MEMORANDUM

TO: Patty Kouyoumdjian
Executive Officer

FROM: Lauri Kemper, PE
Assistant Executive Officer

DATE: September 30, 2015

SUBJECT: Prosecution Team's Comments on September 1, 2015 Draft Cleanup and Abatement Order (CAO) for Chromium Contamination from the PG&E Hinkley Compressor Station, San Bernardino County

The Lahontan Water Board's Prosecution Team appreciates the opportunity to provide our comments on the Advisory Team's September 1, 2015 Draft CAO, for the PG&E Hinkley Compressor Station. The Table of Comments, Attachment 1, is in addition to consensus language coordinated with PG&E and requested by and provided to the Advisory Team on July 8, 2015.

A Unique Case

The PG&E Hinkley Compressor Station Chromium Remediation Project is unique for many reasons and, therefore, requires a site-specific response and approach in terms of requirements specified in Water Board Orders.

- The area of groundwater contaminated is over seven miles in length and two and a half miles in width. The Lahontan Region has no other groundwater contamination case of this size and with as many domestic wells threatened or affected (excluding sites controlled by the Department of Defense).
- The number of affected or threatened domestic wells and persons: At one time, nearly three hundred private domestic wells were being tested by PG&E. Many individuals still reside in close proximity of the contamination and rely on the groundwater for all domestic uses.
- The contaminant, hexavalent chromium, exists in nature, making the establishment of background concentrations more challenging. For a purely man-made substance, such as MTBE, background concentration can be easily set at below non-detectable concentrations. No simple investigation or a conflict resolution process can determine what percentage of the detected hexavalent

chromium is attributable to PG&E's historic discharges of hexavalent chromium, which is why a five year, five million dollar study is now underway.

- The geology is complex in this area and varies across the contaminated zones. This complex geology and pumping by other parties over such a large area of contamination make predicting fate and transport of the chromium and remediation by-products challenging. Over the years of Water Board oversight of the remediation, unpredictable and unforeseen changes in groundwater quality have occurred frequently.
- Wide-spread public interest because of a movie.
- Involvement of the U.S. Geological Survey to conduct a chromium background study to evaluate the occurrence of natural and anthropogenic Cr(VI) in groundwater.

The Prosecution Team Does Not Support Returning to Using "Best Professional Judgment"

At a site with as complex geology as this one, and with so many outside parties pumping the groundwater, the use of best professional judgment has resulted in several different results. Professional licensed geologists can, and do, arrive at different answers using the same information and data available to them. Reasonable, professional minds can differ. At this site, the Water Board has received technical reports with different interpretations from different PG&E consultants. Because of the uncertainty about conditions existing underground, this is not too surprising. It is a good reason to prescribe methodology for contamination plume mapping so that **consistent** and **comparable** maps can be produced every time someone is preparing one. Having consistent, comparable maps and reports aids the community and all interested parties by providing ease of understanding how conditions changed, for better or for worse.

PG&E incorporated "best professional judgment" in its submissions to the Water Board from the 1987 Cleanup and Abatement Order (No. 6-87-160) through October 30, 2011 when a new investigative order took effect (No. R6V-2011-0079). Between 2006 and 2011, Water Board staff often disagreed with the "best professional judgment" by PG&E and its many consultants. The submissions under the "best professional judgment" standard were inadequate and often unsupported. The situation reached a peak at the March 9, 2011 Water Board meeting in Barstow in which nearly 200 public members complained about, among other things, alleged PG&E's biased plume mapping, withholding chromium data collected from domestic wells, delays in installing monitoring wells to define the plume boundaries, and interpretation of the plume's extent. The public insisted that the Water Board take action and be more transparent in responding to PG&E requests.

Based upon the inconsistent mapping resulting from "best professional judgment" of the PG&E consultants, the Water Board issued the September 29, 2011 Investigative Order R6V-2011-0079 specifying criteria for map drawing, map content, and technical report content. The Order required the use of all data including domestic well data when no monitoring wells were in place in a particular area. This action was taken to provide

consistency between the different consultants and to provide **comparable** mapping of the contamination over time.

Recall that the Water Board agreed to a settlement of $3.6 million with PG&E in March 2012 when the Water Board did not agree with PG&E's professional judgment contained in reports for CAO R6V-2008-0002. More than a dozen reports and correspondence PG&E submitted from 2009 to 2011 regarding monitoring well MW-62A couched the rising amount of hexavalent chromium as first an anomaly and later as not being an appropriate sentry well, not evidence of plume migration in its best professional judgment. The Board agreed with the settlement documents that, in fact, the plume had not been contained and issued the administrative civil liability.

The 2011 investigative order mapping and reporting criteria were continued in Cleanup and Abatement Order R6V-2008-0002-A4 that you issued on behalf of the Board on January 15, 2013. The Board's orders in 2011 and 2013 contained this evolved mapping system for its comparable, consistent, and easy to understand properties. To return to the unsatisfying "best professional judgment" standard would undermine past Board orders and backtrack on the progress made in working with PG&E and community towards better transparency of information.

Since the 2011 investigative order, PG&E has been free to provide alternate interpretations of chromium data, plume maps, and clean up actions, in addition to those required by the Water Board. PG&E first started doing this by drawing separate chromium plume maps in quarterly groundwater monitoring reports. In late 2014, after discussions with Water Board staff on the importance of consistency and clarity, and to avoid confusing one map with the other, PG&E changed its mapping submittal by providing its interpretation as insets on the chromium plume maps drawn in compliance with Water Board orders. This system has worked well, has received few public complaints, and should be continued. Continuing this mapping system provides PG&E with known parameters of what to submit in its maps and reports that provide the Board, its staff, and the community with an understandable, comparable, and is flexible enough for PG&E to submit insets representing any data set, factors, interpretation, or emphasis it prefers. If the Board Members and the Advisory Team desire, they can easily continue this alternative mapping with the use of inset maps in the new Cleanup and Abatement Order.

This unique case incorporates a process among the interested parties to continually improve how information is shared, contingent upon how PG&E reports its data. This is <u>not</u> a routine voluntary cleanup matter, and we have all learned from the many years and numerous Board orders. The Prosecution Team respectfully requests that the Board and the Advisory Team continue the mapping and reporting system it instituted in the 2011 investigative order and 2013 CAO, at least until the Background Study results are available, and not return to the ambiguous "best professional judgment" standard that has proven itself inadequate in this matter.

The Northern Plumes in the Hinkley Valley and Harper Dry Lake Valley are Linked to Compressor Station Discharge

PG&E has claimed that the northern two plumes on current maps are not related to historical chromium releases at the Hinkley compressor station. Yet, as seen in the figure as Attachment 2, the three maps show the progression of the chromium plume over time. Chromium in groundwater was mapped as one large plume connected to the compressor station in first quarter 2012, just 3½ years ago. In 2013, the plume was drawn divided as two separate plumes due to remedial actions. In 2014, the northern plume is shown as divided again but that may just be due to lack of monitoring data in the east side of the Hinkley Gap.

The division of contaminant plumes in groundwater is normal during remedial action implementation. This plume behavior is consistent with the plume examples for Deer Park and Patchogue, New York; Port Hueneme, California; and the Rhineland Refinery in Germany, shown in Figures 2 and 3 of the July 2015 Groundwater article "Exceptionally Long MTBE Plumes of the Past Have Greatly Diminished" (Attachment 3). Whether the contaminant is hydrocarbons or metals, such as hexavalent chromium, their dissolved behavior in groundwater is the same in that they migrate wherever groundwater flows.

The northern plume is considered as real in the U.S. Geological Survey's (USGS) proposal for chromium background study. The 2014 study proposal includes a map on Figure 2 (Attachment 4) showing the chromium plume boundary lines in groundwater in the North Hinkley Valley and Harper Dry Lake Valley. The explanation for the map states "Plume extent in upper aquifer (2013); Cr(VI) >3.1 micrograms per liter, dashed where not contiguous with compressor station." This latter part indicates the USGS currently considers the dashed plume in the north to be related to the compressor station. The current background study will be establishing just how wide and long the northern plume boundary lines extend.

The Prosecution Team contends that enough time (56 years) has passed to allow hexavalent chromium discharged to the groundwater from the Compressor Station to have reached all locations currently being mapped as chromium contamination plumes. With remedial actions occurring just in the past 23 of those years, a majority of the chromium plume in groundwater migrated to the north unabated. Although not much is known yet about natural levels of hexavalent chromium in the northern valleys, it is more probable than not some portion of any hexavalent chromium found there can be attributed to PG&E's historical discharges. With over 65 years of professional technical experience, the Prosecution Team concludes that based on all the evidence it is likely that northern plumes in the north Hinkley Valley and Harper Dry Lake Valley consist of chromium from the compressor station.

The Water Board has the authority to revise the CAO and update it when new information becomes available. The Prosecution Team recommends using the January 7, 2014 Project Navigator letter describing what information from the USGS

the Board may consider for action as a set of operating rules for right now (See Attachment 5). The process described in this letter was supported by the parties involved in the Technical Working Group in Hinkley, including PG&E. The Water Board may consider changing its mapping requirements following results of the USGS background study, but until such time, we recommend maintaining the current requirements.

Draft CAO Comments

The attached Table of Comments (Attachment 1) provides the Prosecution Team's specific comments and concerns with a word, sentence, or paragraph in the Draft CAO. Often times, we provide alternate language for your consideration. We are most concerned with chromium plume mapping requirements, and cleanup of the lower aquifer. We are open to discussing further with you and PG&E ways to resolve our concerns so that accountability and consistency in regulation can continue at this site.

Attachments:
1. Prosecution Team Comment Table on Draft CAO
2. Chromium Plume Maps 2012, 2013, 2014
3. July-August 2015, Groundwater, "Exceptionally Long MTBE Plumes of the Past Have Greatly Diminished" pages 515-524
4. Figure 2, Study area location, 2014 USGS Chromium Background Study Proposal
5. Project Navigator January 7, 2014 letter regarding "Actionable Information"

Attachment 1

Prosecution Team's Comments on September 1, 2015 Draft Cleanup and Abatement Order R6V-2015-DRAFT

Submitted to the Advisory Team on September 30, 2015

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
1	Finding (F). 6 / P. 2 (and throughout)	…"interim" maximum background levels…	The use of the term "interim" in reference to the currently adopted background values throughout the Draft CAO is incorrect and confusing. The background values of 3.1/3.2 Cr(VI)/Cr(T), adopted by the Water Board in CAO R6V-2008-002A1 were not termed "interim" values. They are in effect and will remain so until changed by future Water Board action, which is not guaranteed. In finding 16, the criticisms and limitations of the currently adopted background values are acknowledged. However, the current background values remain the best available data for their intended use. The Prosecution Team notes that any regulatory value is subject to change based on new information; for example, public health goals and drinking water standards all can be revised based on new data. But such values are not termed "interim" when they are adopted; rather it is simply recognized that they are subject to review and revision. This is the most straightforward and least confusing approach, and should be applied here as well. We recommend removing the word 'interim' where added by the Advisory Team throughout the CAO.
2	F. 7 / P. 2 (and throughout)	…"uncertain plumes"…	In finding 16, the criticisms and limitations of the currently adopted background values are acknowledged, particularly as they apply to the northern area. The Prosecution Team and PG&E in our consensus language used the term "uncertain" regarding background values in finding 16 in the context of the limitations of the 2007 background study, only, the Advisory Team has applied it as a descriptor for the northern area plumes, over-reaching in its interpretation of the term. The Prosecution Team does not agree that the term should be globally applied to the northern plumes for the following reasons: In first quarter 2014, concentrations of up to 275 ppb Cr(VI) were detected in monitoring well MW-193S3 in the northern area; other MWs in the

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			northern area throughout 2014 showed concentrations up to 17.9 ppb. While we acknowledge questions regarding the accuracy of the currently adopted background values of 3.1/3.2 Cr(VI)/Cr(T) for the northern area, it is very unlikely that a new background study will establish that background values in the area are in the 100s of parts per billion, given the lack of evidence of geologic units known to contain high amounts of chromium minerals (see May 21, 2015 Prosecution Team response A.2, including section i). Evidence previously presented (see May 21, 2015 responses to Advisory Team, Prosecution Team response A.2) to support this conclusion includes presence of groundwater flow through the Hinkley gap from the Mojave River, groundwater flow direction, groundwater velocity and time since waste discharge, and highly elevated levels of chromium in monitoring wells in the contaminant flow path. Also, the issuance of CAO R6V-2008-0002-A4 and other past board orders support the use of "plume" to describe PG&E's chromium release affecting groundwater quality in the north Hinkley Valley and Harper Dry Lake Valley. The Prosecution Team contends the weight of evidence, including general hydrological principles, supports the conclusion that elevated concentrations of chromium detected in the northern area monitoring wells are reasonably attributed, in part, to PG&E's waste discharges from the compressor station. These areas are correctly referred to as chromium plumes that are known and not uncertain. The use of the term "uncertain" is not properly applied to the northern plumes and should be removed.
3	F. 7 / P. 2	Insertion of sentences at end of finding explaining the process for chromium migration to the Lower Aquifer	Finding 7 starts out discussing the contents of PG&E's 2014 3rd Quarter Groundwater Monitoring Report. The Advisory Teams inserted sentences at the end of the finding, based on a different PG&E document, describing the details of chromium migration from the upper aquifer to the lower aquifer. The Prosecution Team believes these two subjects should be in separate findings. In addition, the final inserted sentence

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			appears to be redundant of the third to last sentence. Suggest deleting the final sentence but retaining the part "east of Mountain View Road and near Santa Fe Road" to add to the end of the third to last sentence. The Prosecution Team also thinks it is important to note in this new finding that chromium concentrations in the Lower Aquifer were originally at non-detect concentrations in 2006 before starting to increase due to migration from the upper aquifer. Suggested language can be: Since 2001, PG&E has stated in reports and in technical meetings that it has no plans to conduct a background study in the Lower Aquifer. Thus, it is reasonable for the Water Board to rely on upgradient monitoring wells to set the cleanup goal in the Lower Aquifer. Only after the discharger attempts remediation using best available technology and is unable to achieve cleanup goals, can alternate cleanup goals be proposed (Resolution No. 92-49). In the matter of chromium contamination in the Lower Aquifer in Hinkley, PG&E is still in the process of implementing groundwater extraction to reach background levels and cannot yet propose alternate cleanup goals.
4	F. 8b / P. 3	Insertion of the year "2011" in the first sentence. .	PG&E began mapping chromium as two discontinuous plumes separated from the southern plume in 3rd Quarter 2013, not 2011. . Please make this correction.
5	F. 8b / P. 3	Strike-out of word "plume" in this finding	For discussion on the word "plume" being appropriate for this finding, please see Comment 2.
6	F. 8c / P. 3	Last sentence insertion: "because 16N-01 is not located in downgradient groundwater flow direction."	The reason chromium in well 16N-01 is not believed to be from PG&E's compressor station is because it is too far north of the compressor station to be reasonably attributed to PGE; well 16N-01 is 2.6 miles <u>farther</u> than the calculated fate and transport distance (7.3 mi) of the chromium plume in the footnote of Finding 9. We suggest adding the following text to the end of the sentence: "…because 16N-01 <u>is 2.6 miles farther than the 7.3 mile calculated distance of</u>

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			the chromium plume (the chromium in this well at this time does not appear to be attributed to PG&E's historic discharges from the compressor station)."
7	F. 16 / P. 5	Last sentence insertion: "and will be referred to interim maximum background concentrations."	As explained in Comment #1, the Prosecution Team recommends that the last sentence be deleted.
8	F. 16 / P. 5		The Prosecution Team recommends the insertion of a new finding after Finding 16, describing the setting of background values in the Lower Aquifer: Since 2002 when the detection limit for Cr(VI) was lowered to 0.2 ppb, monitoring wells MW-11C and MW-14C, located in the upgradient gradient flow direction, and MW-21C, located in the cross gradient flow direction, have always shown non-detect levels during monitoring event. And prior to chromium concentrations increasing in MW-23C starting in 2006, background levels in this well were consistently at non-detect concentrations or 0.2 ppb Cr(VI).
9	F. 19/ P. 5 & 6	Insertion of explanation of how PG&E used the chromium plume boundaries to offer replacement water or property buyout	The inserted sentences no longer describes CAO R6V-2008-002A4 but instead describes PG&E use of chromium plume boundary lines to provide replacement water or offer property buyout. Thus, the Prosecution Team recommends that this finding be divided into two separate findings. The second finding should begin with the second inserted sentence, "With the drinking water maximum contaminant level set at 10 ppb for Cr(VI)…"
10	F. 33/ P. 9		The Prosecution Team recommends the insertion of a new finding after Finding 33 describing PG&E's current remedial actions being implemented in the Lower Aquifer: The Water Board approved PG&E's Lower Aquifer workplan, dated November 7, 2014, for adding a new extraction well to enhance chromium cleanup effectiveness in the Lower Aquifer. The new extraction well, EX-37, came online in March 2015. With a total of three extraction wells now working to remove chromium

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			in the Lower Aquifer, clean up to background levels detected in MW-11C and MW-14C is now achievable in a shorter timeframe. The current concentration at MW-92C (27 ppb Cr6) is about 45 percent less than the historical maximum concentration (41.8 ppb Cr6) from August 2011. Based upon the rate of chromium reduction over the past 3 years with two extraction wells, cleanup to background using three extraction wells should be achieved in 3 to 4 years.
11	F. 33/ P. 9		The Prosecution Team recommends the insertion of a new finding after the recommended new finding in Comment #10 to explain the need and justification for setting cleanup levels and cleanup times in the Lower Aquifer: "Since chromium contamination to the Lower Aquifer has only existed since approximately 2006, and has always been below 50 ppb, it is reasonable to set short timeframes to achieve complete cleanup in this area. Groundwater in the lower aquifer should be able to be restored within five years based on extrapolating information seen from PG&E's remediation status reports for the lower aquifer over the last few years and remediation progress seen in the upper aquifer."
12	F. 37c/ P. 11	Deletion of word "plume."	As explained in Comment #2, the Prosecution Team believes that "plume" is the correct term to describe where contamination exists, is consistent with prior board orders, and should be left in due to the detection of chromium in groundwater in monitoring wells.
13	F. 37c/ P. 11	Deletion of explanatory sentences regarding why monitoring is needed	The finding was to support monitoring frequency and explain how the frequency would be modified. The Advisory Team's deletion of the explanatory sentences now makes the intent and readability of this finding unclear. The Prosecution Team recommends either retain the deleted sentences or re-write sentences to provide support for monitoring in northern area. Suggested language is provided below. "The extent of chromium plume boundaries in groundwater is not fully defined in the northern valleys. Dissolved chromium migrates unimpeded with natural groundwater flow to the

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			north. A groundwater monitoring program is necessary to track this movement and to protect public health at domestic wells. The "Groundwater Monitoring and Reporting Program, CAO No. R6V-2015-PROP", in Attachment 8, provides a sufficient monitoring and reporting program in the northern areas to achieve these goals. Additionally, the program includes a process for sampling frequency modifications based upon statistical trends indicating changes over time."
14	F. 37c/ P. 11	. Insertion of the word "uncertain."	The insertion of the word "uncertain" suggests that the northern plume existence is uncertain rather than just the extent of its boundary lines.
15	Order IV.A. & B./ P. 15 & 16 and throughout	Insertion of "best professional judgment"	As stated in the cover memo to these comments, PG&E was allowed to use "best professional judgment" from 1987 to 2011. The Water Board did not agree with the professional judgment being applied as it resulted in under-representing the locations of chromium contamination, leading to the Water Board expounding plume mapping requirements in September 2011. The evolved system has been successful since 2013 and incorporates PG&E's preferences in a map inset, allowing them to display the information as they see best in their professional judgment. Should the Board desire to alter the mapping and reporting system, the Prosecution Team recommends revisiting the matter after the Board obtains the USGS background study results. We suggest adding a finding based on the above information and on the two different maps previously submitted by PG&E during 2010. For example: "Having consistent, comparable maps and reports over the course of time aids in providing transparent information to the community and all interested parties. The mapping and reporting system developed and established in Orders No. R6V-2011-0079 and R6V-2008-0002-A4 provides consistency and comparability of plume maps, along with the flexibility for PG&E to provide inserts using their preferred data sets, factors, and display."

Attachment 1

Prosecution Team's Comments on September 1, 2015 Draft Cleanup and Abatement Order R6V-2015-DRAFT

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
16	Order IV. A.1/ P. 15	Insertion of sentence defining "sufficient resolution"	For the reasons cited in Comments #15 and 18, the Prosecution Teams recommends that in the sentence in A.1, the word "either" be removed in the first line and it end at "…where monitoring wells are no more than 1,320 feet apart." We recommend deleting the last part of the sentence stating, "a California licensed Professional Geologist…"
17	Order IV.A.3/ P. 16	Deletion of the words "undefined plume" and replacement with "may exhibit insufficient resolution."	As explained in Comment #2, the Prosecution Team believes that "plume" is the correct term, is consistent with prior board orders, and should be left in. The words "may exhibit insufficient resolution" are too vague and unclear to the average person. Consider replacing these words with language consistent in the last eight CAOs, such as "…and these areas require better chromium boundary definition (or investigation)."
18	Order. IV.A.4/ P.16	Insertion of "best professional judgment" requirements.	For the past few years, PG&E quarterly groundwater monitoring reports have included alternate figures or insets in figures stating that "best professional judgment" is used to draw its version of chromium plume maps. These alternate drawings, however, show plume lines significantly less in size and area than plume lines drawn using criteria set in board orders, including the most recent CAO R6V-2008-0002-A4. For instance, Figure 5-6 in the First Quarter 2014 Groundwater Monitoring Report, which is PG&E interpretation of "best professional judgment," the northern plumes in the north Hinkley Valley and Harper Dry Lake Valley are absent despite monitoring well data showing chromium concentrations in groundwater up to 275 ppb. Also missing are the western finger, western "bunny" ear and eastern bunny nose (both south of Thompson Road) in the southern plume, despite chromium concentrations in groundwater up to 8 ppb. None of these plume lines should be missing since they are in the downgradient flow path of the chromium release at the compressor station, and within the calculated fate and transport of the chromium plume referenced in the footnote on bottom of page 3 of the Draft CAO. Water Board staff provided more detailed explanations for the chromium plume extending from the Hinkley Valley to the Harper Dry Lake Valley in our May 21, 2015 responses to the Advisory Team.

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			Since PG&E's "best professional judgment" differs from the Water Board staff's best professional judgment, we recommend maintaining the current requirements (those provided by the Prosecution Team) in the proposed CAO, consistent with R6V-2011-0079 and R6V-2008-0002-A4 and the Project Navigator The Prosecution Team recommends removing section IV.A.4. and replacing it with plume mapping criteria consistent with prior board orders R6V-2011-0079 and CAO R6V-2008-0002-A4, Order I.C. in the "Groundwater Monitoring and Reporting Program in Attachment 8. We suggest including a statement such as: "Incorporating the original mapping and reporting criteria will also alleviate resource intensive review of each submission by Board professionals and install consistency and comparability among the maps and reports for ease of understanding and information transparency." The suggested findings in Comments #15 and 16, above, would support this change in the Order portion of the CAO.
19	Order IV. A. & B./ P. 15 & 16	Deletion of the words "undefined plume" and replacement with words "may exhibit insufficient resolution."	As explained in Comment #2, the Prosecution Team believes that "plume" is the correct term, is consistent with prior board orders, and should be left in.
20	Order. IV. B/ P.16	Citation of section VI.A.3 in the first sentence.	The Prosecution Team believes that "VI" is the incorrect section cited. "IV" is the correct section since it refers to "insufficient resolution" of chromium concentrations.
21	Order IV. B./ P.16 & 17	Insertion of "best professional judgment," incomplete sentences.	For the reasons cited in Comments #13 and 17, the Prosecution Team recommends removing all references to using "best professional judgment" and "technical justification." Doing so will require that the word "either" be removed from the first sentence on page 16. Since this then makes the requirement for submitting a workplan necessary, the sentence beginning "If submitting the workplan…" should be returned to the original

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			CAO text. The last sentence in this section stating "As access is gained over time…" conflicts with the Order requirement to submit a workplan within 30 days of the date of this Order. Instead, the last sentence needs to stand as a separate order, such as Order IV.B.1. or keep the original Order IV.B. that starts "PG&E shall submit a workplan to install monitoring wells…" Since it is recommended that "best professional judgment" should be removed from the last sentence in this section, the Prosecution Team recommends revising it to read, "As access is gained over time, PG&E shall submit a workplan to the Water Board within 30 days to better define the chromium plume boundaries when monitoring well distances exceed 1,320 feet apart."
22	Order V. A.2/ P. 18	Insertion of sentence describing hydraulic containment	The Prosecution Team agrees with the inserted sentence and recommends adding the underline part: "…from specific monitoring well pairs and triplets within the <u>most recent</u> mandated capture zone <u>accepted by the Water Board</u>.
23	Order. VI.C.1.a. iii / P. 21	Insertion of term "<u>USGS</u>" referring to background values in this consensus language order.	The insertion of the term "USGS" is incorrect. The reference to "background values" in this consensus language order was intended to mean those values that are in effect when the USGS preliminary report is released in 2017. The USGS preliminary results report referenced in this Order will likely not contain a proposal for new background values for the western area, but more likely may have an assessment if the chromium area is attributable to the compressor station or not. If so, then PG&E will assess the feasibility to clean up to the background values in effect in 2017. It is important to understand that the USGS will not set new background values. Rather, the USGS, in its final background study report, will propose background values for the Water Board to consider adopting.
24	Order VI.C.1.b / P. 21 & 22	Deletion of lower aquifer cleanup requirements,	Given the Advisory Team's changes, the Prosecution Team is not clear on how compliance with this requirement can be measured and

Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
		including cleanup level and timeframe.	enforced. As the Lower Aquifer continues to be used today for domestic and agricultural supply, restoring it to background quality is necessary. Therefore, to ensure that cleanup of chromium occurs in the Lower Aquifer in a timely manner, we recommend leaving requirements as proposed by the Prosecution Team since they are reasonable and feasible. Alternately, the CAO can require cleanup be completed within five years.
25	Order VII. 2. a / P. 25	Advisory Team revision: "Within 45 days of <u>this Order being issued</u> . . ."	This revision now contradicts finding 43. Please clarify if the intent is to require a replacement water plan within 45 days of the order being issued, or within 45 days of identification of a private supply well having increasing trends of chromium indicating likely future exceedances of chromium MCL (original language). The original language is in line with the Water Board authority to require replacement water as outlined in the *Olin Order* (see finding 41, last sentence). The Prosecution Team recommends retaining this language from the consensus CAO draft.
26	Order VII. 2. b and c./ P. 26	"replacement drinking water" . . .	Include "<u>and cooking</u>" to all references to replacement water.

Attachment 1

Prosecution Team's Comments on September 1, 2015 Draft Cleanup and Abatement Order R6V-2015-DRAFT

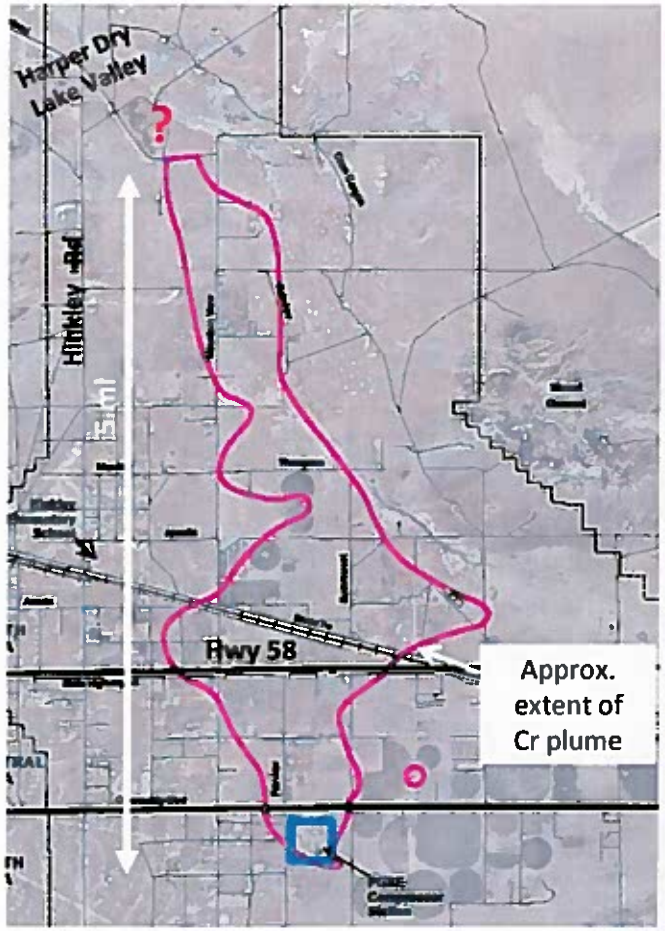
Groundwater Monitoring and Reporting Program, Attachment 8			
Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
1	Third paragraph / P.1 (MRP Program)	"As cleanup progresses…in order to best effectuate those goals."	Suggest removing "in order" which is superfluous. It is not clear what goals are being referred in the phrase, "to best effectuate those goals," since there are no reference to goals in either of the preceding paragraphs. Suggest replacing the phrase with "…to best accommodate changing conditions."
2	D. / P. 4 (and throughout)	…"uncertain plumes"…	The Prosecution Team's objections to the use of "uncertain" in this section and throughout the MRP are the same as described in Comment #1 in the Draft CAO findings. We strongly recommend that "uncertain" be removed in all locations that reference the northern plumes since the word's use is not being properly applied and should be removed.
3	D.1. / P. 5 (and throughout)	…"interim" maximum background levels…	The Prosecution Team's objections to the use of "interim" in this section and throughout the MRP are the same as described in Comment #2 in the Draft CAO findings. We strongly recommend that "interim" be removed in all locations that reference the currently adopted background values since the word's use is incorrect and confusing.
4	I.E./ P. 7 (Monitoring)	In the first sentence, deletion of "plume" and insertion of "where the plume is uncertain" in reference to the northern area	As described in Comment #2 in the Draft CAO, the word "plume" is appropriate for describing the northern plumes. Therefore, the Prosecution Teams recommends leaving the original text as is in the first paragraph under section E with regards to "northern plume area" and "plume area monitoring well…"
5	III.A./ P.9 (MRP Reports)	Insertion of the ending of the sentence, "…to provide sufficient resolution…"	As explained in Comments #2 and #17 in the Draft CAO, the Prosecution Team believes that "plume" is the correct term, is consistent with prior board orders, and should be left in. The words "may exhibit insufficient resolution" are too vague and unclear to be understandable to the average person. Consider replacing these words with language consistent in last eight CAOs, such as "…to provide better chromium boundary definition..."
6	III.B.1.a./ P.9	Deletion of the	The brown lines added to chromium plume maps

Groundwater Monitoring and Reporting Program, Attachment 8			
Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
	(Map Types)	sentence in the original proposed CAO: "These maps are not to show the approximate limit of saturated alluvium in upper aquifer or flow direction arrows."	to show the approximate limit of saturated alluvium in the upper aquifer are confusing. The intent of the brown line is to suggest that there exists insufficient saturated alluvium for the migration of the chromium plume. However, the same maps show domestic wells in the same areas as the brown line, contradicting that there exists insufficient water supply. The brown line and flow direction arrows are more appropriate for inclusion on poteniometric maps reflecting groundwater characteristics such as elevation data, flow direction, and gradient. Thus, the Prosecution Teams recommends adding these requirements to <u>potentiometric maps only</u> in III.B.1.b, instead of chromium plume maps.
7	III.B.1.a.i./ P.9 (Map Types)	Insertion of the ending of the sentence, "…however, data from domestic wells shall not be used to draw the plume boundary lines."	The added part of the sentence is appropriate where adequate monitoring wells exist to provide chromium data in groundwater. However, in some areas of the north, PG&E has not been able to acquire access to private properties or sensitive species habitat for installing monitoring wells. In those instances, Water Board staff and PG&E agreed to use data from domestic wells. The Prosecution Teams suggest adding to the end of the inserted sentence "<u>except in the northern area where no monitoring well is located within one-half mile of domestic wells.</u>"
8	III.B.2.g./ P.11 (Map Content)	Deletion of criteria for discharger to use for drawing plume boundary lines on maps and insertion of language for discharger to use "best professional judgment."	The Prosecution Team's objections to the removal of criteria for plume mapping and insertion of "best professional judgment" are the same as described in Comments #13, #17, and #21 in the Draft CAO. The Prosecution Team recommends reinstating the original text containing plume mapping criteria to be consistent with prior board orders, such as CAO R6V-2008-0002-A4, Order I.C. in the "Groundwater Monitoring and Reporting Program in Attachment 8.
9	III.B.2.h./ P.11 (Map Content)	Insertion of section that begins, "Identify all areas within one-mile outside of the plume boundary where…"	This added requirement contradicts Finding 19, top of page 6 in the Draft CAO: The Advisory Team uses specific language that "prescriptive plume definition and mapping requirements are no longer needed, as the plume map is not being used to determine who gets replacement

Groundwater Monitoring and Reporting Program, Attachment 8			
Comment #	CAO section/page	Advisory Team Language	Prosecution Team Comment
			water." But, as indicated in this section, plume mapping is required for the discharger to comply with this requirement. Therefore, the Prosecution Team recommends removing Finding 19 in the Draft CAO.
10	III.B.3.d.i./ P.12 (Report Content)	Insertion of the criteria of "4 ppb for Cr(VI)/Cr(T)" for water sample results showing a relative percentage difference of 25% or greater to trigger re-analyzing.	Justification for using 4 ppb as the criteria was not provided in this section or in a finding. Given that the maximum chromium background levels are 3.1 ppb Cr(VI) and 3.2 ppb Cr(T), the Prosecution Teams recommends that these numbers be used as the criteria for triggering re-analyzing of water samples.

Attachment 2

PG&E Chromium Plume Maps Over Time



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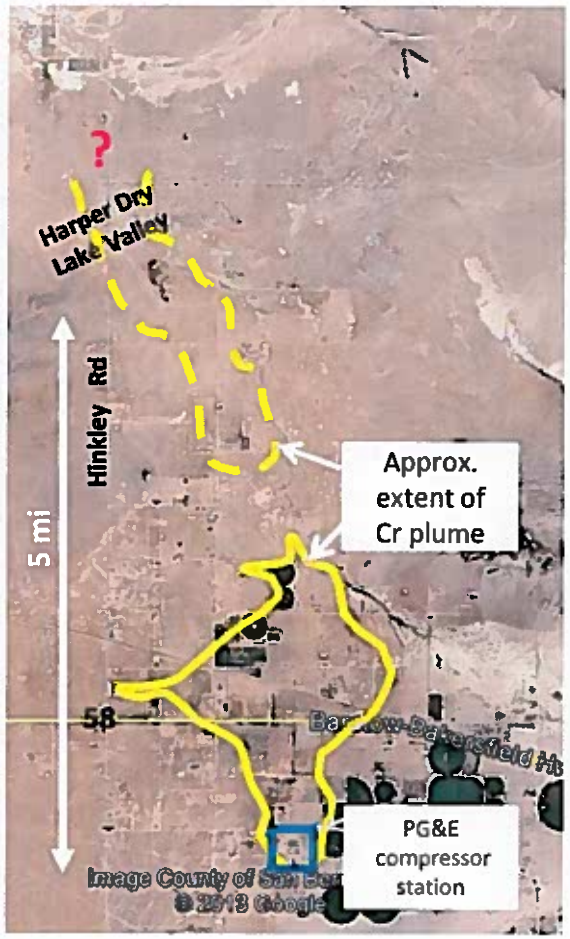

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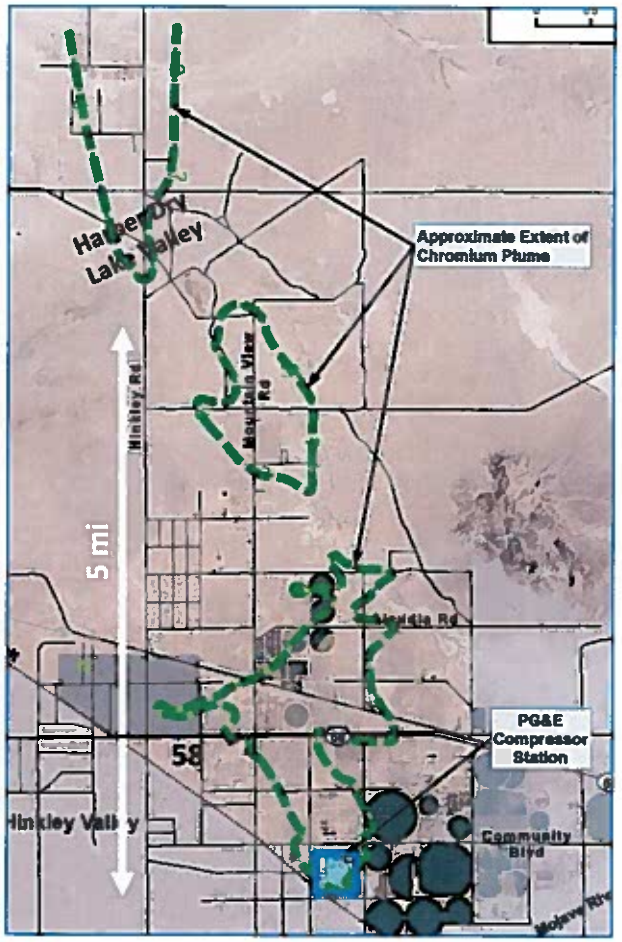

2nd Quarter 2014

Groundwater

Issue Paper/

Exceptionally Long MTBE Plumes of the Past Have Greatly Diminished

by James M. McDade[1], John A. Connor[2], Shawn M. Paquette[2], and Julia M. Small[2]

Abstract

Studies published in the late 1990s and early 2000s identified the presence of exceptionally long methyl tert-butyl ether (MTBE) plumes (more than 600 m or 2000 feet) in groundwater and have been cited in technical literature as characteristic of MTBE plumes. However, the scientific literature is incomplete in regard to the subsequent behavior and fate of these MTBE plumes over the past decade. To address this gap, this issue paper compiles recent groundwater monitoring records for nine exceptional plumes that were identified in prior studies. These nine sites exhibited maximum historical MTBE groundwater plume lengths ranging from 820 m (2700 feet) to 3200 m (10,500 feet) in length, exceeding the lengths of 99% of MTBE plumes, as characterized in multiple surveys at underground storage tank sites across the United States. Groundwater monitoring data compiled in our review demonstrate that these MTBE plumes have decreased in length over the past decade, with five of the nine plumes exhibiting decreases of 75% or more compared to their historical maximum lengths. MTBE concentrations within these plumes have decreased by 93% to 100%, with two of the nine sites showing significant decreases (98% and 99%) such that the regulatory authority has subsequently designated the site as requiring no further action.

Introduction

Methyl tert-butyl ether (MTBE) was used in the United States primarily as an octane enhancer and fuel oxygenate from the late 1970s to 2004, with use continuing until 2006 in some states. When compared to other components of gasoline (i.e., alkanes and aromatics), MTBE has a: (1) higher water solubility; (2) lower sorption coefficient (i.e., lower retardation); and (3) lower Henry's constant (i.e., less volatilization from water). Initial studies in the 1990s posited that MTBE was generally recalcitrant to natural biodegradation (Yeh and Novak 1991; Suflita and Mormile 1993; Hubbard et al. 1994; Mormile et al. 1994; Neilson 1994). As a result of its physical and chemical characteristics, some scientists predicted that releases of MTBE to groundwater would result in MTBE-affected groundwater plumes that were much longer than plumes of the traditional gasoline components, benzene, toluene, ethylbenzene, and xylenes (BTEX) (Fogg et al. 1998; Odencrantz 1998; Weaver et al. 1999; Haas and Trego 2001). The discovery of MTBE plumes that were more than 600 m long (2000 ft) located on Long Island, New York (five sites) and Southern California (one site) (Weaver et al. 1996, 1999; Salanitro et al. 2000; Haas and Trego 2001; Thuma et al. 2001) appeared to support these expectations.

More recent papers continue to cite these exceptional plumes as representative of the dimensions and persistence of typical MTBE plumes over time (Kane et al. 2001; Douthit 2003; Linnemann 2003; Arey and Gschwend 2005; Myrttinen et al. 2009). However, the fate of these nine exceptional plumes over time has never been investigated, and there has been no update in the literature regarding the current plume status. Prior to initiating this investigation, we hypothesized that these exceptional MTBE plumes could have reduced significantly in size

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and concentration over the ensuing decade, consistent with findings of more recent investigations showing that MTBE and its microbial breakdown product, tert-butyl alcohol (TBA), stabilize and diminish at rates comparable to benzene plumes (Stevens et al. 2006; Tarr and Galonski 2007; Kamath et al. 2012; McHugh et al. 2014). The goal of this issue paper has been to provide an update to the current MTBE plume status (i.e., dimensions, plume length, and maximum concentrations) and advance the understanding of the behavior of MTBE plumes based on over a decade of water quality data.

For the purpose of this evaluation, MTBE plumes of 600 m (2000 ft) or more in length have been characterized as "exceptional" with respect to the common lengths of BTEX and/or MTBE plumes reported in a number of studies (Happel et al. 1998; Mace and Choi 1998; Reid et al. 1999; Reisinger et al. 2000; Shorr and Rifai 2002; Rifai et al. 2003; Wilson 2003; Shih et al. 2004; Kamath et al. 2012, Connor et al. 2014). Based on these prior studies, the 90th percentile MTBE plume length is approximately 120 m (400 ft) and the 99th percentile length is approximately 430 m (1400 ft). Consequently, MTBE plumes greater than 600 m (2000 ft) in length represent much less than 1% of plumes.

In total, nine sites have been identified for the purpose of this investigation, including seven underground storage tank (UST) sites, one refinery facility, and one bulk terminal facility (Table 1). Of the nine sites, six were identified in the literature listed above for the Long Island, New York and Southern California sites. We recognize that these nine sites do not represent a comprehensive list of all exceptionally long MTBE plumes; however, these sites are often cited as evidence of MTBE plume dimensions, and this issue paper aims to provide an update to the current conditions of these exceptional plumes.

Methodology

Each of the nine sites evaluated in this study had been delineated in three dimensions (length, width, and depth), thereby confirming that diving or detached plumes had not escaped the monitoring well network (API 2006). The monitoring records at these sites provide from 5 to 19 years of groundwater data, with the total number of monitoring wells at each site ranging from 79 to 445 (includes multilevel sampling wells). At each of the nine sites, the analytical groundwater sampling program included analysis of BTEX and MTBE, with TBA and other fuel oxygenates (i.e., ethanol, tert-amyl methyl ether [TAME], etc.) analyzed at six of the nine sites. Monitoring data were obtained through literature searches, Freedom of Information Act (FOIA) requests from regulatory agency files, and/or contact with regulatory project managers. For each site, we reviewed the available information to extract the following key facts: (1) historical and recent plume lengths and dimensions, (2) groundwater concentrations over time, (3) hydrogeologic and geochemical parameters, (4) the number and volume of gasoline releases, (5) the number

Table 1
Summary Information of Nine Exceptional MTBE Plumes

No.	MTBE Plume Location	Type of Facility	Volume of Release (L)	Groundwater Seepage Velocity (m/year)	Maximum Past MTBE Plume Length (m)	Most Recent MTBE Plume Length (m)	Years Between Observed Maximum and Most Recent Plume Length (Dates)	Percent Reduction in Plume Length over Time
1	Deer Park, New York	Service station	75,700	150	3200	2780	9 (2001 to 2010)	13%
2	East Patchogue, New York	Service station	50,300–55,300	175	1270	530	4 (2003 to 2007)	58%
3	Hampton Bays, New York	Service station	17,000	50–75	820	150	8 (2003 to 2011)	81%
4	Lindenhurst, New York	Service station	Not reported	200	1370	75	11 (1999 to 2010)	94%
5	Riverhead, New York	Service station	Not reported	125	1190	0	8 (1997 to 2005)	>99.9%
6	Uniondale, New York	Service station	28,000	150–180	1860	1740	6 (2003 to 2009)	7%
7	Port Hueneme, California	Service station	40,900	35–110	1460	560	10 (2002 to 2012)	61%
8	San Diego, California	Terminal/pipeline	1,136,000	Shallow: 170	2260	310	9 (2003 to 2012)	86%
9	Rhineland, Germany	Refinery	Not reported	Shallow: 1100	1220	290	3 (2006 to 2009)	76%

and location of additional sources, and (6) remediation activities for both the source zone and the downgradient plume areas. The Supporting Information provided with this paper includes a list of site-specific references that were used to determine plume lengths, concentrations vs. time, hydrogeology, remediation activities, etc. The Supporting Information also includes more detailed site-specific information documenting conditions for the nine sites in this study.

Groundwater plume lengths were defined based upon the applicable regulatory criteria at each location. Therefore, MTBE plumes for sites in New York and California were contoured to the state-specific regulatory criteria for MTBE in groundwater of 10 µg/L and 5 µg/L, respectively (CADHS 1998; NYSDEC 2008). Regulatory criteria were not specified for the Rhineland, Germany site; consequently, plume dimensions were estimated based upon a 10 µg/L concentration limit for MTBE. Plume lengths were defined as the cumulative length of affected groundwater exceeding this concentration limit (i.e., from the furthest upgradient exceedance point to the furthest downgradient exceedance point). This measurement is distinct from the commonly used "extent of the plume" (i.e., the distance of the plume from the source). In addition, the plume lengths presented in this paper include the source zone of light nonaqueous liquid (LNAPL), if present.

The cumulative plume length also accounts for detached plumes with several "pockets" of affected groundwater above the regulatory limits. Detached plumes of this nature were observed at six of the nine sites, but in no case had the detached plumes migrated beyond the extent of the monitoring well network. The percent reductions in MTBE concentrations over time were calculated by comparing the historical maximum concentration to the most recent maximum concentration observed at the site from the total monitoring well population.

Description and History of Nine Exceptional MTBE Plumes

Summary information regarding the site location, release volume, groundwater velocity, and historical and recent MTBE plume lengths are provided in Table 1 (see Tables S1 through S4 for additional details on site conditions, including aquifer geologic characteristics).

Site Remediation Activities

At each of the nine sites, some form of remediation activity has been conducted with the goal of reducing the source mass and/or addressing the downgradient portion of the plume (see Table S3 for remediation activities). In this issue paper, we do not attempt to separate the effects of natural attenuation processes vs. active remediation with regard to their effects on the plume dimensions and concentrations. Rather, we have evaluated each plume to determine the degree to which the plume has persisted or diminished under the combined effect of these processes.

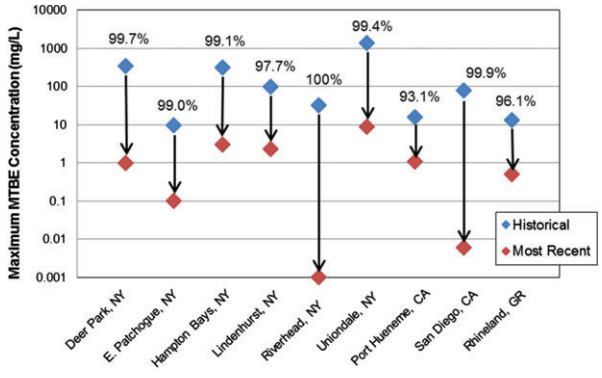

Figure 1. Percent reduction in MTBE maximum concentrations over time.

Results

Reduction in MTBE Plume Concentrations over Time

For all nine sites, the maximum site MTBE concentrations over time decreased by over 90%, with six of the nine sites exceeding 99% reduction (see Figure 1), representing a two order of magnitude decrease in the maximum MTBE concentration (see Table S4 for detailed concentration data). The minimum percent reduction in the maximum MTBE concentration over time was 93.1% (Port Hueneme, California site), which represents an approximate one order of magnitude decrease in the maximum MTBE concentration. Plume concentrations have been evaluated by comparing the historical maximum MTBE concentration among all monitoring wells to the most recent MTBE maximum concentration among all monitoring wells at each site. This method provides a lower-end estimate of the concentration change over time, and is not affected by the possible displacement of the plume center of mass.

Reduction in MTBE Plume Lengths and Source Zone Concentrations over Time

As shown in Table 1 and Figure 2(a) through 2(g), five of the nine MTBE plumes have reduced in length by over 75% from their past reported maximum lengths, and seven of nine plumes have reduced by over 50%. The median length reduction for the nine MTBE plumes is 76%. Two plumes evidence reductions in length of less than 15% (Deer Park and Uniondale, New York), however, as shown on isopleth contours created for the plumes on Figure 3(a) and 3(b), significant mass reductions were nevertheless observed at these sites.

Evaluation of Associated BTEX and TBA Plumes

In general, the observed historical maximum BTEX plumes at these sites were shorter than the historical maximum MTBE plumes; however, BTEX plumes greater than 275 m (900 ft) in length were observed at seven of the nine sites (see Table 2). BTEX plume lengths at the eight sites with data have generally decreased over time, similar to the MTBE plumes.

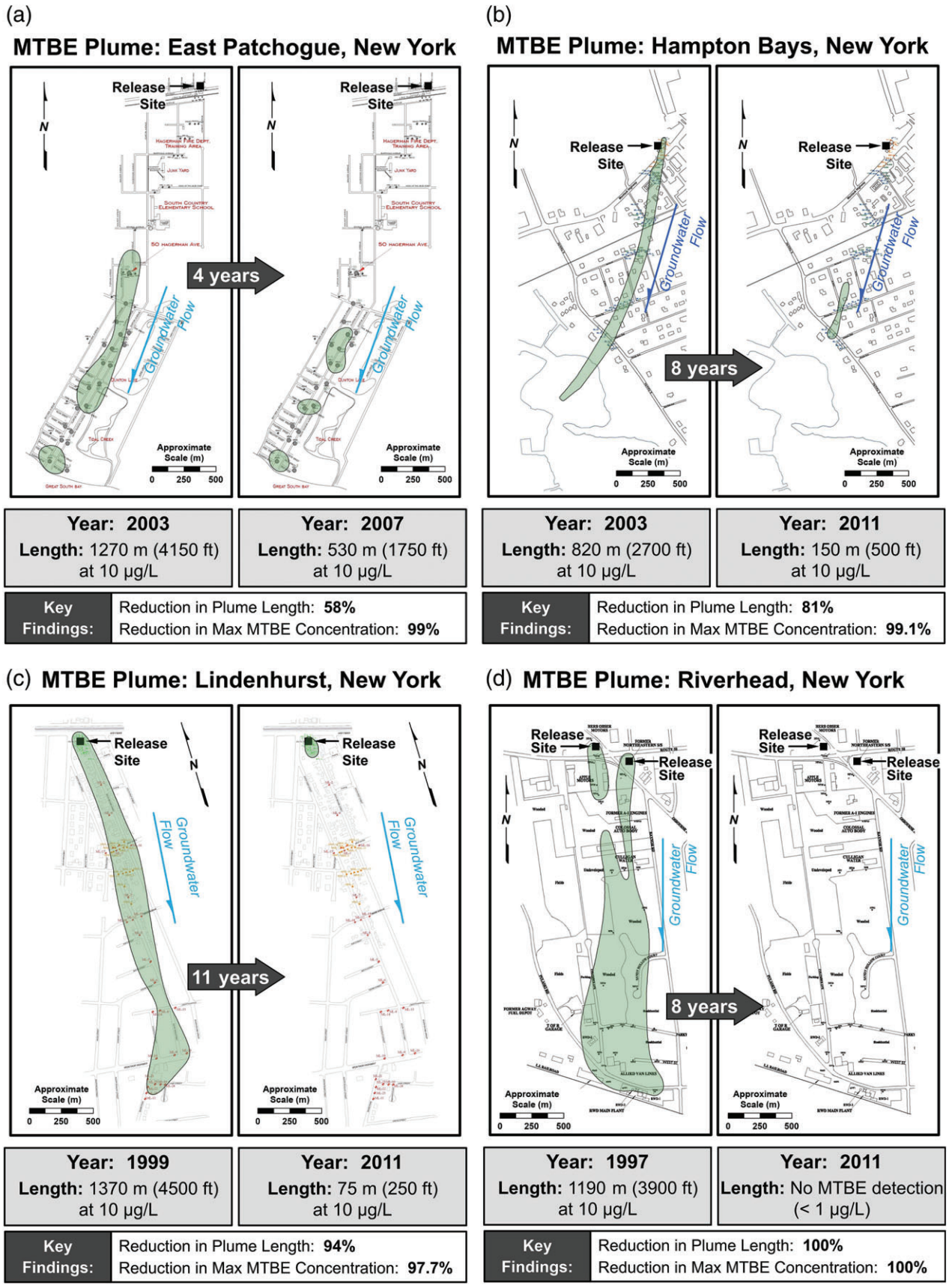

Figure 2. Comparison of maximum plume length vs. most recent plume length (a through g).

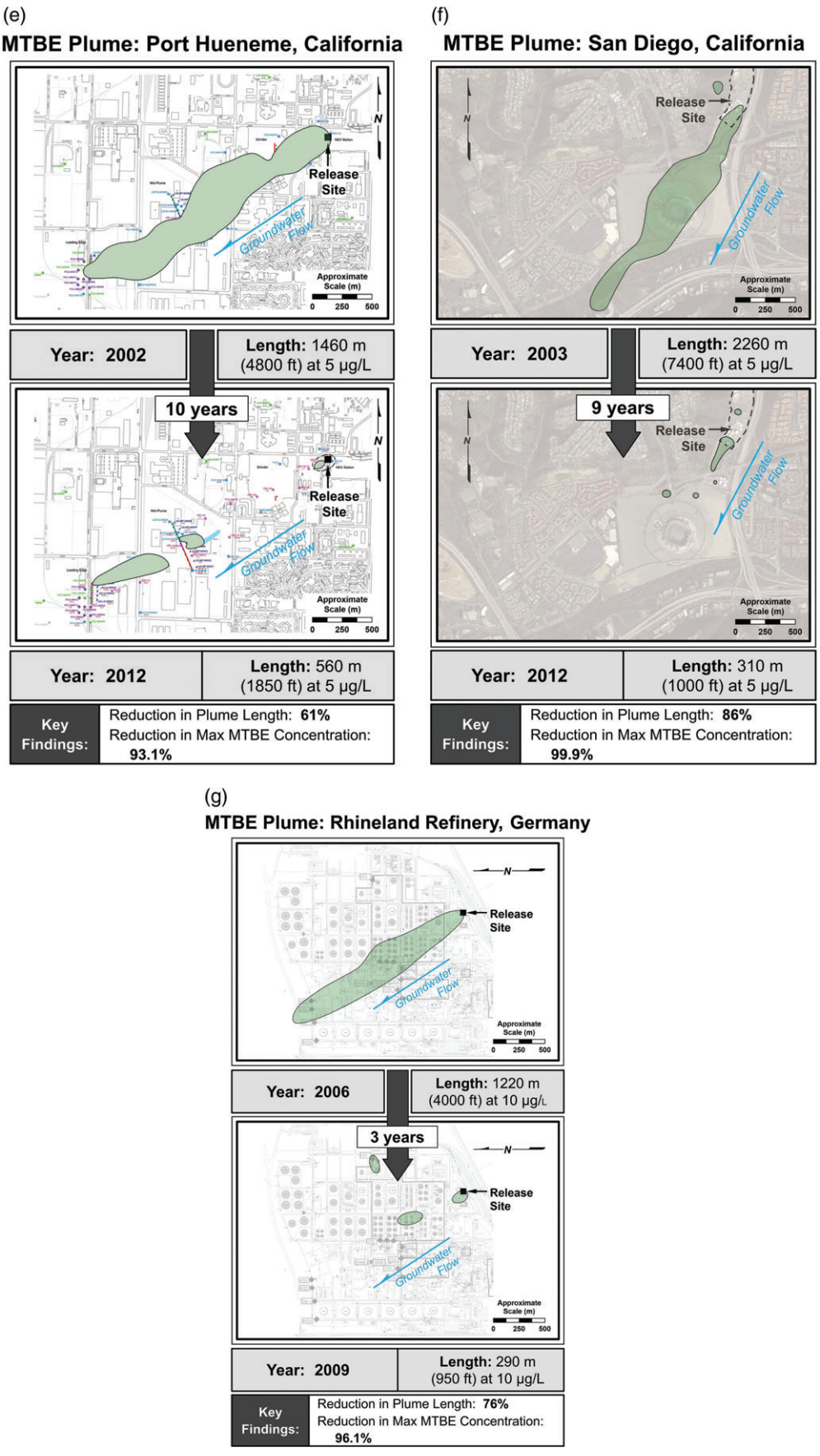

Figure 2. Continued

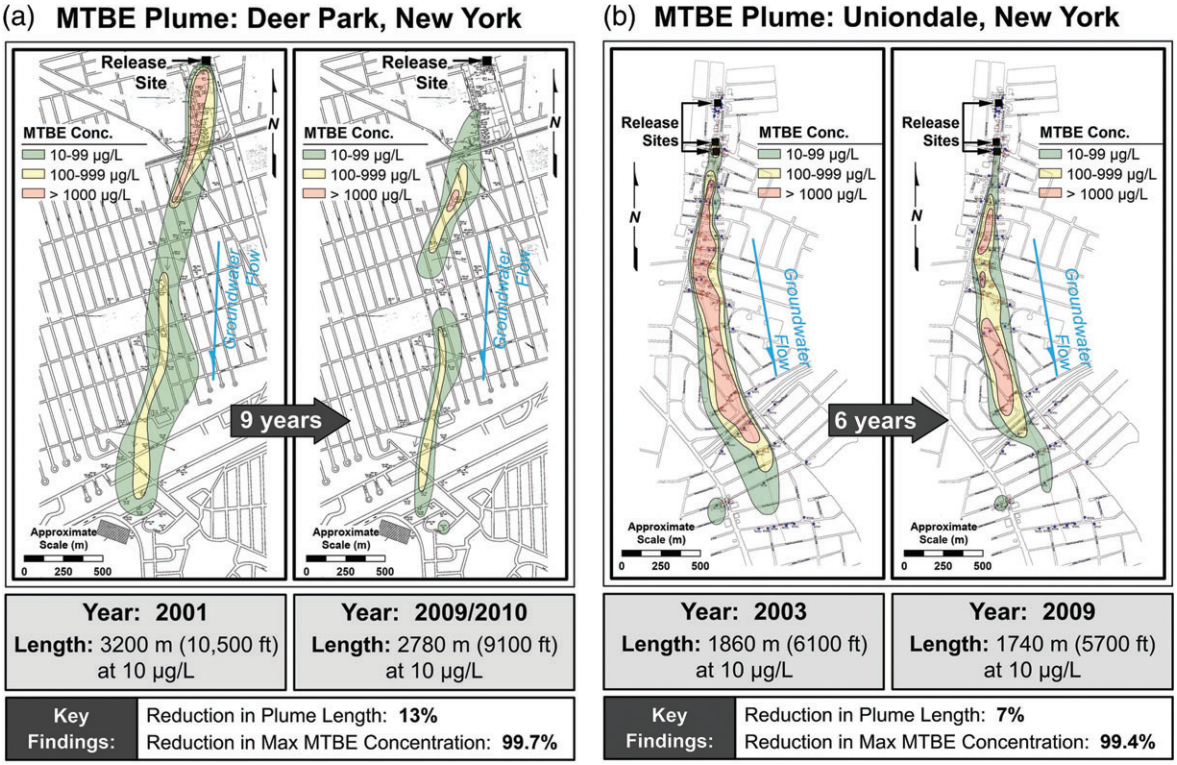

Figure 3. Comparison of maximum plume length vs. most recent plume length with MTBE iso-contours (a and b).

At the three sites where TBA monitoring was routinely conducted (Hampton Bays, New York; Port Hueneme, California; and San Diego, California), the observed maximum TBA plume lengths were approximately the same length or shorter than the MTBE plumes (see Figure 4(a) through 4(c)). As shown in Table 2, TBA groundwater plume lengths ranged from 820 to 1740 m (2700 to 5700 feet) corresponding to 77% to 100% of the maximum length of the corresponding MTBE plume. In general, the plume lengths for the MTBE and TBA plumes at the Hampton Bays, New York site, were of the same length historically, with both plumes decreasing in length at approximately the same rate (see site-specific references in Supporting Information). This is likely due to the fact that the plumes have the same end point with discharge of the plumes into Tiana Bay initially, and subsequently, the downgradient groundwater extraction system located hydraulically upgradient of Tiana Bay (see Figure 4(a)). Maximum TBA plume lengths for the Port Hueneme and San Diego, California sites, were shorter than the corresponding MTBE plume lengths (see Table 3). TBA plumes at the Port Hueneme and San Diego, California sites are likely shorter in length than the corresponding MTBE plumes because of remediation systems located downgradient of the source (i.e., biobarriers and groundwater extraction, respectively) that have effectively limited the length of both MTBE and TBA plumes. More recent reports for both sites indicate that plume lengths and mass flux of TBA are decreasing (see site-specific reference in Supporting Information). For the San Diego, California site, it was estimated that the mass of dissolved TBA had been reduced 94% from 2005 to 2012 (56 to 5.9 kg; see site-specific references in Supporting Information).

Common Factors Contributing to Exceptional MTBE Plumes

Compared to the general population of MTBE plume sites, these nine exceptional MTBE plume sites share the following characteristics:

1 Larger volume gasoline releases: As shown in Table 1, the reported release volumes for the nine sites investigated in this study range from 17,000 to 1,136,000 L (4500 to 300,000 gallons). Excluding the release of 1,136,000 L (300,000 gallons), which was associated with historical releases from aboveground storage tanks and pipelines on a bulk terminal facility, the median release volume is approximately 41,000 L (10,800 gallons). According to a USEPA study, the average reported gasoline release from USTs in the United States is 2300 to 2650 L (600 to 700 gallons) (USEPA 1987). Consequently, the reported release volumes for exceptional MTBE plume sites with UST releases are over 6 to 29 times greater than the average UST release in the United States.
2 Higher groundwater velocity: At all nine sites, the underlying affected aquifer consisted of either sand or gravel, with eight of the nine sites consisting of highly permeable coarse sand/ gravel deposits. Groundwater seepage velocities uniformly exceeded 60 m/year (200 ft/year), and seven of nine sites exhibited seepage

Table 2
Maximum Reported MTBE, BTEX, and TBA Plume Lengths

No.	MTBE Plume Location	Maximum MTBE Plume Length (m)	Maximum BTEX Plume Length (m)	Maximum TBA Plume Length (m)
1	Deer Park, New York	3200	370	IDE
2	East Patchogue, New York[1]	1270	1590	[2]
3	Hampton Bays, New York[1]	820	610	820
4	Lindenhurst, New York	1370	490	IDE
5	Riverhead, New York[1]	1190	270	[2]
6	Uniondale, New York	1860	400	[2]
7	Port Hueneme, California	1460	50	1430
8	San Diego, California	2260	810	1740
9	Rhineland, Germany	1220	Not reported	IDE

IDE = insufficient data to estimate plume length.
[1]Maximum MTBE length terminated at a discharge point (i.e., surface water body or water supply well).
[2]Constituent not reported.

velocities above 120 m/year (400 ft/year) (Table 1). These velocities fall within the upper quartile of seepage velocities as determined in prior surveys of remediation sites in the United States (Newell et al. 1990).

3 Multiple releases or release sites: At four of the nine sites, multiple releases are reported to have occurred at the same site (Deer Park, Riverhead, and Uniondale, New York, and San Diego, California), or multiple plumes from two or more separate sites have merged to create one commingled plume (Riverhead and Uniondale, New York).

4 Groundwater redox condition: The results for the nine sites suggest that the groundwater reduction/oxidation conditions affect the change in plume length over time. Three of the eight sites for which geochemical data were reported (Deer Park, New York; Port Hueneme, California; and San Diego, California) exhibited anoxic groundwater conditions (i.e., dissolved oxygen <1 mg/L). Among these three sites, only the Deer Park site exhibited a decrease in the plume length (13%) over time that was significantly less than that observed at higher-oxygen sites. In addition, all three sites show concentration reductions comparable to the other six sites. These data suggest that anoxic conditions alone are not a reliable predictor of plume behavior, considering the effects of both remediation and natural attenuation.

Conclusions

The updated information for these nine exceptional MTBE plumes indicates that there has been a substantial reduction in concentrations and, in most cases, of plume length over the past decade. Monitoring data show that this plume reduction was not a result of the plume detaching or otherwise moving beyond the monitoring well network. Rather, the plumes were observed to diminish as a function of source or downgradient remediation and natural attenuation factors. As such, our review does not address the full population of exceptional MTBE plumes. Nevertheless, this update to the prior studies should prove useful to other researchers interested in the long-term behavior of MTBE, benzene, and TBA associated with petroleum releases.

Overall Reduction of Exceptional MTBE Plumes

Seven of the nine plumes have decreased in length by over 50% since the time of their past maximum observed lengths, with five of the nine plumes, exhibiting an MTBE plume length reduction of 75% or greater. Additionally, all nine sites exhibited at least a one order of magnitude (i.e., 90%) reduction in the maximum MTBE concentration observed at the site over time, with six of the nine sites exhibiting a reduction in maximum MTBE plume concentrations of two orders of magnitude (more than 99%).

Two sites, Deer Park and Uniondale, New York, exhibited a smaller reduction in MTBE plume length than the other seven sites (13% and 7%, respectively). Limited plume reduction for the Uniondale, New York site may be the result of a comingled MTBE plume with at least four potential sources and multiple releases over time. In addition, at the Deer Park, New York site, sulfate reducing and methanogenic conditions in the groundwater aquifer might be contributing to the limited MTBE plume reduction over time, as attenuation rates might be slower under these reduction-oxidation conditions compared to sites that are more aerobic. Nevertheless, significant reductions in MTBE concentrations and mass were observed at both of these sites, with 99.7% and 99.4% reductions in maximum MTBE concentrations over time, respectively.

Effects of Remediation vs. Natural Attenuation

Insufficient information is available for most of these nine sites to assess the relative effects of remediation vs. natural attenuation on the MTBE plumes. However, at the three sites where TBA concentrations were measured in groundwater, the data show that biodegradation of MTBE to TBA is an important factor in MTBE plume attenuation.

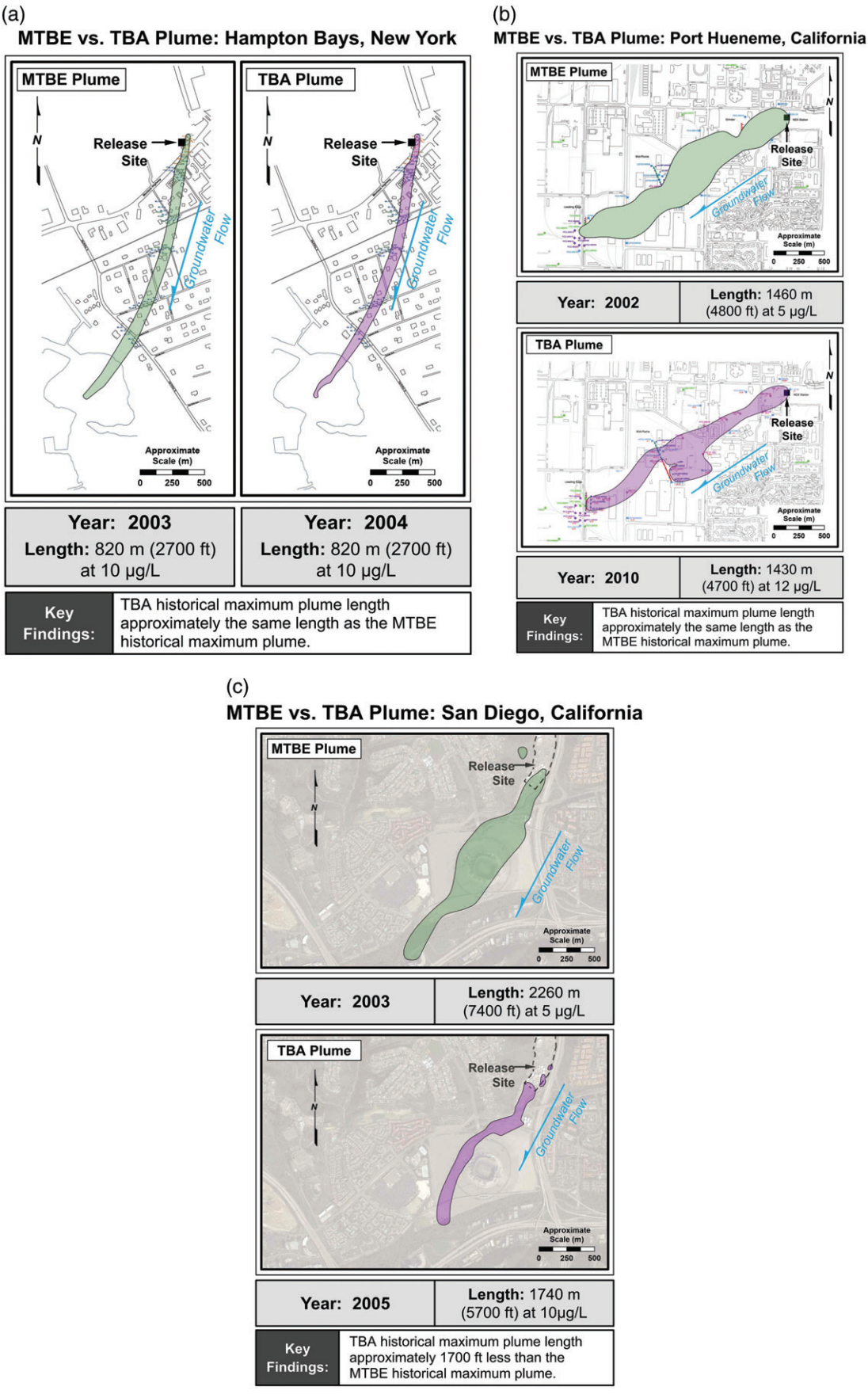

Figure 4. Comparison of maximum MTBE plume length vs. maximum TBA plume length (a through c).

Table 3
Summary of MTBE and TBA Plume Information for Sites with Sufficient Data

Plume Location	Maximum MTBE Plume Length (m)	Year Maximum MTBE Plume Observed	Maximum TBA Plume Length (m)	Year Maximum TBA Plume Observed	Maximum MTBE Conc. Observed (mg/L)	Maximum TBA Conc. Observed (mg/L)
Hampton Bays, New York	820	2003	820	2004	320	84
Port Hueneme, California	1460	2002	1430	2010	16	7.7
San Diego, California	2260	2003	1740	2005	78	49

The conversion of MTBE to TBA is further evidenced by the TBA plume lengths being of similar or shorter length to the MTBE plumes. In addition, observed TBA concentrations are generally consistent with concentrations that would be expected from biodegradation. Detailed studies of natural attenuation of MTBE and TBA have been conducted at the Port Hueneme and San Diego, California sites (see site-specific references in the Supporting Information), and studies at both sites conclude that biodegradation of MTBE to TBA is contributing to the attenuation of the MTBE plumes. For example, site-specific information for the San Diego, California site, indicates that approximately 44% (102 kg) of the total estimated MTBE mass (231 kg) within the plume has been removed by natural attenuation from the period of 2002 to 2012 (see site-specific references in the Supporting Information).

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Site-specific references and reports.
Table S1. Summary Information on Release Conditions for Nine Exceptional MTBE Plumes
Table S2. Hydrogeologic Characteristics Reported for Nine Exceptional MTBE Plumes
Table S3. Remediation Activities for the Source Zone and Downgradient Plume
Table S4. Reduction in Maximum MTBE Concentration over Time

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Project Proposal Summary

Occurrence of natural and anthropogenic Cr VI in groundwater near a mapped plume, Hinkley, CA

By: John A. Izbicki

Problem: The Pacific Gas and Electric Company (PG&E) Hinkley Compressor Station, 3 miles southeast of Hinkley, CA and 80 miles northeast of Los Angeles, is used to compress natural gas as the gas is transported through pipelines from Texas to California. Between 1952 and 1964, cooling water was treated with a compound containing chromium to prevent corrosion within the compressor station. This water was discharged to unlined ponds, resulting in contamination of soil and groundwater within the underlying alluvial aquifer. In 2007, a study intended to characterize naturally-occurring background concentrations estimated average Cr VI concentrations in the area of 1.2 micrograms per liter (µg/L). The normal 95 percent upper tolerance limit of 3.1 µg/L from the 2007 background study was adopted as the cleanup level for remediation at the site. The Regional Water Quality Control Board subsequently agreed to revisit the 2007 background study in response to criticism of the study's methodology and the increase in mapped extent of the plume between 2008 and 2011.

Objectives: The purpose of this study is to evaluate the occurrence of natural and anthropogenic Cr VI, and estimate naturally-occurring background Cr VI concentrations upgradient, near the plume margins, and downgradient from a mapped Cr VI contamination plume near Hinkley, CA.

Approach: The cooperator for this study is the Lahontan Regional Water Quality Control Board. The scope of the study was developed by the U.S. Geological Survey in collaboration with the Technical Working Group (TWG) composed of local stakeholders (the Hinkley Community Advisory Committee, CAC), community advisors (Project Navigator, Inc.), State regulatory agencies (Lahontan Regional Water Quality Control Board), and Pacific Gas and Electric and their consultants. The scope of the study includes the following tasks: 1) evaluation of existing data; 2) sample collection and analyses of rock and alluvium; 3) sample collection and analysis for water chemistry and multiple tracers, 4) evaluation of geologic, hydrologic, and geochemical conditions in western, northern, and eastern subareas within the study area; 5) evaluation of historic and present-day groundwater movement, 6) evaluation of the occurrence of natural and anthropogenic chromium; 7) determination of background Cr VI concentrations; and 8) assessment of the fate of chromium following in-situ reduction. The study will begin in Federal Fiscal Year 2014 and end in 2018. An initial fact-sheet style report describing the study approach, an interim report describing selected preliminary results, and a final report will be produced.

Relevance and Benefits: This proposal will contribute to the U.S. Geological Survey's ability to "ensure adequate quantity and quality of water to meet human and ecological needs in the face of growing competition among domestic, industrial-commercial, agricultural, and environmental uses" as described in the U.S. Geological Survey Science Strategy (U.S. Geological Survey, 2007; Evenson and others, 2013). The proposal is within the U.S. Geological Survey Water Resources Mission Areas to "define and better protect the quality of the Nation's water resources."

there is a narrow gap separating Hinkley and Water valleys. The Mount General Fault passes through this gap and volcanic rocks are exposed within the gap (fig. 2).

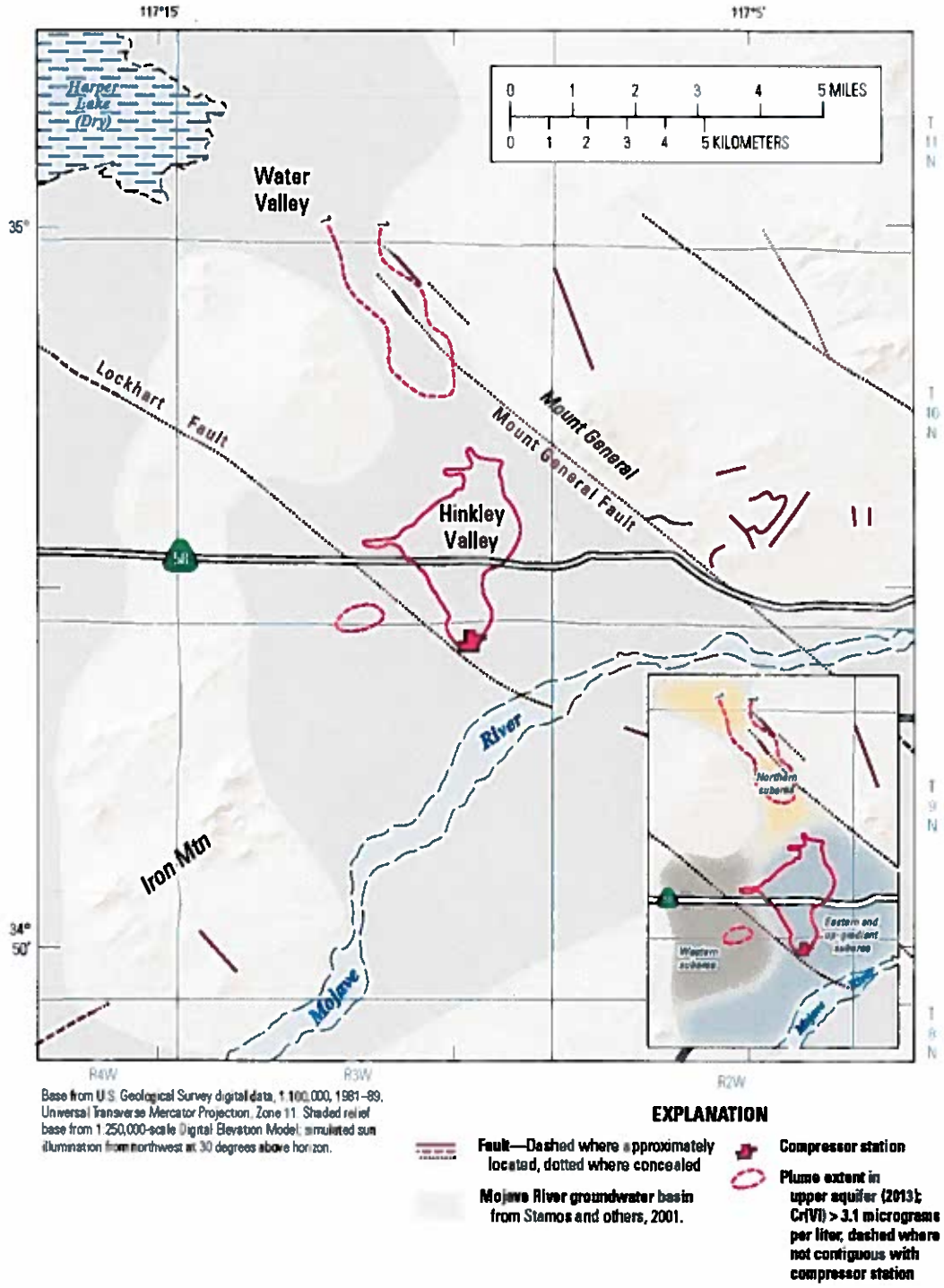

Figure 2.—Study area location.

Alluvial deposits within the valley consist of alluvial-fan deposits eroded from highlands along the valley margins, and alluvium from the Mojave River eroded largely from granitic rock in the San Bernardino Mountains 40 miles to the south. Alluvium within the valley is divided into an upper and lower aquifer

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January 7, 2014

Ms. Anne Holden, PG
Ms. Lisa Dernbach, PG, CHG, CEG
Ms. Lauri Kemper, PE
California Regional Water Quality Control Board, Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe, California 96150

RE: 1. IRP Manager & Community Advisory Committee (CAC) Support and Endorsement of Scope, and
2. USGS's "Actionable Information" Advisory Role to the Background Study's (BGS) Technical Working Group (TWG)[1]: Submission of a BGS "Actionable Information" Decision Tree.

Dear Anne, Lisa and Lauri:

The submission of this BGS-process letter of endorsement, regarding BGS information decision-making, is timely, given that the scope and objectives of USGS's BGS will be presented to the Lahontan Water Board at their meeting in Barstow on January 8, 2013.

BGS stakeholders worked diligently in 2013 to assist USGS's Dr. John Izbicki shape the proposed study's scope of work. A key element of recent discussions has been; "who analyzes and evaluates the incoming information and data, and who has the responsibility for evaluating the quality of such information to make recommendations on possible "project actions? ".

The Technical Working Group (TWG) has extensively discussed these topics, and in both cases, it is the IRP Manager's current opinion that all stakeholders have agreed that within the scope of the BGS proposal, *Dr. Izbicki will be the "decision-maker regarding what information is deemed actionable."* His recommendations regarding such information will then be brought to the TWG for further evaluation.

Equally importantly, this letter introduces a simple BGS decision tree (DT), which the IRP Manager believes the CAC, PG&E, and USGS fully support. This support

[1] The TWG consists of the Water Board (WB), USGS, Pacific Gas and Electric (PG&E) and their consultants Stantec and CH2M Hill, the Community Advisory Committee (CAC) and the IRP Manger.

has been vetted and further verified with these parties since the TWG met in Hinkley in November, 2013.

Key USGS Proposal Discussion Topics at November 21, 2013 TWG Meeting:

Final TWG agreement on the USGS BGS Proposal was reached on November 21, 2013 at a TWG meeting[2] held at the IRP Manager's office. The objective of the meeting was for the TWG to discuss their *final*[3] review of USGS's BGS Proposal, dated September 19, 2013.

In particular, the TWG reviewed and discussed, the aerial extent of the proposed BGS measurements, the path forward on the locations of groundwater sampling for Cr6 measurements, the proposed Cr3 to Cr6 reconversion task (Task 8 of the USGS proposal), the programmatic "adaptive management"[4] style which USGS plans to employ during the conduct of the work, data management, and the recommendations and decision-making process. (On the basis of these key discussions, Dr. Izbicki is also revisiting his projected budgets for each Task).

The objective of this letter is to highlight and report to the Water Board on two important BGS issues and agreements that were reached in the November 21 meeting, and which have subsequently been further verified in separate meetings or discussions the IRP Manager has held separately with the CAC, USGS and PG&E.

The IRP Manager considers these two items to be of such importance, that they are now being submitted in writing to the Water Board:

1. Agreement was reached that Task 8, (Fate of Chromium During *In Situ* Reduction), *will be performed as described* in USGS's draft SOW. There was also recognition and agreement between the TWG members that:
    a) Work on this topic has occurred previously specific to the Hinkley groundwater remediation project[5], and,
    b) The work now planned to be performed by USGS will satisfy the "project stakeholders" as the *last and final* project-specific investigation of Cr3 possible reconversion to Cr6 in the Hinkley Valley groundwaters.

---

[2] The TWG meeting was attended by PG&E, USGS, Water Board, IRP Manager, four CAC Members (Lester White, Daron Banks, Betty Hernandez and Omar Nassar) and the CAC Facilitator (Mindy Meyers).

[3] The planned USGS proposal was discussed at at least six TWG meetings in 2013, held either at USGS in San Diego, or at the IRP Manager's office in Hinkley, CA.

[4] "Adaptive Management" means that the scope and direction of the BGS will be suitably modified when new information is derived via the BGS.

[5] Cr reconversion information discussed in ICF International. *Final Environmental Impact Report: Comprehensive Groundwater Strategy for Historical Chromium Discharges from PG&E's Compressor Station, San Bernardino County.* May 2013. Appendix A.3 pages A.3-1 to A.3-13.

2. The stakeholders' roles in both BGS and global project decision-making were better defined in the meeting. Dr. John Izbicki of USGS will assume the key role in evaluating the importance and quality of information and data being delivered from the BGS for BGS-specific decision making. At a prior November 7, 2013 meeting of the TWG, Dr. Izbicki suggested that, (quote), "solid results can be actionable." This statement was explored further at the November 21, 2013 meeting. Since then, the IRP Manager has condensed the implications of information derived during the conduct of the BGS on the future direction of the BGS, and/or PG&E's activities in general, into a simple **decision-tree (DT)**, which is attached as **Figure 1**. This DT has been reviewed, commented on, and modified via several iterations with USGS, CAC, and PG&E, such that the IRP Manager believes it represents a consensual opinion of how actionable information emanating from the BGS will be generally managed.

Given the collaborative spirit of the BGS planning process to date, and the fact that TWG meetings are immediately pending[6], the IRP Manager considers it prudent and timely to deliver the draft DT to the Water Board for further review and comment.

Should you have any questions or comments, please feel free to contact either of the undersigned at rsanchez@projectnavigator.com or iwebster@projectnavigator.com (714-388-1800 (PNL main number) or 714-388-1821 (RS) or 714-863-0483 (IAW mobile)).

Sincerely yours,

Raudel Sanchez, Ph.D.
Project Manager

Ian A. Webster, Sc.D.
IRP Manager

Attachments

Figure 1: USGS's Cr6 background Study, 2013-2017: "Actionable Information" Decision Tree.

CC:
CAC Members
Patty Kouyoumdjian, Executive Officer, Lahontan Regional Water Quality Control Board
Kevin Sullivan, PG&E
Devin Hassett, Keadjian and Associates
Dr. John Izbicki, USGS
Mindy Meyer, Facilitator, Center for Collaborative Policy

[6] A BGS TWG meeting is planned for January 9, 2014 at the IRP Manager's Office.

FIGURE

HINKLEY Cr6 GROUNDWATER REMEDIATION PROJECT

6th DRAFT

USGS's Cr6 Background Study, 2014-2017

*"Actionable Information" Decision Tree**

USGS Chromium-6 (Cr6) Background Study

- 4 year program
- USGS contracted to Lahontan RWQCB *(Contact: Ann Holden)*
- Budget forecast: TBD
- 8 Main tasks
- Collection and interpretation of data new to Hinkley inciuding:
  - Trend analysis of existing data
  - Sequential extractions from cores and cuttings
  - Tracers of source(s) and hydrologic history of water ($\delta^{18}O$, δD and dissolved gases)
  - Tracers of the age of water (^{3}H, ^{3}He, CFCs, ^{14}C and $^{87/86}Sr$)
  - Tracers of the source(s) of Cr ($\delta^{53}Cr$)
  - Evaluation of local geologic, hydrologic and geochemical conditions
  - Flow modeling (MODFLOW)
  - Fate of Cr6 after *in-situ* reduction

USGS Analysis and Interpretation of Data

- Task specific WPs
- Development of Site Conceptual Model (SCM) from SOW
- Independent data interpretation
- Data Confidence/Quality Assessment

Dr. John Izbicki Defines and Ranks "Actionable Information"†

Range of actions inciude:

- Modifications to direction of BGS (i.e. adaptive management)
- Information which could result in Water Board decision making

Information is Discussed within BGS Technical Working Group (TWG)

- Affects direction of BGS, and/or
- Information could result in Water Board actions

Actions Required?

YES → Conclusions Cause SOW Modifications

NO → No Further Action

- USGS, PG&E, Water Board, CAC Members and IRP Manager met on November 21, 2013 in Hinkley, CA in the presence of Mindy Meyer (facilitator) to discuss the scope of the BGS, and specifically "Actionable Information."

† "Actionable Information" decisions must be based on a limited basis so as not to impede the flow of the BGS. "Actionable Information" may also be reported in the form of USGS short update reports.

- Other technical and programmatic agreements at the November 21, 2013 BGS TWG included (and will be codified separately):
  - The BGS study will employ an "adaptive management philosophy," consistent with above decision-tree.
  - Actionable decisions will be "limited" and occur on reporting timescales of "years."
  - USGS will bring its findings first to the TWG for technical review.
  - BGS Task 8, (investigating Cr3 reconversion), will remain in the BGS scope.
    - There was agreement amongst the Parties that Task 8 will be the "definitive and final word" on the science of Cr3 reconversion (as it applies to the Hinkley project).
    - If Task 8 does show that reconversion could occur, this fact, by itself, does not preclude the use of *in-situ* reductive technologies for Cr6 treatment at Hinkley.
    - Task 8 will also be performed independently of the planned permitting process for expanding/modifying the IRZ(s).

Project Navigator, Ltd.

6th DRAFT

Background Study Decision-Making: Footnotes from Decision Tree

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