



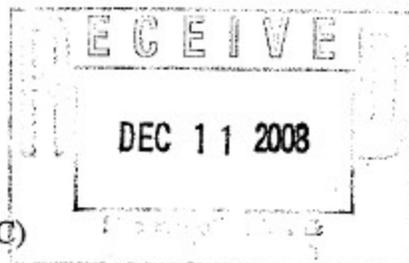
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DuPont Titanium Technologies
Edge Moor Plant
104 Hay Road
Edge Moor, DE 19809

Via Hand Delivery

December 11, 2008

Mr. Wilmer Reyes
Project Manager
Site Investigation and Restoration Branch
Waste Management Section, Division of Air and Waste Management,
Department of Natural Resources and Environmental Control (DNREC)
381 Lukens Drive
New Castle, Delaware 19720-2774



**Response to DNREC Comments on the
Draft Remedial Investigation/Risk Assessment (RI/RA) Report Addendum
Hay Road Sludge Drying Site (DE-0024)
Wilmington, Delaware**

Dear Mr. Reyes:

This letter provides a point-by-point response to comments received by DuPont in final version by email of a pdf file from DNREC on December 4, 2008 concerning the September 12, 2008 draft version of the RI/RA Report Addendum for the Hay Road Sludge Drying Site. The final DNREC comment letter, which also transmits comments by Schnabel Engineering, is dated November 20, 2008. The final version of the RI/RA Report Addendum has been submitted, and several of the following responses to comments refer to specific sections and subsections of the final document. This letter includes the following:

- Response to Schnabel comments
- Response to DNREC comments
- Attachments 1, 2, and 3 related to specific responses to comments

SCHNABEL COMMENTS

(Letter dated November 5, 2008 and attached to DNREC's November 20, 2008 letter)

Schnabel Comment 1 – General Comments on DuPont's RI/RA Addendum Report: The level of technical writing in the submissions provided by DuPont is not satisfactory, and their reports continue to obfuscate a clear presentation of facts. We recommend that there be a clear division between the objective reporting of results and the protocols used. The division should be distinctly and organizationally separate from discussion and interpretation. All speculative narratives and opinions should be removed from the submissions. Data, modeling assumptions, and simulation results should adhere to the same presentation format.

Section 2 should be reorganized and focused on an objective reporting of the field data collection (borings, well installations, water level measurements, etc.) and dredged material (DM) and iron rich material (IRM) testing programs. Emphasis should be placed on materials, methods, and the

actual measurements. Borings (presented as revised Section 2.1) should be co-plotted on a fence diagram. The geologic context/interpretations should follow in a later section. All hydrogeologic information, discussion, and narrative should be postponed and included in a revised Section 4.0. The revised Section 2.2 should focus on a means and methods reporting of DM materials testing. ASTM or other appropriate established protocols should be explicitly cited in the text and tables (especially Tables 2 and 3). Tables should also include sample IDs so they can be effectively matched with the borings logs, which should also be presented in this section. Currently the sample ID and associated grain size data in Appendix F does not match Table 2 and should be corrected. It is important to note that there is no grain size data presented for IRM in Appendix F. Any relevant calculation procedures, if any, should be justified and documented. The IRM materials testing (Section 2.3) should be likewise organized. Field tests such as slug tests, etc., should be presented beginning with Section 2.4. The complete materials testing results from the soils lab for the DM and IRM should be presented as a stand-alone Appendix.

In summary, we are recommending the above organizational changes to the report so that a person reviewing this report and its associated attachments can better understand and follow the process leading to the conclusions.

DuPont Response to Schnabel Comment 1: Section 2 of the draft RI/RA Report Addendum has been reorganized and is presented as Sections 2 and 3 of the final RI/RA Report Addendum. Fence diagrams for the Sludge Drying Site are presented as Figures 2-3 and 2-4 in the final RI/RA Report Addendum. The ASTM International, Inc. (ASTM), testing methods for the geotechnical laboratory tests have been added to Tables 2 and 3 of the final RI/RA Report Addendum.

Schnabel Comment 2 – (by LRM) Section 1.3 DuPont Property Location and Description: Page 3 of the RI/RA Addendum states that the original coatings applied to the IRM have been changed to a fiber-reinforced cement (Posi-Shell[®]) coating, with the latest application occurring in Spring 2008. Additional information, including photographs, should be included in the RI/RA Addendum Report to demonstrate the effectiveness of the new coating as the original coatings did not prohibit vegetative growth and potential human and ecological exposure to soils and vegetation on the IRM (see Schnabel Engineering, 2006).

DuPont Response to Schnabel Comment 2: DuPont believes that the temporary coatings have been very effective as an interim measure. DuPont conducts monthly inspections to monitor the continued integrity of the Posi-Shell[®] coating and the effectiveness of the surrounding sediment and erosion control measures. Inclusion of requested information does not serve to further the evaluation of the most effective final remedy for the Staged IRM Pile.

Schnabel Comment 3 – Section 2.2.2 Sludge Drying Site Hydrogeology: An accurate determination of the hydraulic conductivity (K) of the IRM, DM, and the underlying water bearing zones is required to correctly model the hydrogeology of these units and to assess the risk of the proposed remedy. As required by DNREC, DuPont collected additional samples

(Shelby tubes) of these three units for in-lab K determination during the recent field investigation portion of the Site Investigation (SI).

The dredged material (DM) narrative contained in Section 2.2.2 (top of Page 12) of the RI/RA containing the words "typically," "characteristically," "typically exceed," "characteristic of clays and silts," leads one to believe that the vertical K factors were assumed or estimated. The source of this information should be clarified. To determine the horizontal K, DuPont performed slug tests on the DM in older wells (MW-33R and MW-35), which were off the footprint and in newer monitoring wells (MW-72 [off the footprint], MW 71 and MW-73 [edge of footprint] and Pile-1 [in the footprint]). The narrative in Section 2.2.2 should be modified to reflect that slug tests were performed on these wells. The location and spacing of the additional slug tests appear to have encompassed the conditions of the DM beneath the proposed footprint.

As part of our review, we requested the actual geotechnical laboratory reports regarding the ASTM testing (not received as of the date of this report). We recommend that a copy of these reports be included in the RI/RA as an Appendix to the report.

There is a reference on Page 12 of the RI/RA concerning the Pigeon Point and Cherry Island landfills being located by the Delaware Solid Waste Authority (DSWA) on this type of sediment due to its impermeability. We recommend that this reference be removed from the document since it has nothing to do with the project site.

DuPont Response to Schnabel Comment 3: The work completed during the Supplemental Investigation (SI) was conducted in accordance with a DNREC-approved SI Work Plan. The report text, Sections 2.1.3 and 2.1.7, have been revised to address the second paragraph of this comment.

The ASTM testing methods for the geotechnical laboratory tests have been added to Tables 2 and 3 of the final RI/RA Report Addendum. The reference to the low permeability of the dredge materials underlying the DSWA landfills is directly relevant, as this same material underlies the Staged IRM. Its selection and approval as a suitable base material for landfilling is an important consideration for selecting a remedy for the Staged IRM.

Schnabel Comment 4 – Section 2.3 Iron Rich Material: As was the case with the DM discussion, the narrative describing the K of the IRM in Section 2.3, Page 13, uses the same set of phrases and words to establish a typical K factor for the IRM. As part of our review, we requested the actual geotechnical laboratory reports regarding the ASTM testing (not received as of the date of this report). We recommend that a copy of these reports be included in the RI/RA as an Appendix to the report.

It is important to note that Shelby tube samples of the IRM were collected in the new borings and monitoring wells from the top several feet (three samples) and from the bottom several feet (two samples) of the IRM pile. IRM at these horizons may be weathered.

Additionally, the words "trace amounts of sand and gravel" referring to 7 ft of silty sand in a 13-ft horizon should be rephrased.

DuPont Response to Schnabel Comment 4: The ASTM testing methods for the geotechnical laboratory tests have been added to Tables 2 and 3 of the final RI/RA Report Addendum. A copy of the geotechnical laboratory data sheets is presented as Appendix N of the final RI/RA Report Addendum. The work completed during the SI was conducted in accordance with a DNREC-approved SI Work Plan, under field oversight by DNREC personnel. Field observations, boring logs, and analytical results do not provide indications that any modification from this approach was necessary to obtain appropriate samples. The report text Section 3.1 has been revised to address the third paragraph of this comment.

Schnabel Comment 5 – (by LRM) Section 3.1 Identification of COCs and Screening Criteria: On Page 17 of the RI Addendum, the statement is made that all chemicals detected to date are included as chemicals of potential concern (COCs) and evaluated as part of the COC screening evaluation; these results were presented on Table 4 of the RI Addendum. However, a simple comparison of Table 4 with Table 1a of Appendix M (which reportedly summarizes the constituents detected in the IRM and the dredge material [DM]) indicates that numerous detected chemicals have been omitted from the COC screening process in Section 3.1 of the RI Addendum. These include many volatile organic compounds (VOCs), semi VOCs (SVOCs), and heavy metals. The COC screening in Section 3.1 and on Table 4 should include all chemicals detected to date and should be accordingly revised.

Also, the first two sentences in the final paragraph of Section 3.1 on Page 16 should be removed since they are incorrect.

DuPont Response to Schnabel Comment 5: DuPont does not concur with Schnabel's evaluation of Section 3.1 of the draft RI/RA Report Addendum and its associated tables. Table 4 presented a comparison of primary constituents of concern (COCs) associated with Staged IRM to the applicable DNREC-generic Uniform Risk Based Standard (URS) screening criteria. Additional constituents detected, in environmental media sampled by DuPont during the SI, above URS values were also included in Table 4 as defined in the footnotes on the table. A comparison of the analytes listed in Table 4 with the media-specific analysis (presented in Appendix I) does not indicate an omission of any chemicals detected, above URS values from the summary table, as Schnabel incorrectly concludes. A comparison of Table 4 to Table 1a of Appendix M is not appropriate because the screening criteria used in the site-specific Risk Evaluation differed from the screening criteria used in the SI data evaluation (i.e., URS values vs. U.S. Environmental Protection Agency (USEPA) Region III Risk-Based Screening Concentrations). However, the text of Section 4.1 and Table 4 of the final RI/RA Report Addendum have been revised to more clearly define the contents.

Likewise, DuPont does not concur with removing the first two sentences in the final paragraph of Section 3.1 on Page 16. The statements are correct and are consistent with

USEPA Region III policy regarding the selection of constituents of potential concern (COPC) in baseline risk assessments (USEPA, 1989¹; USEPA Region III, 1993²; and USEPA Region III, 2007³).

Schnabel Comment 6 – Section 3.3 Dredge Material: Section 3.3 on Page 20 of the report states that the sample depth of the DM is from the top of the DM. This is incorrect and should be changed. It is important to note that only BORING Pile-1 and BORING Pile-5 satisfied the DNREC requirement that DM samples be collected at 2.5 ft intervals.

DuPont Response to Schnabel Comment 6: Section 4.3 of the final RI/RA Report Addendum has been modified to more clearly define locations/depths of Dredge Material: Low-Permeability Unit (DM:LPU) samples. The work completed during the SI was conducted in accordance with the DNREC-approved SI Work Plan (see Table 1 of Appendix A of the final RI/RA Report Addendum).

Schnabel Comment 7 – Section 3.4.3 Additional Observations: The fact that chloride is an important player in the overall geochemistry and hydrogeology of the site warrants a much more detailed evaluation and understanding of this contaminant. The fact that there are no Uniform Risk-Based Standards (URS) for chloride in ground water does not eliminate the importance of its movement and potential interaction with other compounds. The statement about a "transient effect" should be re-examined since the referenced activities are recent compared to the thousands of years that the risk model is projecting for movement of metals, organics, and other compounds across the site.

Schnabel's experience with Delaware River/Schuylkill River DM regarding chloride is limited to Synthetic Precipitation Leaching Procedure (SPLP) data. This data indicates a range of 1 to 5 mg/L of chloride in the leachate from DM samples. Since chloride is extremely leachable, we believe the representative source may have a very low concentration. Because of this, we do not believe that the DM can be a source for such high concentrations of chloride in the site's ground water, and therefore the reference to DM as a possible source for chloride should be removed from this section on Page 24 or revised.

DuPont Response to Schnabel Comment 7: Chlorides are discussed in Attachment 1, "Evaluation of Iron in Staged IRM and Dredge Material" (also included as Appendix O of the final RI/RA Report Addendum).

¹ United States Environmental Protection Agency (USEPA), 1989. *Risk Assessment Guidance for Superfund (RAGS) Interim Final. (Volume 1 Part A Human Health Evaluation Manual)*. EPA/540/1-89/002. December 1989.

² USEPA Region III. 1993. *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening*. USEPA Region III Hazardous Waste Management Division Office of Superfund Programs. EPA/903/R-93-001. January.

³ USEPA Region III, 2007. Risk-based Concentration Table, October 1997.

Schnabel Comment 8 – (by LRM) Section 5.1 DNREC Remediation Standard Evaluation:
On Page 33 and in Table 5, risk estimates are generated for direct and indirect exposure to COCs in soil and ground water for the onsite industrial exposure scenario; however, only select COCs are included in these calculations. Many detected chemicals have been apparently excluded from these risk calculations because their detected concentrations are below URSs. This methodology is flawed given that the numerous other COCs, including many highly toxic VOCs, SVOCs, and heavy metals detected to date (see Table 1a of Appendix M) contribute to the cumulative health risks calculated in Table 5 and referred to on Page 33. Importantly, the cumulative effect of detected chemicals is not limited to chemicals whose individual risk exceeds the target risk level (e.g., 1×10^{-6}) and or hazard quotient (0.1); rather, risk/hazards below these levels can contribute to the overall risk/hazard, resulting in potentially significant cumulative risks/hazards.

Also worth noting is that the incomplete cumulative risks/hazards shown on Table 5 already exceed and/or infringe on acceptable/target risk/hazard levels; hence, the addition of the incremental risk/hazards for the many other detected chemicals shown in Table 1a will necessarily result in further exceedance of acceptable risk levels. For completeness and technical merit, the risk calculations should be accordingly revised.

DuPont Response to Schnabel Comment 8: DuPont does not concur with Schnabel's comment that the risk calculations should be revised. Risk calculations presented in the draft RI/RA Report Addendum were conducted consistent with DNREC and USEPA Region III guidance. All constituents detected above the URS screening criteria for protection of human health were carried forward in the risk characterization calculations. Screening criteria utilized in the evaluation were based on a cancer risk of 1 in 1,000,000 (1×10^{-6}) and a hazard quotient of 0.1 to account for cumulative effects. Results were compared to DNREC's target cumulative cancer risk level of 1 in 100,000 (1×10^{-5}) and a hazard index (HI) of 1 for groups of toxicants that affect the same target organ (DNREC, 1999).

As noted previously in the response to Schnabel Comment 5, it is inaccurate to compare COCs identified in Table 4 with those identified in Table 1a of Appendix M. A review of constituents detected below the conservative URS screening criteria did not indicate any analytes that would significantly add to cumulative risks/hazards already presented in Table 5. In addition, as outlined in the report, the risk calculations are considered highly conservative estimates of cumulative risk because of the following:

- Maximum detected values were used in the calculations instead of central tendency values.
- Groundwater is assumed as a source of drinking water (it is not).
- Exposure assumptions for the on-site industrial worker (250 days per year for 25 years) exceed the potential for direct contact to the Staged IRM or DM:LPU under both current and future site conditions, which should be minimal.

Schnabel Comment 9a – Miscellaneous Comments on DuPont's RI/RA Addendum Report:
Results from the Shelby tube sample recovered from approximately 21 ft below ground surface (BGS) in BORING Pile-1 could not be located within the documents.

DuPont Response to Schnabel Comment 9a: These results were provided on Page 1 of Table 3 in the draft RI/RA Report Addendum with the other geotechnical analyses. This information remains in the same location in the final document. The work completed during the SI was conducted in accordance with a DNREC-approved SI Work Plan.

Schnabel Comment 9b: Also, compositional (Appendix I) or geotechnical data (Appendix F; Table 3) cannot be located for Sample 2 from BORING Pile-3, the bulk geotech sample for the IRM.

DuPont Response to Schnabel Comment 9b: The boring logs indicate observations made and samples collected in the field. Not all collected samples were submitted for laboratory analysis. The work completed during the SI was conducted in accordance with a DNREC-approved SI Work Plan.

Schnabel Comment 9c: The description of the zone from 4 to 20 BGS should be labeled as "IRM visually classified as..." to be consistent with all other borings logs.

DuPont Response to Schnabel Comment 9c: The boring logs have been modified as suggested and are provided in the final RI/RA Report Addendum (see Appendix E).

Schnabel Comment 9d: All other IRM samples were collected at the fringes of the IRM (top/bottom interfaces) where mixing and weathering may have significantly changed the IRM composition.

DuPont Response to Schnabel Comment 9d: The work completed during the SI was conducted in accordance with a DNREC-approved SI Work Plan, under field oversight by DNREC personnel. Field observations, boring logs, and analytical results indicate the approved approach was appropriate to obtain representative samples.

Schnabel Comment 9e: The DM sample from MW-72 does not appear to have been evaluated for geotech or totals purposes (cannot find data).

DuPont Response to Schnabel Comment 9e: This sample was analyzed for geotechnical parameters in accordance with the SI Work Plan (see Appendix A), and the results were provided on Page 2 of Table 3 in the draft RI/RA Report Addendum, with the other geotechnical data. In the final RI/RA Report Addendum, these results are presented on Pages 4 and 5 of Table 3.

Schnabel Comment 9f: K values in the RI/RA Addendum Report require dual consideration of diffusive and advective transport. The report completely neglects the former, and it is the dominant mode in low K materials.

DuPont Response to Schnabel Comment 9f: Hydraulic conductivity is relevant only to calculations of advective transport. In contrast, the rate of diffusion is determined by the

concentration gradient and diffusion coefficient. The evaluation of transport through the Dredge Material Water-Bearing Zone (DM:WBZ) given in Appendix M does consider diffusive-type transport, although it is insignificant compared to advection and mechanical dispersion. The estimate of vertical transport through the Staged IRM and DM:LPU given in Appendix M does not explicitly consider diffusion. Diffusion is a very slow process, and given the long transport distances downward through the Staged IRM and DM:LPU, it will be insignificant compared to advection. In addition, the estimate of vertical transport through the vadose zone also did not consider the effects of retardation, which would tend to decrease the rate of transport. On balance, the simple analysis of vertical transport presented in Appendix M will tend to overestimate rather than underestimate the rate of constituent migration. Additionally, the vertical profile of iron concentrations in the DM:LPU is not consistent with either leaching or diffusive transport from the Staged IRM into this material. Please refer to Attachment 1 of this document ("Potential of Staged IRM as the Source of Iron and Chlorides in the DM:WBZ") and Appendix M of the final RI/RA Report Addendum for further information.

Schnabel Comment 9g: SPLP data clearly indicate that soluble cations (Na, Ca, Mg, etc.) are higher in IRM than in the other media. Vertical gradient exists; it is just a matter of water flow. Arsenic, however, may be associated with the DM, as our data from Fort Mifflin DM indicates.

DuPont Response to Schnabel Comment 9g: Please refer to Appendix O, "Evaluation of Iron in Staged IRM and Dredge Material," and Appendix M of the final RI/RA Report Addendum for further information.

Schnabel Comment 9h: SPLP pH data should be shown in Appendix 1. Soluble salts data that goes with the metals was apparently not included but should be.

DuPont Response to Schnabel Comment 9h: The work completed during the SI was conducted in accordance with a DNREC-approved SI Work Plan. All analytical data from the SI samples, including those that underwent SPLP testing, are provided in Appendix I. The initial pH data for the samples that underwent the SPLP testing were provided on Table 1 of Appendix I of the draft RI/RA Report Addendum. All SPLP results from samples specified in the SI Work Plan are found on Table 2 in Appendix I.

Schnabel Comment 9i: Section 2.8 is inappropriate, presumptive, and should be removed in its entirety. The section has nothing to do with the newly collected data.

DuPont Response to Schnabel Comment 9i: Section 2.8 has been modified and moved to Section 3.8.

Schnabel Comment 9j: The objective for presenting fines distribution on Figure 8 should be clarified.

DuPont Response to Schnabel Comment 9j: The objective of the draft RI/RA Report Addendum Figure 8 has been clarified in Section 2.1.3 of the final document, and the figure is designated Figure 2-5.

Schnabel Comment 10 – Appendix M, Section I Introduction: Per its title, this appendix is meant to address updates to the previous risk assessment based on newly collected soil and ground water data; however, the updates presented are to the soil-leaching-to-ground water and the subsequent ground water-discharge-to-surface water exposure pathway. For consistency and technical merit, all exposure pathways included in the previous assessment should be updated and evaluated quantitatively, incorporating the points made in Comment 8 above.

DuPont Response to Schnabel Comment 10: As noted in the draft RI/RA Report Addendum in Sections 4 and 5 (Sections 5 and 6 in final RI/RA Report Addendum), several risk assessment evaluations have been performed historically. These efforts were described in various documents that are part of the original 2004 RI/RA report. Based on these efforts it was determined that the soil-leaching-to-groundwater and the subsequent groundwater-discharge-to-surface-water exposure pathway was the critical pathway for further quantitative evaluation. This is reflective of what is presented in Appendix M of the final RI/RA Report Addendum. Appendix M includes an exposure evaluation that similarly concludes that this is the relevant pathway for quantitative evaluation.

Schnabel Comment 11 - Appendix M, Section I Introduction: The approach used in Appendix M to evaluate potential risks to human and ecological receptors at the surface water bodies is based on the risk-based criteria (RBC) approach (American Society for Testing and Materials [ASTM] 1997)⁴.

Specifically, this approach back-calculates risk-based concentrations (referred to in the Appendix a closure screening levels [CSLs]) for COCs in IRM soils and leachate from ambient water quality criteria (AWQC) for ecological impacts and risk-based surface water concentrations based on protection of human health during swimming. The back-calculation is based on the calculated attenuation along the path of migration from the IRM to assumed points of exposure within the surface water bodies. Subsequently, the COC-specific CSLs are compared to detected concentrations of COCs in IRM soils and IRM leachate to determine whether significant ecological and/or human health impacts may occur at points of exposure in the surface water bodies.

A significant shortcoming of the above approach as implemented is that it does not account for the cumulative effects of COCs to aquatic or human receptors at the surface water bodies. Note

⁴ ASTM. (1997). Standard Guide for Risk-Based Corrective Action Applied at Chemical Release Sites, version 9.0, August.

that the CSLs have been developed independent of the presence and/or impact of any other chemical to the receptor. They are developed and used in the screening process as if no other chemical or exposure pathway results in exposure to and/or health impacts on ecological or human receptors. In actuality, these effects are cumulative and must be accounted for based on the contribution from all COCs and all exposure pathways yielding chemical mass to the surface water bodies. Hence, estimation of baseline risks/hazards is necessary to properly evaluate the significance of the COCs detected at the site.

As an example, if the detected concentration of a chemical is equal to 90% of its CSL back calculated from the AWQC, then the ecological hazard associated with that chemical is 0.9. While seemingly protective of the target hazard of 1.0 when considered by itself, the conclusion may be made that there are no significant ecological hazards associated with that chemical at the site; however, there are indeed numerous other chemicals, which are also compared to their respective CSLs, each contributing a proportional incremental hazard to that receptor. The net ecological hazard must account for the sum of all such proportions, reflecting the cumulative effect of all COCs impacting the surface water bodies. Based on the numbers already presented in Tables 11a through 12b of Appendix M, cumulative COC hazards and risks exceed target levels for select exposure scenarios, warranting further evaluation and/or corrective action.

DuPont Response to Schnabel Comment 11: DuPont believes that the back calculation approach is appropriate. We disagree with the example calculations that are provided in the comments. The AWQC are regulatory criteria that are derived to be met regardless of other constituents. The use of the AWQC forgoes the need to specifically address cumulative effects in the way described in Comment 11.

Schnabel Comment 12 – Appendix M Section II.A Exposure and Risk Evaluation: While Appendix M acknowledges the potential for leaching of COCs from the IRM to underlying ground water and the subsequent migration to the surface water bodies, it does not appear to quantitatively evaluate the potential for leaching of COCs detected in DM soils and/or first water-bearing zone (WBZ) soils. This section of the report should clearly describe and distinguish between the sources of COCs in soil (i.e., IRM, DM, and WBZ) used to evaluate the soil leaching-to-ground water and subsequent ground water-discharge-to surface water migration pathway. Inclusion of impacts associated with COCs in DM and WBZ soils will only increase the already significant cumulative risks discussed in Comment 5.

DuPont Response to Schnabel Comment 12: The scope of the ENVIRON evaluation was limited to constituents originating in Staged IRM and potential exposure pathways for Staged IRM. This risk evaluation is focused on the potentially most significant exposure pathway: the potential of leaching of constituents from Staged IRM, migration through groundwater, and discharge to surface water. An evaluation of the impacts of COCs (i.e., iron and manganese) already present in the groundwater is now provided in Section 4.6 of the final RI/RA Report Addendum. Additionally, the evaluation of iron in Staged IRM and DM is addressed in Attachment 1 of this document and Appendix O of the final RI/RA Report Addendum.

Schnabel Comment 13 – Appendix M Section II.A Exposure and Risk Evaluation:

Expanding on Comment 3, Appendix M appears to ignore the more direct ground water-discharge-to-surface water pathway for COCs, which have already leached to ground water underlying the IRM. This pathway represents the most prevalent and imminent exposure pathway in terms of potential impacts to the two surface water bodies. Specifically, the impact to surface water associated with the maximum concentration of all COCs detected in ground water at their respective locations should be quantitatively evaluated. Once again, this evaluation should recognize that the ecological and human health impacts posed by discharge of currently impacted ground water to the surface water bodies are additive with the impacts posed by future leaching of COCs from soils within the three zones (IRM, DM, and WBZ) discussed in Comments 5 and 8.

Also worth noting are the fate and potential exposure pathways to the runoff component of the rainfall landing on the IRM, which do not appear to have been addressed. As shown on Figure 1 of Appendix M, this runoff eventually reaches the ground surface, at which point it may: (1) pool and be subject to human exposure; (2) pool and infiltrate into the DM, eventually reaching the WBZ and the surface water bodies; and/or (3) runoff directly to the surface water bodies. The direct exposure by daily site occupants and the COC mass contribution to the surface water bodies from these exposure pathways warrant a quantitative evaluation and should be added in terms of cumulative impacts to surface water receptors.

DuPont Response to Schnabel Comment 13: It is assumed that this comment refers to Comment 12, rather than Comment 3.

The issue of potential runoff has been addressed for potential historic release, current conditions, and in the future as follows:

- Exposures via direct contact with the Staged IRM Pile were minimal because the site is fenced, worker activity is monitored, and an interim measure was implemented to apply a temporary cover to the pile.
- Prior to the use of temporary coatings, there was potential for wind-dispersed material to be deposited in the nearby surface water bodies: the Delaware River and Shellpot Creek. An evaluation was performed to determine the potential impact of both windblown and surface runoff (Cherry Island Staging Area Potential Historic Release Assessment, DuPont, Nov. 2001, Sept. 2002, Dec. 2003⁵). The conclusions were as follows:
 - Resulting exposures to surface water and sediment receptors were possible but were unlikely to be significant. A Posi-Shell[®] cover has been applied to the Staged IRM Pile to limit dust and infiltration.
 - Estimated concentrations in the Delaware River and Shellpot Creek did not exceed AWQC.
 - Using “reasonable worst-case assumptions,” cumulative risks of PBTs (resulting from potential historic wind-blown deposition and surface runoff of Staged IRM

⁵ DuPont. 2003. *Cherry Island Staging Area, Potential Historic Release Assessment*. December 8. (Original dated November 2001; revised September 2002; final revision December 8, 2003.)

materials to surface water) were expected to be approximately an order of magnitude below *de minimus* levels (less than 1×10^{-6} risk).

After the implementation of the proposed final capping remedy, the runoff from the cap is not expected to contain appreciable concentrations of constituents of potential concern. The soil cover and other layers of the cap are specifically designed to prevent contact of rainfall with the Staged IRM. Thus, exposure pathways related to rainfall runoff are expected to be incomplete.

The focus of this evaluation is on the Staged IRM. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in Proposed Plan of Remedial Action (PPRA), groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

Schnabel Comment 14 – Appendix M Section II.B Exposure and Risk Evaluation: Selection of COCs for the soil-leaching-to-ground water and subsequent ground water-discharge-to-surface water pathway was based primarily on adoption of the five metals and the focused set of persistent, bioaccumulative, and toxic (PBT) compounds defined by the US Environmental Protection Agency (USEPA, 2001). However, this document was not included on the reference list and no other bases were provided.

In addition to the above-referenced COCs reportedly defined by the USEPA, Page 5 of Appendix M states that other detected chemicals were included as COCs based on a screening of their maximum detected soil concentrations versus USEPA Region III Soil Screening Levels (SSLs); detected chemicals in soil with no assigned SSLs were reportedly automatically included as COCs. However, as shown on Table 1a of this appendix, there are several chemicals, which were indeed detected within IRM and DM soils, but were not included as COCs despite not having published SSLs. These include multiple SVOCs such as acenaphthylene, benzo(a)pyrene, benzo(g,h,i)perylene, 1,4-dichlorobenzene, 4-methylphenol, and phenanthrene, many with known elevated aquatic toxicities. In addition, naphthalene was incorrectly excluded as a COC on Table 1a, despite significant exceedance of its reported SSL. According to the rationale used in this appendix, all of these compounds should be included as COCs, with their respective ecological hazard and human health risk contribution added to those of the other soil and ground water COCs.

Related to the SSL screening, it should also be noted that the report makes use of the SSL corresponding to a dilution-attenuation-factor (DAF) of 20, herein referred to as SSL20; however, no proper reference was provided for the SSLs (the link has apparently expired), no technical bases were set forth in the report for the assumptions used by the USEPA in developing

the SSL20, and there are no defensible bases for the report's selection of SSL20. Importantly, USEPA (1996)⁶ states that since the migration-to-ground water SSLs are most sensitive to the DAF, site-specific dilution factors should be calculated in lieu of the DAF 20 values. This sensitivity is observed in Table 1a, where if the SSLs are reduced by one-order-of-magnitude, several more chemicals detected in IRM and DM would have to be added to the list of COCs; these include benzo(a)anthracene, 4-chloroaniline, antimony, barium, selenium, and silver.

Lastly, exclusion of any chemical known to be present in IRM, DM, and WBZ soils would inherently and inappropriately eliminate the ability to estimate total cumulative human health risks and ecological hazards at the surface water bodies. To maintain technical defensibility, all chemicals detected in IRM, DM, and WBZ soils should be included as soil COCs and quantitatively evaluated for their cumulative impacts to the surface water bodies; this eliminates the need for the indefensible SSL screening.

DuPont Response to Schnabel Comment 14: The USEPA document has been added to the reference list in the final RI/RA Report Addendum.

The COC list was developed by comparing maximum concentrations detected in Staged IRM with the USEPA Region III SSLs. Since the scope of the risk evaluation was focused on evaluating risks from Staged IRM, the concentrations in the DM were not relevant to the COC selection process and are provided in Table 1a for reference only. In particular, naphthalene was not detected in Staged IRM at concentrations exceeding the SSL; therefore, it was not included as a COC. The other SVOCs mentioned in the Comment 14 were not detected in Staged IRM, and consequently, were not considered COCs in the risk evaluation. The COC screening process was conducted using the SSLs with a DAF of 20 because these screening levels are based on very conservative assumptions. In particular, the SSLs are based on protection of groundwater quality to drinking water standards, even though the groundwater beneath the Hay Road site is not being used for drinking water supply. In addition, the dilution that is predicted to occur at the site is many times greater than 20. As shown in Table 8 of Appendix M, the minimum dilution factor considering only attenuation in the groundwater is over 2,000. There is additional dilution that will occur in surface water, with a minimum attenuation factor of 10. Thus, the minimum dilution factor for the site is over 1,000 times greater than the USEPA default dilution factor of 20. As a result, the COC screening process is very conservative and highly unlikely to screen out any constituents that could pose a significant risk to surface-water receptors.

The focus of the SI and the final RI/RA Report Addendum is the Staged IRM. Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the

⁶ USEPA (1996). *Soil Screening Guidance User's Guide*, 2nd Edition. Retrieved from: <http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg496.pdf>

DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

Schnabel Comment 15 – Appendix M Section II.B Exposure and Risk Evaluation: Page 6 of Appendix M states that toxic equivalents were calculated using the 1998 World Health Organization (WHO) toxic equivalency factors (TEFs), using one-half the detection limit as a surrogate for non-detected analytical results. As previously commented (Schnabel Engineering, 2006), the WHO has since updated its TEFs (WHO, 2005)⁷, and their use over the older TEF values is recommended.

DuPont Response to Schnabel Comment 15: The 1998 TEFs were used in order to maintain consistency with the DNREC water quality regulations, which specify the use of the 1998 TEF values (DNREC, 2004⁸). It is important to note that the differences between the 2005 TEFs and the 1998 TEFs are not large enough to change the overall conclusions of the risk evaluation. This issue was addressed in the Uncertainty section of Appendix M.

It should be noted that the WHO 2005 TEFs (Van den Berg, *et al.*, 2006)⁹ have not been officially adopted by the USEPA. Nonetheless, when this and another publication from the National Academy of Sciences were pre-published in July 2006, DuPont reviewed both documents for their potential impact on the Hay Road evaluation. This review document was provided to DNREC in August 2006. It is provided as Attachment 2 to this document, for reference.

Schnabel Comment 16 – Appendix M Section II.D Modeling of Leaching and Groundwater Transport: The application of the HELP model for estimating of recharge to ground water is not well documented in Appendix M. Correspondingly, copies of the highly useful model input and output data files are not provided, prohibiting confirmation of the calculations and a clear understanding of the approach.

While the RI Addendum text is generally vague and highly unclear as to the occurrence of ground water, including depth to ground water, within the various hydrogeologic units, Figure 1

⁷ WHO. (2005). *The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds*. Retrieved from:

http://www.dow.com/facilities/namerica/michigan/dioxin/WHO_TEFJe-evaluation.pdf

⁸ DNREC. 2004. State of Delaware Surface Water Quality Standards. Dover, Delaware. July 11. Retrieved from: <http://www.dnrec.state.de.us/DNREC2000/Divisions/Water/WaterQuality/WQStandard.pdf>

⁹ Van den Berg, Martin; Birnbaum, Linda S.; Denison, Michael; De Vito, Mike; Farland, William; Feeley, Mark; Fiedler, Heide; Hakansson, Helen; Hanberg, Annika; Haws, Laurie; Rose, Martin; Safe, Stephen; Schrenk, Dieter; Tohyama, Chiharu; Tritscher, Angelika; Tuomisto, Jouko; Tysklind, Mats; Walker, Nigel, and Richard E. Peterson. 2006. "The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds." *Toxicological Sciences*. 93(2):223-241. ToxSci Advance Access published on October 1, 2006. DOI 10.1093/toxsci/kfl055.

of Appendix M suggests shallow ground water occurs within the DM. This would suggest that the bottom boundary of the one-dimensional domain used by the HELP model would correspond to the water table at some point within the DM; insufficient information is included in the report to decipher this. Moreover, if the above conceptualization (i.e., Figure 1) is correct, then the vertical flux of water between the DM and the underlying WBZ must be calculated using Darcian flow (Todd, 1980)¹⁰; no such calculations are presented. From the write up, it appears that the HELP model was used to estimate recharge directly to the WBZ, assuming that the lower portions of the DM is unsaturated; this is inconsistent with the schematic in Figure 1. Either way, consistency in conceptualization and model usage is needed.

Also not documented are the calculations and resulting values for the concentrations of COCs applied to the estimates of recharge obtained from the HELP model. While the report suggests that COC concentrations in recharge water are based on equilibrium partitioning calculations, no such calculations are presented.

DuPont Response to Schnabel Comment 16: Copies of the HELP model output are provided in Attachment 3 to this document. The output files also describe all of the input parameters.

Figure 1 of Appendix M of the final RI/RA Report Addendum has been revised in order to clarify that the blue line in the DM:LPU represents the piezometric surface of the DM Water-Bearing Zone. The blue line does not represent a water table present in the DM:LPU. In the conceptual model of the hydrogeology of the site, the DM:WBZ is a confined unit, with the DM:LPU being the low-permeability confining layer that overlies the DM:WBZ.

The approach used in the risk evaluation was to back-calculate the maximum acceptable concentrations in Staged IRM soils and leachate, based on protection of surface-water quality. In this approach, the acceptable concentrations in the leachate or recharge are the outputs of the calculation, not inputs. The calculation of the closure screening level (CSL) in solids from the CSL in leachate using equilibrium partitioning is described by the equation given in a footnote to Tables 10, 11, and 12 of Appendix M of the RI/RA Report Addendum. As described in that footnote, the CSL in solids is equal to the CSL in leachate multiplied by the soil-water partition coefficient (K_d).

Schnabel Comment 17 – Appendix M Section II.D Modeling of Leaching and Groundwater Transport: The application of ground water fate and transport modeling is also poorly documented in Appendix M, prohibiting the ability to confirm calculations. There are also a number of inconsistencies in the application of the model; these include:

The hydraulic conductivity (K) value used in the ground water model was estimated based on the geometric mean value of slug test results from four locations within the WBZ (see Table 5 of Appendix M). However, elsewhere on Table 5, a combination of harmonic means, arithmetic

¹⁰ Todd, D.K. (1980). *Groundwater Hydrology*, 2nd Edition, J. Wiley & Sons, New York, NY.

means, and geometric means is used to estimate overall K values, with no rationale outlined other than one reference (Freeze and Cherry, 1979) to the use of harmonic mean for layered soils. This arbitrary use of a range of methods to "average" K values lacks scientific defensibility. To maintain the necessary conservatism inherent to risk assessment efforts, the maximum value of K for each zone should be used. At a minimum, such values should be used in a sensitivity analysis to evaluate their significance on the modeling and risk assessment conclusions; no such uncertainty analysis has been performed. The need for a sensitivity analysis is further emphasized given the significant uncertainty and potential underestimation of K values obtained from slug test results (Butler, McElwee, and Liu (2005)¹¹.

The estimation of attenuation factors along the path of ground water migration from the IRM to the surface water bodies included the effects of adsorption, which is a highly complex, site-specific, and reversible process under actual field conditions (Su and Lu, 2007)¹². In contrast, the AT123D model used in the analysis represents this process via a simple linear isotherm based in large part on user-defined chemical-specific distribution coefficients (Kd), soil bulk density, and porosity. In turn, the Kd's are in part based on the site-specific fraction of organic carbon in soils. Of particular concern is that none of the key parameters (porosity, bulk density, fraction of organic carbon content) necessary to estimate the retardation factors were based on site-specific measurements.

Recognizing the highly complex and reversible nature of retardation, the absence of key site-specific data, and the inability to generate defensible estimates of retardation factors, the AT123D model should be applied without the use of retardation. At a minimum, such simulations should be incorporated into a sensitivity analysis for the modeling and risk assessment.

The representation of the COC source term in the ground water model lends itself to a potentially significant concern. The rectangular vertical source term used in AT123D assumes a fully penetrating source term within the WBZ. As such, in estimating the source term concentration, the COC mass estimated to recharge (i.e., presumably estimated as the product of the recharge rate and the pore water concentration at equilibrium with the COC soil concentrations - calculation not shown) was uniformly mixed and diluted within the entire aquifer thickness in the WBZ. In the absence of localized ground water pumpage and density-driven mixing, the actual mixing zone depth of recharge is expected to be measurably less than the entire aquifer thickness, resulting in higher source concentrations within the upper portions of the aquifer. By uniformly mixing this mass within the entire aquifer thickness rather than a fraction of the aquifer thickness (see Equation 3 on Page 12 of Appendix M), the COC concentrations inserted into the ground water model were reduced. As with several other parameters, the value used to represent the mixing zone depth was arbitrarily assigned with no technical justification, resulting

¹¹ Butler, J., McElwee, C.D., and Liu, W. (2005). Improving the Quality of Parameter Estimates Obtained from Slug Tests, *Ground Water*; 34 (3): 480 - 490.

¹² Su, F. and Lu, C. (2007). Adsorption kinetics, thermodynamics and desorption of natural dissolved organic matter by multiwalled carbon nanotubes. *J Environ Sci Health A Tox Hazard Subst Environ Eng*; 42 (11): 1543-1552.

in the lowest source term possible in the ground water model; this approach lacks technical defensibility.

Worth noting is that the USEPA has developed technical approaches for estimation of mixing zone depths (e.g., Sharp-Hansen et al., 1990)¹³, which should be used in lieu of arbitrarily assigned depths. In addition, sensitivity analysis of this term should also be performed.

The effective porosity term in the model is not well supported and appears to be inconsistently selected. On Page 11 of the RI Addendum, the ground water seepage velocity within the WBZ is calculated based on an effective porosity of 0.25 without the benefit of any site-specific measurements and/or references. In the ground water model, the effective porosity for the WBZ was arbitrarily increased to 0.30 (see Table 7 of Appendix M), thereby reducing the ground water velocity by approximately 20 percent. Note also that for the silty sands such as those within the WBZ, effective porosities on the order of 0.15 are not unusual, yielding significantly greater seepage velocities than those estimated in the RI Addendum and by the model. Consistency and defensibility in such key parameters is necessary. As before, a sensitivity analysis on this parameter is also recommended.

DuPont Response to Schnabel Comment 17: The methods used to average the hydraulic conductivity measurements in the Staged IRM and DM:LPU are standard methods to define representative values of hydraulic conductivity for different types of heterogeneity. These methods are described in most introductory groundwater textbooks, including the textbook cited. The results of the HELP model are very insensitive to the conductivities of the IRM and DM:LPU because the infiltration rate is mostly controlled by the Low-Density Polyethylene (LDPE) layer, which has a much lower hydraulic conductivity than any of the other layers.

For example, if the hydraulic conductivity of the Staged IRM layer is changed to its maximum measured value of $2.4E-05$ cm/s (an increase by a factor of 7), the infiltration rate predicted by HELP increases by a factor of 4. This would lead to a corresponding decrease in the CSLs by a factor of 4. Since the measured constituent concentrations in Staged IRM are generally several orders of magnitude below the CSLs, decreasing the CSLs by a factor of 4 would have no impact on the conclusions of the risk evaluation. The hydraulic conductivity of the DM:LPU has even less impact on the results. If the hydraulic conductivity of the DM:LPU is increased to its maximum measured value of $4.7E-06$ cm/s (an increase by a factor of 30), the infiltration rate predicted by HELP does not noticeably change. Thus, while the methods of calculating representative average conductivities used in the risk evaluation are reasonable, the risk evaluation results are not sensitive to changes in the averaging method.

The assumption that the mixing zone under the Staged IRM Pile will extend through the depth of the DM:WBZ is reasonable. This can be confirmed by using the standard

¹³ Sharp-Hansen, S., Salhotra, A.M., Mincart, P., and Allison, T. (1990). Multimedia Exposure Assessment Model (MULTIMED)-Evaluating the land disposal of wastes-Model Theory. USEPA Office of Research and Development, Environmental Research Laboratory, Athens, GA.

mixing-zone depth equation provided in USEPA's Soil Screening Guidance (USEPA, 1996)¹⁴. For example, employing the site-specific parameters for Shellpot Creek given in Table 7 of Appendix M of the final RI/RA Report Addendum into USEPA's mixing-zone depth equation gives a predicted mixing-zone depth of 95 feet (ft). Because mixing in the low-permeability layer underlying the DM:WBZ (Marsh Deposits) is likely to be minor, the mixing-zone thickness was conservatively limited to the total thickness of the DM:WBZ.

The method used to estimate retardation is the standard approach recommended in USEPA guidance, including the Soil Screening Guidance (USEPA, 1996). It is important to understand, however, that retardation only slows down the movement of constituents. After steady-state conditions are reached, retardation has no effect on predicted concentrations in surface water. As a result, the CSLs for the steady-state case would be unchanged if retardation were neglected. Because none of the COPCs are predicted to cause an exceedance of surface water criteria even after steady-state conditions are reached, the conclusions of the risk evaluation are not sensitive to assumptions related to the retardation factor, including the type of sorption isotherm and values used for soil properties (fraction of organic carbon, bulk density, and porosity).

The effective porosity of the DM:WBZ has been changed to 0.15, and this updated value has been used consistently in both the final RI/RA Report Addendum (Section 3.3.2) and Appendix M of that report. The CSLs have been updated accordingly. However, the conclusions of the risk evaluation remain the same—under the proposed capping remedy, leaching, and migration of Staged IRM constituents to nearby surface-water bodies would not occur at potentially significant concentrations for at least 1,000 years.

AT123D was not used in evaluation. Instead, the specific equations are provided in Appendix M of the final RI/RA Report Addendum.

Schnabel Comment 18 – Appendix M Section II.E Groundwater Mixing with Surface Water: As with the original risk assessment, there remains a fundamental flaw in the use of attenuation factors beyond the points of ground water discharge to surface water bodies in an effort to dilute the exposure point concentrations (and maximize CSLs) at surface water bodies.

First, the estimation of an attenuation factor (for human receptors) based on the ratio of the ground water flux to the overall surface water flux in the river is not only incorrect, but essentially guarantees the continued pollution of the surface water bodies into the future. It goes without saying that this attenuation factor will be significantly high, given the minute proportion of ground water discharge in comparison to flux in rivers as large as the Delaware River; not surprisingly, Todd (1980) suggests ground water contribution to base flow in rivers constitutes approximately 20 percent of the river's total flow.

¹⁴ USEPA. 1996. *Soil Screening Guidance: Technical Background Document*. Office of Emergency and Remedial Response. EPA/540/R-95/128. May.

The primary problem with this approach is that it suggests that one can discharge as much mass as necessary into a river, as long as that mass is met with sufficient dilution based on the flux ratio between the river and ground water. Functionally, this would allow every polluter along the river to discharge significant mass into the river and simply achieve compliance by performing a flux-only based dilution calculation, which will favor discharging almost any amount of soluble mass into the river. This is in direct conflict with the need to protect the water quality of the rivers at stake.

Second, even if dilution within a river is considered a justifiable means to eliminating pollution, the dilution calculation should not be solely based on the ratio of the flux of the two sources of water; rather, it should account for the existing mass of each COC already within the surface water system in order to eliminate the potential for each polluter to indefinitely discharge chemical contamination into the river without any recognition of mass limits. No such accounting was made in the calculations in either risk assessment, despite the known detection of COCs in the river and within fish species tested. Along the lines above, the use of a dilution factor of 10 for the ecological component of this analysis is similarly inappropriate, not to mention entirely arbitrary and without technical basis.

With respect to relying on surface water dilution, it should be noted that many regulatory agencies prohibit the use of such dilution for the reasons stated. In fact, not only do many agencies not allow for surface water dilution in such analyses, they in fact suggest that the AWQC be applied not at the point of ground water discharge to the bay, but at a distance inland corresponding to the inland extent of tidal effects. Tidally influenced ground water, which at the subject site exceeds 200 ft inland from the rivers, is accordingly considered a part of the surface water body given its rapid and daily hydraulic communication with the surface water body. As such, application of the AWQC to an ecological protection zone in land (i.e., distance defined by tidal influence) ensures protection of aquatic organisms and minimizes the potential for continued manifestation of river impacts. This approach, which has been adopted by the California Environmental Agency at the San Francisco International Airport site (California Regional Water Quality Control Board San Francisco Bay Region, 1999)¹⁵, is a marked difference from what has been proposed at the subject site.

DuPont Response to Schnabel Comment 18: We disagree with the characterization of the approach. The use of a mixing zone is consistent with the following USEPA guidance documents:

- USEPA's Exposure Assessment Methods Handbook (EAMH) (USEPA, 1989)¹⁶
- USEPA's NPDES Permit Writer's Manual (USEPA, 1996b)¹⁷

In addition, the current USEPA guidance regarding environmental indicator (EI) evaluations and the 1996 Advanced Notice of Proposed Rule Making (ANPRM) regarding establishing

¹⁵ California Regional Water Quality Control Board San Francisco Bay Region (1999). Order No. 99-45. *Adoption of Revised Site Cleanup Requirements and Rescission of Order Nos. 95-136, 95-018, 94-044, 92-152, and 92-140 for: The City and County of San Francisco, The United States Coast Guard, and San Francisco International Airport Tenants/Operators*. Retrieved from: www.waterboards.ca.gov/sanfranciscobay/board_info/orders/99-045.doc

¹⁶ USEPA, 1989. *Exposure Assessment Methods Handbook*. Draft EPA/600. September.

¹⁷ USEPA, 1996b. *NPDES Permit Writer's Manual*. EPA/833/B-96/003. December.

point of compliance for surface-water discharges (USEPA, 1996a¹⁸) supports the use of a mixing-zone approach. Precedent has been established both in USEPA Region III and in other EPA regions, allowing the use of a mixing zone in evaluating groundwater to surface-water discharge and establishing media cleanup objectives.

COMMENTS BY SCHNABEL
(On DNREC'S 10/10/08 Data Report Evaluation)

Schnabel Comment 19 – Evaluation Results: In general, we concur with the findings under this header. Regarding Bullet No.2, it is important to note that DuPont has presented conflicting information regarding the dredged material in their March 2, 2007, comments document and in their recent RI/RA Addendum Report. In particular, no data or understanding of the DM was presented in earlier documents and in the recent RI/RA Addendum Report, a thorough history is presented on how the DM was placed and what the DM contains.

Regarding the solid bullets at the end of this section, we concur with every item.

DuPont Response to Schnabel Comment 19: DuPont obtained additional information about the DM during the SI in late 2007 and 2008 and appropriately included it in both the draft and final versions of the RI/RA Report Addendum.

Schnabel Comment 20 – DNREC Evaluation of COCs:

Organic Contaminants: Please see comments above regarding organic contaminants.

Inorganic Contaminants: Based on our preliminary review of these items and information, we concur with DNREC's review, conclusions, and recommendations.

DuPont Response to Schnabel Comment 20: Please see responses to DNREC comments below.

COMMENTS BY DNREC FROM "DNREC Additional Comments on Remedial Investigation and Risk Assessment Report Addendum"
(Attachment 1 of Schnabel's November 5, 2008 letter)

DNREC Comment 1 – General Impression: Overall, the report does a good job in compiling the data, information, and analyses available for this site.

DuPont Response to DNREC Comment 1: DuPont appreciates DNREC's overall impression of the draft RI/RA Report Addendum.

¹⁸ USEPA, 1996a. Advanced Notice of Public Rulemaking for Corrective Action for Releases from Solid Waste Management Units at Hazardous Waste Management Facilities; Proposed Rule, (FR.19432, May 1, 1996) [Available on the EPA HQ Web Site: <http://www.epa.gov/epaoswer/hazwaste/ca/subparts.htm> and from NCEPI, Document No. EPA 530-Z-96003.

DNREC Comment 2 – Sufficiency of Cap-in-Place Remedy to Protect Human Health: The report concludes that the "...results of the updated site-specific exposure and risk evaluation demonstrate that the implementation of the cap-in-place remedy is appropriate as it is protective of human health and the environment." The cap-in-place remedy should be sufficient to protect humans from elevated exposure to organic contaminants, in particular PCBs, dioxins and furans, and hexachlorobenzene. This position is based largely on the tendency of these contaminants to strongly adsorb to soil rather than leach into groundwater. So long as wind and water erosion are controlled through use of a permanent cap, release to the surrounding environment should be minimized going forward. The fact that a permanent cap may be sufficient to control organic COCs in the future doesn't mean that these organic COCs were fully controlled in the past; this includes COCs which have already migrated to significant depths within the iron-rich material (IRM) and dredge material (DM), and those which have leached to groundwater and are subject to continued discharge to the surface water bodies independent of the effects of a permanent cap. Evidence that they weren't fully controlled will be presented and discussed later in these comments.

DuPont Response to DNREC Comment 2: DuPont agrees that the cap-in-place remedy will minimize leaching from the Staged IRM. This should provide a remedy that is protective of both human and ecological receptors from exposure to the staged materials.

The focus of the SI and the final RI/RA Report Addendum is the Staged IRM. Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

DNREC Comment 3 – Sufficiency of Cap-in-Place Remedy to Protect the Environment: The cap-in-place remedy by itself seems to be no sufficient to fully protect aquatic life in the Shellpot Creek. Specifically, mass balance calculations performed as a part of this review indicate that there is a reasonable potential for soluble iron discharged via groundwater from the first Water Bearing Zone (WBZ) beneath the pile to cause or significantly contribute to exceedances of the applicable numeric water quality criterion for iron in the lower Shellpot Creek during low flow conditions. There is also a reasonable potential for the groundwater discharge of iron (and possibly manganese) to violate the narrative criterion in Delaware's Surface Water Quality Standards that requires waters of the State to be free from wastes that may coat or cover submerged surfaces and create a nuisance condition. Soluble iron and manganese discharged from the groundwater rapidly form solid precipitates under normal pH and oxygen conditions typical of surface waters. These precipitates have been observed along the banks of

the Shellpot, although the areal extent is not clear. Additional comments concerning the groundwater discharge of iron from the WBZ to the Shellpot Creek follows.

DuPont Response to DNREC Comment 3: As noted above, we agree that the cap-in-place remedy will minimize leaching from Staged IRM. This should provide a remedy that is protective of both human and ecological receptors from exposure to the staged materials.

Per DNREC's request, forward transport modeling calculations for iron in Staged IRM leachate (concentration at its SPLP detection limit) have been performed and are presented in Appendix M-1 of the final RI/RA Report Addendum. These results indicate that even without a cap, calculated concentrations in Shellpot Creek (resulting from migration of leachate from the Staged IRM Pile to groundwater and subsequently to surface water) do not exceed the DNREC SWQS for iron under both current and steady state conditions (10,000 years). With the cap-in-place remedy, results similarly indicate that the estimated concentrations are well below the SWQS.

There is strong evidence that the Staged IRM is not the source of significant quantities of iron in Shellpot Creek via groundwater discharge. A detailed discussion is provided in the document entitled, "Evaluation of Iron in Staged IRM and Dredge Material" (Attachment 1 of this document).

The focus of the SI and the final RI/RA Report Addendum is the Staged IRM. Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

DNREC Comment 4 – Section 5.2 Site-Specific Groundwater to Surface Water Evaluation:

This section of the report describes how maximum theoretical screening levels for IRM and IRM pore water/leachate were back calculated from ambient water quality criteria. The back-calculation procedure involved the application of 2 'attenuation factors', one to account for dilution in the Shellpot Creek and another to account for fate processes in the groundwater. The back-calculated maximum theoretical concentration in the pile was then compared to measured concentrations in the pile. The main concern with this back-calculation procedure is that it appears to ignore the elevated concentrations of soluble iron already in the first WBZ. In essence, the procedure assumes that the only iron of concern is iron in the IRM situated above the WBZ and whether iron leaches from the IRM. Since iron was not detected above 52.2 ug/L in the leaching tests on the IRM, the authors improperly conclude that iron does not leach from

the IRM. These results simply mean that iron was not detected above a detection level of 52.2 ug/L, not that iron doesn't leach from the pile. This is likely a situation where detection levels were not sufficiently sensitive to properly characterize the leaching potential of the IRM. Indirect evidence that iron is in fact leaching from the pile (at concentrations less than 52.2.ug/L) is the existence of a strong vertical concentration gradient for chloride in the pile (see section 3.2.3). Chloride is a major constituent of the IRM. It is highly soluble and a vertical gradient suggests dissolution of IRM within the pile.

If the assumption is made that IRM is essentially ferric chloride, then 1 mole of iron would be released for every 3 moles of chloride. The higher chloride concentration at depth could also mean that dissolution of the IRM is more likely to occur at the bottom of the pile where redox may be low (separate leaching tests of IRM collected at the bottom of the pile and run in the absence of oxygen might yield higher leachable iron). Further, lower pH at the bottom of the pile at the IRM/DM interface would also favor conversion of solid ferric iron to soluble ferrous iron, providing another possible explanation for the high soluble iron concentrations in the DM and WBZ. The point of all this is that the groundwater modeling performed apparently did not consider some important geochemical processes that are likely to have an effect on this situation. Further, by focusing exclusively on how much iron could leach from the IRM, the authors neglect the high concentrations of soluble iron already in the WBZ that lies within groundwater flow pathway between the IRM and the Shellpot Creek.

Although DuPont appears to neglect the soluble iron in the back-calculation exercise, they acknowledge its presence elsewhere in the report (section 3.4.1). They imply that the source of that iron is the dredged material (DM) at the bottom of the pile. Even if all of the soluble iron in the first WBZ did come from the DM, which is doubtful for reasons discussed above, the act of placing nearly 30 feet of IRM on top of the DM likely changed the redox conditions in the DM, facilitating the conversion of insoluble and immobile ferric iron to soluble and mobile ferrous iron. DuPont further fails to recognize that they own not only the IRM in the pile, but also the land under the pile. As such, they are responsible for controlling the release of soluble iron from the first WBZ beneath the pile, regardless of whether the IRM is the source of all, some, or none of the iron the first WBZ. At this point, it is unclear whether a permanent cap will significantly alter groundwater flow and the discharge of soluble iron to the Shellpot Creek. Further analysis of this question is warranted.

DuPont Response to DNREC Comment 4: DuPont is providing clarification regarding the composition and properties of the Staged IRM, as well as the site operational history. A detailed explanation is provided in the document entitled, "Evaluation of Iron in Staged IRM and Dredge Material" (Attachment 1 of this document). DuPont has also modified the final RI/RA Report Addendum to clarify these issues (see Sections 1.2 and 1.3, and Appendix B).

Per DNREC's request, forward transport modeling calculations for iron in Staged IRM leachate (concentration at its SPLP detection limit) have been performed and are presented in Appendix M-1 of the final RI/RA Report Addendum. These results indicate that even without a cap, calculated concentrations in Shellpot Creek (resulting from migration of leachate from the Staged IRM Pile to groundwater and subsequently to surface water) do not

exceed the DNREC SWQS for iron under both current and steady state conditions (10,000 years). With the cap-in-place remedy, results similarly indicate that the estimated concentrations are well below the SWQS.

The focus of the SI and the final RI/RA Report Addendum is the Staged IRM. Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

DNREC Comment 5 – Ambient Concentrations of Iron near the IRM Staging Area:

Readily available and existing data on iron concentrations in surface water and sediments from the Shellpot Creek and Delaware Estuary were compiled and reviewed to place the IRM Staging Area into broader context. Selected findings from those reviews include the following:

- a. The concentration of total iron in surface water samples collected from the Shellpot Creek increases significantly in the downstream direction going from Route 13 to Hay Road to the lower tidal reach adjacent to the IRM Staging area. The applicable water quality criterion for iron (1000 ug/L) is seldom exceeded in the upstream samples, while virtually always exceeded at the Hay Road station and the station in the lower tidal reach adjacent to the IRM staging area.
- b. The concentration of iron in the sediments of the lower Shellpot Creek ties the maximum published concentration of iron in sediments from the entire Delaware Estuary from Trenton to Cape Henlopen to Cape May.
- c. There is a statistically significant increase in total iron concentrations in the water column of the Delaware Estuary as one travels from Marcus Hook (upstream) to Cherry Island (adjacent to the IRM pile). The water quality criterion at the Marcus Hook station is exceeded in 40% of the samples while the criterion is exceeded in 90% of the samples collected at Cherry Island station. Below the C&D Canal, the concentration of iron in the water column drops off significantly, with only 30% of the samples collected at Liston Point exceeding 1000 ug/L. In terms of time trends, there is some evidence that contemporary (2006-2007) water column iron concentrations in the Delaware Estuary downstream of the IRM pile are much higher than historic levels (1957). This finding is subject to verification, however, since field and laboratory methods associated with the older data may not be comparable to methods used to collect and analyze the more current data.
- d. The concentration of iron in the sediments of the Delaware Estuary increases as one travels from the PA/DE line (near Marcus Hook) downstream into Zone 5 of the Estuary. Concentrations then drop off dramatically as you move into the Delaware Bay. The

DuPont Response to DNREC Comment 5: The condition of surface water in Shellpot Creek at its confluence with the Delaware River is assessed twice per year by surface water sampling at two locations as required by the DNREC Solid Waste Permit for the adjacent Hay Road Landfill. This sampling program provides a more representative data base for surface water and sediment quality in Shellpot Creek than the one round of SI sampling. One location in Shellpot Creek is upstream of the landfill, west of the Hay Road Bridge and beyond the influence of the Staged IRM. The other location is downstream of the landfill (across from the Staged IRM) at the confluence of Shellpot Creek and the Delaware River. These locations are currently analyzed for chloride and metals (arsenic, cadmium, chromium, copper, iron, lead, and selenium).

Appendix P of the final RI/RA Report Addendum contains a historical data summary table for sampling. This table was originally found in the "2007 Annual Hydrogeological Report for the Hay Road Landfill, DuPont Edge Moor Plant, Edgemoor, Delaware". The surface-water sampling spans 14 years, from May 1993 to October 2007 and has 30 individual sampling events. The data documents that both the upstream and downstream water quality in Shellpot Creek is very poor. For example, all but one sample result for total iron exceed the DNREC SWQS and EPA Ambient Water Quality Criterion (AWQC) of 1.0 mg/L at the upstream location, with values ranging from 0.928 mg/L to 2,910 mg/L. At the downstream location, total iron ranges from 0.6 mg/L to 62.9 mg/L. Upstream surface-water sample values for lead, arsenic, cadmium, and chromium have also exceeded their respective DNREC SWQS and EPA AWQC. This discussion of ambient concentrations of iron in Shellpot Creek near the IRM Staging Area has been added to Section 4.5 of the final RI/RA Report Addendum.

The significance of current detections in Shellpot Creek, relative to the Sludge Drying Site, is unclear at this time and warrants further monitoring. The site is located at the confluence of Shellpot Creek and the Delaware River, and both water bodies experience tidal ingress and egress behavior with water freely mixing between the two surface water bodies. Organic constituents detected in Shellpot Creek are also detected in the Delaware River, where multiple different sources may have contributed the same compounds. Furthermore, as noted above, Shellpot Creek surface water and sediment data collected upstream of the DuPont Property and the tide gate document historical and current upstream exceedances for PCBs and metals (including iron).

DNREC Comment 6 – Section 2.4 Surface Water Hydrology and Storm Water Runoff:

This section notes that, "All surface water drainage is controlled by...perimeter berms. All storm water runoff exits the Sludge Drying Site to the Delaware River at the southeastern corner after passing through several sediment control devices." Although perhaps beyond the

immediate scope of Section 2.4, it is unclear whether storm water runoff would continue discharge to the Delaware River through these same sediment control devices based on the final grading and permanent capping envisioned by DuPont. It is also unclear whether these sediment control devices have been maintained to ensure peak efficiency and whether they will continue to be maintained and monitored should a permanent cap be installed. This section also notes that, "The Sludge Drying Site is surrounded by a berm made of low permeability silts/clays, probably from historical DM or clayey/silt river deposits." Given that the IRM has been allegedly used in other berm and cover installations in the area, the question arises whether IRM was also used in the berms at the Sludge Drying Site.

If so, there may be a need to cap the berms as well to prevent the erosion of contaminants of concern into the lower Shellpot Creek and Delaware River. Finally, this section indicates that, "Because the Sludge drying Site is located at the confluence of the Shellpot Creek and the Delaware River and below the Shellpot Creek tidal gate structure, a large amount of water exists in Shellpot Creek next to the site relative to the stream flows recorded upstream at the gaging station....A value of 10 cfs is considered representative for a conservative long-term average flow past the Sludge Drying Site." It is true that the lower Shellpot Creek is tidal in the reach adjacent to the Sludge Drying Site. It is not true that increased dilution is available just because the lower Shellpot is tidal. In tidal waters, water moves upstream during flood tide and downstream during ebb tide. The net movement of water in the downstream direction is in fact determined by the nontidal component of the flow through the tidal reach, which is the freshwater flow entering the tidal reach. DuPont understands this concept in the case of the tidal Delaware River in which they present a mean harmonic freshwater flow of 7,402 cfs for the Delaware River in the vicinity of the Sludge Drying Site (although they fail to present a net advective flow under critical low flow conditions). In the case of the Shellpot Creek, the 7Q10 low flow at the Shellpot Creek gage located downstream of North Market Street in Wilmington is 0.22 cfs. That flow translates to a 7Q10 of 0.29 cfs near the mouth of the Shellpot Creek based upon the ratio of drainage areas above the tidal reach in comparison to the gage. The long-term median (50%) flow at the gage is 2.9 cfs, which translates to a long-term median flow of 3.77 cfs at the mouth of the Shellpot. Hence, DuPont's characterization of 10 cfs as being representative for a conservative long-term average flow past the Sludge Drying Site is not accurate. Further, it significantly understates the amount of flow available during critical low flow (e.g., 7Q10) conditions.

DuPont Response to DNREC Comment 6: Based on the current status and anticipated direction of the Staged Iron-Rich Pile cap design, surface-water runoff would continue to be diverted to Outlet D-002. Monthly inspections of the Sludge Drying Site are conducted as an extension to the monthly inspections of the adjacent closed landfill cells, and any problems with the interim remedial action are documented and subsequently repaired if necessary and appropriate. Based on discussions with URS Corporation, DuPont CRG, and Edge Moor staff, there is no evidence that Staged IRM was utilized in any of the site perimeter berms.

DNREC does not provide the sources of information or methods (e.g., SWSTAT, DFLOW, etc.) used to estimate flow at the mouth of Shellpot Creek, but the assumptions appear to be similar to those used for the Naamans Creek Total Maximum Daily Load (TMDL) analysis

report (DNREC, 2005)¹⁹. That report contains inconsistent references (e.g., citing sources that predate the data employed), so these assumptions cannot be confirmed; however, DuPont notes the following points of interest.

The drainage basin ratio employed by DNREC neglects any contribution of groundwater inflow to the lower reach of Shellpot Creek. By employing the drainage basin area upstream of Reach 5, it provides flow estimates based upon the upper portion of the reach, rather than at the mouth of Shellpot Creek, evidently assuming that flow from beneath the site is the only contribution to Shellpot Creek in its lower reach. This is an overly conservative assumption, albeit relatively minor in magnitude.

The Shellpot Creek flow estimate was only used in the modeling for the Human Health exposure risk assessment. Employing the 7Q10 flow estimate provided by DNREC (0.29 cfs) rather than the 10 cfs annual mean flow cited in the draft RI/RA Report Addendum would change the DAF by a factor of 34 (i.e., 10 cfs ÷ 0.29 cfs). The results of modeling were sufficiently protective that this change would not impact the modeling conclusions for Human Health exposure. However, 7Q10 flow estimates are appropriate only for Aquatic Life evaluations, not for Human Health evaluations.

In evaluating Aquatic Life exposure, ENVIRON employed a conservative DAF and did not use the Shellpot Creek flow estimates. This approach assumes that benthic organisms would receive exposures to groundwater prior to extensive mixing with surface water, and is a more protective approach than even using the 7Q10.

In consideration of these points, Appendix M has been revised to use flow statistics for Shellpot Creek calculated from measured stream flows at the United States Geological Survey (USGS) gage in Wilmington, which is upstream of the site. In accordance with DNREC guidance (DNREC, 2004), the harmonic mean flow was employed for Human Health evaluation for carcinogens, and 30Q5 flow was employed for Human Health evaluation of non-carcinogens when determining dilution factors. Rather than employ the 7Q10 flow for Aquatic Life, DuPont chose to use a more conservative AF₁, in consideration of the benthic nature of potential receptors.

DNREC Comment 7 – Section 3.5.2 Comparison of Organic COCs to Screening Criteria:

This section states that, “Total PCB concentrations [in surface water samples] ranged from 24,700 picograms per liter (pg/L) upstream of the Sludge Drying Site (DNREC location I-495 to Wires) to 11,708 pg/L (SI location SC-2). However, individual PCB congener and dioxin/furan distribution patterns generally differed from the IRM ‘fingerprint’ as defined in Section 3.2.2.” It is true that the PCB and dioxin/furan fingerprints in the surface samples differ from that of pure, 100% IRM. However, the presence and dominance of PCB-209 in water samples collected between the tide gate and mouth of the Shellpot is unmistakable (Greene, 2008e). The PCB

¹⁹ DNREC. 2005. *Total Maximum Daily Loads (TMDLs) Analysis for Naamans Creek, Delaware*. Watershed Assessment Section, Division of Water Resources, Delaware Department of Natural Resources and Environmental Control Dover, Delaware. October.

fingerprint of the surface water at this location represents a mixture between the PCB fingerprint of the IRM and non-IRM PCB. Furthermore, the concentration of PCB-209 in the water sample collected between the tide gate and mouth by DNREC in the Fall of 2007, 757 pg/L, exceeded the human health criterion of 64 pg/L by itself, independent of any other congeners in the sample.

DuPont Response to DNREC Comment 7:

The focus of this evaluation is on the Staged IRM. Results demonstrate that the Staged IRM is not an ongoing source of organic constituents to the surface-water body. The updated exposure and risk evaluation and site-specific transport modeling support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials.

The significance of current detections in Shellpot Creek, relative to the Sludge Drying Site, is unclear at this time and warrants further study. The site is located at the confluence of Shellpot Creek and the Delaware River, and both water bodies experience tidal ingress and egress behavior with water freely mixing between the two surface-water bodies. Organic constituents detected in Shellpot Creek are also detected in the Delaware River, where multiple different sources may have contributed the same compounds. Furthermore, Shellpot Creek surface-water and sediment data collected upstream of the DuPont Property and the tide gate (as part of the Hay Road Landfill Post Closure Care monitoring permit) document historical and current upstream exceedances for PCBs and metals (including iron).

DNREC Comment 8 – Section 3.6.2 Comparison of Organic COCs to Screening Criteria:

This section notes that, "...individual PCB congener and dioxin/furan distribution patterns generally differed from the IRM 'fingerprint' as defined in Section 3.2.2. OCDF was detected at lower concentrations than OCDD, and PCB 209 did not dominate the total PCB mass present." Again, although it's true that the PCB fingerprint for sediments collected below the tide gate are not 100% derived from the IRM, it is perfectly clear that IRM has been incorporated into these sediments. As for the surface water sample collected at the same location, the PCB fingerprint for the sediments collected between the tide gate and the mouth represents a mixture between the fingerprint of the IRM and PCBs on non-IRM origin.

DuPont Response to DNREC Comment 8: See response to DNREC Comment 7.

DNREC Comment 9 – Section 3.8 Biota: The second paragraph in this section needs to be completely rewritten since it is largely inaccurate and incomplete. Here are some facts related to the Shellpot Creek fish tissue sampling conducted by DNREC in the October of 2007:

- a. These samples were collected in support of several different DNREC programs, including: TMDLs, fish advisories, waste site cleanup, and natural resource damage assessment.
- b. Fish tissue samples were collected at 6 stations throughout the Shellpot Creek, spanning the entire watershed from its headwaters down to the reach between the tide gate and the

mouth. No sample was collected from the Delaware River as a part of that work as indicated in the text of DuPont's report.

- c. Based on availability, small whole body fish were collected and analyzed from some stations, while separate fillet and remains samples were collected and analyzed from other stations. The stations with separate fillet and remains results were combined based upon their relative masses and concentrations to calculate contaminant concentrations in the whole body of the fish. This allowed comparison of contaminant concentration on a whole body basis across the watershed.
- d. A preliminary assessment of the data indicates that Total PCB in whole body fish ranged from 40.5 ppb ww (Cardiff Park, headwaters) to 2,782 ppb ww (below I-495). Concentrations increase from Lea Blvd to the 'below I-495' station, then decline to the 'tide gate to mouth' station.
- e. The concentration of PCB-209 in the 'tide gate to mouth' fish sample is much higher than in any of the other samples. The PCB fingerprint for this sample reflects the accumulation of PCB-209 in fish associated with the release of the IRM to the lower Shellpot Creek. Again, the PCB fingerprint in the fish at this station is not identical to 100% IRM. Rather, the fingerprint in the fish at this station reflects a mixture between that of the IRM and that of non-IRM PCB.
- f. The concentration of dioxin and furan TEQs in whole body fish increased from 0.29 pg/g ww (Cardiff Park, headwaters) to 4.25 pg/g ww (tide gate to mouth sample). Dioxin (2,3,7,8-TCDD) was detected in all 3 samples downstream of Governor Printz Blvd, but not in the samples upstream of Governor Printz Blvd.
- g. Fingerprinting revealed that OCDD dominated the dioxin and furan mass in all fish samples except the one collected between the tide gate and mouth. This latter sample was composed of a broader mix of dioxins and furans than the other samples. Dioxin and furan TEQs in all of the fish samples were dominated by lower molecular weight dioxins, particularly 1,2,3,7,8-PeCDD. OCDF, which is a dominant congener in IRM, contributed an extremely small percentage (<0.01%) of the dioxin and furan TEQ in all of the fish samples, including the one collected between the tide gate and mouth.

DuPont Response to DNREC Comment 9:

Although COCs have been detected in fish tissues in the tidal portion of Shellpot Creek adjacent to the site, the low proportion of site-related to non-site related constituents present indicates that these constituents are related not only the site but to regional sources as well. Tidal water from the Delaware River that mixes with the water from Shellpot Creek along with potential upstream sources in Shellpot Creek may be responsible for the presence of constituents not found in Staged IRM. The significance of current detections in Shellpot Creek fish tissue samples, relative to the Sludge Drying Site, is unclear at this time and warrants further monitoring.

DNREC Comment 10 – Section 5.2 Site-Specific Groundwater to Surface Water

Evaluation: In addition to the detailed comments presented on this section in comment 3 above, the following comment is also made. On page 35, the statement is made that "...unlimited COC concentrations could be present in the capped IRM Pile and still not result in an exceedance of

risk-based AWQC in Shellpot Creek or the Delaware River." It is strongly advised that this statement be revised or removed because it is presumptuous and not universally true (e.g. if NAPL were present, which it isn't).

DuPont Response to DNREC Comment 10: The draft RI/RA Report Addendum Section 5.2 has been revised as requested, and the content from that section is designated Section 6.3 in the final RI/RA Report Addendum.

COMMENTS BY DNREC FROM DATA REPORT EVALUATION, DNREC-SIRB OCTOBER 2008

(Last attachment to DNREC's November 20, 2008 letter)

DNREC Comment 11: Sampling findings are in general in concurrence with DNREC evaluation of the data in regards to the contaminants of concern. This information is presented in detail in Appendix I. However, tables summarizing the COCs per each specific media have omitted some of the COCs (i.e. total PCBs) already identified in the Appendix tables. A revision of these summary tables and Figure 16 is needed for consistency.

DuPont Response to DNREC Comment 11: Figure 16 of the draft RI/RA Report Addendum has been revised to correct discrepancies noted with Table 4 and Appendix I of the report and is now referenced as Figure 4-1 in the final RI/RA Report Addendum. Revision of Table 4 was not necessary as all constituents detected above URS screening criteria are indicated, including total PCBs.

DNREC Comment 12: DNREC disagrees with DuPont in regards to the conclusions that elevated concentrations of some COCs (iron, manganese) are because of a regional background. DNREC believes that elevated iron concentrations in the sampled media have been increased as a direct contribution of the iron rich material. This statement is based on evaluation of historical data and regional data for iron.

DuPont Response to DNREC Comment 12: There is strong evidence that the Staged IRM is not the source of significant quantities of iron in Shellpot Creek or other media. A detailed discussion is provided in the document entitled, "Evaluation of Iron in Staged IRM and Dredge Material" (Attachment 1 of this document).

DNREC Comment 13: A preliminary assessment of the human health risk appears to have been performed correctly. However, a detail review is being performed. However, the ecological risk assessment needs to be expanded and should include evaluation of available fish data for the Shellpot Creek and the Delaware River.

DuPont Response to DNREC Comment 13: The updated exposure and risk evaluation and site-specific transport modeling support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials.

Although COCs have been detected in fish tissues in the tidal portion of Shellpot Creek adjacent to the site, the low proportion of site-related to non-site related constituents present indicates that these constituents are related not only to the site but to regional sources as well. Tidal water from the Delaware River that mixes with the water from Shellpot Creek, along with potential upstream sources in Shellpot Creek, may be responsible for the presence of constituents not found in Staged IRM. The significance of current detections in Shellpot Creek fish tissue samples, relative to the Sludge Drying Site, is unclear at this time and warrants further monitoring.

DNREC Comment 14: The impact of historical releases to the environment is not fully addressed. One option would be to address this through Natural Resource Damage Assessment (NRDA) as a separate item and it should be stated in the report as such.

DuPont Response to DNREC Comment 14: The focus of the SI and the final RI/RA Report Addendum is the Staged IRM. Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPR, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity, should such monitoring demonstrate the necessity of further action.

DNREC Comment 15: Discussion presented in Section 4 of the report in regards to potential for wind-dispersed material needs to be revised to include results of potential historic release assessment report performed by DuPont.

DuPont Response to DNREC Comment 15: The third paragraph in Section 4 on page 30 of the draft RI/RA Report Addendum refers the reader to Sections 4 and 5 of the 2004 RI/RA report (Appendix D of the draft RI/RA Report Addendum), which contain the results of the potential historic release assessment. This information is also contained in Appendix D of the final RI/RA Report Addendum.

DNREC Comment 16: Percentile contributions of organics contaminants, especially PCBs and dioxin/furans to the ambient media are higher than initial estimate. Although below the USEPA

guidance criteria for remedial action, recent data shows a higher contribution of PCBs and dioxin/furan compounds to the surface water and sediments for the Shellpot Creek and Delaware River. (Before contribution was estimated to be less than 1%. Using current data, it is estimated at about 10%). Therefore, it is DNREC opinion that the IR pile has contributed at a higher percentage to the historic contamination found in the Shellpot Creek and the Delaware River.

DuPont Response to DNREC Comment 16: See response to DNREC Comment 7.

DNREC Comment 17: Discussion of organic COCs to screening criteria for the iron rich and dredge materials omits TEQs results. This information is important to determine any exceedances of the TEQs action levels.

DuPont Response to DNREC Comment 17: A discussion of TEQs is found in Appendix M of the final RI/RA Report Addendum.

DNREC Comment 18: The modeling results to demonstrate leaching and migration of IRM material from the pile to surface water bodies needs to be complemented with mass loading calculations based on site conditions without a permanent cap.

DuPont Response to DNREC Comment 18: The requested mass-loading calculations are contained in Section 4.6 of the final RI/RA Report Addendum.

DNREC Comment 19: Related to the above comments, further clarification is needed on the following items. If possible, data available needs to be used to support the discussions.

- Presence of sand lenses in the dredge material.
- Marsh deposits isolation from the Water Bearing Zone to the first aquifer zone.
- Influence of the potentiometer head in the PILE-1 well by precipitation events, indicating the percolation through the IR and DM during rain events.
- Ecological setting (p 15). It should consider aquatic life in the adjacent area of the pile. Now, it focuses on wildlife in the footprint of the site only.

DuPont Response to DNREC Comment 19:

- As stated in Section 3.2.2 of the final RI/RA Report Addendum, thin, discontinuous sand lenses were observed in the cut face of the DM along the Delaware River, and the presence of these lenses was confirmed in the SI and historic borings, which are presented in Appendices E and F, respectively.
- As stated in Section 3.2.4 of the final RI/RA Report Addendum, the DM:LPU ranges from approximately 20 feet thick in the western portion of the site to approximately 60 feet thick in the eastern portion of the site (Woodward-Clyde, 1990²⁰). This

²⁰ Woodward-Clyde Consultants. 1990. Geotechnical Investigation Proposed Cell No. 4 Cherry Island Landfill.

thickness of low-permeability material serves to isolate the First Aquifer from the DM:WBU.

- ❑ Precipitation data have been plotted prominently as an overlay to the monitoring well tidal-study hydrographs on Figures 2-7a and 2-7b (formerly designated 10a and 10b) of the final RI/RA Report Addendum to illustrate that precipitation did not impact the potentiometric surface of the DM:WBZ during the tidal study.
- ❑ Section 2.8 of the draft RI/RA Report Addendum has been revised (now Section 3.8) to include a description of aquatic life in Shellpot Creek and the Delaware River.

DNREC Comment 20: DNREC evaluation of COCs and Organic Contaminants

Dioxins and furans found to be below the USEPA guidance action levels of 5 to 20 ppb for commercial use. However, contribution of these contaminants to the total ambient contamination is higher than initially estimated.

Total PCBs are above URS levels and therefore are COCs. This information is not clearly presented in the text and Figure 16 for the different media.

Deca-PCBs contribution to the total PCBs in sediment is higher than previously estimated. Contribution is up to 11.8% to the total PCBs detected in Shellpot Creek and up to 12.3% contribution to the total PCB in the Delaware River. Note that contribution of deca-PCBs to the total concentration of PCBs in an upstream sample in Shellpot Creek (Rt. 495) is about 0.1%.

The concentration of total PCBs in fish tissue has in general a similar "behavior" than concentration found in sediments. For fish tissue, the contribution of deca-PCBs to the total concentration of PCBs is 3.44% for the sample collected at the Tide-Gate-Mouth (downstream) and less than 1% for all the other samples collected along the Shellpot Creek (upstream).

Hexachlorobenzene determined not to be a NAPL, although detections in the IR material are above URS values for human health and below URS values for the environment.

DuPont Response to DNREC Comment 20:

DuPont has revised Figure 16 (now Figure 4-1) to correct discrepancies regarding identification of total PCBs above URS criteria in DM:LPU. However, total PCBs are clearly identified as COCs in the text. Therefore, no revision of the text was considered necessary. Table 4 correctly reports all constituents detected above URS screening criteria for all media, including total PCBs and hexachlorobenzene.

The focus of this evaluation is on the Staged IRM. Results demonstrate that the Staged IRM is not an ongoing source of organic constituents to the surface-water body. The updated exposure and risk evaluation and site-specific transport modeling support a cap in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials.

The significance of current detections in Shellpot Creek, relative to the Sludge Drying Site, is unclear at this time and warrants further study. The site is located at the confluence of Shellpot Creek and the Delaware River, and both water bodies experience tidal ingress and egress behavior with water freely mixing between the two surface-water bodies. Organic constituents detected in Shellpot Creek are also detected in the Delaware River, where multiple different sources may have contributed the same compounds. Furthermore, Shellpot Creek surface-water and sediment data collected upstream of the DuPont Property and the tide gate (as part of the Hay Road Landfill Post Closure Care monitoring permit) document historical and current upstream exceedances for PCBs and metals (including iron).

DNREC Comment 21: DNREC evaluation of COCs: Inorganic contaminants: DNREC concurs with DuPont that elevated concentrations of iron in the groundwater are because of the historical contamination of the dredge materials. However, it is DNREC opinion that iron concentrations in the media sampled has significantly increased as a result of contribution of iron concentrations present in the iron rich material. Additional analysis of fate and transport for iron is needed to resolve this contradiction. The rationale for DNREC data interpretation is based on:

- Analysis of historical data:
 - Results of monitoring data collected as part of the monitoring program for the DuPont landfill cells show historic iron concentrations above the URS standard of 300 ug/L.
 - Iron concentrations in the wells located along the Shellpot Creek increased significantly after 1991. Concentrations were from up to 7,900 ug/L (MW33, 1977-1991) to 1,220,000 (MW-73, 2008).
 - Iron concentrations in the wells located south of the IRM show similar increase. Concentrations were from up to 23,000 ug/L (MW41, 1977-1991) to 1'210,000 (MW71, 2008).
 - There is not a significant increase in iron concentrations in the eastern monitoring well (MW36A). However, clarification is needed on whether this well represents the water bearing zone or the first aquifer unit. Currently, there is a contradiction between data reported between the RI and the data submitted to SHWMB in regards to this well.
 - This concentration pattern is in concurrence with the predominant south-north groundwater flow direction.
- Analysis of regional data:
 - Groundwater results for the Edgemoor Site II Ash Landfill located west of the IR pile show iron concentrations above the drinking water standard.
 - However, iron concentrations in the Ash Landfill are 10 times lower than iron concentrations at the IR site. Concentrations at the landfill site ranged from 42,200 ug/L in an upgradient well to 87, 300 ug/L in a downgradient well.
- Iron SPLP test:
 - Although concentrations of leachable iron from the IRM were found below the GW standard of 300 ug/L, SPLP test indicates some leaching potential of iron at concentrations below 52.2 ug/L (detection limit). Considering the mass of the IR

material in the pile, this concentration is estimated to be significant for contribution of iron from the IR material into the GW.

- SPLP test results show that iron is mobile under acidic conditions. This is reflected in the SPLP results for the dredge material, where iron is leachable at lower concentrations found in the IR pile (pH in the dredge material is above 5 and pH in the IR material is above 7).

DuPont Response to DNREC Comment 21: There is strong evidence that the Staged IRM is not the source of significant quantities of iron in Shellpot Creek or other media. A detailed discussion is provided in the document entitled, "Evaluation of Iron in Staged IRM and Dredge Material" (Attachment 1 of this document). In Section 4.5 and the new Appendix P of the final RI/RA Report Addendum, 14 years of surface-water data for iron in Shellpot Creek is presented, which documents that the upstream concentrations of iron are usually higher than the downstream concentrations.

DNREC Comment 22 Conclusions and Recommendations:

Conclusions about the modeling results that demonstrates that leaching and migration of IRM constituents from the Pile to the nearby surface water bodies would not occur at potentially significant concentrations, even if those concentrations were present at solubility limits in IRM pore water/leachate needs to be removed.

DuPont Response to DNREC Comment 22: See response to DNREC Comment 10.

DNREC Comment 23 Conclusions and Recommendations: Remedial Action Objectives: Bullet 4 to be revised to incorporate the option of performing groundwater remediation if required by the department.

DuPont Response to DNREC Comment 23: The Remedial Action Objectives have been revised and are found in Section 7.3.1 of the final RI/RA Report Addendum.

DNREC Comment 24 Conclusions and Recommendations:

Remedial Action to be revised to include the implementation of remedial action through operable units, as discussed

DuPont Response to DNREC Comment 24: Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. DuPont recommends initiation of activities to implement the PPRA, a cap-in-place remedy for the Staged IRM combined with institutional controls. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

DNREC COMMENTS FROM SIRB, DWR, and SHWMB
Draft Review of RI/RA Report Addendum
(Review dated October 2008 and given to DuPont during an October 30, 2008 meeting)

DNREC Comment 25a Executive Summary: The report states that the evaluation of additional technical information was done to verify that the cap-in place remedy selection for the Site is appropriate. This statement is not accurate. The additional information was collected to support the findings of the initial investigation, to reevaluate the risk, and to determine the appropriate remedial action for the site based on the supplementary data.

DuPont Response to DNREC Comment 25a: DuPont concurs that the new data obtained for the SI was collected to support the findings of the initial investigation, to re-evaluate the risk, and to determine the appropriate remedial action for the site based on the supplementary data. Sections 1.3 through 1.5 of the draft RI/RA Report Addendum have been modified to discuss the purpose of the SI and RI/RA evaluation. These revisions remain as Sections 1.3 through 1.5 in the final RI/RA Report Addendum.

25b Executive Summary: The report states that the results of the updates exposure and risk evaluation demonstrate that the remedy is appropriate as it is protective to human health and the environment. DNREC believes that the investigation results show a potential of an ecological risk from the site. The assessment ignores contribution of contaminants already present in the dredge material and WBZ to the environment. DNREC believes that the proposed cap -in place remedy by itself is not protective to the environment.

DuPont Response to DNREC Comment 25b: The focus of the SI and the final RI/RA Report Addendum is the Staged IRM. Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

25c Executive Summary – Background: IR as a saleable product: why to include this statement in the document?

DuPont Response to DNREC Comment 25c: The nature of IRM as a saleable product is important to understanding the site history, as this was the reason for initial staging of the IRM in the Sludge Drying Area.

25d Executive Summary – Background: PPRA for site closure: The report states that the PPRA presented the cap-in-place option as the preferable remedy for the closure of the Sludge Drying Site. This statement is not accurate. The proposed cap-in place remedy included engineering and institutional controls to ensure efficiency of the remedy during its implementation and over time. The PPRA was clear to state that additional remedial options may be required based on the results of the groundwater monitoring program.

DuPont Response to DNREC Comment 25d: DuPont has modified discussions of the PPRA to include institutional and engineering controls.

25e Executive Summary – Background: HCR 22. The resolution is missed in the discussion for supporting how the independent evaluation was required and implemented.

DuPont Response to DNREC Comment 25e: A discussion about HCR 22 has been added to the final RI/RA Report Addendum.

25f Executive Summary: Background: Data validation: This section needs to specify who performed the data validation.

DuPont Response to DNREC Comment 25f: This information has been added to Section 2.1.5 of the final RI/RA Report Addendum.

25g Executive Summary – Findings: (2nd bullet): Contribution of the iron rich pile to the contamination of dredge materials and WBZ is missing in this statement.

DuPont Response to DNREC Comment 25g: There is strong evidence that the Staged IRM is not the source of significant quantities of iron in the DM:WBZ or other media. A detailed discussion is provided in the document entitled, "Evaluation of Iron in Staged IRM and Dredge Material" (Attachment 1 of this letter).

25h Executive Summary – Conclusions: (2nd bullet): It ignores the fact that operational practices of dewatering and sludge drying that may have impacted the nature of the dredge materials prior the use of the site as an IRM staging area were conducted by DuPont. Therefore, the responsibility of DuPont as an owner and operator of this facility can not be dismissed.

(3rd bullet): The updated exposure and risk assessment does not support the cap-in-place remedy as fully protective of the environment.

DuPont Response to DNREC Comment 25h: The Executive Summary has been revised for the final RI/RA Report Addendum.

DNREC Comment 26 Report Contents and Organization: Text and Appendices to be revised to ensure consistency of data. Currently some data presented in the appendices do not match the

data summarized in the text and figures. Also, some relevant data is not presented in the appendices.

DuPont Response to DNREC Comment 26: The text, appendices, and figures have been reviewed for the final RI/RA Report Addendum. DuPont believes information presented in the appendices is consistent with the presentation in the text and figures.

DNREC Comment 27 Report Contents and Organization: Several speculative narratives and opinions need to be entirely removed from the report.

DuPont Response to DNREC Comment 27: DuPont has reviewed the entire text of the draft RI/RA Report Addendum and revised the text to respond to specific DNREC and Schnabel comments.

DNREC Comment 28 Report Contents and Organization: Section 2 is suggested to be entirely reorganized and focused on an objective reporting of the field data collection?

DuPont Response to DNREC Comment 28: Section 2 of the draft RI/RA Report Addendum has been reorganized to focus on an objective reporting of the field-data collection, as suggested, and this is presented as Sections 2 and 3 of the final RI/RA Report Addendum.

DNREC Comment 29 Report Contents and Organization: Risk assessment neglects to include the analysis of contaminants of concern already present in the dredge materials and WBZ. The impact of historical releases to the environment is not fully evaluated. One option would be to address this through Natural Resource Damage Assessment (NRDA) as a separate item and it should be stated in the report as such.

DuPont Response to DNREC Comment 29: The focus of the SI and the final RI/RA Report Addendum is the Staged IRM. Results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

DNREC Comment 30 Report Conclusions: Sufficient of the cap-in place remedy to protect human health: DNREC believes that this remedy should be sufficient to protect humans from elevated exposure to organic contaminants, in particular PCBs, dioxins and furans and hexachlorobenzene. However the fact that a permanent cap may be sufficient to control organic COCs in the future does not mean that these organic COCs were fully controlled in the past.

Sufficient of the cap-in place remedy to protect the environment: DNREC believes that the remedy by itself seems to be insufficient to fully protect aquatic life in the Shellpot Creek. DNREC mass loading calculations indicate that there is a reasonable potential for soluble iron discharged via groundwater from the first WBZ beneath the pile to cause exceedances of the water quality criterion for iron in the Shellpot Creek during low flow conditions.

DuPont Response to DNREC Comment 30: Similar to the response to DNREC comment 29 above, results from the SI support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials. Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic DM placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

DNREC Comment 31 Report Conclusions: DNREC disagrees with DuPont in regards to the conclusions that elevated concentrations of some COCs (iron, manganese) are because of a regional background. DNREC believes that elevated iron concentrations at the site and surrounding area have been increased as a direct contribution of the iron rich material. This statement is based on evaluation of historical data and regional data for iron.

DuPont Response to DNREC Comment 31: There is strong evidence that the Staged IRM is not the source of significant quantities of iron in Shellpot Creek. A detailed discussion is provided in the document entitled, "Evaluation of Iron in Staged IRM and Dredge Material" (Attachment 1 to this document) and Section 4.5 of the final RI/RA Report Addendum.

Mr. Wilmer Reyes
Department of Natural Resources and Environmental Control (DNREC)
December 11, 2008
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If you have any questions, please feel free to contact me at (302) 761-2298 or Michelle Johnson
at (302) 992-6770.

Sincerely,



Thomas S. Andersen
Environmental Manager
DuPont Edge Moor Plant

cc: File: 508705

Attachment 1: Evaluation of Iron in Staged IRM and Dredge Material (Appendix O of the
Final RI/RA Report Addendum)

Attachment 2: Review of the July 2006 WHO and NAS Reports as They Pertain to Remedy
Selection at the DuPont Hay Road Iron Rich Staging Area

Attachment 3: HELP Model Output

ATTACHMENT 1

**EVALUATION OF IRON IN STAGED IRM AND DREDGE
MATERIAL (APPENDIX O OF THE FINAL RI/RA REPORT
ADDENDUM)**

APPENDIX O

**EVALUATION OF IRON IN STAGED IRM AND DREDGE
MATERIAL**

Evaluation of Iron in Staged IRM and Dredge Material

By J.A. Dyer, Ph.D., P.E. (DuPont Engineering)
and L.D. Matson, P.G. (URS Diamond)

Many of the comments and objections provided by DNREC on the leachability of iron from neutralized Staged Iron-Rich Material (Staged IRM) and its subsequent fate and transport in groundwater below the Staged IRM appear to be based upon incorrect assumptions. Further clarification of the composition and properties of the Staged IRM as well as the site operational history confirms that the data do not support the conclusion that the staged IRM is a major contributor of iron to the underlying dredge materials (DMs) or the nearby surface water bodies.

IRM Composition

The iron-flux calculations provided by DNREC were based upon the major assumption, and an associated confirmatory molar calculation, that the composition of the Staged IRM is primarily ferric chloride. Additionally, the presence of chloride at the base of the Staged IRM at concentrations higher than those measured near the Staged IRM surface suggested to DNREC that dissolution of ferric chloride itself was occurring at the IRM/DM interface.

Although both ferrous chloride and ferric chloride were major components of the waste metal chloride liquor, calcium hydroxide (lime) was added to and mixed with the waste (changing the material into what is known as IRM) prior to its staging at the site. The Staged IRM, therefore, is a neutralized material with a pH of approximately 7-8 SU, composed primarily of a mixture of ferrous and ferric oxyhydroxide-type precipitates, not ferric chloride. Table 1 shows the expected composition of neutralized IRM, based upon the NEMODs model¹. Mixed ferrous/ferric precipitates (such as magnetite and green rust) and ferrous sulfide may form under these conditions. All of these precipitates have a lower solubility in water than either ferrous hydroxide or ferrous carbonate. This is discussed in more detail in Exhibit 1.

Calculation of the expected iron concentration of neutralized IRM, based on the stoichiometry of the simplified chemical reactions for the neutralization of ferrous and ferric chloride, is presented as Exhibit 2. Similarly, Exhibit 3 illustrates the expected composition of the neutralized IRM based on the composition predicted by the NEMODs model (see Table 1). Both calculated results fall within the general range of measured iron concentrations (235,000 to 332,000 mg Fe/kg on a dry basis) for the Staged IRM.

¹ NEMODs (North End Models) is an in-house, proprietary Microsoft Excel-based mass-balance flowsheet model of the environmental area of the titanium-dioxide manufacturing process. NEMODs performs a material balance for constituents such as ferrous and ferric chloride. These metal chloride streams are neutralized with lime and then filtered to remove solids. The filtered solids are considered Iron-Rich Material, while the aqueous filtrate is directed to on-site wastewater treatment.

Chloride Concentrations

The chloride concentrations near the base of the staged IRM are not attributable to the dissolution of ferric chloride itself, but can be explained by the IRM composition as it was emplaced. Approximately 6.4 wt% of the IRM as staged was calcium chloride, and the water content was nearly 50% (46.6 wt%). Calcium chloride is highly soluble in water, so one would expect chloride ion to readily migrate from top to bottom as water percolates downward through the Staged IRM Pile. This fact is supported by the results of a 1992 study, provided as Exhibit 4.²

Additionally, if dissociation of iron chloride was actively occurring at the IRM/DM interface, one would expect an iron concentration gradient within the Dredge Material: Low-Permeability Unit (DM:LPU) under the Staged IRM that decreased with depth below the IRM/DM interface. In actuality, iron concentrations are higher at depth within the DM.

Reductive Dissolution

One concern expressed by the reviewers was that the IRM Pile might be creating conditions conducive to leaching of iron from the DM:LPU [i.e., causing the development of a negative oxidation-reduction (redox) potential (ORP) within the DM:LPU that would lead to reductive dissolution of Fe(III) precipitates]. However, there is no evidence to indicate that the DM is oxidized, even in borings outside the IRM Pile footprint, and the presence of the IRM Pile is unlikely to change whether or not the DM:LPU is a source of iron to the underlying DM:WBZ. Humic material is present throughout the DM:LPU, as indicated by the Supplemental Investigation (SI) sample analyses [i.e., Total Organic Carbon (TOC) levels ranging from 1.5% to 5.9% by weight]. Finally, the presence of the pile may potentially serve to actually *reduce* leaching of iron from the DM by buffering the acidity of precipitation that percolates down through the neutralized IRM. As shown in Table 1, neutralized IRM contains approximately 1.5 wt% of residual alkalinity as Ca(OH)₂, which is very substantial relative to the moles per liter base necessary to neutralize pH 4.5-5.5 acid precipitation.

In addition, the groundwater in wells screened in the Dredge Material: Water Bearing Zone (DM:WBZ) has a negative ORP, meaning that the interface between the iron-containing DM:LPU and the saturated DM:WBZ represents an ideal environment for reductive dissolution of iron. There are several factors that strongly suggest that the DM:LPU material could easily account for the presence of iron within the DM:WBZ:

- ❑ There is an abundant source of iron mass within the DM:LPU itself (3-5 wt% iron).
- ❑ The DM:LPU (pH 5.5-6.5) is more acidic than the Staged IRM (pH 7-8), increasing the solubility of the ferrous iron precipitates as seen in the solubility graph in Exhibit 1.

² DuPont Environmental Remediation Services. October 19, 1992. *Iron-Rich 101 Chloride Leachability Study Report, Du Pont Edge Moor Facility, Edge Moor, Delaware*. Wilmington, Delaware. DERS Project No. 1205.

- ❑ Conditions within the DM:LPU are conducive to reductive dissolution of iron as evidenced by the low redox potential in monitoring wells (-100 to -150 mV) and the high humic content (1.5-5.9 wt% TOC).
- ❑ Iron-reducing bacteria are ubiquitous in nature.
- ❑ Groundwater within the DM:WBZ is in contact with the iron-bearing DM:LPU.
- ❑ Likely controls on the solubility of ferrous iron that is generated by bacterial reduction of ferric iron at the wet interface between the DM:LPU and DM:WBZ are ferrous sulfide, ferrous carbonate, and green rust. Over the pH range 5.5-6.5, the solubility of these three precipitates can be as low as 1 ppm to as high as 500 ppm (see Exhibit 1), without even considering the contributions of historical operational practices and complexation of iron with dissolved organic carbon.

Iron Mass-Flux Calculation

The potential mass flux of iron from the IRM into the DM:WBZ for the 11 years since emplacement of the Staged IRM began was calculated based on the seepage rate determined from the HELP model (assuming uncapped conditions) and the results of Synthetic Precipitation Leaching Procedure (SPLP) analysis of the Staged IRM. The mass-flux estimate is simply the product of the liquid seepage rate (through the IRM/DM:LPU), the assumed iron concentration in the liquid (determined from the Staged IRM SPLP results), and the time (age of the IRM Pile).

Assuming an uncapped pile, the HELP model yields a seepage rate through the IRM and DM:LPU of 8.33×10^{-9} feet per second (ft/sec) (see Appendix M). The footprint of the Staged IRM pile is 15.9 acres, so the total seepage per year through the IRM Pile is 5.77×10^{-3} cubic feet per second (1.82×10^5 cubic feet per year, 1.36×10^6 gallons per year, or 5.16×10^6 liters per year).

Iron was not detected in the SPLP leachate at a detection limit of 52.2 micrograms per liter ($\mu\text{g/l}$), and DNREC requested the use of $\frac{1}{2}$ the method detection limit (MDL) (26.1 $\mu\text{g/l}$) for this calculation. However, to maintain consistency with the conservative assumptions presented in Appendix M of the RI/RA Addendum, the iron detection limit of 52.2 $\mu\text{g/l}$ has been assumed as the concentration in the liquid potentially migrating through the IRM/DM:LPU.

The estimated total iron flux from the IRM into the DM:WBZ is 269 grams per year (g/yr) [0.594 pounds per year (lbs/yr)]. Over the 11 years of the IRM Pile's existence, the total iron contribution from the IRM has been 2.96 kilograms (6.53 pounds).

Conclusion

Based upon the lines of evidence available, the presence of the Staged IRM has not contributed significantly to the concentrations of iron within the DM:WBZ or Shellpot Creek. More likely sources of these elevated iron concentrations include pre-existing conditions of the DM as emplaced, historical operational practices, and/or reductive dissolution of iron from the DM:LPU at its interface with the DM:WBZ.

References

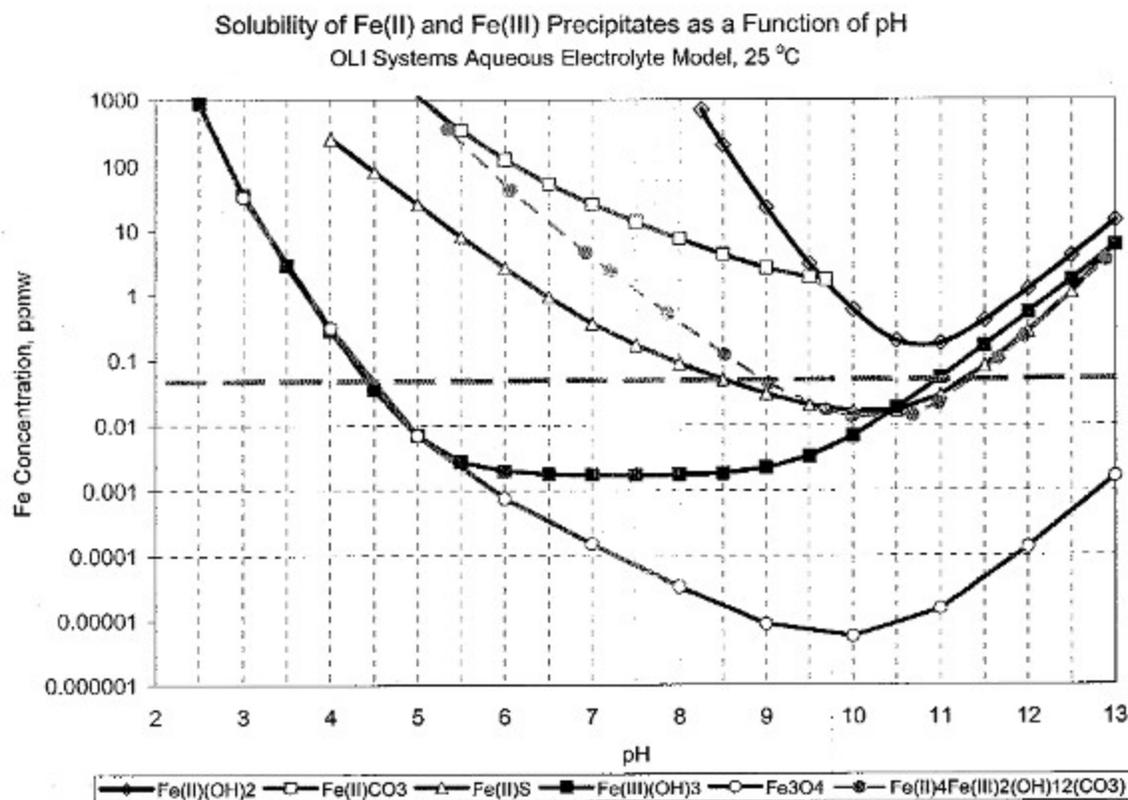
- Drissi, S. H.; Refait, Ph.; Abdelmoula, M.; and Génin, J.M.R. 1995. "The Preparation and Thermodynamic Properties of Fe(II)-Fe(III) Hydroxide-Carbonate (Green Rust 1); Pourbaix Diagram of Iron in Carbonate-Containing Aqueous Media." *Corrosion Science*. Vol. 37, No. 12, pp. 2025-2041. Elsevier Science Ltd. ISSN 0010-938X doi:10.1016/0010-938X(95)00096-3.
- DuPont Environmental Remediation Services. October 19, 1992. *Iron-Rich 101 Chloride Leachability Study Report, Du Pont Edge Moor Facility, Edge Moor, Delaware*. Wilmington, Delaware. DERS Project No. 1205.
- Williams, Aaron G. B.; and Sherer, Michelle M. 2001. "Kinetics of Cr(VI) Reduction by Carbonate Green Rust." *Environmental Science & Technology*. Vol. 35, No. 17. Publication Date (Web): August 1, 2001. doi:10.1021/es010579g

Table 1
IRM Composition from NEMODs Model

Basis 18 tph with 100% Va Blends	lb/hr Flows	
	Unwashed Cake	%
<i>Crystalline Solid Phase</i>		
Carbon	1097	2.7%
1 TiO ₂	831	2.1%
3 Al ₂ O ₃	107	0.3%
9 P ₂ O ₅	46	0.1%
10 SiO ₂	513	1.3%
12 ZrO ₂	215	0.5%
<i>Amorphous Solid Phase</i>		
Ti(OH) ₄ (from soluble Ti)	79	0.2%
Al(OH) ₃ (from soluble Al)	62	0.2%
Purif. inerts & Sulfur	1463	3.7%
FeOOH	4026	10.0%
Fe(OH) ₂	8310	20.7%
Ca(VO ₂ (OH) ₂) ₂	225	0.6%
Mn(OH) ₂	1144	2.9%
Ca(OH) ₂	601	1.5%
<i>Aqueous Solution Phase</i>		
CaCl ₂	2555	6.4%
H ₂ O	18667	46.6%
TOTAL (lb/hr)	40065	100.0%
<i>Solid Phase Properties</i>		
insoluble solids (lb/hr)	18831	
wt% solid insoluble	47.0%	

Exhibit 1 Iron-Rich Material NEMODS Model Composition

The neutralization reactions shown above for ferrous and ferric chloride are representative of the overall reaction stoichiometry for IRM; however, very low iron leachate concentrations ($< 52 \mu\text{g/L}$) obtained in SPLP tests indicate that mixed Fe(II) and Fe(III) precipitates of low solubility are most likely controlling iron solubility. The graph below shows the solubility curves for a number of Fe(II) and Fe(III) precipitates in pure water as a function of pH at 25 °C. The pH range from 7 to 8 is highlighted to represent the measured pH range of IRM. Also noted on the graph is a horizontal line at $52 \mu\text{g/L}$.



J. A. Dyer, DuPont Engineering

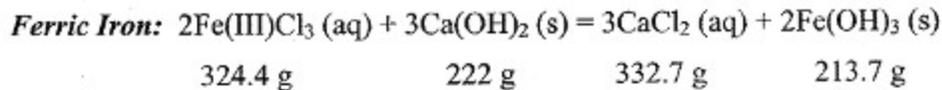
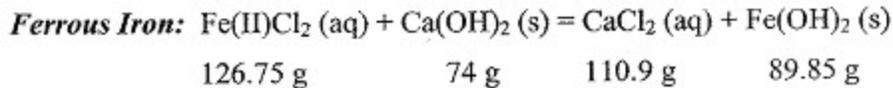
As is evident in the graph, the solubility curves for $\text{Fe}(\text{OH})_2$ and FeCO_3 lay well above the $52 \mu\text{g/L}$ SPLP line over the pH range 7-8; therefore, it is more likely that a combination of $\text{Fe}(\text{II})\text{S}$ and one or more of the mixed redox state iron oxides and oxyhydroxides will limit ferrous iron solubility. In addition, unreacted excess lime or calcium carbonate will help buffer the IRM to infiltrating acid rain over an extended time period. As shown in the NEMODS Model output, sulfur is present in the IRM, and under low redox potential conditions, sulfide sulfur will be present. Previous geochemical modeling of water analysis data for typical monitoring wells around the Hay Road site indicates that $\text{Fe}(\text{II})\text{S}$ is above the saturation point and will precipitate.

Examples of the mixed ferrous-ferric precipitates include the green rust compounds and magnetite [$\text{Fe(II)Fe(III)}_2\text{O}_4$ or Fe_3O_4]. The fact that the unneutralized iron chloride liquor is a 1/3 Fe(III) and 2/3 Fe(II) mixture to begin with makes the existence of these mixed redox state iron compounds entirely feasible. Magnetite is very insoluble and could easily account for low Fe(II) solubility over an extended pH range. Green rust compounds are somewhat more soluble, but could also be limiting Fe(II) solubility to some extent under neutral to slightly alkaline conditions. Green rust compounds are iron hydroxide carbonate, iron hydroxide sulfate, or iron hydroxide chloride intermediates that exist along the oxidation pathway from pure ferrous to pure ferric iron. More specifically, they are layered double hydroxides where octahedral sheets of Fe(OH)_2 are substituted with Fe^{3+} , and the charge is neutralized by interlayer anions, such as chloride (Cl^-), carbonate (CO_3^{2-}), or sulfate (SO_4^{2-}) ions. Further oxidation of green rust compounds leads to the more stable magnetite and FeOOH precipitates (FeOOH is not shown in the graph above, but its solubility curve falls below that of Fe_3O_4).

Additional information on green rust may be found in Drissi, *et al.* (1995) and Williams and Scherer (2001).

Exhibit 2
Iron-Rich Material
Stoichiometry of Neutralization Reactions

The two neutralization reactions, which largely determine the overall composition of the Iron-Rich Material (IRM), are:



From these two reactions, one can calculate the expected iron concentration in the neutralized IRM. Assuming that unneutralized metal chloride liquor is 1/3 Fe(III)Cl₃ and 2/3 Fe(II)Cl₂ on a mass basis:

Ferrous: $55.85 \text{ g Fe} / (110.9 + 89.85 \text{ g sludge}) \times 10^6 = 278,000 \text{ mg Fe(II)/kg}$

Ferric: $((55.85)(2) \text{ g Fe}) / (332.7 + 213.7 \text{ g sludge}) \times 10^6 = 204,000 \text{ mg Fe(III)/kg}$

IRM Blend: $(1/3)(204,000) + (2/3)(278,000) = \underline{\underline{253,333 \text{ mg Fe/kg IRM}}}$ on a dry basis

This value falls within the measured range of iron concentrations in the IRM: 235,000 mg/kg near the top of the pile to 332,000 mg/kg near the bottom of the pile.

Exhibit 3
Iron-Rich Material
NEMODs Model Composition

An analysis similar to that of Exhibit 2 (Stoichiometry of Neutralization Reactions) can be completed using the IRM composition predicted by the NEMODs Model.

FeOOH: 10 wt% FeOOH x 55.85 g Fe/88.85 g FeOOH x 10⁴ = 62,857 mg Fe(III)/kg on a wet basis

Fe(OH)₂: 20.7 wt% Fe(OH)₂ x 55.85 g Fe/89.85 g Fe(OH)₂ x 10⁴ = 128,665 mg Fe(II)/kg on a wet basis

Total Mass (Wet Basis): 191,522 mg Fe/kg on a wet basis

Total Mass (Dry Basis): 191,522/(1 - 0.466) g dry/g wet = **358,700 mg Fe/kg** on a dry basis

This value falls at the upper end of the measured range of iron concentrations in the IRM: 235,000 mg/kg near the top of the pile to 332,000 mg/kg near the bottom of the pile.

EXHIBIT 4

***IRON-RICH 101 CHLORIDE LEACHABILITY STUDY REPORT,
DU PONT EDGE MOOR FACILITY, EDGE MOOR, DELAWARE.
DU PONT ENVIRONMENTAL REMEDIATION SERVICES
OCTOBER 19, 1992***

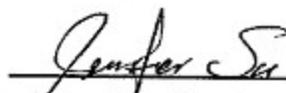
**IRON-RICH 101 CHLORIDE
LEACHABILITY STUDY REPORT**
Du Pont Edge Moor Facility
Edge Moor, Delaware

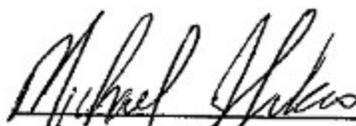
October 19, 1992

DERS Project No. 1205

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APPENDIX

**Appendix A Catalogue Description of Flexible-Walled Permeameter
and Control Panel**

1.0 INTRODUCTION

The purpose of this report is to discuss the results of a chloride leachability study performed on Iron-Rich 101. The primary objective of this study was to determine the dissolved chloride concentration in the drainage system on a monthly and annual basis by coupling the results from the pore flush study with the Hydrologic Evaluation of Landfill Performance (HELP) model.

This leachability study was completed in accordance with the Du Pont Environmental Remediation Services *Iron-Rich 101 Chloride Leachability Study Work Plan* dated July 1, 1992. This report presents the laboratory procedures used and the results and conclusions of the study.

2.0 BACKGROUND

Iron-Rich 101, a solid product containing a relatively high concentration of chloride, is proposed for use as a capping material at the Cherry Island Landfill. During rainfall events, it is expected that the chlorides will be washed from the Iron-Rich material and carried into the surface water collection system to be discharged through future National Pollutant Discharge Elimination System (NPDES)-permitted outfalls into the Delaware River and Shellpot Creek.

An extensive study on the kinetics of chloride removal from Iron-Rich 101 was completed by the University of Delaware. This study shows that the desorption of chlorides from Iron-Rich 101 is a first-order nonchemical kinetic related process. This study also indicated that

- The rate of the chloride removal decreased with number of flushes.
- No chemical reactions occurred during the course of the study.

Based on the results of the kinetic study, a leachability evaluation was designed using a flexible wall permeameter and the HELP model to determine the maximum dissolved chloride concentration that can be transported into an NPDES-permitted outfall during individual rainfalls.

3.0 SAMPLE COLLECTION

The Iron-Rich 101 was obtained from the Edge Moor plant. These samples were delivered to the laboratory one day prior to the experiment. The Du Pont Engineering Testing Center (ETC) analyzed the material for total chloride content. Results from this analysis provided the total chloride concentration occurring in the Iron-Rich 101 material prior to being flushed.

4.0 LABORATORY PROCEDURE

4.1 PORE FLUSH STUDY

In the laboratory, the leachability study was performed on the following two types of samples:

- "as is"
- "as is/dry" samples

The "as is" sample was retrieved from the sample provided by the Edge Moor plant without further treatments. The "as is/dry" sample was prepared by drying the "as is" sample at 110°C overnight after flushing the sample with 10 flush volumes or void volumes. This was performed to simulate the wet/dry seasonal changes and evaluate the effect of drying on the removal of chloride from the Iron-Rich 101.

The sample was tightly packed into a flexible-walled permeameter. A catalogue description of this permeameter and the control panel is included in Appendix A. The permeameter is designed so that constant pressure can be applied to the top, bottom, and sides of a sample. Maintaining an equally higher pressure along the bottom and sides and a lower pressure on the top, the water is forced to flow from the bottom to the top of the permeameter. To provide a constant head drop across the soil sample, the difference between the top and bottom pressures was kept constant throughout the study.

Similar infiltration conditions for the soil samples were established by maintaining a similar rate of water flow into and out of the specimen. As expressed by Darcy's Law, flow rate is a function of cross-sectional area, pressure head, and apparent permeability of the soil. For this study, the apparent permeability of the sample changes with degree of compaction and

percent moisture; therefore, the hydraulic head applied to the samples was adjusted accordingly to compensate for these differences. Table 1 presents the hydraulic pressure applied to each sample, the resulting flow rate, and the permeability of the samples.

The water leaving the permeameter was drawn into a collector. The collector was replaced every flush until a total of 10 flush volumes or void volumes were collected. For this study, the flush volume of Iron-Rich 101 was approximated by the following equation:

$$V_v = (A) (H) (n)$$

where V_v = volume of the voids milliliter (ml)
 A = cross-sectional area of the soil sample (square inches)
 H = sample height (inches)
 n = porosity of Iron-Rich 101

The total void volume is the amount of water needed to saturate the soil sample. The total void volume of Iron-Rich 101 used in this study was calculated to be 15 ml. This is determined using a porosity of 20 percent (based on historic data), a sample height of 3 inches and a cross-sectional area of 1.54 square inches.

The water samples collected from this study were analyzed for free chloride ion concentration. A combined chloride electrode was used for this analysis. For this study, a total of three standards of 0.1, 0.01, and 1 molar sodium chloride solution was prepared to establish a calibration curve for the chloride analysis. Figure 1 depicts the chloride concentration and its corresponding response value in millivolt.

The residual chloride concentration was determined by sending the soil sample from the pore flush study to the ETC for total chloride analysis.

4.2 HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE MODEL

The HELP model was used to identify the infiltration into the drainage system through the proposed cap design at the Cherry Island Landfill. The proposed cap consists of

- A final grading layer on the waste to provide a stable base for subsequent system components.
- An impermeable layer of a 20-mil geomembrane.
- A 12-inch sand layer with a hydraulic conductivity of 1×10^{-3} centimeters per second.
- A final cover with 18 inches of soil to provide rooting depth and moisture for plant growth and 6 inches of topsoil to support vegetative growth.

See Figure 2 for the cross section of the proposed cap design, assumptions, and inputs as simulated by the HELP model.

5.0 RESULTS AND DISCUSSIONS

Table 2 presents the free chloride detected in the flush water from each of the flushes. Figure 3 is the plot of chloride concentration verses the number of flushes.

The results indicate that a majority of the chloride ions were removed from the "as is" sample during the first three flushes. The chloride concentration decreases with the number of flushes and reaches an asymptotic state after eight flushes. A similar phenomenon was observed for the "as is/dry" sample, but lower chloride concentrations were detected and the maximum chloride concentration was not reached until four flushes afterward. This is most likely due to a local equilibrium between the solids and solution having to be established prior to removal of chloride.

Table 3 demonstrates the mass balance between the initial total chloride present in Iron-Rich 101 and the total amount of chloride removed from the pore flush study. The results indicate that 72 percent of the chloride was removed during the first three flushes and a total of 91 percent chloride was removed after 10 flushes from the "as is" sample. Drying of the flushed sample drops the rate of chloride removal; however, this is expected because time is required for the chloride ions to partition from the solids into the solution. It is believed that drying the flushed sample does not inhibit the removal of chloride from the Iron-Rich 101.

Table 4 shows the monthly drainage collected from the drainage system computed from the HELP model and the corresponding pore volumes for a 1.4-square-inch-diameter soil sample. Data shows that a total of 110 ml or an equivalent of seven flushes at 15 ml per flush will be infiltrated through the

capping material after one year. It is estimated that a majority (greater than 70 percent) of the chloride can be removed three to four months after the cap is installed.

6.0 CONCLUSION

The following conclusions were drawn based on the results from this study:

- Approximately 72 percent of the chloride was removed from the "as is" sample the first three flushes. A total of 91 percent of the chloride was removed from the "as is" sample after 10 flushes.
- Drying the flushed sample drops the rate of chloride removal, but this is expected since time is required for the chloride ions to partition from the solids into the solution. It is believed drying the flushed sample does not inhibit the removal of chloride from the Iron-Rich 101.
- The HELP model results show that an equivalent of seven flushes at 15 ml per flush will be infiltrated through the capping material after one year. It is estimated that a majority (more than 70 percent) of the chloride can be removed three to four months after cap installation.

FIGURES

Figure 1
CALIBRATION CURVE FOR FREE CHLORIDE ANALYSIS

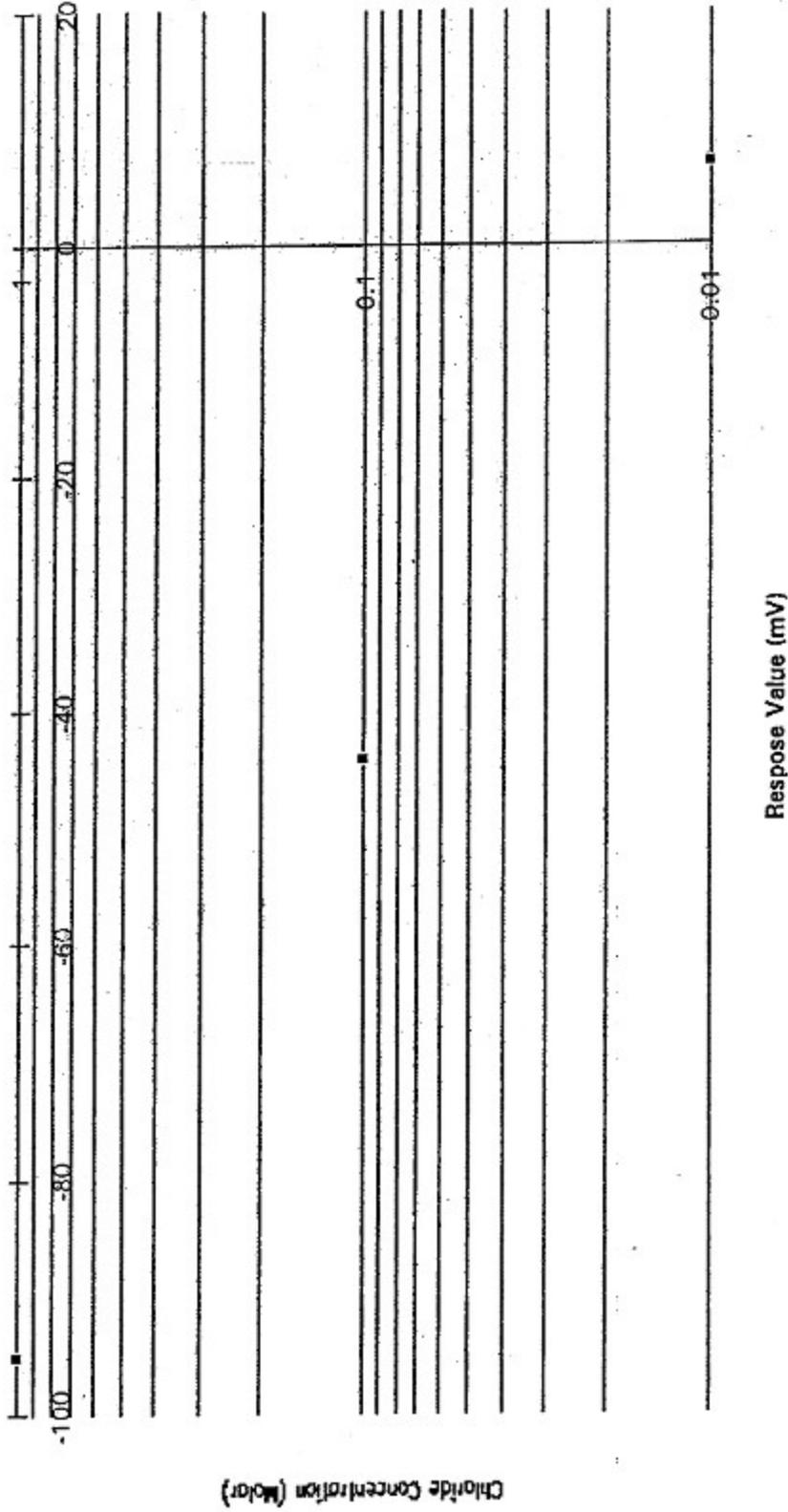
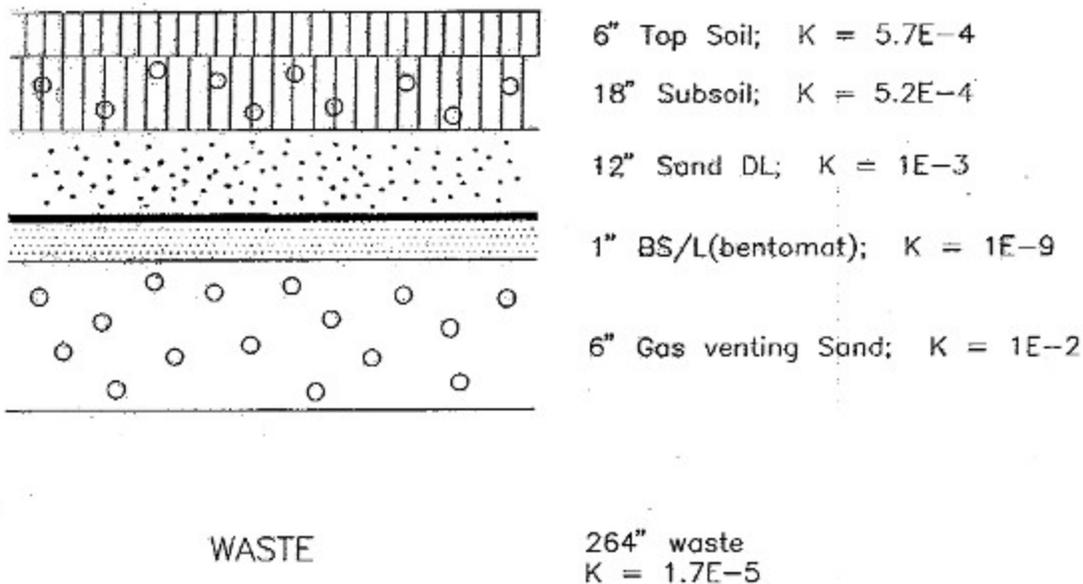


Figure 2 Assumptions, Inputs, and Cross Section for HELP Model

ASSUMPTIONS & INPUTS

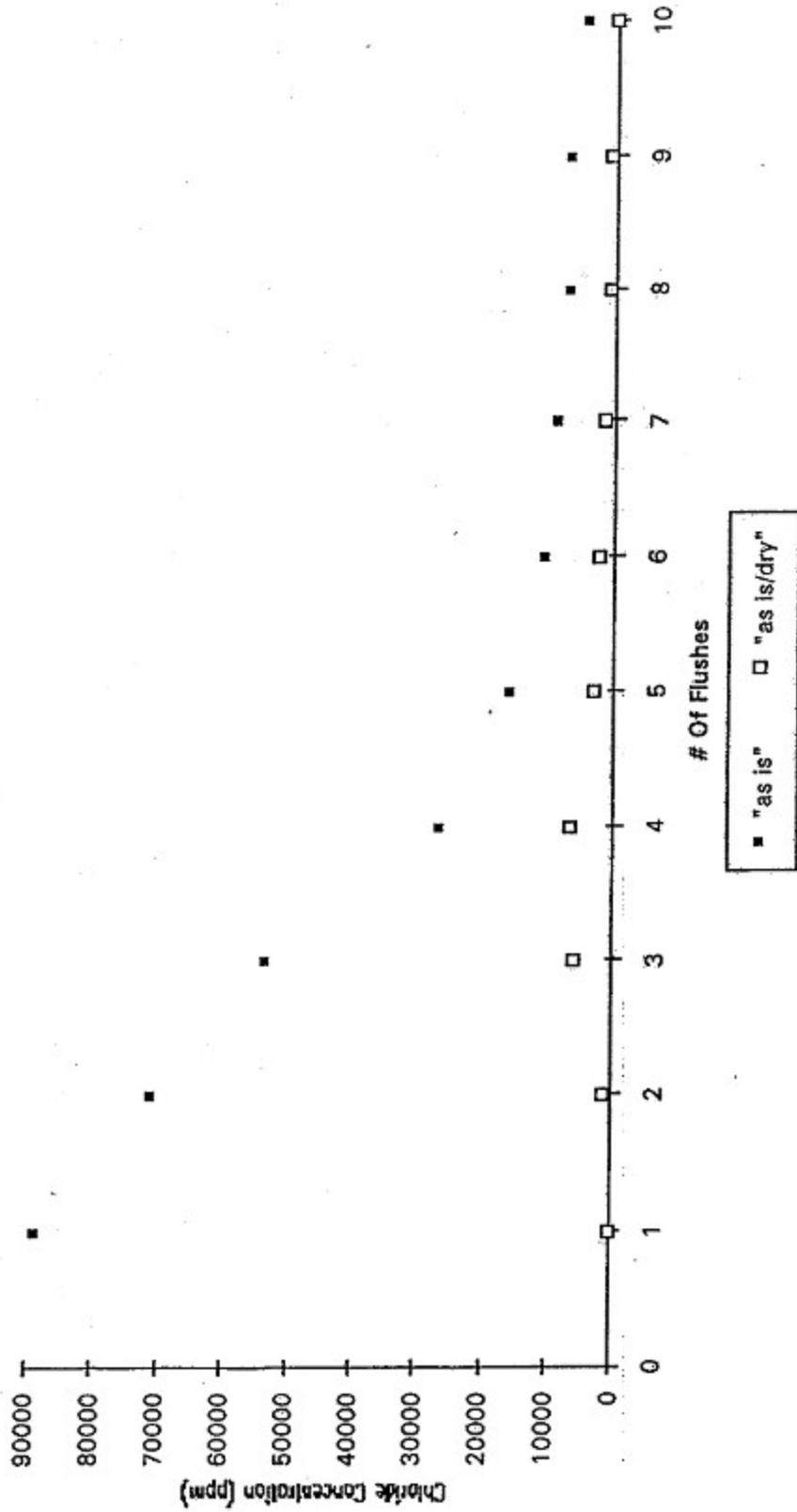
- Wilmington, DE
- 20 yrs. of precipitation data
- Max. leaf index = 2
- E.P. zone depth = 21 in
- SCS #: 72
- Fair grass
- Area = 470,448 ft
- Slope(top = 4%, bottom = 2%)
- Drainage distance = 100 ft
- Leakage fraction = 0.0002



Legend

K	Hydraulic Conductivity (cm/sec)
DL	Drainage Layer
BS	Barrier Soil
BS/L	Barrier Soil with Liner

Figure 3
CHLORIDE CONCENTRATION VS NUMBER OF FLUSHES



TABLES

Table 1

APPLIED PRESSURE HEAD, RESULTING FLOW RATE, AND
SAMPLE HYDRAULIC CONDUCTIVITY

	Run No. 1 (ps. (s ¹))	Run No. 2 (ps. (s ¹))
Pressure Head (psi)	2	1
Flow Rate (Q) (ml/sec)	0.011	0.027
Hydraulic Conductivity (K) (cm/sec)	5.90E-05	1.00E-05

Notes:

1 psi = 2.5 ft. of water.

Q is calculated by Darcy's Law .

Table 2

FREE CHLORIDE DETECTED IN FLUSH WATER

Flush No.	Accum. Pore Volume (ml)	Run No. 1 ("as is") Chloride Concentration (ppm)	Run No. 2 ("as is/dry") Chloride Concentration (ppm)
1	15	88,750.00	11.72
2	30	71,000.00	1,171.50
3	45	53,250.00	5,857.50
4	60	26,625.00	6,443.25
5	75	15,975.00	2,928.75
6	90	10,650.00	2,108.70
7	105	8,875.00	1,405.80
8	120	7,100.00	820.05
9	135	7,100.00	820.05
10	150	4,686.00	117.15

Table 3

A MASS BALANCE BETWEEN INITIAL TOTAL CHLORIDE AND TOTAL CHLORIDE REMOVED FROM PORE FLUSH STUDY

Initial Total Chloride* (mg/kg)	Total Chloride Flushed "as is" (mg/kg)	Total Chloride Flushed "as is/dry" (mg/kg)
59750	54465	6500
% Removal	91	12

* Concentration is reported on dry weight basis.

Table 4

MONTHLY DRAINAGE COLLECTED FROM
THE DRAINAGE SYSTEM AND ITS CORRESPONDING PORE VOLUME

Month	Drainage (in)	Corresponding Pore Volume* (ml)
1	0.3762	8.89
2	0.3575	8.44
3	0.4165	9.84
4	0.4759	11.24
5	0.4702	11.11
6	0.4138	9.77
7	0.3857	9.11
8	0.3440	8.13
9	0.2977	7.03
10	0.2758	6.51
11	0.2400	5.67
12	0.2905	6.86

* Pore volume is calculated based on a sample with a cross sectional area of 9.3 sq. cm.

APPENDIX

Appendix A

**CATALOGUE DESCRIPTION OF FLEXIBLE-WALLED
PERMEAMETER AND CONTROL PANEL**

FLEXIBLE WALL PERMEAMETER*

The B-K Permeability Cell has been built specifically for performing permeability tests on fine grained soils using flexible walls and back pressure saturation.

The Cell's head and base are machined from an aluminum alloy and anodized for corrosion resistance. Each Cell is supplied complete with stainless steel 2.8" cap and pedestal with porous stones.

Double drain lines at each end of the sample simplify saturation and give greater flexibility in controlling drainage, back-pressure and pore pressure measurement. Continuous teflon tubing goes directly to the end caps from the stainless steel valves, avoiding connections that are potential air traps. As an option, the Cell's valves can be plumbed with stainless steel tubing.

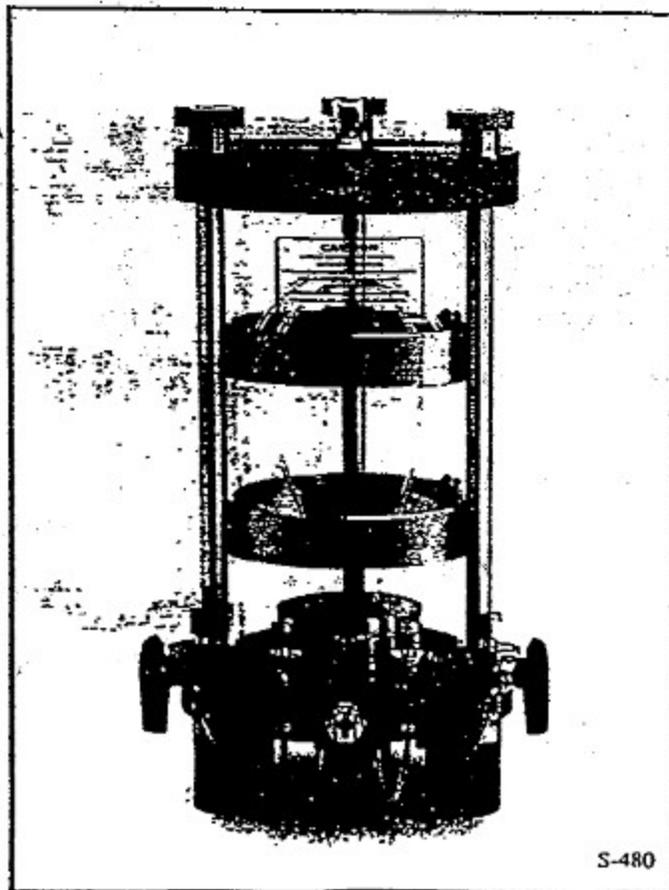
The Cell when used with the Triaxial/Perm. Panel (S-500) provides the complete system for controlling and measuring flow during the permeability tests. In addition, pore pressure transducers and digital readout device allow monitoring of the confining and pore pressures. The Permeameter comes complete as described, and includes 2.8" stainless steel cap and pedestal, 2.8" porous stones, teflon tubing, "O" rings, stainless steel valves and banding.

When using a hazardous or corrosive permeant, the B-K Bladder Accumulator (S-470) is recommended.

Shipping Weight: 16 lbs

MODEL	
S-480	Flexible Wall Permeameter
ACCESSORIES	
S-48010	4" Cap and Pedestal, S.S.
S-48020	Stainless Steel Tubing
RELATED PRODUCTS	
E-400	Digital Transducer Readout
S-470	Bladder Accumulator
S-500	Triaxial/Permeability Panel
E-124	Pore Pressure Transducer 0-150 psi

*Refer to Technical Bulletin TBS-020 for complete specifications.

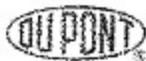


S-480

ATTACHMENT 2

**REVIEW OF THE JULY 2006 WHO AND NAS REPORTS AS
THEY PERTAIN TO REMEDY SELECTION AT THE DUPONT
HAY ROAD IRON RICH STAGING AREA**

DuPont Corporate Remediation Group
Berley Mill Plaza, 19-1272
P.O. Box 80027
Wilmington, DE 19880-0019



August 8, 2006

Hand Delivered

Mr. Wilmer Reyes
DNREC – Site Investigation & Restoration Branch
391 Lukens Drive
New Castle, Delaware 19720-2774

Subject: Review of the July 2006 WHO¹ and NAS² Reports as They Pertain to Remedy Selection at the DuPont Hay Road Iron Rich Staging Area

Dear Mr. Reyes,

Recently (July, 2006), two scientific review reports^{1,2} pertaining to dioxins were made available to the public. While neither of these reports are official regulatory guidance, they represent recent expert scientific thinking on several relevant issues on dioxins and dioxin like compounds (DLC). As such, DuPont has reviewed the information in these documents to determine if revisions to the risk evaluation and remedy selection for the Hay Road (formerly referred to as Cherry Island) Iron Rich Staging Area are warranted.

We find that the information in the recent WHO and NAS documents do not affect the choice of capping as the remedy for the following reasons.

- (1) While the WHO pre-publication includes changes in toxicity equivalent factors (TEFs), the resulting change in concentration (from 1.03 to 1.16 ppb Toxic Equivalents, TEQ) in Iron Rich is marginal and still well below the EPA's preliminary remediation goal of 5-20 ppb for commercial/industrial settings. Further, our assessments are likely conservative taking into account recommendations that TEFs not be used for abiotic media because the current TEF scheme does not take into account likely reduced cancer potency due to the fate, transport and bioavailability of some congeners like OCDD and OCDF relative to TCDD.

¹ The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds, van den Berg, et. al., ToxSci Advance Access

² Health Risks from Dioxin and Related Compounds Evaluation of the EPA Reassessment, Pre-Publication Report of the National Academy of Science, Committee on EPA's Exposure and Human Health Reassessment of TCDD and Related Compounds, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies

- (2) The NAS report makes no specific pronouncements on revising the toxicity of dioxins. However, the report is clear that EPA's use of the linear dose-response model may actually overestimate the cancer potency of dioxins and DLCs.

Additional discussion in support of the above is provided in the attached.

To re-iterate our original conclusions, the results of the revised assessment performed by ENVIRON (2005) indicate implementation of the capping option poses substantially lower potential human health risks than implementation of the excavation/off-site incineration alternative. These included hypothetical off-site exposures, construction risks and transportation risk, with specific results as follows:

- a. The calculated lifetime cancer risk and chronic noncancer Hazard Index (HI) values for hypothetical off-site exposures are both approximately 50-fold higher under the excavation alternative than under the capping remedy. The calculated subchronic HI for the excavation alternative is approximately 20-fold higher than the capping alternative.
- b. For remediation workers, construction-related risks (e.g., injuries involving on-site equipment accidents) associated with the excavation/off-site incineration alternative are approximately 2-fold higher than for the proposed capping alternative.
- c. Transportation-related risks associated with the excavation/off-site incineration alternative are approximately 150-fold higher than for the proposed capping alternative.

Please do not hesitate to call, if you need clarification on any of these points. I can be reached at 302-992-6771.

Sincerely,



Bob Genau
Principal Project Leader
DuPont Corporate Remediation Group

Attachment

cc: Qazi Salahuddin, DNREC
Tom Andersen, DuPont Edge Moor

**Review of the July 2006 WHO¹ and NAS² Reports as They Pertain to Remedy Selection at
the DuPont Hay Road Iron Rich Staging Area**

***The 2005 World Health Organization Re-evaluation of Human and Mammalian
Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds, van den Berg, et. al.,
ToxSci Advance Access***

Description (What it is): This document is an advance copy of a peer review journal article to be published in the Journal ToxSci, the official journal of the Society of Toxicology. This pre-publication provides the results of a June 2005 WHO-IPCS expert meeting that was held in Geneva during which the toxic equivalency factors (TEFs) for dioxin like compounds, including some polychlorinated biphenyls (PCBs), were re-evaluated. While members of the panel were from several regulatory agencies (including the USEPA, FDA), there is a clear disclaimer that the results are those of the individual members of the panel and not the policy of the respective agencies. Hence, while the changes suggested in the report may be adopted in the future, they are not current policy of any regulatory agency. The following discussion relating to the use of these factors for the Hay Road Staging Area is, therefore, theoretical and has no regulatory consequence.

Summary of key points as it relates to the Hay Road evaluation: Polychlorinated dibenzodioxins (PCDD), dibenzofurans (PCDF) and biphenyls (PCB) congeners with a 2,3,7,8 chlorine substitution pattern are believed to share a common mechanism of action. As a result of this generally accepted "additivity", the toxic equivalency concept was developed during the mid 1980s. It uses the relative effect potency (REP) determined for individual PCDD, PCDF and PCB compounds for producing toxic or biological effects relative to a reference compound, usually 2,3,7,8-TCDD. The total Toxic Equivalent (TEQ) is defined by summing the products of the concentration of each compound multiplied by its TEF value. Hence, the TEQ represents an

¹ The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds, van den Berg, et al., ToxSci Advance Access

² Health Risks from Dioxin and Related Compounds Evaluation of the EPA Reassessment, Pre-Publication Report of the National Academy of Science, Committee on EPA's Exposure and Human Health Reassessment of TCDD and Related Compounds, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies

estimate of total 2,3,7,8-TCDD-like activity of the mixture. While the USEPA produced an initial set of TEFs in the late 1980s, more recently the WHO has served to provide consensus TEFs with two iterations WHO-TEF₉₄ and WHO-TEF₉₈ before the current proposal.

In the current 2005 review, TEFs have been proposed for seven (7) PCDDs, ten (10) PCDFs and 12 PCBs. While most of the TEFs remained unchanged, changes were made to one (1) PCDD, three (3) PCDFs and ten (10) PCBs as follows:

- 2,3,4,7,8-pentachlorodibenzofuran (PeCDF): TEF decreased from 0.5 to 0.3;
- 1,2,3,7,8-pentachlorodibenzofuran (PeCDF): TEF decreased from 0.05 to 0.03;
- octachlorodibenzo-p-dioxin (OCDD) and octachlorodibenzofuran (OCDF): TEFs increased from 0.0001 to 0.0003;
- 3,4,4',5-tetrachlorobiphenyl (PCB 81): TEF increased from 0.0001 to 0.0003;
- 3,3',4,4',5,5'-hexachlorobiphenyl (PCB 169): TEF increased from 0.01 to 0.03; and
- a single TEF value of 0.00003 is proposed for all eight (8) relevant mono-ortho substituted PCBs. This represents a decrease for seven (7) and an increase for one (1) congener.

A key point emphasized by the expert panel (from page 28, emphasis added) is that the *“correct application of the present TEF scheme (see table 1) and TEQ methodology in human risk assessment is only intended for estimating exposure to dioxin-like chemicals from consumption of food products and breast milk, etc.”*

Further, the panel expressed concern (page 28)

“about direct application of the TEF/TEQ approach to abiotic matrices such as soil, sediment etc., for direct application in human risk assessment”.

The reason for this caution is that the current TEFs are derived largely from relative effect potency (REP) studies based on oral intake (typically in animals), often through the diet. In abiotic media, e.g., soils, the same inferences cannot be made because there are differences in both physical/chemical properties that affect the fate and transport of the different congeners in the environment as well as different matrix-specific bioavailability. These highly hydrophobic

PCDDs and PCDFs bind strongly to particulate matter (specifically organic carbon) such as soils, which significantly reduces their bioavailability for living organisms. The panel noted (page 28):

As a result, application of these WHO TEFs for calculating the TEQ for e.g., OCDD and OCDF in abiotic environmental matrices has limited toxicological relevance and use for risk assessment unless the aspect of reduced bioavailability is taken into consideration.

The panel was clear that the application of TEFs for abiotic media leads to the inaccurate assessment (likely overestimation) of risk. From page 28:

For example, direct application of these WHO TEFs for assessment of OCDD or OCDF present in soil, sediment or fly ash would lead to inaccurate assessment of the potential toxic potency of the matrix.

The panel recommends that fate, transport and bioavailability be taken into account on a congener-specific basis rather than on a TEQ basis. Otherwise, as noted above, this would lead to an inaccurate assessment of potency and risk. From page 29:

Accordingly, it is recommended that when a human risk assessment is to be done from abiotic matrices, factors such as fate, transport, and bioavailability from each matrix be specifically considered before a final estimate of the toxicological relevant TEQ is made. If a human risk assessment is done for abiotic matrices, the expert panel recognized that it would be preferable to use congener-specific equations throughout the whole model rather than base it on total TEQ in an abiotic matrix.

Effect of these changes on the Remedy Selection for Hay Road Iron Rich Staging Area: Using the TEFs in this pre-publication, the TEQ concentration in Iron Rich marginally increases from an average of approximately 1.03 ppb to 1.16 ppb. As noted in the NAS report, use of the TEQ methodology for abiotic media such as soils will overestimate toxic potency of the matrix particularly for congeners like OCDD and OCDF. OCDD and OCDF comprises greater than 90% of the dioxins and DLCs in Iron Rich. The fact that the assessments that have been performed so far, do not take into account the fate, transport and reduced bioavailability of specific congeners explicitly would lead one to conclude that the assessments overestimate potential risk in this regard. This notwithstanding, both the original TEQ level as well as those calculated with the proposed TEFs are well below the OSWER Directive (OSWER Directive

9200.4-26 Approach for Addressing Dioxin in Soil at CERCLA and RCRA Sites, 1998)
preliminary remediation goal of 5-20 ppb for commercial/industrial settings, which is appropriate
for the Hay Road Staging Area.

Further, the results of the comparison of the potential risk during remedy implementation for the
capping versus excavation/offsite incineration options are not expected to change since the
revised TEQ levels would have an equivalent effect on both options.

***Health Risks from Dioxin and Related Compounds Evaluation of the EPA Reassessment, Pre-
Publication Report of the National Academy of Science
Committee on EPA's Exposure and Human Health Reassessment of TCDD and Related
Compounds, Board on Environmental Studies and Toxicology, Division on Earth and Life
Studies***

Description (What it is): In 2004, the USEPA requested a review of its 2003 draft document
titled *Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin
(TCDD) and Related Compounds* (the Reassessment) from the National Research Council
(NRC) of the National Academies. Over many years starting in the mid 1980s, the USEPA has
focused a lot of efforts on understanding the health effects associated with 2,3,7,8-tetrachloro-
para-dioxin (TCDD) and related compounds, which had become ubiquitous in the environment.
TCDD is characterized as one of the most toxic chemicals.

The NRC report provides a critical review of the 2003 document, which is a culmination of
about two decades of effort on the part of EPA. However, the NRC report is not a risk
assessment. Hence, it does not offer alternative toxicity metrics or safe exposure levels. Instead
it provides the USEPA with guidance on how best to improve the "*scientific robustness and
clarity of the Reassessment for its ultimate use in risk management of TCDD, other dioxins, and
DLCs in the environment by federal, state, and local regulatory agencies.*"

Summary of key points as it relates to the Hay Road evaluation: The NRC report praises the EPA for its extensive and comprehensive review and analysis of the extensive scientific literature on dioxins, and DLCs.

However, the NRC found that the EPA could improve substantially on its quantitative approaches. Indeed the report questions the EPA's use of a default linear model for carcinogenicity as likely over-predicting toxicity for typical (i.e., other than occupational) exposures. From the page 4 of the Pre-publication copy:

The committee concludes that EPA's decision to rely solely on a default linear model lacked adequate scientific support. The report recommends that EPA provide risk estimates using both nonlinear and linear methods to extrapolate below PODs⁺. If background exposures to humans result in doses substantially less than the dose associated with the POD (the most likely case in most instances but perhaps not for occupational exposures), then an estimate of risk for typical human exposures to TCDD, other dioxins, and DLCs would be lower in a sublinear extrapolation model than in the linear model. Given the important regulatory implications of this assumption, the committee recommends that EPA communicate the scientific strengths and weaknesses of both approaches so that the full range of uncertainty generated by modeling of the data is conveyed in the Reassessment.

The committee was divided on whether the evidence met *all* the criteria necessary for classification of TCDD as "carcinogenic to humans," although the committee unanimously agreed on a classification of at least "likely to be carcinogenic to humans." The committee suggested that EPA re-visit this classification for TCDD as well as the "likely to be carcinogenic to humans" for DLCs, taking into account the Agency's more recent cancer guidelines of 2005.

On the issue of the TEF approach, the report supports its use but recognizes the uncertainty in environmental fate and transport of the different congeners. The report advises the Agency to

⁺ POD = Point of Departure, which corresponds to the lowest dose associated with observable adverse effects within the range of data from a study

continue to work with international organizations, like the WHO, to define the most appropriate IEFs.

The report encourages EPA to develop reference doses (with are somewhat similar to the WHO acceptable daily intake) for non-cancer effects that could be used in a margin of exposure analyses.

Effect of these changes on the Remedy Selection for Hay Road Iron Rich Staging Area: We find no effect of this report on the selection of the remedy, since the NRC report makes no pronouncement on changes to the toxicity criteria. Instead, a key finding is that the Agency's use of the default linear model may overestimate cancer risk and recommends that the Agency use alternate models to help provide more realistic estimates of cancer potency. These recommendations would suggest that our current evaluations are conservative.

Summary:

We find that the information in the recent WHO and NAS documents do not affect the choice of capping as the remedy for the following reasons.

- (1) While the WHO pre-publication includes changes in TEFs, the resulting change in concentration (from 1.03 to 1.16 ppb TEQ) in Iron Rich is marginal and still well below the EPA's preliminary remediation goal of 5-20 ppb for a commercial/industrial setting. Further, our assessments are likely conservative taking into account recommendations that TEFs not be used for abiotic media because the current TEF scheme does not take into account likely reduced potency due to the fate, transport and bioavailability of some congeners like OCDD and OCDF relative to TCDD.
- (2) The NAS report makes no specific pronouncements on revising the toxicity of dioxins. However, the report is clear that EPA's use of the linear dose-response model may actually overestimate the potency of dioxins and DLCs.

ATTACHMENT 3
HELP MODEL OUTPUT



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*****
*****
**
**
**
**          HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
**          HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)
**          DEVELOPED BY ENVIRONMENTAL LABORATORY
**          USAE WATERWAYS EXPERIMENT STATION
**          FOR USEPA RISK REDUCTION ENGINEERING LABORATORY
**
**
*****
*****
    
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PRECIPITATION DATA FILE:  C:\HELP\DATA4.D4
TEMPERATURE DATA FILE:   C:\HELP\DATA7.D7
SOLAR RADIATION DATA FILE: C:\HELP\DATA13.D13
EVAPOTRANSPIRATION DATA: C:\HELP\DATA11.D11
SOIL AND DESIGN DATA FILE: C:\HELP\DATA10.D10
OUTPUT DATA FILE:        C:\HELP\OUT7.OUT
    
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TIME: 13:41 DATE: 7/ 2/2008

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*****
TITLE: Dupont: Cherry Island - Revised on 5/27/2008 - 6 Layers
*****
    
```

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
 COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
 MATERIAL TEXTURE NUMBER 6

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4530	VOL/VOL
FIELD CAPACITY	=	0.1900	VOL/VOL
WILTING POINT	=	0.0850	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1838	VOL/VOL

EFFECTIVE SAT. HYD. COND. = 0.720000011000E-03 CM/SEC
 NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 4.90
 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 5

THICKNESS = 12.00 INCHES
 POROSITY = 0.4570 VOL/VOL
 FIELD CAPACITY = 0.1310 VOL/VOL
 WILTING POINT = 0.0580 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.2397 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 20

THICKNESS = 0.20 INCHES
 POROSITY = 0.8500 VOL/VOL
 FIELD CAPACITY = 0.0100 VOL/VOL
 WILTING POINT = 0.0050 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.0834 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 10.0000000000 CM/SEC
 SLOPE = 5.00 PERCENT
 DRAINAGE LENGTH = 520.0 FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 36

THICKNESS = 0.04 INCHES
 POROSITY = 0.0000 VOL/VOL
 FIELD CAPACITY = 0.0000 VOL/VOL
 WILTING POINT = 0.0000 VOL/VOL
 INITIAL SOIL WATER CONTENT = 0.0000 VOL/VOL
 EFFECTIVE SAT. HYD. COND. = 0.399999993000E-12 CM/SEC
 FML PINHOLE DENSITY = 1.00 HOLES/ACRE
 FML INSTALLATION DEFECTS = 3.00 HOLES/ACRE
 FML PLACEMENT QUALITY = 3 - GOOD

LAYER 5
-----TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	366.00	INCHES
POROSITY	=	0.4710	VOL/VOL
FIELD CAPACITY	=	0.3420	VOL/VOL
WILTING POINT	=	0.2100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.333000003000E-05	CM/SEC

LAYER 6
-----TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	96.00	INCHES
POROSITY	=	0.4710	VOL/VOL
FIELD CAPACITY	=	0.3420	VOL/VOL
WILTING POINT	=	0.2100	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	*	0.154000006000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 5.8% AND A SLOPE LENGTH OF 413. FEET.

SCS RUNOFF CURVE NUMBER	=	62.50	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	4.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.645	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	1.812	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.340	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	161.999	INCHES
TOTAL INITIAL WATER	=	161.999	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
WILMINGTON DELAWARE

STATION LATITUDE = 39.80 DEGREES
 MAXIMUM LEAF AREA INDEX = 4.00
 START OF GROWING SEASON (JULIAN DATE) = 107
 END OF GROWING SEASON (JULIAN DATE) = 298
 EVAPORATIVE ZONE DEPTH = 4.0 INCHES
 AVERAGE ANNUAL WIND SPEED = 9.20 MPH
 AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 67.00 %
 AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 67.00 %
 AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
 AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 71.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.11	2.99	3.87	3.39	3.23	3.51
3.90	4.03	3.59	2.89	3.33	3.54

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31.20	33.20	41.80	52.40	62.20	71.20
76.00	74.80	67.80	56.30	45.60	35.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE
AND STATION LATITUDE = 39.80 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

PRECIPITATION						

TOTALS	3.26 3.88	3.00 3.97	4.08 3.47	3.39 2.85	3.39 3.12	3.46 3.35
STD. DEVIATIONS	1.67 1.87	1.45 2.39	1.88 2.16	1.46 1.84	1.63 1.64	1.83 1.72
RUNOFF						

TOTALS	0.726 0.005	1.397 0.002	0.722 0.002	0.003 0.002	0.000 0.000	0.000 0.091
STD. DEVIATIONS	1.094 0.035	1.474 0.012	1.250 0.013	0.034 0.018	0.000 0.000	0.001 0.389
EVAPOTRANSPIRATION						

TOTALS	0.787 2.443	0.720 2.344	1.827 1.638	2.207 1.150	2.250 1.135	2.226 0.869
STD. DEVIATIONS	0.256 0.882	0.338 0.877	0.460 0.722	0.696 0.458	0.901 0.262	0.924 0.202
LATERAL DRAINAGE COLLECTED FROM LAYER 3						

TOTALS	1.5243 1.2939	0.9294 1.6719	2.1874 1.7065	1.3455 1.7123	1.1601 1.7555	1.3338 2.0340
STD. DEVIATIONS	1.3893 1.0197	0.9875 1.5793	1.5329 1.5573	0.9607 1.5695	0.8189 1.4404	1.0671 1.4400
PERCOLATION/LEAKAGE THROUGH LAYER 4						

TOTALS	0.0000 0.0000	0.0000 0.0001	0.0001 0.0001	0.0000 0.0001	0.0000 0.0001	0.0000 0.0001
STD. DEVIATIONS	0.0001 0.0001	0.0000 0.0001	0.0001 0.0001	0.0000 0.0001	0.0000 0.0001	0.0001 0.0001
PERCOLATION/LEAKAGE THROUGH LAYER 6						

TOTALS	0.0001 0.0000	0.0000 0.0001	0.0000 0.0001	0.0000 0.0001	0.0000 0.0001	0.0000 0.0001
STD. DEVIATIONS	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001

0.0001 0.0001 0.0001 0.0001 0.0001 0.0001

 AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0407	0.0116	0.0633	0.0182	0.0116	0.0349
	0.0512	0.0770	0.0932	0.0850	0.0633	0.0812
STD. DEVIATIONS	0.0986	0.0270	0.1789	0.0452	0.0281	0.0826
	0.1486	0.1791	0.1712	0.1858	0.1495	0.1986

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
	-----	-----	-----	-----
PRECIPITATION	41.20	(6.096)	149568.3	100.00
RUNOFF	2.951	(2.4074)	10713.47	7.163
EVAPOTRANSPIRATION	19.597	(2.4356)	71137.33	47.562
LATERAL DRAINAGE COLLECTED FROM LAYER 3	18.65482	(4.63284)	67717.008	45.27496
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00053	(0.00035)	1.909	0.00128
AVERAGE HEAD ON TOP OF LAYER 4	0.053	(0.039)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00053	(0.00037)	1.911	0.00128
CHANGE IN WATER STORAGE	0.000	(0.9991)	-1.39	-0.001

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.26	19093.801
RUNOFF	2.502	9081.5439
DRAINAGE COLLECTED FROM LAYER 3	1.09565	3977.20898
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000368	1.33491
AVERAGE HEAD ON TOP OF LAYER 4	15.433	
MAXIMUM HEAD ON TOP OF LAYER 4	25.806	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	84.3 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000038	0.13631
SNOW WATER	6.75	24496.1250
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4523
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0850

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.1112	0.1852
2	2.8328	0.2361
3	0.0132	0.0661

4	0.0000	0.0000
5	125.1720	0.3420
6	32.8320	0.3420

SNOW WATER 0.000

