Industrial Benefits of Controlling Saltwater Intrusion in the Neches River

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Abstract

The Lower Neches Valley Authority in Texas uses the Neches River to supply water to its agricultural, industrial, and municipal customers. Temporary saltwater barriers are currently being used to prevent saltwater intrusion on the lower Neches River from the Gulf of Mexico. This study estimates the industrial benefits of a proposed federal permanent saltwater barrier.

Introduction

The Lower Neches Valley Authority (LNVA), which includes the Jefferson, Hardin, and Tyler Counties of Southeast Texas, distributes fresh water to municipal, industrial, and agricultural water users through a system comprised of five major pumping plants and approximately 400 miles of canals and associated structures (Hebert 1994). The LNVA was created in 1933 as a Conservation and Reclamation District. The sources of the fresh water delivered by LNVA are the Neches River and the Pine Island Bayou, a tributary of the Neches.

Saltwater intrusion is a documented problem that has persisted in the lower reaches of the Neches River for quite some time. Because of the Neches River's proximity to the Gulf of Mexico, and because it has been dredged to about 40 foot depths to support the deep water ports of Beaumont and Port Arthur, an unimpeded avenue has been created for the upstream movement of saltwater from the Gulf. If allowed, the saltwater may encroach upon the intakes of LNVA, thereby jeopardizing the fresh water supply for its users.

The Beaumont-Port Arthur area, one of the world's largest petroleum and petrochemical complexes, has twenty-six (26) industries that use about 45% of the LNVA water and also employ a large portion of the local workforce (Hebert 1994). The type of industries ranges from refining, petrochemical, and tire and rubber to raw products for resin. Because there are no alternative sources of water for the industry, the industrial sector is entirely dependent on the LNVA water and cannot accept water with more chloride than 150 Parts Per Million(PPM) for processing and 250 PPM for cooling

(Hebert 1996). In particular, high quality water is required for resin production and the area produces about 70% of resins (used for plastic) made in the U.S. (McCauley 1996).

Historically, the LNVA and the US Army Corps of Engineers have prevented saltwater intrusion by the use of temporary saltwater barriers and also by water releases from Lake Sam Rayburn. Whenever the lake drops into a critical zone, the Corps of Engineers notify the LNVA to commence installation of the temporary saltwater barriers. When the barriers are installed, the Corps of Engineers reduces reservoir releases to equal the rate of downstream diversions. The barriers remain in place until stream flow rates are sufficient to suppress upstream movements of saltwater, or water stored in upstream reservoirs is sufficient to supplement stream flow and prevent upstream salt movement. The temporary barriers thus accomplish two objectives: (1) they prevent the catastrophic effects of saltwater intrusion, and (2) they permit the conservation of up to 2,500 cubic feet per second of fresh water presently being released to keep stream flow rates at levels sufficient to prevent the salt from moving upstream (U.S. Army Corps of Engineers).

During the regulatory permitting process on the temporary barriers, it was determined that the present method of temporary saltwater barriers does not provide an acceptable long-term solution to the problem of salinity intrusion because of the long-range adverse effects on the flora and fauna in the nearby Big Thicket National Preserve area, the interference with navigational use of the river as well as with migration of fresh water fish from downstream of the barriers, and the susceptibility of the temporary barriers to breaching during floods. The LNVA, U.S. Army Corps of Engineers, and other parties involved are thus considering the construction of a federal permanent saltwater barrier while preserving the environment, protecting the property owners from flood damage, and maintaining free and reasonable unobstructed use of the river by existing and future navigation. The Corps of Engineers has decided that the LNVA would receive one final permit to utilize the temporary barrier to prevent saltwater intrusion. The permit was issued on March 21, 1994 and will expire on December 31, 1999. An extension may be issued if construction of the permanent saltwater barrier is evident. Until 2000, the LNVA operations will continue as they have for the last sixty years. After January 1, 2000, either the construction of the permanent saltwater barrier will be underway or the LNVA customers will be faced with supply disruptions due to salinity.

The objective of this study is to estimate the industrial benefits of a permanent saltwater barrier on the Neches River. While the present authors have simultaneously investigated the agricultural and municipal benefits of a permanent saltwater barrier (Chowdhury et al.), this paper is focused only on the industrial benefits. It is also worth mentioning that this paper investigates only the primary economic benefits, and the estimation of environmental costs or benefits as well as secondary benefits due to the permanent saltwater barrier is beyond the scope of this paper. The remaining sections of this paper comprise a discussion of methodology and data, estimation, and results and implications.

Approach and Procedure

Survey

A questionnaire was prepared and mailed to all industrial customers served by LNVA. Data requested from the local companies included water use, size and type of industry, available alternative(s) if LNVA water was not available, and cost or loss per day under those alternative plans. A few large companies did not participate in the survey and the responses for these companies were extrapolated from the responses of a similar company.

The survey responses show that most companies do not have salt treatment or water storage capabilities and also do not have any feasible alternative to LNVA water. While a few companies explicitly stated that they would either shut down or relocate, many were unclear and vague about their course of action if the LNVA water was not available to them due to salinity. The survey also reveals that the economic loss due to salinity will vary across companies due to their size, available resources and alternatives, and nature of business. On the whole, however, it is evident from the survey that the industrial sector will be seriously affected by the absence of LNVA water and almost all companies strongly voiced their concern regarding this matter. Along with a few large companies, a few small companies did not participate in the survey and they are not included in the study. Because these companies are small and very minor water users, they are not expected to have any significant impact on the results of the study. At the request of the companies who participated in the survey, the survey responses are kept confidential

@RISK Simulation Model

The typical way of handling uncertainty in benefit-cost analysis is to recalculate the benefits and costs using differing assumptions or values for crucial variables. While such sensitivity analysis is useful to describe the sensitivity of output to particular input variables, they are imperfect descriptions of the underlying uncertainty. Sensitivity tests describe the range of uncertainty, but they do not provide any information concerning the probability distribution of estimates. More importantly, if several variables are included in the sensitivity analysis, the procedure becomes complicated and it remains difficult to isolate the possible interaction of one combination of ranges from the other. Thus, while sensitivity tests are useful and undoubtedly an improvement over merely accepting "best estimates," they do not provide an adequate resolution of the problems of uncertainty and joint variation.

Another method used to incorporate uncertainty into the water resource investment decision is to add a risk premium to the discount rate in the present value algorithm. The inability to reliably determine risk premium makes this method open to question. Furthermore, the argument for a risk premium lacks merit since a project should be judged not by the expected value of benefits and costs, but also by the probabilities of a range of benefits and costs, i.e., a measure of variability.

A preferred procedure for evaluation of the impact of uncertainty and joint variation is to generate probability distributions for the relevant input variables and aggregate these distributions to produce a probability distribution for the output. For a problem such as the Neches River saltwater barrier, there is sufficient historical evidence available to estimate probability distributions or relative frequencies of saltwater intrusion. For cases where an objective probability distribution can not be calculated because of lack of enough data, a subjective probability distribution can be used based on available information. Typically, the procedure for working with subjective probabilities begins with three estimates of possible values for an input component: a pessimistic value, an expected value, and an optimistic value. Subjective probability distributions are thus considered "second best" and preferable to the option of omitting a measure of uncertainty altogether.

Recognizing the importance of a probabilistic methodology, the risk simulation model "@RISK" (Palisade Corporation) was used in this study for model building and risk analysis. As an "add-in" to a spreadsheet such as Microsoft Excel or Lotus 1-2-3, @RISK "links" directly to Excel or Lotus to add risk analysis capabilities. In general, the techniques in @RISK risk analysis consist of four steps: (i) developing a model, (ii) identifying the uncertainty, (iii) analyzing the model with simulation, and (iv) presentation of results and making a decision.

A wide variety of distribution types are available in @RISK ranging from normal, uniform, and triangular to more complex forms such as gamma and weibull, each of which describes a range of possible values and their likelihood of occurrence. Using Monte Carlo or Latin Hypercube sampling technique, @RISK performs hundreds of "what if" scenarios where the distribution of possible outcomes is generated as the model recalculates the worksheet over and over again, each time using different randomly selected sets of values for the probability distributions in the cell values and formulas. By showing that some outcomes are more likely to occur than others, the output probability distributions give the decision maker a complete picture of all possible outcomes and help to make a decision.

Estimation of Industrial Benefit

@RISK Modeling

According to the survey responses regarding available alternatives to LNVA water, the companies were divided into six categories: (1) shutdown, (2) groundwater, (3) self-sufficient, (4) relocate (domestic), (5) relocate (overseas), and (6) operate at a fraction. Data on loss per day was provided by companies who indicated their option as 'shutdown,' 'relocate' or 'operate at a fraction.' Economic losses without saltwater barrier were assumed to be zero if the company indicated that it was self-sufficient, i.e., the company either has salt-removing capability or has its own reservoir. Similarly, zero costs were assumed if the company's intention is to relocate inside the U.S. when the LNVA water is not available due to salinity. The basis of this assumption for national costs is that the gain in another part of the U.S. is expected to offset the loss in Southeast Texas.

Some companies indicated that they might use groundwater if LNVA water was not available due to salinity. For these companies, costs of ground water were calculated by using the ground water cost data from McCauley (1994). A ground water option included well establishment costs, pipeline installation costs (to transport water), and costs for obtaining land with water rights in north Jefferson County or South Hardin County. During times of no salinity, the company may decide to use LNVA water, and for these years a well maintenance cost was included. The well maintenance cost was assumed to be the well pumping costs for half a day every month during times of LNVA water use. Finally, 50% of total loss per day was used to develop an estimate for costs if the company's alternative option was to operate at a fraction of capacity.

During 1934-1993, the saltwater barrier was installed in 26 of the years for periods ranging from 4 to 255 days. The average period of installation during these past 60 years was 123 days. Using this historical record, a probability distribution was calculated and used inside the @RISK model.[1] The model operates with the following steps: first, the model calculates daily loss of a company in the absence of a saltwater barrier based on the survey response. For the cases of 'shutdown,' 'self-sufficient,' 'relocate,' and 'operate at a fraction,' the calculation of daily loss was relatively straightforward since these data were obtained from the survey. For the case of groundwater, however, a number of scenarios were incorporated in the model which include (i) no saltwater intrusion during current or previous year, (ii) saltwater intrusion during current year but none in previous year, (iii) saltwater intrusion in previous year, but none in current year, and (iv) saltwater intrusion during both current and previous years. Based on the frequency distribution of saltwater intrusion, the scenarios are chosen by the model and the appropriate yearly costs are computed. Along with pumping costs, the investment costs for well establishment are added by the model when salinity is encountered for the first time. Thereafter, only well pumping costs are added when groundwater is used. To avoid double counting for this scenario, LNVA water costs were calculated and subtracted when the company used groundwater. Based on the probability distribution, well maintenance costs are added to a company's cost when the company is not experiencing saltwater intrusion and thus has started to use the LNVA water again.

Second, after calculating the loss of gross profit, net profit was calculated by multiplying the gross profit with a rate of margin. The companies served by LNVA did not disclose their profit margin. Since profit margin varies from year to year, a triangular distribution was used where a 'pessimistic,' 'most likely,' and 'optimistic' rate of margin was assumed to be 10%, 20%, and 30%, respectively (U.S. Department of Commerce).[2]

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[1] The @RISK model uses information from the probability distribution with the help of a function called "RiskDiscrete" where the frequencies of occurrence are entered first followed by the associated probabilities.

[2] The probability density function of a triangular random variable X is of the form:

$f(x) = 2(x-x_c)/(x_b-x_c)(x_a-x_b)$ $\quad x_c \le x \le x_b$

$f(x) = 2(x_a-x)/(x_a-x_b)(x_a-x_c)$ $\quad x_b \le x \le x_a$

$f(x) = 0$ elsewhere

where, x_c = optimistic estimate, x_b = expected value, and x_a = pessimistic estimate

These three subjective estimates form the limits of a triangular distribution. The triangular distribution's uncomplicated shape makes it attractive when used in a simulation model.

Third, net profit loss was converted to present worth using a discount rate of 7.625%, the current rate prescribed by the Water Resources Council. Finally, the present values of benefit were added for fifty years and the total benefit was simulated with one hundred iterations to generate a probability distribution for industrial benefits. Simulation in this sense refers to a method whereby the distribution of possible outcomes is generated by letting a computer recalculate the worksheet over and over again, each time using different randomly selected sets of values for the probability distribution in the cell values and formulas.

Results

Table 1 reports the industrial benefits of a permanent saltwater barrier based on @RISK simulation. These are the total present value of benefits over fifty (50) years. The average industrial benefit is estimated to be approximately $140.7 million with a standard deviation of approximately $44 million. The maximum and minimum benefits ($278.9 million and $44.9 million, respectively) represent the upper and lower limit of industrial benefit and serve as an important information for the policy makers. The difference

Table 1. Industrial Benefits of a Permanent Saltwater Barrier Over 50 years (in millions)

Mean Benefit	Standard Deviation	10th Percentile Benefit[1]	90th Percentile Benefit[2]	Maximum Benefit	Minimum Benefit
$140.7	$43.9	$85.8	$196.3	$278.9	$44.9

[1]Implies that only 10% of values in the distribution of benefits are below and 90% are above this value.
[2]Implies that 90% of values in the distribution of benefits are below and only 10% are above this value.

between the 10th and 90th percentile value is approximately $112 million which indicates that the spread relative to the mean is large. The frequency distribution of industrial benefits is plotted in a histogram (Figure 1) which shows that the industrial benefits are significantly skewed to the right with a long positive “tail,” i.e., a large number of high benefit values are concentrated to the right of the mean. This is also reflected in the cumulative probability distribution curve (Figure 2), where instead of a smooth gradual rise, the cumulative probability curve becomes almost flat beyond 85% probability. In other words, while it is clear that there is a 0% probability that industrial benefits will be less than $43 million, beyond 85% probability, a specific probability can only be assigned to a *range* of benefits. The permanent saltwater barrier’s most recent construction cost estimate is approximately $74.7 million (U.S. Army Corps of Engineers) and obviously the average industrial benefit far exceeds the cost of permanent saltwater barrier.

It must be noted that the above benefit estimates may also be used for future projection of industrial benefits. This conclusion can be based on the industrial growth rate as well as the overall population growth rate in the study area. During 1990-1995, the population growth for the Jefferson County, Texas was less than 1% (Texas Almanac). With regard to the growth of industries, only a few companies have experienced moderate growth during the past few years. These companies are minor water users and do not have major impact on the overall industry. The majority of companies, however, have either downsized or have maintained the same capacity (no growth) during the past several years. According to LNVA's record, although industrial water use has fluctuated slightly, the average industrial water use has been at the same level for the past several years (Hebert, 1996).

Concluding Comments

It is important to reemphasize that the use of groundwater in this study is not meant to be a recommendation. The costs of groundwater were used to derive a measure of industrial benefits of a permanent saltwater barrier. As a supplement to surface water, one needs to deal with multiple large wells that would undoubtedly produce severe land subsidence in the area (Thorkildsen and Quincy). Other problems associated with ground water developments are elevated chloride concentrations caused by saline water encroachment in areas of concentrated pumpage. Thus, it can be concluded that complete or even partial reliance on ground water may not be practical, and this further highlights the importance of a permanent saltwater barrier to maintain surface water needs.

References

Chowdhury, M.E., R.D. Lacewell, G.N. McCauley, and R. Freeman. “Agricultural, Industrial, and Municipal Benefits of a Permanent Saltwater Barrier.” Draft Report Submitted to the U.S. Army Corps of Engineers, Galveston, Texas, November 1996.

Hebert, A. T., Jr., General Manager, Lower Neches Valley Authority. *Written Communications to Ron Lacewell*, January - March 1996.

Hebert, A.T., Jr. "A Summary of Facts: The Lower Neches Valley Authority." Unpublished Report Compiled by LNVA General Manager, May 1994.

McCauley, Garry N. "Impact of No Saltwater Barrier on Non-Agricultural Consumers from the Neches River." Final Report Submitted to the U.S. Army Corps of Engineers, Galveston, Texas. September 5, 1994.

McCauley, Garry N. *Personal Communication,* June 1996.

Palisade Corporation. "Risk Analysis and Simulation Add-In for Microsoft Excel." Release 1.12, New York, NY, July 1, 1993.

Texas Almanac, Published by the Dallas Morning News, Dallas, Texas, 1996.

Thorkildsen, D. and R. Quincy. "Evaluation of water resources of Orange and Eastern Jefferson Counties, Texas." Texas Water Development Board, Report 320, January 1990.

U.S. Army Corps of Engineers. Neches River and Tributaries, Saltwater Barrier at Beaumont, Texas: Preconstruction Engineering and Design Reevaluation Report, September, 1994.

U.S. Department of Commerce. *Survey of Current Business*, 1993-1996.

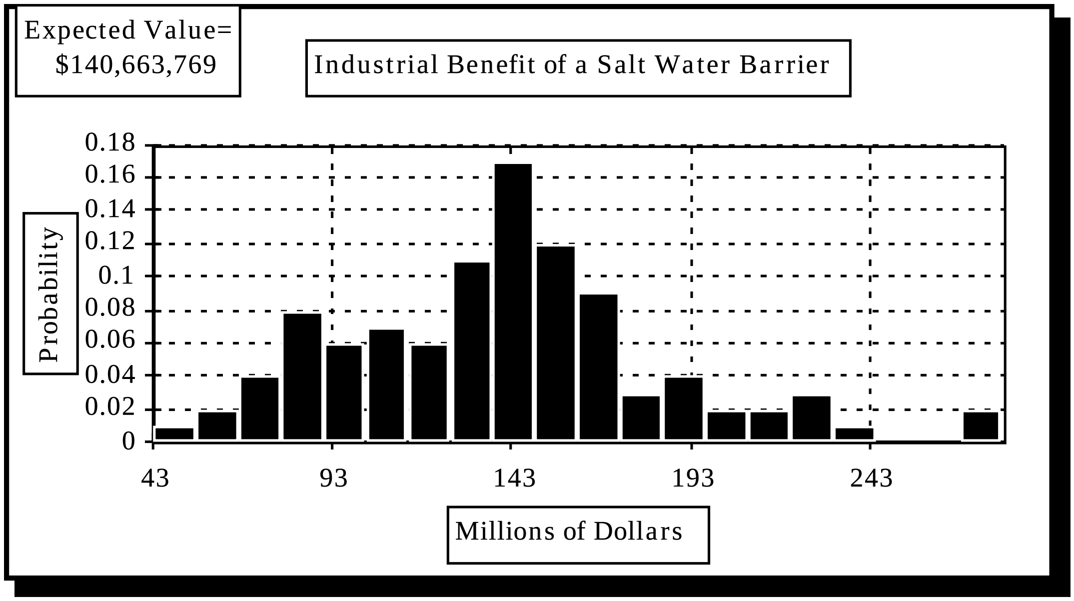

Figure 1. Frequency Distribution of Industrial Benefits

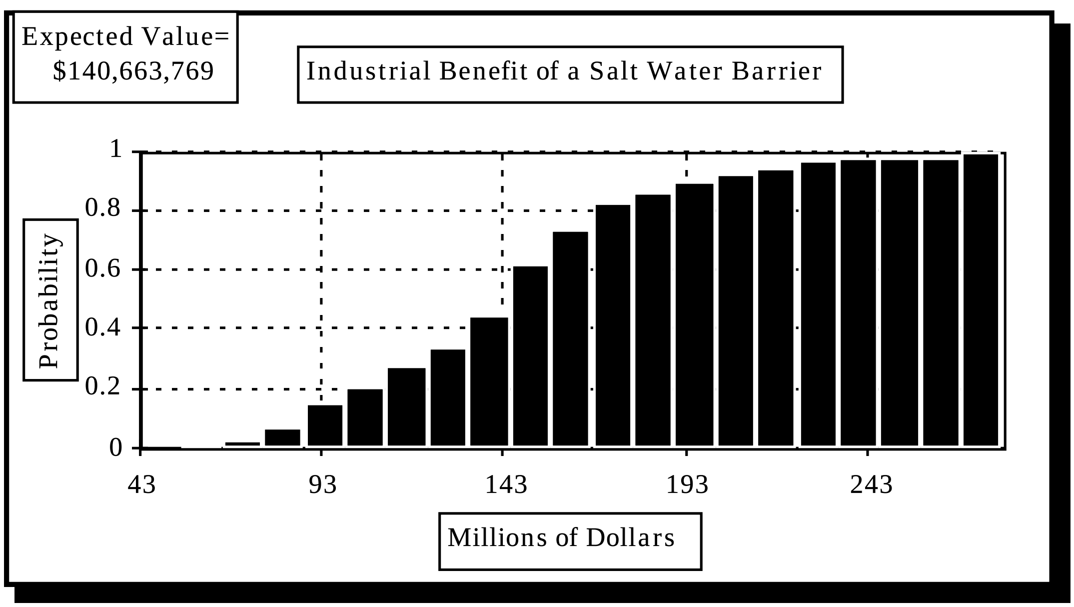

Figure 2. Cumulative Probability Distribution of Industrial Benefits