Appendix F
Equating Contaminant-Related Ecological Service Losses and Restoration-Generated Service Gains for the Hylebos Waterway Using Habitat Equivalency Analysis

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The Hylebos Habitat Equivalency Analysis

The Commencement Bay Natural Resource Trustees are using Habitat Equivalency Analysis (HEA) to develop a proposal for resolving natural resource damage claims associated with the Hylebos Waterway. HEA is a tool for identifying the amount of habitat restoration needed to compensate for natural resource injuries resulting from specified causes, in this case from releases of hazardous substances. The HEA developed for the Hylebos Waterway natural resource damage settlement proposal (Hylebos HEA) follows the basic principles and concepts outlined in the paper "Habitat Equivalency Analysis: An Overview" (October 4, 2000) (see Appendix A). As Appendix A notes, HEA determines the appropriate scale of compensatory restoration actions in terms of the ecological services lost due to natural resource injuries and gained from habitat restoration projects.

For this proposal, the Trustees developed a case-specific HEA as detailed below. To meet the needs of the case, the Hylebos HEA takes into consideration the impact of multiple contaminants on a variety of habitat types and subject to different remediation strategies. The Hylebos HEA covers injuries occurring over a series of years. It also includes proposed compensatory restoration projects involving habitat types different from those injured by the contaminants. Because the Trustees have not pre-selected specific compensatory restoration projects, the Hylebos HEA is conducted in two stages. In the first stage, the Trustees determine the scale of the natural resource injuries by calculating discounted service acre-years (DSAYs) lost due to contamination for the waterway as a whole. A separate process, described in Appendix H, allocates those losses among waterway facilities. In the second stage, the Trustees will use the Hylebos HEA to calculate DSAY gains from restoration projects proposed in settlement negotiations.

Calculating DSAY Losses From Contamination

In general, to calculate DSAY losses the Hylebos HEA considers the ecological services the affected area of habitat would have provided without the contamination, the reductions in services resulting from the contamination, the year the service reductions started, and the year in which the reductions are expected to end. Losses from past and future years are converted to a present value by applying a discount factor (see Appendix B). The discounted figures for each year are summed to generate a DSAY loss figure for the affected area. A similar process is followed for each affected area and the figures for all areas are summed to generate the total DSAYs lost for the waterway.

Appendices C and D describe the analyses the Trustees have followed in determining the ecological service levels to assign to different habitat types, the percent service losses resulting from contamination and how to aggregate the effects of multiple contaminants. Appendix E describes how the Trustees have used a geographic information system (GIS) to develop a database of information regarding the habitat characteristics of different areas of the waterway, the presence and concentration levels of different contaminants, the presence of conditions that diminish or alter habitat values, and whether an area is scheduled to be actively remediated or to be left to recover naturally. The GIS displays these different factors as layers of data contours overlain on a base map. When all the data layers are combined, the resulting map shows the waterway divided into discrete areas or polygons, each with a unique combination of the displayed factors.

The information in the GIS database serves as the primary input to the Hylebos HEA. The database contains spreadsheets in which each row on the spreadsheet corresponds to a map polygon. Within each row (record) are spreadsheet cells, each of which contains data representing the different mapped factors. The record for each polygon also includes data on the size (acres) of the polygon. The GIS database is output from the GIS computer and input to the computer running a SAS® program making up the Hylebos HEA model. The Hylebos HEA model computer program itself runs a complex mathematical calculation.

The Hylebos HEA uses the database imported from the GIS to calculate a DSAY loss figure for each polygon. The program examines each record in the database, using the data in each cell to assign a number to a variable in the HEA formula. The program then calculates the formula to determine the services lost per year for that polygon. The spreadsheet cells for water depth, substrate type and presence or absence of limiting or enhancing conditions contain data the program uses to determine the ecological services the area would provide without contamination. Data in the cells corresponding to each of the contaminants are used to determine the services lost each year as a result of contamination.

For example, if the data show the polygon being analyzed has an elevation of -4 to +13 feet, substrate with less than 20% rock, and no shading or wood debris problems, it would be classified as intertidal and assigned a baseline ecological service value of 0.75. If the data show zinc contamination at level 5 (3800 ppm dw and above) and hexachlorobenzene (HCB) contamination at level 4 (130 ppd dw and above), the model would apply a 20% service loss for the zinc and a 15% service loss for the HCB, or a combined service loss of 32%.[1] The 32% service loss applied to the baseline service value of 0.75 per acre, would result in a loss of 0.24 in service value per acre. If the data show that the polygon is 1.3 acres in size, the model would multiply the service value loss times the size to yield a figure of 0.312 service-acres lost for the year analyzed.

To determine the total service losses for all years covered by the Trustees' analysis, the Hylebos HEA uses database information indicating whether or not the area

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[1]A 20% service loss would leave 80% of the baseline service level in the affected area. A 15% service loss, applied to the remaining 80% of services, would result in a further loss of 12 % (0.15 x 0.8 = 0.12) of the baseline services, for a combined loss of 32% of the baseline services. A memorandum included with Appendix D describes how the effects of multiple contaminants are handled.

involved will be actively remediated. The Trustees are calculating service losses beginning in 1981, and continuing each year through the point at which the area returns to its full without-contamination ecological services potential following active remediation or natural recovery. The Trustees assume that remediated areas will return to their full services potential 10 years following remediation, and that natural recovery areas will return to full services potential 25 years following remediation of the rest of the waterway. For remediated and natural recovery areas, the program calculates the same service loss value per year from 1981 through 2003, when the Trustees assume the remediation will be complete. Depending upon whether the area is subject to remediation, the program calculates services losses diminishing at a fixed rate per year for an additional 10 or 25 years.

The program converts past and future losses to a current (2001) value by multiplying the losses for each year by a discount factor corresponding to the calendar year in which the loss occurs (based on 3% per year). Thus, the program multiplies losses incurred in 2000 by 1.03, and losses projected to occur in 2002 by 0.97. The program sums the discounted service acre-years for each year of the analysis and calculates a total DSAY loss figure for the polygon. The program then repeats this process for the next polygon, and sums the results of all these operations to calculate a total DSAY loss figure for the waterway. The Hylebos HEA calculated that all the contaminants in the waterway together have generated a total loss of 2438.68 DSAYS.

Allocating DSAY Losses Among Facilities

Appendix H details the analysis used to allocate liability for DSAY losses among Hylebos Waterway facilities. While the HEA and the allocation are two separate processes, the Hylebos HEA program contains some elements designed to facilitate the allocation. As Appendix H describes, liability has been allocated using one of three approaches: a footprint analysis, a mass loading analysis, and a hybrid of the two.

In performing the footprint analysis, the Trustees identify discrete patterns of contaminants from the GIS maps. Because of the way the map polygons are created, each chemical footprint can include multiple polygons, and each polygon may fall within multiple footprints. For example, one patch of sediments may be contaminated only with zinc while an adjacent patch may be contaminated with zinc and HCB. Since the two patches have different compositions, they would constitute separate polygons. However, from the pattern of the contamination the Trustees may assign both polygons to the zinc footprint for analyzing liability for zinc contamination, and may also assign the polygon with the zinc and HCB to the HCB footprint for analyzing HCB contamination.

The Hylebos HEA calculates service losses in terms of polygons, based upon the effect of all contaminants within the polygon. To allocate liability by the footprint of a specific contaminant, the Trustees must apportion the DSAY losses for each polygon containing multiple contaminants among each contaminant within the polygon. To facilitate this step, the GIS database includes information identifying the footprint assignments for each polygon. A portion of the Hylebos HEA program uses this footprint identification to divide the DSAY losses among the contaminants and sums the losses for all polygons within the same footprint for each contaminant.

Appendix H describes how the liability for polychlorinated biphenyl (PCB) and polycyclic aromatic hydrocarbon (PAH) contamination is allocated by a mass loading analysis. That analysis relies on waterway segments rather than footprints. The GIS database also includes information assigning polygons to waterway segments. Following an approach similar to that used with the footprint analysis, a portion of the Hylebos HEA program apportions a share of the DSAY losses for each polygon containing PCBs or PAHs to those contaminants, and sums the losses for all polygons within a segment for each of those contaminants.

The Trustees apply the results of the allocators' analysis to the output of the HEA to produce the final compilation of allocated DSAY losses. The allocators assign each footprint's share (or a percentage of a footprint's share) of DSAY losses to a particular facility. For PCBs and PAHs, the allocators assign each responsible facility a percentage of the DSAY loss liability for those contaminants in the waterway segments to which the facility is assigned. The DSAY losses allocated to a facility for all contaminants are summed to give the total DSAY loss figure for which the Trustees consider the facility liable.

Calculating DSAY Gains From Restoration

The process for estimating habitat benefits is similar to calculating habitat losses. The Trustees' goal is to generate through restoration actions a level of ecological service gains that will compensate for the service losses due to contamination. Consequently, the Trustees begin by determining the starting level services provided by a proposed restoration site, then determining the level of services that will be provided by the restoration project, and then calculating the total difference in services that the project will generate. The Trustees have assumed that the restoration projects will take place on uncontaminated sites so issues of remediation or service loss do not enter in the benefits calculation. Because the calculation of service gains requires the consideration of far fewer variables than the calculation of service losses, the Trustees have prepared a simplified version of the HEA, based on a series of Excel® spreadsheets, for use in evaluating proposed restoration projects.

The process starts with a conceptual project design using GIS, CAD or other mapping or drawing programs. The Trustees determine the number of acres of different habitat types that currently exist on the project site. Based on site visits and visual inspection, the Trustees determine the level at which the existing habitats are currently functioning to assign a starting ecological services value to the different habitat types. From the proposed project design the Trustees determine the number of acres of different habitat types that will be developed by the project, and the projected ecological service levels. These data, along with assumptions regarding the date of project development, and whether and how the site might otherwise change,[2] are entered into the restoration model.

The model calculates the increase in ecological services the project would generate per year by subtracting the services each acre of different habitat types on the project site would produce without the project from the services each acre in the proposed project is expected to produce. Based on assumptions about how long different habitat types take to develop, the model credits a fraction of the increase each year beginning with project construction until the project is assumed to reach full function. For example, where a portion of a proposed project involves planting unvegetated fill to develop the habitat type Upland Greenbelt, the gain in services per acre will be 0.15. (The Trustees' model assigns fully functioning Upland Greenbelt a value of 0.15 and unvegetated fill a value of 0.0.) The Trustees assume it will take eight years for newly created Upland Greenbelt to reach its fully functioning value. The benefits from creating the Upland Greenbelt for the first year of the project are calculated by multiplying 1/8 by 0.15, the projected gain. The same calculation is repeated, increasing the fraction by 1/8 each year, until the eight year when the benefits are 8/8 times 0.15.

A similar process is followed for each element of the project to calculate total project service-acre gains per year for each year of the project. Thus, for each project element the service value produced without the project is subtracted from the service value the project element would produce, and an increasing fraction of the gain is credited for each year until the project element achieves full function. The service gains per year for all project elements are summed for each future year and discounted to a present value, and the discounted gains for all years are summed to generate a total DSAY gain figure for the project.

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[2]A proposed restoration project that primarily involves preserving the existing condition of the project site may nevertheless generate DSAY service gains if the Trustees judge that there is a likelihood that the ecological services currently being provided by the site will be lost due to development unless the site is preserved. In that case, the Trustees would project how the site is likely to change and over what time frame in determining the present discounted service acre-years the site would produce without the project.