KING COUNTY TONNAGE FORECAST MODEL

April 28, 1994

FORECASTS: METHODOLOGY AND RESULTS.

This paper provides a brief description of the King county solid waste division's disposal forecast model. It also presents the total disposal tonnage forecasts through the year 2000. Because the forecasts depend upon our estimates of waste reduction, an appendix is included that describes in detail our current methodology for estimating waste reduction.

Solid waste tonnage forecasts are needed by the division for the purposes of long range planning, budget preparation, and rate determination.

PART 1: PLANNED PROGRAM FORECASTS.

Solid waste disposal forecasts are derived through the use of econometric equations. First, the historical relationships between disposal tonnage and the variables[1] that are expected to impact disposal are estimated. The disposal equation we currently use includes the following variables: disposal price (the inflation adjusted transfer station tipping fee), income (inflation adjusted regional per capita income), household size (population per household), population, and curbside availability (the fraction of households with access to curbside recycling). By using regression analysis, the relationship between the preceding variables and disposal tonnage is estimated. Our current forecasts are based upon the following estimated equation (t-statistics[2] are reported in parenthesis below their respective coefficients):

$$\text{EQ1. Disposal} = \underset{(.82)}{1464520} + \underset{(2.82)}{.87}\text{x(population)} - \underset{(-.45)}{870}\text{x(price)} - \underset{(-3.07)}{156542}\text{x(curbside)}$$

$$- \underset{(-1.51)}{843152}\text{x(household size)} + \underset{(1.79)}{57.13}\text{x(income)} - \underset{(-1.27)}{54892}\text{x(dcdl).}$$

R-squared = .98
Adjusted R-squared = .97
Durbin-Watson statistic = 1.64
Standard error of the regression = 31364.1

The variable dcdl is a zero one dummy variable that represents the policy banning CDL from the waste

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The variables that are expected to impact disposal are referred to as the independent variables, and disposal tonnage is referred to as the dependent variable.

T-statistics are a measure of the degree of confidence we have that the estimated coefficient is different from zero. For example, using a one tailed test (which is appropriate when the expected sign of the variable is known) with nine degrees of freedom, a t-statistic of 1.383 tells us that we are 90% confident that the estimated coefficient is different from zero. Note that some of the variables in our equation are not significantly different from zero at the 90% confidence interval. Nevertheless, because they have theoretical importance and because their presence impacts the other estimated coefficients, it would be inappropriate to remove them from the forecast equation.

stream starting in September 1993. This variable is one for 1993 and zero for all preceding years.[3] The other independent variables are described above.

The coefficients for each independent variable represent the expected change in disposal tonnage associated with a change in each independent variable. Initial disposal forecasts are obtained by inserting forecasts of the independent variables into equation 1. The forecasts for population, income and household size are obtained from the Puget Sound Regional Council. The fraction of households receiving curbside recycling is assumed to remain at its current level (this of course can be adjusted as new programs are developed), and, for prices beyond known rate periods, the transfer station tipping fee is assumed to rise at the same rate as inflation.

We then adjust our initial disposal forecasts to incorporate anticipated changes in solid waste tonnage. For example, starting in the fall of 1993, we estimated a 1.5% reduction in disposal due to the combined effect of the ban on yard waste from curbside disposal collection in unincorporated King county and the ban on appliance disposal at King county transfer stations. A two percent reduction in tonnage is assumed to begin in June of 1994 due to the opening of two new CDL facilities. An additional one percent reduction is assumed to start in June of 1994 due to the ban on yard waste from curbside disposal collection for incorporated King county. And, an additional five percent reduction in disposal is assumed to begin in 1996 due to the planned total ban on yard waste.

Once we have made these adjustments, we have our Planned Program Forecasts. These forecasts tell us our expected disposal levels given the programs that are currently planned. However, these are not our final forecasts. To obtain our final forecasts, we need to consider that other (currently unknown) programs and policy changes are likely to be undertaken in the future in order to achieve our 65% waste reduction and recycling goal.

Currently, the dcdl variable is being used as a control variable to prevent bias from entering our equation due to the impact of the CDL policy change. As time goes on and additional data comes in, this variable can be used to directly estimate the impact of the CDL policy change on our waste stream. Currently, we are assuming a 15% reduction in our disposal stream due to the CDL policy change. This assumption was based upon estimates obtained from another econometric model which monitors monthly disposal. For the purposes of forecasting, we have also adjusted our historical disposal stream to account for past changes in CDL due to the Mt. Olivett and Newcastle landfill closures. On net, after adjusting our data, the reduction in equation 1 due to the new CDL policy is 10%. Therefore, our initial disposal forecasts obtained from equation one are adjusted downward by 10% to account for the new CDL policy.

PART 2: GOALS BASED FORECASTS.

In order to monitor our progress toward reaching our waste reduction and recycling goals and to adjust our forecasts to reflect anticipated changes in disposal associated with achieving those goals, it is necessary to forecast recycling tonnage as well as disposal tonnage. Using historical recycling data from 1977 through 1992[4], the following econometric equation was estimated:

EQ2. Per Capita Recycling = -.50 + .001x(price) + .158x(curbside) + .000045x(income).
(-5.78) (1.87) (7.73) (6.51)

R-squared = .98
Adjusted R-squared = .97
Durbin-Watson statistic = 1.81
Standard error of the regression = .012736

Using equation 2 and projections for population and the independent variables, initial forecasts for recycling tonnage are obtained. Since by definition, waste generation is equal to recycling plus disposal, by adding equation 1 to equation 2 we obtain forecasts for waste generation.[5]

Waste reduction is defined as a reduction in waste generation. For the purposes of forecasting, we are currently assuming a 2% per year waste reduction rate. Appendix A discusses our methodology for estimating waste reduction and our current waste reduction estimates upon which this assumption is based.

Our forecasts for waste generation do not include waste reduction. Therefore, we have to add estimates for waste reduction to our waste generation forecasts in order to obtain a waste generation plus waste reduction forecast. Once we have a waste generation plus waste reduction forecast, we can then calculate the required waste reduction and recycling tonnage needed in each year in order to achieve our waste reduction and recycling goals. We then subtract our goal based waste reduction and recycling tonnage from our forecast waste generation plus waste reduction tonnage. This gives us our Goals Based Disposal Forecast.

If the Goals Based Disposal Forecast is smaller than the Planned Program Forecast, then we need to increase our waste reduction and recycling efforts in order to achieve our goals. To derive our final forecasts, we compare the Goals Based forecasts with the Planned Program forecasts and take the smaller of the two.

The recycling data for the years 1977 through 1987 were obtained from estimates provided by R. W. Beck and Associates. The Recycling data from 1988 through 1992 were obtained from the Department of Ecology's recycling survey. Because ferrous metals have not been consistently reported in our historical data, we have taken ferrous metal estimates out of the historical recycling data. This allows for a consistent data comparison and a more accurate econometric model. We then add ferrous metals back into the recycling data on a per capita basis using our most recent ferrous metals estimates (1992 data). This adjustment provides us with a more consistent data base.

Because our primary source of recycling data is the DOE survey estimates, for the purpose of forecasting, we are defining recycling to include the same categories as reported in the DOE survey.

As mentioned in footnote 3, our disposal forecasts have been adjusted downward to account for changes in our CDL policy. It is also necessary to adjust our generation forecasts by the same amount. So, our generation forecasts are derived by adding equation 2 to equation 1 **after** the CDL adjustments are applied to equation one. This reduces our generation forecasts and therefore prevents us from counting the reduction in disposal due to the CDL ban as part of our waste reduction or recycling estimates.

Our current total disposal forecasts (including special waste) through the year 2000 are reported in table 1 below:

TABLE 1. Disposal Forecasts.

YEAR	PLANNED PROGRAM DISPOSAL	GOALS BASED DISPOSAL	FINAL FORECASTS
1994	832000	960000	832000
1995	844000	918000	844000
1996	820000	906000	820000
1997	846000	889000	846000
1998	875000	868000	868000
1999	903000	843000	843000
2000	933000	816000	816000

The methodology used for obtaining our goals based forecasts requires a forecast for waste generation. Our current forecasts for waste generation through the year 2000 are reported in table 2 below. We have also included forecasts for recycling which, in this paper, are calculated as waste generation minus disposal. The disposal forecasts reported in table 2 exclude special waste.[6] Forecasts for recycling rates are also reported, where recycling rates are calculated as forecast recycling divided by forecast generation. Forecasts for our combined waste reduction and recycling rates are also reported in table 2.

TABLE 2. Generation, Disposal and Recycling Forecasts.

YEAR	Generation Forecasts	Recycling Forecasts	Disposal Forecasts	Recycling Rate	Waste Reduction and Recycling Rate
1994	1511000	685000	826000	45%	52%
1995	1559000	721000	838000	46%	54%
1996	1606000	792000	814000	49%	57%
1997	1654000	814000	840000	49%	58%
1998	1703000	840000	862000	49%	59%
1999	1753000	917000	836000	52%	62%
2000	1811000	1002000	809000	55%	65%

Our waste reduction and recycling rates are supposed to be based upon mixed municipal solid waste disposal. Therefore, when calculating our waste reduction and recycling rate, we exclude special waste from our definition of disposal. The disposal forecasts listed in table 1 include special waste. The disposal forecasts listed in table two exclude special waste.

PART 3. FORECAST LIMITATIONS.

It should be emphasized that the future is unknown. The forecasts obtained above are merely projections into the future and as such they are subject to forecast error. There are several sources of forecast error that we can discuss. First, the primary assumption whenever econometric models are used for forecasting is that the basic relationships between the independent variables and the dependent variable remain constant over time. To the extent that these basic relationships change, then the forecasts will be inaccurate. Second, the disposal forecasts are based upon forecasts for the independent variables. To the extent that our independent variable forecasts are inaccurate, then the disposal forecasts will also be inaccurate. For example, if future population growth exceeds the Puget Sound Regional Government's forecasts for population growth, then we would expect future solid waste tonnage to exceed our current solid waste tonnage forecasts. Third, the forecasts are based upon a statistical model that contains random (or unexplained) variation. This variation may be due to left out variables in the forecast equations or it may be due to purely random events. This portion of the forecast error is something we can estimate and use to develop a confidence interval for our forecasts. Using an 80% confidence interval, high and low total tonnage forecasts are derived and are reported in table 3 below. It must be remembered that this confidence interval does not incorporate potential error due to inaccurate forecasts of the independent variables or due to changes in the relationship between the independent and dependent variables.

TABLE 3. Forecast Range.

YEAR	LOW FORECASTS	FINAL FORECASTS	HIGH FORECASTS
1994	780000	832000	884000
1995	791000	844000	897000
1996	771000	820000	869000
1997	798000	846000	894000
1998	782000	868000	954000
1999	757000	843000	929000
2000	728000	816000	904000

APPENDIX A: WASTE REDUCTION.

Waste reduction is defined as a reduction in waste generation, where waste generation is defined as solid waste disposal plus recycling. Waste generation is identified by the following equation:

EQ3. $G = D + R$

where G represents waste generation, D represents disposal and R represents recycling. Since equation 1 is an identity, we can differentiate it to get:

EQ4. $dG = dD + dR$

which states that a change in generation is equal to a change in disposal plus a change in recycling. By definition, waste reduction is equal to a negative change in waste generation. It is important to recognize that all of the variables in equation 3 (generation, disposal and recycling) are influenced by demographic characteristics such as population growth, household size, and income. Therefore, when measuring waste reduction, it is necessary to control for changes in demographic characteristics that would otherwise impact measured generation. We can control for these changes in demographics by using an econometric equation to estimate waste reduction.

For example, the following equation was estimated using waste generation data for the years 1977 through 1992.

Dependent variable: NATURAL LOGARITHM OF PER CAPITA WASTE GENERATION
Current sample: 1977 to 1992
Number of observations: 16

Mean of dependent variable =	-.059203
Std. dev. of dependent var. =	.189382
Sum of squared residuals =	.020201
Variance of residuals =	.183644E-02
Std. error of regression =	.042854
R-squared =	.962451
Adjusted R-squared =	.948796
Durbin-Watson statistic =	2.02597
F-statistic (zero slopes) =	70.4870
Schwarz Bayes. Info. Crit. =	-5.80819
Log of likelihood function =	30.6940

Variable	Estimated Coefficient	Standard Error	t-statistic
CONSTANT	-14.3617	6.45552	-2.22471
INCOME	2.11674	.504763	4.19354
HOUSEHOLD	-5.47931	1.87965	-2.91507
PRICE	-.120270	.079569	-1.51151
TREND88	-.036516	.012718	-2.87111

The dependent variable is the natural logarithm of per capita waste generation. The independent variables include income, household size and disposal price (defined as the inflation adjusted price per ton of disposal charged at transfer stations). All of these variables are converted to their natural logarithms. A constant term is also included in the equation.

Finally, a trend variable that starts with one in 1988[7] and increases by one for every year beyond 1988 is also included (TREND88). This variable tells us that starting in 1988 King county has experienced a 3.65% per year reduction in waste generation[8]. Because this is a trend variable, it cannot tell us the source of the waste reduction. It merely indicates the measured reduction in per capita waste generation experienced since 1988, while controlling for differences in the other independent variables.[9]

Although the measured waste reduction rate is 3.65% per year, King county has chosen to adopt a more conservative 2% per year waste reduction rate for the purposes of forecasting.

It should be noted that the estimated waste reduction rate is defined as a change in waste generation. This is not the same as a change in disposal. The estimated change in generation will impact both disposal and recycling. For example, with a recycling rate of 50%, the 3.65% per year waste reduction rate would reduce disposal by only 1.825% per year (or half of the estimated 3.65%). This must be kept in mind when evaluating programs or making comparisons across

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1988 was chosen as the base year to start measuring waste reduction because that was the first year that curbside recycling programs were introduced in King County. It is believed that a general public awareness of solid waste as a potential social problem began at about the same time.

The coefficient for the variable TREND88 represents the partial derivative of the dependent variable with respect to the independent variable. This equals:

EQ5. $d\ln(G/P)/dTREND88 = (d(G/P)/(G/P))/dTREND88$,

where G = generation and P = population. Equation 5 represents the percentage change in per capita generation due to a change in TREND88. Since the change in TREND88 is equal to one for each year since 1988, the coefficient represents the annual percentage change in per capita generation starting in 1988.

Because the trend variable cannot identify the source of the waste reduction, it is possible that we are picking up changes in measured waste generation that do not reflect true waste reduction. For example, since our source for recycling data since 1987 is the Department of Ecology's recycling survey, we may be picking up recycling that was not measured by the DOE recycling survey. That is, since the DOE survey relies on recyclers to report all recycling to them, and since some recyclers do not respond to the survey, this data source may be underestimating true recycling tonnage. To the extent that underestimated recycling is the source of our estimated waste reduction rate, it is still appropriate to include our estimated waste reduction as part of our waste reduction and recycling goal.

It is also possible that a source of the estimated waste reduction rate is merely leakage out of the King county system. To the extent that leakage out of our system is a source of our estimated waste reduction rate, we would not want to include the leakage as part of our waste reduction and recycling goal. However, we are confident that leakage is not a major source of our waste reduction estimates. To address the possibility of leakage we included disposal data from both Snohomish county and from the city of Seattle in the regression equation. In both cases, the TREND88 variable was not affected by the other jurisdictions' disposal data, so we are confident that the TREND88 variable is not picking up leakage to either Seattle or to Snohomish county. If we can obtain disposal data from other jurisdictions that are potential sources for leakage, we can test to see if their data is correlated with our measured waste reduction rate. Another reason we are confident that leakage is not a major source of our estimated waste reduction rate is that we are already controlling for reductions in tonnage that are due to increased disposal prices. By maintaining a price variable in the regression equation we are already controlling for the leakage out of our system that is due to higher disposal prices. We therefore believe that leakage is not an important source of our measured waste reduction rate.

jurisdictions. We may be interested in evaluating only that portion of waste reduction that impacts disposal directly. For example, if we are adding a given percentage for waste reduction to our stated waste reduction and recycling goals, we only add that portion of the waste reduction rate that impacts disposal directly. So, if the recycling rate is 50%, given our assumed waste reduction rate of 2% per year, the assumed disposal reduction rate would be only 1% per year starting in 1988. However, because this is a cumulative impact, a 1% per year disposal reduction rate starting in 1988 would convert to an 8% total disposal reduction rate by the year 1995 (again assuming a 50% recycling rate). Thus if the 1995 measured recycling rate were 50%, the estimated waste reduction and recycling rate would convert to 58%