear what factors contributed to events where AF = 10-2 (i.e., only a 100- fold contaminant reduction). Also, the range in the distance of clean soil associated with the AF values is not clearly indicated. On p. 12, Davis (2010) notes “significant attenuation is observed when the petroleum contaminant source has 2 to 10 feet of clean overlying soil”. Written communication by Lahvis provided in Attachment 6 includes analysis of data derived from databases reported in Davis (2009) and Wright (2011). Specifically, Figure 5 (p. 33) shows AF values for benzene over 5 ft or less for 29 sampling events. On the basis of this more detailed analysis of AF values (compared to Davis, 2010) we concur that an AF of 1000x over 5 ft is conservative. However, an improved understanding of whether other site conditions, besides low source concentrations, would be beneficial to proper implementation of the proposed Policy.	Agreement with the scientific basis of the Policy.
3.12		In a paper (Little, J. C., Daisey, J. M. and Nazaroff, W. W. “Transport of Subsurface Contaminants into Buildings,” Environmental Science & Technology, Vol. 26, 2058-2066, 1992) published 20 years ago (Little et al. 1992) a screening-level assessment showed that for a planar source located between 1 and 10 m below a building, an abiotic attenuation factor of between 0.003 and 0.0003 could be expected, based simply on contaminant diffusion through the unsaturated zone and subsequent dilution inside the building. The paper concluded with a recommendation that research be undertaken to investigate the rate of microbiological decay of the organic compounds diffusing through the unsaturated zone, noting that “biotic mechanisms could have a large impact on the concentration of petroleum hydrocarbons arriving at a building's zone of influence”. In the intervening two decades, substantial field and laboratory research has shown that the aerobic biodegradation of gasoline vapors in the unsaturated zone is very rapid, and that attenuation factors that include these biotic transformations are orders of magnitude lower than those that account solely for abiotic conditions.	Agreement with the scientific basis of the Policy.

Comment No.	Reviewer(s)	Comment	Staff Response
4.00	Professor Robert C. Spear, Ph.D.	Prior to addressing the Findings, Assumptions, and Conclusions detailed in the material forwarded to me in Attachment 2, I note that the intent of the proposed policy is to "to increase UST cleanup policy efficiency" in part to preserve "limited resources for the mitigation of releases posing a greater threat to human and environmental health." In that context, I find the Policy itself, as articulated in Attachment 4, to be well presented and easily understood. In particular, I found the general criteria presented on pages 12-14 to be quite helpful. I note only that, although it is mentioned in the introductory sections, there is no indication where the details of the Conceptual Site Model are to be found. This turned out to be in Section 3 of Attachment 7. Also, there are several abbreviations used in this Attachment which are not defined therein, but in other attachments e.g. bgs in Table 1 and TPH-g and TPH-d in the captions of Scenarios 1-4.	Endorsement of the proposed Policy.
4.01		Assertions for Groundwater The majority of the cited references address the extent and time course of plume expansion and/or contraction. These processes are well summarized in an overview by API(1998) for benzene plumes, updated and expanded to include MTBE and TPHg based on California data by Shih et al.(2004), and expanded further to include MTBE and TBA by Kamath et al. Buscheck et al. provide the most compelling linkage to the above assertion in noting that these data provide the primary evidence that a dissolved contaminant plume stabilizes locally relatively quickly once the source is removed followed by a variable decay towards background depending on local conditions. Buscheck et al. also argue that the secondary evidence for the processes of stabilization and reduction in concentration in individual monitoring wells includes indicator parameters of bioremediation and quantitative estimates of attenuation rates based on chemical analysis of dissolved species over time. Various of the references provide estimates of attenuation rates which allow estimates of reduction in concentrations to various regulatory endpoints. Overall this assertion is well justified but, as implied by Buscheck et al., direct and detailed in situ studies of the relative importance of biodegradation versus dispersion, diffusion, dilution, or volatilization are not presented and, perhaps, not available. However, the data are consistent with biodegradation being of primary importance.	Agreement with the scientific basis of the Policy.
4.02		As clarified in the material sent in response to my enquiry regarding relevant DWR well standards, DWR (1991) gives guidelines for the horizontal distance between various potential contaminant sources and wells. The maximum distance given on page 12 therein is 150 feet for cesspools or seepage pits. Hence, the Assertion is correct.	Agreement with the scientific basis of the Policy.
4.03		As noted under the Assertion 1 comment above, there is considerable data on the extent of plumes from LUST releases and their movement and concentration over time. These data are generally supportive of the set-backs required in classes 1-4 of the Policy. However, I believe it would be more accurate to include the words "with high probability" in Assertion 3. That is: "3. The required separation distances from the edge of a plume to an existing well combined with the requirement for plume stability will protect existing wells from impacts with high probability unless unique site specific conditions exist."	Agrees with assertion 3, "The required separation distances from the edge of a plume to an existing well combined with the requirement for plume stability will protect existing wells from impacts unless unique site specific conditions exist." However, suggests that it would be more accurate to include the words "with high probability".
4.04		A second editorial note concerns the apparent inconsistency or redundancy of elements of the description of groundwater contamination Classes 1, 2, and 4 on page 16 of the Policy with respect to free product. Class 1 simply states, :b. There is no free product, whereas Class 2 also states b. There is no free product, but also that : d.The dissolved concentration of benzene is less than 3000 ug/l and the dissolved concentration of MTBE is less than 1000 ug/l. In Attachment 5 these concentration limits are said to be evidence of the absence of free product. For consistency, presumably the concentration limits should also be in the Class 1 requirement. In the same context, in Class 4 there is to be no free product and there are concentration limits, but with a different value for the benzene limit of 1000 ug/l. I found no mention of the rationale for the value of 1000 ug/l. A final point is that it is not stated, but implied, that the concentration limits apply to all groundwater samples collected at the site in final survey prior to site closure.	Editorial comments noted.
4.05		Assertions for Vapor Intrusion Among the cited references, the paper by Borden and Bedient briefly summarizes the history of studies of microbial degradation of hydrocarbons focusing mainly on aerobic processes and the availability of oxygen in the unsaturated zone. The field investigation reported by Lahvis et al (1999) clearly demonstrates the appropriateness of the application of these ideas as well as a good deal of subsequent modeling work to studies of UST release sites. Clearly, the importance of vadose-zone bioattentuation processes is regarded as central to the current framework for addressing UST releases from both a regulatory and risk assessment perspective as evidenced by the professional literature and presentations cited in Attachment 6.	Agreement with the scientific basis of the Policy.
4.06		Assertion 5 is based most directly on the data assembled and reviewed by Davis (2009, 2010) and the simulation studies by Abreu et al. (2005, 2009). Most of these data and the simulations are for benzene, but a good case is made that benzene is a conservative chemical to use in assessing the risk from other petroleum hydrocarbons in this context. While the 2009 Abreu paper is an application of the model developed by these authors earlier and published in 2005 in Environmental Science and Technology, the Davis material is a conference presentation, some of which was published earlier (Davis 2009) in the LUSTline Bulletin, and some in a conference paper by Wright (2011). It is stated that the origins of the Davis 2009 database was initiated earlier as part of a working group including USEPA representatives as well as state regulatory representatives and that this database is now being used by both federal and state authorities to develop new vapor intrusion guidelines. Hence, despite the fact that I cannot determine how much of this body of material might be considered formally peer-reviewed, the synthesis and outcome of the analysis by these authors and others (API 2009, Hartman 2010, Lahvis 2011) is consistent and supportive of the Assertion with a safety factor on the order of 2 or 3.	Agreement with the scientific basis of the Policy.
4.07		As discussed on the comment on Assertion 5 above, the same body of material supports the foregoing zone depths and concentration criteria as being conservative. That is, the Assertion rests principally on the extensive modeling work of Abreu et al (2009), supported by analyses of the field data sets of Davis (2009) and Wright (2011) and summarized in the written communication of Lahvis and in Davis (2010). For example, Abreu's Figure 10, page 25, Attachment 6, predicts attenuation factors on the order of 10-7 for a two meter separation of sandy soil. The 4% oxygen concentration is consistent with the analysis of the Davis database by Lahvis (2011) who observed that, although there is a poor correlation between benzene soil gas concentrations of benzene and oxygen, generally oxygen content in the unsaturated zone exceeds 4% which indicates a zone of aerobic biodegradation. Again, this is supported for low concentration dissolved sources by the simulations studies of Abreu (2009). Hence, for sources less than 1000 ug/l, it is reasonable to require a 10 ft. bioattentuation zone where there is no oxygen data or if the concentration is below 4%, but a 5 ft. zone for oxygen concentrations above 4%. These criteria are conservative in both cases.	Agreement with the scientific basis of the Policy.

Comment No.	Reviewer(s)	Comment	Staff Response
4.08		Again, assertion 7 is based on the same body of evidence as Assertions 4-6 above. The specific evidence for the additional1000X attenuation factor is well summarized in the discussion on page 7 of Attachment 2 and, as above, the assertion is conservative.	Agreement with the scientific basis of the Policy.
4.09		Assertions for Direct Contact and Outdoor Air Exposure Pathways The derivation of the soil screening levels is, as extensively explained in Attachment 7, based on standard USEPA-CalEPA carcinogen risk assessment methodology, both qualitatively and quantitatively. Hence, the methods applied have an extensive history and documentation in the regulatory literature. The application of these methods to mixtures is awkward as is implied in section 2.2 of Attachment 7 in which it is explained that total petroleum hydrocarbons (TPH) are not considered as a unique entity. Rather, several specific chemical components of the mixture are selected for assessment. As a consequence, possible interactions in environmental chemistry and/or their toxicology are not considered. Nonetheless, the methods used are state of the regulatory art and. as is often implied in Attachment 7, very likely to yield very conservative screening levels for cancer risk in the present application. Hence, whatever criticisms that might be lodged at this assessment relate to the general approach, not the details of this particular application. As a second example, any set of equations that contain 50 or more parameters, each subject to some degree of uncertainty and/or variability will produce end estimates of risk with very large variance which is generally not addressed. These two examples are, of course, the rationale for the conservatism used at every step in the process. Some might argue that effort would be better spent in assessing, at least in some preliminary fashion, the likelihood of non-carcinogenic endpoints that could be of greater concern.	Agreement with the scientific basis of the Policy.
4.10		Insofar as the risk assessment is solely focused on carcinogenic endpoints, assumption 10 is sensible and conservative. For an endpoint like asthma or other immunologically-mediated outcomes this may not be the case. An editorial note: only in the footnote to Table 8 of Attachment 7 is it mentioned that “the PAH screening level is only applicable where soil was affected by waste oil and/or Bunker C fuel.” This should be mentioned in section 2.2.	Agreement with the scientific basis of the Policy. Editorial comment noted.