TCEQ REGULATORY GUIDANCE
Remediation Division
RG-366/TRRP-18 ● Revised October 2008

Risk Levels, Hazard Indices, and Cumulative Adjustment

Overview of This Publication

Objectives: This guidance document provides instruction in the correct use of carcinogenic risk levels and noncarcinogenic hazard indices for effect, due to the presence of both individual and multiple chemicals of concern (COCs) when setting human health PCLs.

Audience: Regulated Community and Environmental Professionals

References: The regulatory citation for the Texas Risk Reduction Program Rule (TRRP) is Title 30 Texas Administrative Code (TAC) Chapter 350.

The TRRP rule, together with conforming changes to related rules, is contained in 30 TAC Chapter 350 and was initially published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). The rule was amended in 2007 (effective March 19, 2007; 32 TexReg 1526-1579).

Find links for the TRRP rule and preamble, Tier 1 PCL tables, and other TRRP information at: <www.tceq.state.tx.us/remediation/trrp/>.

TRRP guidance documents undergo periodic revision and are subject to change. Referenced TRRP guidance documents may be in development. Links to current versions are at: <www.tceq.state.tx.us/remediation/trrp/guidance.html>.

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Introduction

The Texas Risk Reduction Program (TRRP) rule prescribes carcinogenic risk levels and a noncarcinogenic hazard quotient/hazard index to be used in developing Protective Concentration Levels (PCLs) for chemicals of concern (COCs) which are protective of human health. This document explains the rule requirement for this subject, provides some insights that should be considered, provides a systematic process by which to comply with the rule, and provides examples to illustrate the process.

Target risk levels and hazard quotients/indices are indicated for evaluating individual COCs and combined (cumulative) impacts due to the presence of multiple COCs. Regarding individual COCs, §350.72(a) states that:

> (1) *Carcinogenic COCs.* The risk-based exposure limit (RBEL) and PCL for each carcinogenic COC, including those PCLs based on combined exposure pathways, shall be based on a carcinogenic risk level of 1×10^{-5} (1 in 100,000) except when other standards shall be

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used as RBELs as discussed in §350.74 of this title (relating to Development of Risk-Based Exposure Limits).

(2) *Noncarcinogenic COCs*. The RBEL and PCL for each noncarcinogenic COC, including those PCLs based on combined exposure pathways, shall be based on a hazard quotient of 1 except when other standards shall be used as RBELs as discussed in §350.74 of this title (relating to Development of Risk-Based Exposure Limits).

Regarding the cumulative risk level and hazard index, which is required when evaluating multiple COCs, §350.72(c) states that:

(1) *Carcinogenic COCs*. The cumulative carcinogenic risk level for multiple carcinogenic COCs shall not exceed 1×10^{-4}.

(2) *Noncarcinogenic COCs.* The hazard index for multiple noncarcinogenic COCs shall not exceed 10.

As discussed in the preamble (§350.72) (24 TexReg 2208, March 26, 1999) for the 1999 rule, the purpose of the cumulative evaluation is to determine which PCLs, if any, need to be downwardly adjusted to meet the rule requirements. Individual risk levels and hazard quotients cannot be upwardly adjusted to meet the cumulative risk level or hazard index. Specifically, the preamble states:

> *It is important to note that if multiple carcinogens or noncarcinogens are present, the individual risk level for each carcinogen or hazard quotient for each noncarcinogen can never exceed one in 100,000 or one, respectively. Therefore, individual risk levels and hazard quotients cannot be upwardly adjusted to meet the cumulative risk levels. Taking carcinogens as an example, when ten or more carcinogens are present at their one in 100,000-based protective concentrations, the allowable one in 10,000 cumulative risk level would be reached. If there are more than ten carcinogens, each at their one in 100,000-based protective concentration level, then the protective concentration level for at least one individual carcinogen will have to be downwardly adjusted to a concentration less than the one in 100,000-based value (e.g., one in 1,000,000) so that the cumulative risk of one in 10,000 is not exceeded.*

Therefore, to use carcinogens as an example, if 10 carcinogens are present, each at their respective PCL (i.e., 1×10^{-5} risk), the cumulative adjustment would not be necessary, as the cumulative risk would be 1×10^{-4} (i.e., $(1 \times 10^{-5})(10)$). However, if 11 carcinogens were present, each at their respective PCL, the cumulative adjustment would be necessary as

the cumulative risk is now greater than 1×10^{-4} (i.e., $(1 \times 10^{-5})(11) = 1.1 \times 10^{-4}$). This document will discuss the requirements applicable to the cumulative evaluation and will describe various approaches that may be used for adjusting PCLs based on cumulative criteria.

Important Points

As discussed in §350.72(b), when there are more than 10 carcinogenic COCs and/or 10 noncarcinogenic COCs detected in a single medium, the impact of multiple COCs must be addressed and individual PCL(s) may need to be lowered to meet the cumulative risk level and/or hazard index. For example, if there are 12 carcinogens and 9 noncarcinogens present in surface soil, the cumulative evaluation is required only for the carcinogens. *Note that the cumulative adjustment needs to be performed for each applicable individual and combined human health exposure pathway as defined in §350.71(c) before final critical PCLs are chosen*. However, this does not imply that a cumulative evaluation should be performed on the individual human health pathways that are part of the $^{Tot}Soil_{Comb}$ PCL (e.g., $^{Air}Soil_{Inh\text{-}VP}$, $^{Soil}Soil_{Ing}$, $^{Soil}Soil_{Derm}$, $^{Veg}Soil_{Ing}$ (for residential land use)), as cumulative impacts due to these pathways are evaluated when addressing cumulative effects for the $^{Tot}Soil_{Comb}$ PCL. Note that the cumulative evaluation needs to be performed for *all* relevant pathways, not for just the pathway with the lowest initial PCL (the critical PCL).

For COCs having both carcinogenic and noncarcinogenic toxicity values, both types of effects must be addressed in the cumulative evaluation regardless of which value was initially identified as the critical PCL. To do so, the COC should be included in the cumulative evaluation for carcinogens as well as for noncarcinogens. Tier 1 PCL Tables 4 and 5, as well as the Toxicity Factors Table, should be used to determine if a COC must be evaluated as a carcinogen, noncarcinogen, or both. (See TCEQ guidance document *Tier 1 PCL Tables* (RG-366/TRRP-23) for further information on use of the PCL tables. The tables may be downloaded from the TRRP web page <www.tceq.state.tx.us/remediation/trrp/trrppcls.html>.

PCLs are established using a 3-tiered process. PCLs for any given exposure pathway (e.g., $^{Tot}Soil_{Comb}$) can each be established under any of the 3 tiers and need not all necessarily be established under the same tier. *However, the cumulative evaluation should include all COCs across all tiers for which the person is required to establish PCLs.* For example, if a person has an affected property where 5 COCs are being evaluated under Tier 1, 6 COCs are being evaluated under Tier 2, and 3 COCs are being considered under Tier 3, the cumulative evaluation needs to be performed as there are more than 10 COCs total and should include all 14 COCs across all tiers.

Another important issue is that if, after the cumulative adjustment, critical PCLs are adjusted to be below the initial assessment levels, then

additional assessment may be needed to define the affected property limits or PCL exceedance (PCLE) zone. Assessment levels are the basis for determining the affected property (see TCEQ guidance document *Affected Property Assessment Requirements* (RG-366/TRRP-12) for further information regarding assessment levels). However, it is only necessary to establish PCLs for and consider the cumulative impacts of those COCs which have not been screened out under §350.71(k). Therefore, an assessment may commonly involve:

- first assessing to unadjusted assessment levels,
- screening under §350.71(k) based on the results of the initial assessment (see TCEQ guidance document *Screening Target Chemicals of Concern from PCL Development* (RG-366/TRRP-14) for further information on the §350.71(k) screening process),
- adjusting PCLs as needed to account for cumulative effects for COCs not eliminated from further consideration using §350.71(k),
- and then completion of further assessment if the extent of COCs was not defined to the adjusted critical PCLs (i.e., if the PCLE zone is not defined).

As discussed in §350.71(j), an additional consideration is the cumulative exposure to COCs in different environmental media. For example, if someone is actually drinking affected groundwater and being exposed to affected surface soil, consideration across the soil and groundwater in the cumulative evaluation may be warranted. This is only required when directed by the TCEQ. In that instance, COCs in both media are counted and simultaneously considered in the cumulative adjustment equation presented later in this document.

Figure 1 illustrates a decision process that can be followed to identify when cumulative adjustments are required as well as potential options for making such adjustment. The decision process should be repeated for each exposure pathway that is complete or reasonably anticipated to be completed at any particular affected property. Some pathways may require cumulative adjustments, while others may not. Each decision point or action step is discussed in detail in this document.

Grouping of COCs for the Cumulative Evaluation

Determining the correct area over which to group COCs is important, but not necessarily straight forward. Therefore, this section is provided to explain how COCs should be grouped when determining the need for cumulative adjustments.

Soil

The total number of COCs within each individual affected property should be determined for the surface and subsurface soil for each pathway as required (see Figure 1). At any one sampling location, fewer COCs may be present than is the case considering the entire extent of the affected property. The number of COCs should not be determined sampling location by sampling location, but rather should be based on the total number of COCs within the affected property (on-site or off-site). For example, Figure 2 depicts a commercial/industrial property consisting of three affected properties: Affected Property A, Affected Property B, and Affected Property C. These areas each contain a different set of COCs. Therefore, the number of COCs should be determined within the footprint of each affected property. However, there is a special consideration depicted in Figure 2. Because Affected Properties B and C overlap, the number of COCs in those two affected properties should be combined. Note that the *number* of COCs should be determined separately for on-site and off-site areas, as the receptors for these areas are different.

If the exposure area concept (§350.51(l)(3) and (4)) is being used to support statistical evaluation of the representative concentration of COCs in *surface soil* for the $^{Tot}Soil_{Comb}$ pathway, then the method of counting COCs is different. In that situation, the number of COCs within each exposure area is counted. For example, in Figure 2, the overlain squares represent the limits of individual 0.5 acre-based exposure areas. Within each individual exposure area, the number of COCs is counted. The count includes the COCs represented by the portion of each affected property that is contained within an exposure area as this is the area over which it is assumed a person will be exposed and any response action will take place. In this example, only the three exposure areas designated with an "X" contain more than 10 carcinogenic and/or noncarcinogenic COCs. Therefore, the cumulative evaluation is only required for those three exposure. areas.

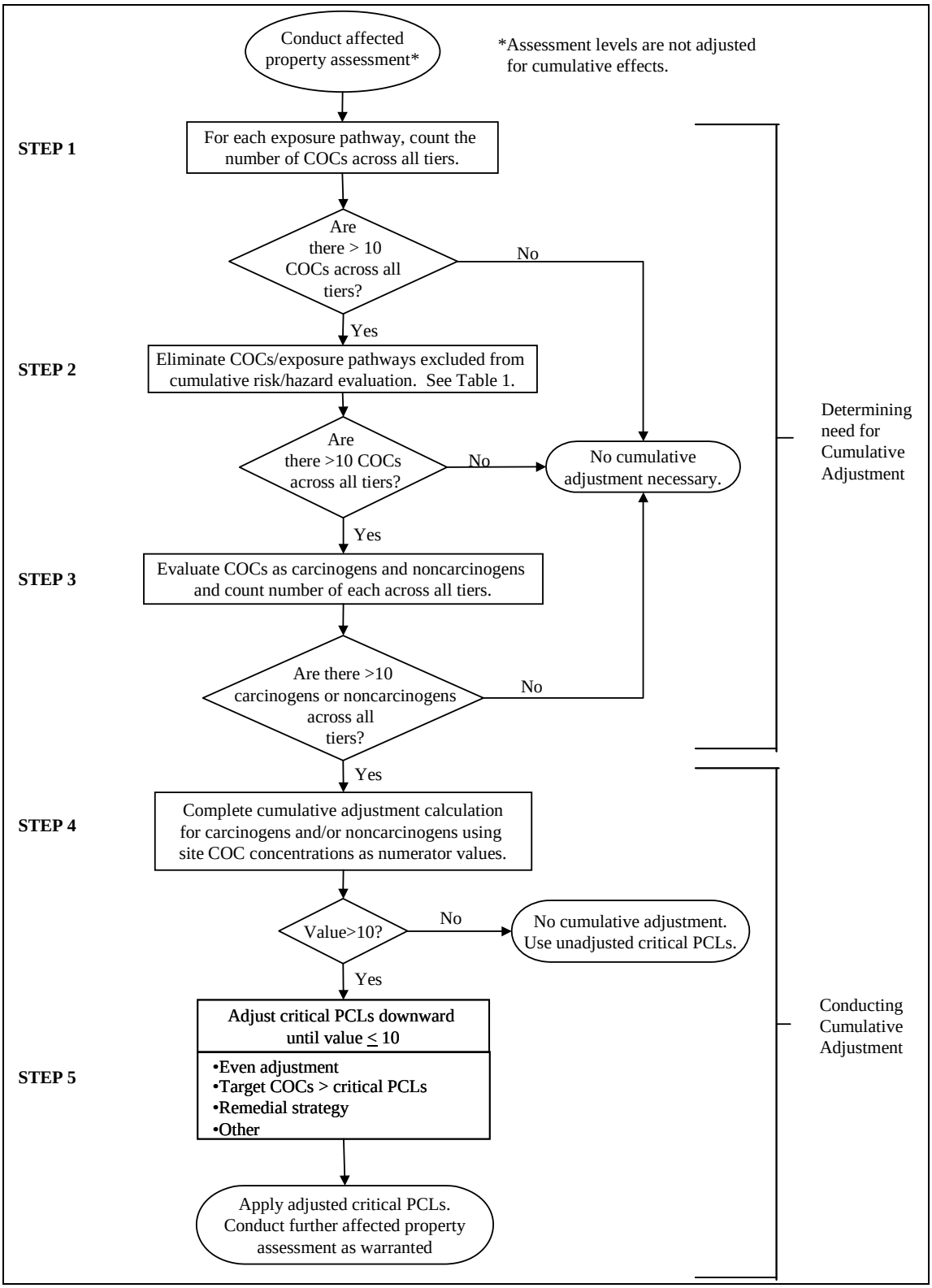

Figure 1 Cumulative Adjustment Decision Process.

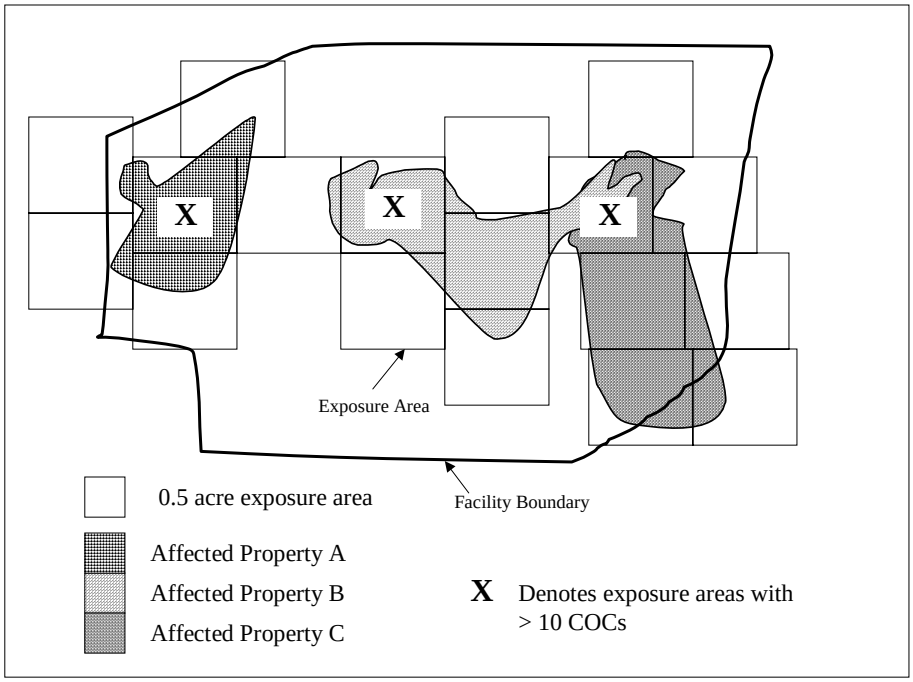

Figure 2 Map view of a commercial/industrial property with the surface soil portions of three affected properties and the boundaries of the defined exposure areas.

Groundwater

For groundwater, a cumulative evaluation should be performed over the affected property and not on a well-by-well basis. The number of carcinogenic and noncarcinogenic COCs in groundwater across the affected property should be determined (see Figure 1). Note that the exposure area concept is applicable to surface soils for the $^{Tot}Soil_{Comb}$ pathway only and not groundwater. The number of COCs should not be determined separately for on-site and off-site areas (the number of COCs should represent a combined value), unless conditions discussed below are met. If there are more than 10 carcinogenic or noncarcinogenic COCs, a cumulative evaluation should be performed and any necessary PCL adjustments should be made. For example, in Figure 3 the groundwater portion of an affected property is depicted in map view. The number of COCs (different COCs are indicated by the different letter labels for each monitoring well) should be determined within the footprint of the entire affected property (across wells). However, there is an area of flexibility. If the person can demonstrate that certain COCs are isolated to only certain portions of the affected property and can present valid hydrogeologic and COC chemical/physical property arguments (including pumping) as to why these COCs would not mix with the COCs in other portions of the affected property, then the person may be allowed to divide up the number of COCs within the respective isolated portions of the groundwater. For example, as further illustrated in Figure 3, an appropriate well pumping test is performed that simulates reasonable

groundwater use. Subsequently, it is determined that the observed radius of influence within the affected property indicates that pumping in the area upgradient (to the left) of the vertical dashed line would not influence the COCs downgradient (to the right) of the dashed line. Note that there are only two COCs in the upgradient portion and eleven COCs in the downgradient portion. Therefore, a cumulative evaluation is only warranted in the downgradient portion, if a minimum of 10 of the 11 COCs are carcinogenic or noncarcinogenic. There may be other technical bases for subdividing the number of COCs, but such bases must be sufficiently demonstrated.

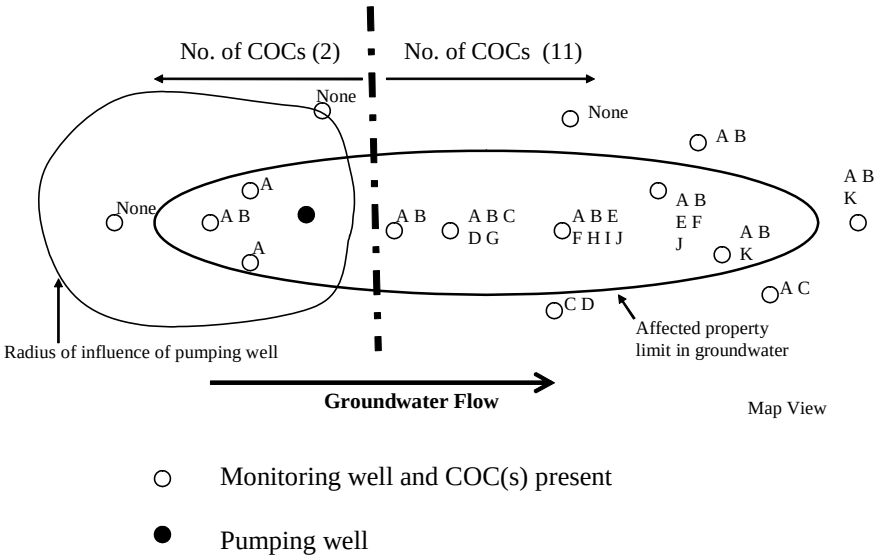

Figure 3 Map view of the groundwater portion of an affected property.

Exceptions to the Cumulative Risk Level and Hazard Index Criteria

An additional step in determining the total number of carcinogenic and noncarcinogenic COCs involves consideration of the exclusionary criteria contained in the rule. Such criteria are summarized in Table 1. It is important to note that several of the criteria apply to a specific pathway (e.g., Class 3 groundwater, groundwater protection PCLs) and as such, the COC is only excluded for that specific pathway.

Table 1 Exclusions from Cumulative Adjustment.[1]

Exclusion Criteria	Rule Citation
MCLs: COCs having a $^{GW}GW_{Ing}$ value that is based on a primary or secondary Maximum Contaminant Level (MCL) or federal action level may be excluded from the cumulative evaluation. For example, if there are 12 noncarcinogens present in groundwater, but 3 of the 12 have a MCL, then only 9 COCs are left and therefore the cumulative criteria do not apply to the groundwater ingestion pathway. However, such COCs may still need to be included in the cumulative evaluation for soils if present in that medium and unable to be eliminated under §350.71(k).	§350.72(b)(1)
Class 3 groundwater PCL: $^{GW}GW_{Class\ 3}$ (Note: $^{Air}GW_{Inh\text{-}V}$ is not excluded)	§350.72(b)(2)
Groundwater protection PCLs: $^{GW}Soil_{Ing}$, $^{GW}Soil_{Class3}$, $^{Air}GW\text{-}Soil_{Inh\text{-}V}$	§350.72(b)(3)
Groundwater-to-surface water PCL: ^{SW}GW	§350.72(b)(4)
COCs with non-risk-based PCLs: $^{Tot}Soil_{Comb}$ and $^{Air}Soil_{Inh\text{-}V}$ for lead, dioxins, and PCBs (only exclude PCBs when the Toxic Substances Control Act (TSCA) is used to establish the PCLs).	§350.72(b)(5)
TPH: TPH in combination with other COCs. TPH is evaluated for cumulative adjustment in isolation and should not be combined with other COCs.	§350.76(g)(5)
COCs which have been screened: COCs eliminated from PCL development in accordance with the criteria established in §350.71(k) may be excluded from the cumulative evaluation. (See TCEQ guidance document *Screening Target Chemicals of Concern from PCL Development* (RG-366/TRRP-14) for information on COC screening). However, COCs, including those reported as not detected, which are **not** screened out using the procedures described in §350.71(k), would need to be retained for the cumulative evaluation. (See §350.51(n) for a discussion on determining appropriate proxy values for nondetects).	§350.71(k)

Note: When other reasonably anticipated to be completed pathways are present, Toxicology Section staff should be consulted regarding the applicability of the cumulative adjustment, as the cumulative requirement may or may not apply for these pathways.

Cumulative Adjustment Calculation

The following equation (Figure: 30 TAC §350.72(d)) should be used to adjust the PCLs when there are more than 10 carcinogenic or noncarcinogenic COCs present.

$$10 \geq \frac{PCL-adj_1}{PCL_1}+\frac{PCL-adj_2}{PCL_2}+\ldots+\frac{PCL-adj_i}{PCL_i}$$

where:

$$10=\frac{RL_{cum}}{RL}\ or\ \frac{HI}{HQ}$$

Equation 1 Cumulative Adjustment Calculation

where:

1. RL_{cum} = the cumulative carcinogenic risk level for multiple carcinogenic COCs (i.e., 1×10^{-4});

2. RL=the carcinogenic risk level for a single carcinogenic COC (i.e., 1×10^{-5});
3. HI= the hazard index for multiple noncarcinogenic COCs (i.e., 10);
4. HQ= the hazard quotient for a single noncarcinogenic COC (i.e., 1);
5. PCL-adj$_i$= PCL for COC "i" adjusted for cumulative effects associated with multiple COCs (mg/kg or mg/L); and
6. PCL$_i$= PCL, unadjusted, for individual exposure pathways or combined exposure pathways for COC "i" (mg/kg or mg/L)

The process is essentially a budgeting exercise, where the person chooses which PCL(s) is/are adjusted downward to a lower concentration and the magnitude of the reduction. The unadjusted PCL (PCL$_i$) will remain constant in the denominator, while the numerator is adjusted (PCL-adj$_i$). The numerator is adjusted until the sum of the ratios of the individual PCLs is less than or equal to 10. When COC concentrations at the affected property are below the PCLs, it is helpful to use those concentrations as numerator values. Representative COC concentrations should be determined in accordance with §350.51 (see also TCEQ guidance document *Determining Representative Concentrations* (RG-366/TRRP-15)). This utilizes the benefit of low concentrations by allotting room for other COCs which will have a more significant contribution to the cumulative risk or hazard. In the event that the cumulative risk or hazard level is exceeded, a potential next step would be to target COCs already exceeding PCLs for cumulative adjustment, as a response action is already triggered for these COCs. Alternatively, if COCs exceeding PCLs are difficult to remediate, the person may choose to target COCs which can more easily be remediated even though individual PCLs may not be exceeded, as this approach allots room for those difficult to remediate COCs. Another option is to adjust all of the PCLs evenly; *however, the person can choose to downwardly adjust 1, 2, or any number of the PCLs, by any amount, as long as the cumulative criteria are met.* Be aware that adjustments, depending on how they are approached, can result in an exceedance of a PCL where there would not otherwise be one. Examples of how to determine whether a response action is necessary based on exceedances of the individual or cumulative risk or hazard criteria are provided in the appendix. After the cumulative adjustment process is completed, critical PCLs are established.

Verification of Sufficient COC Concentration Delineation

Although it may be a rare circumstance, when an adjusted PCL becomes the critical PCL that critical PCL may end up being a lower concentration than the residential assessment level that was used to define the affected property. Because of this possibility, if a critical PCL is based on an adjusted PCL then the results of the affected property assessment need to

be reevaluated to determine if the concentrations that exceed the critical PCL have been defined. For example, assume the residential assessment level for surface soil for a COC is 50 mg/kg and the critical PCL becomes 30 mg/kg following the cumulative adjustment. Unless concentrations in surface soil were defined to 30 mg/kg or a lower concentration during the affected property assessment, further assessment is necessary in order to define the extent of COC concentrations that exceed the critical PCL (i.e., define the boundary of the PCLE zone). The area that exceeds the 30 mg/kg critical PCL will also be considered affected property.

Appendix: Examples of Cumulative Risk and Hazard Criteria Evaluation

Two hypothetical examples for evaluation of the cumulative criteria specified in the rule are provided below. Example procedures for meeting the cumulative requirements are presented in a stepwise fashion, **consistent with the steps presented in Figure 1**. Note that the procedures presented for cumulative adjustment are just one example of the series of steps which may be taken. Alternative approaches may be used as well, provided that the cumulative criteria specified in the rule are met. For simplicity, the examples presented here are based on use of maximum concentrations and the assumption that screening of COCs under §350.71(k) has already occurred. TCEQ guidance document *Screening Target Chemicals of Concern from PCL Development* (RG-366/TRRP-14) should be consulted for guidance on screening COCs in accordance with §350.71(k). Statistically-derived concentrations could potentially be used instead of maximum concentrations if appropriate (see TCEQ guidance document *Determining Representative Concentrations* (RG-366/TRRP-15)). In addition, for illustration purposes, it was assumed that the human health PCLs are lower than the respective ecological PCLs and greater than associated background concentrations and method quantitation limits (MQLs). As such, the lowest human health Tier 1 PCL is referred to in the examples as the critical PCL. In practice, the human health PCL may not be the critical PCL, as some of these other criteria may be the applicable critical PCL (see TCEQ guidance document *Critical PCLs* (RG-366/TRRP-25)). For example purposes, only the standard exposure pathways were determined to be relevant to the affected properties; other pathways were not determined to be complete or reasonably anticipated to be completed in this example.

Example 1. Affected Property A

Affected Property A is in a commercial/industrial area with COCs extending into an off-site residential area. There are 19 COCs present in the soil, including arsenic, barium, benzene, benzo-a-pyrene, benzo-b-fluoranthene, benzo-k-fluoranthene, chlordane (technical), chromium (VI), endosulfan, ethyl benzene, fluorene, mercury, naled, phenanthrene, TCDD, tetrachloroethylene, toluene, xylenes (total), and zinc. The source area is 0.5 acre, the underlying groundwater is Class 1, and the soil pH is 6.8. Commercial/Industrial Tier 1 PCLs for a 0.5 acre source area will be used for example purposes.

The following example is limited to on-site surface soils and does not include consideration of subsurface soil, off-site soils or a groundwater assessment. For Affected Property A, a cumulative evaluation should be performed in a similar fashion for subsurface soil, the off-site residential

portion of the affected property and the underlying groundwater (if there are more than 10 COCs present).

Step 1

Following the affected property assessment, the first step in determining whether cumulative adjustment is necessary is to count the number of COCs across all tiers, for each exposure pathway, and determine whether there are >10 COCs across all tiers (Figure 1). For Affected Property A, the relevant soil exposure pathways include $^{Tot}Soil_{Comb}$, $^{GW}Soil_{Ing}$, and $^{Air}GW\text{-}Soil_{Inh\text{-}V}$. Note that if other pathways are complete or reasonably anticipated to be completed, these should be considered as well (see §350.71(c)(8)). As discussed above, Tier 1 PCLs will be used in this example.

As there are 19 COCs present in soils at Affected Property A (>10), a cumulative adjustment may be necessary so the evaluation must proceed to Step 2.

Step 2

The next step is to eliminate COCs/exposure pathways which are excluded from the cumulative risk and hazard evaluation and then to determine whether there are still >10 COCs remaining across all tiers (Figure 1). These exclusions are discussed in part in §350.72(b)(3), as well as in the section of this document entitled "Exceptions to the Cumulative Risk Level and Hazard Index Criteria" (Table 1). The cumulative evaluation is not required for the soil-to-groundwater PCLs (e.g., $^{GW}Soil_{Ing}$, $^{Air}GW\text{-}Soil_{Inh\text{-}V}$). Therefore, for Affected Property A in this example, $^{Tot}Soil_{Comb}$ is the only soil pathway for which PCLs may need to be lowered to meet the cumulative criteria.

As part of this step, a determination is made as to which COCs meet any of the exclusion criteria described in §350.72(b)(1)-(5) as well as in Table 1 of this document. Based on these criteria, TCDD is the only COC present at Affected Property A which may be excluded from the cumulative evaluation (see Table 2). Therefore, 18 COCs remain and a cumulative adjustment may be necessary for the $^{Tot}Soil_{Comb}$ pathway for Affected Property A. So the evaluation must proceed to Step 3.

Step 3

The next step is to determine whether each COC needs to be evaluated as a carcinogen, as a noncarcinogen, or as both and then to determine whether there are 10 carcinogens and/or noncarcinogens across all tiers (Figure 1). By looking at the Toxicity Factors table provided on the TRRP webpage <www.tceq.state.tx.us/remediation/trrp/trrppcls.html>, it can be determined which COCs have carcinogenic and/or noncarcinogenic toxicity factors, as shown in Table 2.

As there are 15 COCs with noncarcinogenic toxicity factors, it is necessary to conduct a cumulative evaluation for noncarcinogenic effects by proceeding to Step 4. The PCL for any or all of the COCs may be adjusted to meet the cumulative hazard index (i.e., the person may determine if PCLs should be lowered for several COCs or all of the COCs). As there are less than 10 COCs with carcinogenic toxicity factors, it is not necessary to conduct a cumulative evaluation for carcinogenic risk.

Step 4

Step 4 involves performing a cumulative adjustment calculation for COCs identified as noncarcinogens in this example. In doing so, the initial step involves using the measured COC concentrations in the surface soil as numerator values in the equation presented below (and also in Figure: 30 TAC §350.72(d)). If the sum of the PCL ratios is less than or equal to 10, the cumulative criteria of the rule are met and the unadjusted critical PCLs may be used. If the sum of the PCL ratios exceeds 10, further adjustment is necessary.

$$10 \geq \frac{PCL-adj_1}{PCL_1} + \frac{PCL-adj_2}{PCL_2} + \ldots + \frac{PCL-adj_i}{PCL_i}$$

where:

$$10 = \frac{RLcum}{RL} \text{ or } \frac{HI}{HQ}$$

Equation 2

where:

1. RLcum= the cumulative carcinogenic risk level for multiple carcinogenic COCs (i.e., 1 x 10^{-4});
2. RL=the carcinogenic risk level for a single carcinogenic COC (i.e., 1 x 10^{-5});
3. HI= the hazard index for multiple noncarcinogenic COCs (i.e., 10);
4. HQ= the hazard quotient for a single noncarcinogenic COC (i.e., 1);
5. PCL-adj_i= PCL for COC "i" adjusted for cumulative effects associated with multiple COCs (mg/kg or mg/L); and
6. PCL_i= PCL, unadjusted, for individual exposure pathways or combined exposure pathways for COC "i" (mg/kg or mg/L)

Table 2 Characterization of Surface Soil COCs, Affected Property A.

COC	Carcinogenic Toxicity Factors[a]	Noncarcinogenic Toxicity Factors[a]	Acceptable Exclusion Criteria (§350.72(b)(1–5))
Arsenic	X	X	N/A
Barium		X	N/A
Benzene	X	X	N/A
Benzo-a-pyrene	X		N/A
Benzo-b-fluoranthene	X		N/A
Benzo-k-fluoranthene	X		N/A
Chlordane (technical)	X	X	N/A
Chromium (VI)	X	X	N/A
Endosulfan		X	N/A
Ethyl benzene		X	N/A
Fluorene		X	N/A
Mercury		X	N/A
Naled		X	N/A
Phenanthrene		X	N/A
TCDD, 2,3,7,8- (dioxin)			COC-Specific Approach (§350.76(e))
Tetrachloroethylene	X	X	N/A
Toluene		X	N/A
Xylenes		X	N/A
Zinc		X	N/A
Total	7	15	N/A

Note : [a]These designations were current at the time of publication. The most recent version of the Tier 1 PCL tables should be used to evaluate an affected property as the designations may have changed from those listed above.

N/A = none applicable

For Affected Property A, if each of the 15 COCs were present at their respective PCLs, the hazard index of 10 would be exceeded ((15)(1)=15, 15> 10). However, as discussed above, measured COC concentrations can be entered into the cumulative adjustment equation as the numerator and, depending on the ratio between the actual concentrations and the PCLs, the PCLs may not require any further adjustment or may require less adjustment than initially anticipated.

Table 3 below presents the commercial/industrial noncarcinogenic $^{Tot}Soil_{Comb}$ PCLs for a 0.5 acre source area and the affected property surface soil concentrations for Affected Property A.

Table 3 Affected Property A Noncarcinogenic $^{Tot}Soil_{Comb}$ PCLs and Surface Soil Concentrations

COC	Noncarcinogenic $^{Tot}Soil_{Comb}$ PCL[a] (mg/kg)	Soil Concentration[b] (mg/kg)
Arsenic	3.3E+02	4.0E+00
Barium	1.0E+05	4.0E+02
Benzene	5.6E+02	7.5E+01
Chlordane	3.9E+02	3.0E+00
Chromium (VI)	1.0E+03	9.9E+02
Endosulfan	1.1E+02	7.0E+00
Ethyl benzene	1.8E+04	1.2E+04
Fluorene	2.5E+04	2.2E+03
Mercury (pH = 4.9)	6.2E+00	1.8E+01
Naled	2.8E+02	1.0E+01
Phenanthrene	1.9E+04	1.4E+03
Tetrachloroethylene	3.7E+03	2.0E+02
Toluene	4.6E+04	2.0E+02
Xylenes	2.1E+03	8.0E+01
Zinc	2.5E+05	1.1E+02

[a]These Tier 1 PCLs were current at the time of publication. The most recent version of the Tier 1 PCL tables should be used to evaluate an affected property as the values may have changed from those listed above.

[b]Concentrations should be determined according to §350.51. See also *Determining Representative Concentrations* (RG-366/TRRP-15).

An example of the procedure discussed above for Affected Property A, where the Tier 1 $^{Tot}Soil_{Comb}$ noncarcinogenic PCLs serve as the denominator and the measured COC concentrations in the surface soil are used as the numerator (see Table 3), is as shown below. Remember, Tier 1 PCLs are used as the denominator because Tier 1 PCLs were used for all COCs in this example. If a Tier 2 or 3 PCL had been used for a COC, that value would be used in the denominator for that COC.

$$10 \geq \frac{4.0E+00}{3.3E+02} + \frac{4.0E+02}{1.0E+05} + \frac{7.5E+01}{5.6E+02} + \frac{3.0E+00}{3.9E+02} + \frac{9.9E+02}{1.0E+03} + \frac{7.0E+00}{1.1E+02} + \frac{1.2E+04}{1.8E+04}$$
$$+ \frac{2.2E+03}{2.5E+04} + \frac{1.8E+01}{6.2E+00} + \frac{1.0E+01}{2.8E+02} + \frac{1.4E+03}{1.9E+04} + \frac{2.0E+02}{3.7E+03} + \frac{2.0E+02}{4.6E+04} + \frac{8.0E+01}{2.1E+03} + \frac{1.1E+02}{2.5E+05}$$
$$10 \geq 5.1$$

Equation 3

In this example, the actual affected property concentrations of each COC are low enough that the cumulative requirements are met using the concentrations alone and no further adjustment is required. Therefore, for

surface soils in this example, the cumulative evaluation process stops at Step 4 (Figure 1). If the measured COC concentrations were higher and the cumulative check did identify an exceedance of the applicable cumulative benchmark, then the person would proceed to Step 5 and decide which specific PCLs to adjust.

Note again that this example is limited to on-site surface soils and does not include the subsurface soil, off-site residential evaluation or a groundwater evaluation. For Affected Property A, a cumulative evaluation should be performed in a similar fashion for subsurface soil and the off-site residential portion of the affected property. A cumulative evaluation must also be conducted for the underlying groundwater. It is important to note that the number of COCs in the groundwater on- and off-site must be considered together, unless the conditions for flexibility described earlier in the Groundwater portion of the Grouping of COCs for the Cumulative Evaluation section of this document are met. In this example, commercial/industrial PCLs would apply on-site, while residential PCLs would apply off-site. For groundwater, PCLs for the individual groundwater pathways (e.g., $^{Air}GW_{Inh\text{-}V}$, $^{GW}GW_{Ing}$) should be evaluated separately for cumulative concerns before a final critical PCL is chosen. COCs with an MCL available should be excluded from the cumulative evaluation for the groundwater ingestion pathway ($^{GW}GW_{Ing}$) (§350.72(b)(1)). If there are more than 10 COCs with carcinogenic effects present in the subsurface soil or groundwater across an affected property, then a cumulative evaluation would need to be performed in a manner similar to the noncarcinogenic procedure.

Note that once the cumulative criteria of the rule have been satisfied and PCLs have been downwardly adjusted as necessary, the final step is to ensure that the critical PCLs are met for Affected Property A. This is accomplished by comparing the on-site portion of the affected property COC concentrations to the relevant critical (lowest) PCLs (adjusted for cumulative concerns as necessary). As discussed in the introduction to this section, in this example, it has been assumed, that the Tier 1 human health PCLs are the critical PCLs. In practice, ecological PCLs, background concentrations, or MQLs could serve as the critical PCL as outlined in §350.78. Tier 1 $^{Tot}Soil_{Comb}$, $^{GW}Soil_{Ing}$, and $^{Air}GW\text{-}Soil_{Inh\text{-}V}$ PCLs (obtained from Tier 1 PCL Table 2) are presented in Table 4 and are compared to their respective representative on-site surface soil COC concentrations.

As shown in Table 4, concentrations for 10 COCs exceed the corresponding Tier 1 critical PCL (benzene, benzo-a-pyrene, chromium (VI), ethyl benzene, fluorine, mercury, naled, phenanthrene, tetrachloroethylene, and toluene) based on a risk level of 1×10^{-5} or a hazard quotient of 1 for the particular COC. Note that these PCL exceedances must be addressed. As an alternative to remediating to the Tier 1 values, Tier 2 or 3 values may be calculated using the options described in §350.75(i)(7) for comparison to representative concentrations to determine if a response action is warranted. Thus, these individual PCL

exceedances indicate that a response action is necessary unless higher individual PCLs are subsequently established under Tier 2 or 3 and indicate that such action is not warranted.

Example 2: Affected Property B

Affected Property B is in a commercial/industrial area with no COCs extending off-site. There are 18 COCs present in soil and groundwater, including acrylamide, benzidine, benz-a-anthracene, benzo-a-pyrene, benzo-b-fluoranthene, benzo-k-fluoranthene, benzo-g,h,i-perylene, chrysene, cyanazine, 2,2-dichloropropane, 1,2-diphenylhydrazine, indeno-1,2,3-c,d-pyrene, 1-methyl chrysene, 2-methyl chrysene, methylene bromide, 4-nitroaniline, styrene, and 2,4-toluenediamine. The source area is 30 acres for each of the COCs and the affected groundwater is Class 1. Tier 1 PCLs will be used for example purposes.

The following example is limited to groundwater and does not include a soil evaluation. For Affected Property B, a cumulative evaluation should be performed in a similar fashion for the affected soil as well.

Step 1

As with the first example (Affected Property A), following the affected property assessment, the first step in determining whether cumulative adjustment is necessary is to count the number of COCs across all tiers, for each exposure pathway, and determine whether there are >10 COCs across all tiers (Figure 1).

For this Affected Property B, the only relevant groundwater exposure pathways include ${}^{GW}GW_{Ing}$ and ${}^{Air}GW_{Inh\text{-}V}$. As discussed above, Tier 1 PCLs will be used in this example.

Table 4. Affected Property A Surface Soil Concentrations vs. PCLs[a]

COC	$^{Tot}Soil_{Comb}$ [b,c] (mg/kg)	$^{GW}Soil_{Ing}$ [b] (mg/kg)	$^{Air}GW\text{-}Soil_{Inh\text{-}V}$ [b] (mg/kg)	Soil Concentration[d] (mg/kg)	Concentration vs. Critical PCL
Arsenic	2.0E+02	5.0E+00	---	4.0E+00	no exceedance
Barium	1.0E+05	**4.4E+02**	---	4.0E+02	no exceedance
Benzene	1.8E+02	**2.6E-02**	1.6E+03	7.5E+01	**>critical PCL[g]**
Benzo-a-pyrene	**2.4E+00**	7.6E+00	1.0E+06	1.1E+01	**>critical PCL[f]**
Benzo-b-fluoranthene	**2.4E+01**	1.3E+02	1.0E+06	1.0E+01	no exceedance
Benzo-k-fluoranthene	**2.4E+02**	1.4E+03	1.0E+06	1.0E+01	no exceedance
Chlordane	6.6E+01	**9.6E+00**	1.0E+06	3.0E+00	no exceedance
Chromium (VI)	1.0E+03	**2.8E+01**	---	9.9E+02	**>critical PCL[g]**
Endosulfan	1.1E+02	**1.4E+01**	5.1E+04	7.0E+00	no exceedance
Ethyl benzene	1.8E+04	**7.6E+00**	2.4E+05	1.2E+04	**>critical PCL[g]**
Fluorene	2.5E+04	**8.9E+02**	---	2.2E+03	**>critical PCL[g]**
Mercury (pH = 4.9)	6.2E+00	**7.8E-03**	4.0E+01	1.8E+01	**>critical PCL[e]**
Naled	2.8E+02	**1.1E+00**	2.2E+04	1.0E+01	**>critical PCL[g]**
Phenanthrene	1.9E+04	**1.2E+03**	---	1.4E+03	**>critical PCL[g]**
TCDD, 2,3,7,8- (dioxin)	5.0E-03	1.7E-02	---	2.0E-03	no exceedance
Tetrachloroethylene	3.6E+02	**5.0E-02**	5.5E+03	2.0E+02	**>critical PCL[g]**
Toluene	4.6E+04	**8.2E+00**	8.9E+05	2.0E+02	**>critical PCL[g]**
Xylenes	2.1E+03	**1.2E+02**	2.9E+04	8.0E+01	no exceedance
Zinc	2.5E+05	**7.0E+03**	---	1.1E+02	no exceedance

[a]Bolded values indicate the critical PCL. The critical PCL is the lowest PCL for a particular environmental medium considering all the exposure pathways for which a PCL is developed (§350.78(a)).

[b]These $^{Tot}Soil_{Comb}$ PCLs represent the lowest of the noncarcinogenic and carcinogenic Tier 1 $^{Tot}Soil_{Comb}$ PCLs. [c]These Tier 1 PCLs were current at the time of publication. The most recent version of the Tier 1 PCL tables should be used to evaluate an affected property as the values may have changed from those listed above. [d]Concentrations should be determined according to §350.51. See also *Determining Representative Concentrations* (RG-366/TRRP-15).

[e]The critical PCL is $^{GW}Soil_{Ing}$, but $^{Tot}Soil_{Comb}$ is exceeded as well.

[f]The critical PCL is $^{Tot}Soil_{Comb}$, but $^{GW}Soil_{Ing}$ is exceeded as well.

[g]Only the critical PCL ($^{GW}Soil_{Ing}$) is exceeded; $^{Tot}Soil_{Comb}$ is not.

As there are 18 COCs present in groundwater at Affected Property B (>10), a cumulative adjustment may be necessary so the evaluation must proceed to Step 2.

Step 2

The next step is to eliminate COCs/exposure pathways which are excluded from the cumulative risk and hazard evaluation and then to determine whether there are still >10 COCs remaining across all tiers (Figure 1). These exclusions are discussed in part in §350.72(b)(3), as well as in the section of this document entitled "Exceptions to the Cumulative

Risk Level and Hazard Index Criteria" (Table 1). Based on these criteria, neither of the two relevant groundwater exposure pathways ($^{GW}GW_{Ing}$ and $^{Air}GW_{Inh\text{-}V}$) may be excluded from the cumulative evaluation for Affected Property B. Additionally, benzo-a-pyrene and styrene may be excluded from the cumulative evaluation for the groundwater ingestion pathway ($^{GW}GW_{Ing}$) for Affected Property B, as the $^{GW}GW_{Ing}$ PCLs for these COCs are based on MCLs (see Table 5 below). Note that the MCL exclusion does not apply for the groundwater volatilization pathway ($^{Air}GW_{Inh\text{-}V}$). In this example, the cumulative evaluation must proceed to Step 3, as there are 16 remaining COCs to be considered for the $^{GW}GW_{Ing}$ pathway and 18 COCs to be considered for the $^{Air}GW_{Inh\text{-}V}$ pathway for Affected Property B. Note that for example purposes, the cumulative evaluation from this point on will be shown for only the $^{GW}GW_{Ing}$ pathway; the same procedure should be performed for the $^{Air}GW_{Inh\text{-}V}$ pathway as well.

Step 3

The next step is to determine whether each COC needs to be evaluated as a carcinogen, as a noncarcinogen, or as both and then to determine whether there are 10 carcinogens and/or noncarcinogens across all tiers (Figure 1). By looking at the Toxicity Factors table, it can be determined which COCs have carcinogenic and/or noncarcinogenic toxicity factors, as shown in Table 5.

Table 4 Characterization of Groundwater COCs for $^{GW}GW_{Ing}$ for Affected Property B

COC	Carcinogenic Toxicity Factors[a]	Noncarcinogenic Toxicity Factors[a]	Acceptable Exclusion Criteria[a]
Acrylamide	X	X	N/A
Benzidine	X	X	N/A
Benz-a-anthracene	X		N/A
Benzo-a-pyrene	X [b]		MCL ((§350.72(b)(1))[b]
Benzo-b-fluoranthene	X		N/A
Benzo-k-fluoranthene	X		N/A
Benzo-g,h,i-perylene		X	N/A
Chrysene	X		N/A
Cyanazine	X	X	N/A
2,2-Dichloropropane	X	X	N/A
1,2-Diphenylhydrazine	X		N/A
Indeno-1,2,3-c,d-pyrene	X		N/A
1-Methyl chrysene	X		N/A
2-Methyl chrysene	X		N/A
Methylene bromide	X	X	N/A
4-Nitroaniline	X	X	N/A
Styrene		X [b]	MCL ((§350.72(b)(1))[b]
2,4-Toluenediamine	X		N/A
Total	**15**	**7**	**N/A**

[a]These designations were current at the time of publication. The most recent version of the Tier 1 PCL tables should be used to evaluate an affected property as the designations may have changed from those listed above.

[b]Note that the MCL exclusion applies only for $^{GW}GW_{Ing}$, not for $^{Air}GW_{Inh\text{-}V}$. For the $^{Air}GW_{Inh\text{-}V}$ pathway, benzo-a-pyrene's contribution to the carcinogenic risk level and styrene's contribution to the hazard index would need to be considered.

N/A = none applicable

As there are 15 COCs with carcinogenic toxicity factors, it is necessary to conduct a cumulative evaluation for carcinogenic effects by proceeding to Step 4. The PCL for any or all of the COCs may be adjusted to meet the cumulative carcinogenic risk level (i.e., the person may determine if PCLs should be lowered for several COCs or all of the COCs). Because there are less than 10 COCs with noncarcinogenic toxicity factors, it is not necessary to conduct a cumulative evaluation for noncarcinogenic hazard.

Step 4

Step 4 involves performing a cumulative adjustment calculation for the COCs identified as carcinogens in this example. In doing so, the initial step involves using site COC concentrations as numerator values below (and also in Figure: 30 TAC §350.72(d)). If the sum of the PCL ratios is less than or equal to 10, the cumulative criteria of the rule are met and the unadjusted critical PCLs may be used. If the sum of the PCL ratios exceeds 10, further adjustment is necessary.

$$10 \geq \frac{PCL-adj_1}{PCL_1} + \frac{PCL-adj_2}{PCL_2} + \ldots + \frac{PCL-adj_i}{PCL_i}$$

where:

$$10 = \frac{RL_{cum}}{RL} \text{ or } \frac{HI}{HQ}$$

Equation 4

where:

1. RL_{cum}= the cumulative carcinogenic risk level for multiple carcinogenic COCs (i.e., 1 x 10^{-4});
2. RL= the carcinogenic risk level for a single carcinogenic COC (i.e., 1 x 10^{-5});
3. HI= the hazard index for multiple noncarcinogenic COCs (i.e., 10);
4. HQ= the hazard quotient for a single noncarcinogenic COC (i.e., 1);
5. PCL-adj_i= PCL for COC "i" adjusted for cumulative effects associated with multiple COCs (mg/kg or mg/L); and
6. PCL_i= PCL, unadjusted, for individual exposure pathways or combined exposure pathways for COC "i" (mg/kg or mg/L)

For Affected Property B, if each of the 15 COCs were present at their respective PCLs, the cumulative risk level of 1 x 10^{-4} would be exceeded ((15)(1 x 10^{-5})=1.5 x 10^{-4}, 1.5 x 10^{-4} > 1 x 10^{-4}). However, as discussed above, actual concentrations can be entered into the cumulative adjustment equation as the numerator and, depending on the ratio between the actual concentrations and the PCLs, the PCLs may not require any further adjustment or may require less adjustment than initially anticipated.

The carcinogenic $^{GW}GW_{Ing}$ PCLs and affected property groundwater concentrations are shown below in Table 6 for Affected Property B.

An example of the procedure discussed above for Affected Property B, where the Tier 1 $^{GW}GW_{Ing}$ carcinogenic PCLs serve as the denominator, and the measured COC concentrations in groundwater are used as the numerator (see Table 6) is as follows:

Equation 5

$$10 < \frac{4.2E-04}{4.5E-04} + \frac{4.9E-06}{8.9E-06} + \frac{4.1E-03}{2.8E-03} + \frac{3.0E-03}{2.8E-03} + \frac{2.6E-02}{2.8E-02} + \frac{5.1E-01}{2.8E-01} + \frac{6.7E-01}{2.4E-03} + \frac{1.0E-02}{3.0E-02} + \frac{8.2E-04}{2.6E-03} + \frac{1.2E-03}{2.8E-03} + \frac{9.0E-02}{2.8E-01} + \frac{8.0E-02}{2.8E-01} + \frac{4.8E-01}{2.7E-01} + \frac{1.0E-01}{5.4E-02} + \frac{6.1E-04}{6.4E-04}$$

$$10 < 292$$

Since the sum of the ratios (292) exceeds 10, the cumulative criteria of the rule are *not* met and further adjustment will be necessary. Therefore, the evaluation must proceed to Step 5.

Table 5 Affected Property B Carcinogenic $^{GW}GW_{Ing}$ PCLs and Groundwater Concentrations

COC	Carcinogenic $^{GW}GW_{Ing}$ PCL[a] (mg/L)	Groundwater Concentration[b] (mg/L)
Acrylamide	4.5E-04	4.2E-04
Benzidine	8.9E-06	4.9E-06
Benz-a-anthracene	2.8E-03	4.1E-03
Benzo-b-fluoranthene	2.8E-03	3.0E-03
Benzo-k-fluoranthene	2.8E-02	2.6E-02
Chrysene	2.8E-01	5.1E-01
Cyanazine	2.4E-03	6.7E-01
2,2-Dichloropropane	3.0E-02	1.0E-02
1,2-Diphenylhydrazine	2.6E-03	8.2E-04
Indeno-1,2,3-c,d-pyrene	2.8E-03	1.2E-03
1-Methyl chrysene	2.8E-01	9.0E-02
2-Methyl chrysene	2.8E-01	8.0E-02
Methylene bromide	2.7E-01	4.8E-01
4-Nitroaniline	5.4E-02	1.0E-01
2,4-Toluenediamine	6.4E-04	6.1E-04

[a]These Tier 1 PCLs were current at the time of publication. The most recent version of the Tier 1 PCL tables should be used to evaluate an affected property as the values may have changed from those listed above.

[b]Concentrations should be determined according to §350.51. See also *Determining Representative Concentrations* (RG-366/TRRP-15).

Step 5

One option for addressing cumulative concerns is to target those COCs whose measured concentrations exceeds the critical PCL based on consideration of individual risk and hazard criteria since a response action is already triggered for those COCs. Alternatively, if the COCs which exceed the critical PCL are particularly costly or difficult to remediate, it may not be desirable to downwardly adjust those any further. Alternatively, the person could target those COCs whose initial concentrations are less than their PCLs. An additional option is to adjust all PCLs evenly.

A comparison between the unadjusted ${}^{GW}GW_{Ing}$ PCLs and groundwater concentrations is shown below in Table 7 for Affected Property B.

As shown in Table 7, concentrations of 6 COCs exceed the Tier 1 ${}^{GW}GW_{Ing}$ PCL (benz-a-anthracene, benzo-b-fluoranthene, chrysene, cyanazine, methylene bromide, and 4-nitroaniline). One option for addressing these COCs is to calculate Tier 2 or 3 PCLs, which would change the denominator value for them in the cumulative adjustment equation. However, as already discussed, for this example, a decision was made to use Tier 1 PCLs and to remediate to those Tier 1 values. As such, the Tier 1 ${}^{GW}GW_{Ing}$ carcinogenic PCLs should be used as the numerator for those 6 COCs whose site concentrations were found to exceed the Tier 1 ${}^{GW}GW_{Ing}$ PCL as the person to meet the Tier 1 PCL, while the actual site concentrations should be used as the numerator for all other COCs. Again, the Tier 1 ${}^{GW}GW_{Ing}$ PCLs serves as the denominator in all cases. COCs whose concentrations were limited at the Tier 1 ${}^{GW}GW_{Ing}$ value are indicated by "*" in the equation below.

$$10 < \frac{4.2E-04}{4.5E-04} + \frac{4.9E-06}{8.9E-06} + \frac{2.8E-03*}{2.8E-03} + \frac{2.8E-03*}{2.8E-03} + \frac{2.6E-02}{2.8E-02} + \frac{2.8E-01*}{2.8E-01} + \frac{2.4E-03*}{2.4E-03}$$
$$+ \frac{1.0E-02}{3.0E-02} + \frac{8.2E-04}{2.6E-03} + \frac{1.2E-03}{2.8E-03} + \frac{9.0E-02}{2.8E-01} + \frac{8.0E-02}{2.8E-01} + \frac{2.7E-01*}{2.7E-01}$$
$$+ \frac{5.4E-02*}{5.4E-02} + \frac{6.1E-04}{6.4E-04}$$
$$10 < 11$$

Equation 6

Table 6 Affected Property B Carcinogenic $^{GW}GW_{Ing}$ PCLs and Groundwater Concentrations

COC	$^{GW}GW_{Ing}$[a,b] (mg/L)	Groundwater Concentration[c] (mg/L)	Concentration vs. PCL
Acrylamide	4.5E-04	4.2E-04	no exceedance
Benzidine	8.9E-06	4.9E-06	no exceedance
Benz-a-anthracene	2.8E-03	4.1E-03	> PCL
Benzo-a-pyrene	2.0E-04	1.2E-04	no exceedance
Benzo-b-fluoranthene	2.8E-03	3.0E-03	> PCL
Benzo-k-fluoranthene	2.8E-02	2.6E-02	no exceedance
Benzo-g,h,i-perylene	2.2E+00	5.5E-04	no exceedance
Chrysene	2.8E-01	5.1E-01	> PCL
Cyanazine	2.4E-03	6.7E-01	> PCL
2,2-Dichloropropane	3.0E-02	1.0E-02	no exceedance
1,2-Diphenylhydrazine	2.6E-03	8.2E-04	no exceedance
Indeno-1,2,3-c,d-pyrene	2.8E-03	1.2E-03	no exceedance
1-Methyl chrysene	2.8E-01	9.0E-02	no exceedance
2-Methyl chrysene	2.8E-01	8.0E-02	no exceedance
Methylene bromide	2.7E-01	4.8E-01	> PCL
4-Nitroaniline	5.4E-02	1.0E-01	**> PCL**
Styrene	1.0E-01	6.0E-02	no exceedance
2,4-Toluenediamine	6.4E-04	6.1E-04	no exceedance

[a]These $^{GW}GW_{Ing}$ PCLs represent the lowest of the noncarcinogenic and carcinogenic Tier 1 $^{GW}GW_{Ing}$ PCLs.

[b]These Tier 1 PCLs were current at the time of publication. Use the most recent version of the Tier 1 PCL tables to evaluate an affected property as the values may have changed from those listed above.

[c]Concentrations should be determined according to §350.51. See also *Determining Representative Concentrations* (RG-366/TRRP-15).

As the sum of the ratio still exceeds 10, the PCLs must be downwardly adjusted even more. Again, the person may adjust whichever PCLs they choose to meet the cumulative carcinogenic risk level of 1×10^{-4}. In this case, it has been determined that the affected property concentrations for polycyclic aromatic hydrocarbons (PAHs) will be lowered by a factor of 2, as the remedial strategy of choice targets PAHs. Concentrations for the remaining COCs will remain unchanged. By making these adjustments, the cumulative criteria of the rule (cumulative carcinogenic risk level of 1×10^{-4}) are satisfied, as shown in the following equation, which employs the adjusted PAH concentrations as numerator values. Adjusted concentrations for the 5 carcinogenic PAHs (benzo-a-anthracene, benzo-b-fluoranthene, benzo-k-flouranthene, chrysene, and indeno-1,2,3-c,d-pyrene) are indicated by "*."

$$10 \geq \frac{4.2E-04}{4.5E-04} + \frac{4.9E-06}{8.9E-06} + \frac{2.0E-03*}{2.8E-03} + \frac{1.5E-03*}{2.8E-03} + \frac{1.3E-02*}{2.8E-02} + \frac{2.6E-01*}{2.8E-01} + \frac{2.4E-03}{2.4E-03}$$
$$+ \frac{1.0E-02}{3.0E-02} + \frac{8.2E-04}{2.6E-03} + \frac{6.0E-04*}{2.8E-03} + \frac{9.0E-02}{2.8E-01} + \frac{8.0E-02}{2.8E-01} + \frac{2.7E-01}{2.7E-01}$$
$$+ \frac{5.4E-02}{5.4E-02} + \frac{6.1E-04}{6.4E-04}$$
$$10 \geq 9.3$$

Equation 7

Thus, by selectively reducing the concentrations of PAHs, no additional adjustments were necessary to meet the cumulative risk level. These adjusted PCLs (numerator values) now serve as the critical PCLs. **Note that once PCLs are adjusted based on cumulative concerns, the critical PCLs may shift and further assessment may be necessary to adequately define the PCLE zone.**

At this point, a similar cumulative evaluation should be conducted for the $^{Air}GW_{Inh\text{-}V}$ values and for the affected soil. Note that once the cumulative criteria of the rule have been satisfied and PCLs have been downwardly adjusted as necessary, the final step is to ensure that the critical PCLs are met for Affected Property B. This is accomplished by comparing the affected property COC concentrations to the relevant critical (lowest) PCLs (adjusted for cumulative concerns as necessary). As discussed in the introduction to this appendix, it has been assumed, for example purposes, that the Tier 1 human health PCLs are the critical PCLs. In practice, ecological PCLs, background concentrations, or MQLs could serve as the critical PCL as outlined in §350.78. Tier 1 $^{GW}GW_{Ing}$ and $^{Air}GW_{Inh\text{-}V}$ values (lowest values obtained from Tier 1 PCL Table 3 and the cumulative adjustment equation above) are presented in Table 8 and are compared to their respective representative COC concentrations in groundwater.

As shown in Table 8, concentrations for 8 COCs exceed the applicable Tier 1 critical PCL; 6 of these were identified as exceeding PCLs based on individual risk levels (benz-a-anthracene, benzo-b-fluoranthene, chrysene, cyanazine, methylene bromide, and 4-nitroaniline), while 2 COCs (benzo-k-fluoranthene and indeno-1,2,3-c,d-pyrene) have been added as a result of the cumulative adjustment, (see also Table 7). These PCL exceedances must be addressed. As an alternative to remediating to the Tier 1 values, Tier 2 or 3 values may be calculated using the options described in §350.75(i)(7) for comparison to representative concentrations to determine if a response action is warranted. Thus, these PCL exceedances indicate that a response action is necessary unless higher individual PCLs are subsequently established under Tier 2 or 3 and indicate that such action is not warranted. Note that the critical PCLs presented in Table 8 are the lowest of the adjusted carcinogenic PCLs and the noncarcinogenic PCLs, as applicable, for each COC. Although the cumulative evaluation was only

necessary for carcinogenic effects, any exceedance of noncarcinogenic PCLs must also be addressed.

Table 7 Affected Property B Groundwater Concentrations vs. Adjusted Lowest PCLs

COC	Adjusted Lowest $^{GW}GW_{Ing}$ [b, c] (mg/L)	$^{Air}GW_{Inh\text{-}V}$ [c] (mg/L)	Groundwater Concentration [d] (mg/L)	Concentration vs. Critical PCL
Acrylamide	4.2E-04	6.5E+01	4.2E-04	no exceedance
Benzidine	4.9E-06	1.4E+00	4.9E-06	no exceedance
Benz-a-anthracene	2.0E-03	4.4E+02	4.1E-03	> critical PCL
Benzo-a-pyrene	2.0E-04	8.4E+01	1.2E-04	no exceedance
Benzo-b-fluoranthene	1.5E-03	3.5E+02	3.0E-03	> critical PCL
Benzo-k-fluoranthene	1.3E-02	2.1E+04	2.6E-02	> critical PCL
Benzo-g,h,i-perylene	2.2E+00	---	5.5E-04	no exceedance
Chrysene	2.6E-01	1.3E+05	5.1E-01	> critical PCL
Cyanazine	2.4E-03	---	6.7E-01	> critical PCL
2,2-Dichloropropane	1.0E-02	1.0E+01	1.0E-02	no exceedance
1,2-Diphenylhydrazine	8.2E-04	8.3E+02	8.2E-04	no exceedance
Indeno-1,2,3-c,d-pyrene	6.0E-04	2.0E+03	1.2E-03	> critical PCL
1-Methyl chrysene	9.0E-02	1.7E+05	9.0E-02	no exceedance
2-Methyl chrysene	8.0E-02	1.7E+05	8.0E-02	no exceedance
Methylene bromide	2.7E-01	1.4E+02	4.8E-01	> critical PCL
4-Nitroaniline	5.4E-02	1.3E+04	1.0E-01	> critical PCL
Styrene	1.0E-01	5.8E+03	6.0E-02	no exceedance
2,4-Toluenediamine	6.1E-04	2.3E+04	6.1E-04	no exceedance

[a] Bolded values indicate the critical PCL. The critical PCL is the lowest PCL for a particular environmental medium considering all the exposure pathways for which a PCL is developed (§350.78(a)).

[b] These $^{GW}GW_{Ing}$ PCLs represent the lowest of the noncarcinogenic and adjusted carcinogenic Tier 1 $^{GW}GW_{Ing}$ PCLs.

[c] These Tier 1 PCLs were current at the time of publication. Use the most recent version of the Tier 1 PCL tables to evaluate an affected property as the values may have changed from those listed above.

[d] Concentrations should be determined according to §350.51. See also *Determining Representative Concentrations* (RG-366/TRRP-15)