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Sent: Thursday, September 29, 2011 1:27 AM
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Subject: Review Academishian, Professr Luna Leopold on the Report of Runoff and Delta prepared by M.Rozengurt

Dear Colleagues,

*It's my privilege and honor to propose to your attention the review of a Member of National Academy of Sciences, Professor of University of California, Berkeley, Ph.D., and engineer - hydrologist, Luna Leopold - on the report 87: " **Analysis of influence of water withdrawals on runoff to the Delta - San Francisco Bay ecosystem**".*

*In this report a special statistical analysis had been construed, based on different periods of runoff observation by Dept. of Public Works and Water Depart.of State of California, for a total period of **1878 - 1983** yrs.; American and International methods (UNESCO) had been implemented as well as some Universal Principal of HYDRODYNAMICS.*

Note that this report had been subjected by numerous presentations on local, regional, and International meetings, and in some Committees of US Congress, and Parliament of Canada.

*About 250 copies of the reports had been distributed by San Francisco State University, which "fathered" the above mentioned studies at its branch: **Tiburon Center for Environmental Studies**; much local entities, involved in struggle "to be or not to be the Delta", as well as libraries of American Institute Hydrology, or California Academy of Sciences, or Library of US Congress, and some others.*

It was obvious that cumulative effects of the impoundment and inland water withdrawals of million of acre feet have resulted in chronic depletion of the spring runoff ranging from -35 to -90%, as opposed to its natural deviation ± 25 to 30% of the perennial norm (average over 55 years). It should be emphasized that this fact has been accompanied by the loss of million of tons of oxygen, organic and inorganic matter and sediment load which are vital to the survival of coastal ecosystems the world over. That it's why It had taken only 10 to 15 years to have the functioning of river-coastal ecosystems continuum impeded due to an anomalous predominance of years of subnormal wetness regardless of would be natural watershed runoffs. As a result, this has triggered accumulation of

***Entropy** whose visible indicators are: sluggish circulation, increased detention time, the lack of self-purification of water bodies from natural and man-induced pollutants, salt intrusion from adjacent the San Francisco Bay and a coastal sea into the delta, that exacerbated hypoxia and anoxia, eutrophication, and a precipitous decline of commercial and recreational fishery. In short, man's perceived needs have produced the new, artificial ecosystems on a global scale, namely: "the impounded river-lakes, or river-delta-estuary-coastal seas."*

*Three major failures have increased the detrimental effects of excessive impoundment and perennial losses of water, namely: (1) statistics of impaired (deterministic) runoff has been analyzed by the mistaken use of methods of stochastic hydrology; (2) accordingly, modeling and prediction of water and salt balance of modified ecosystems have not been adequately performed; and (3) the Laws of Thermodynamics have been ignored in evaluation of the scales of ecological tolerance and limitations of ecosystems beyond of which **Entropy***

tends to reach measurable maximum and rein, especially, over the Delta. As a result, the despoliation of ecosystem habitats has occurred.

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Cordially,

M.Rozengurt,P.H. ,Ph.D.,



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October 6, 1987

For your consideration:

Enclosed please find a review by Dr. Luna Leopold, a Member of the National Academy of Sciences and former Chief and Senior Research Hydrologist at the U.S. Geological Survey, of the report "Analysis of the influence of water withdrawals on runoff to the Delta-San Francisco Bay ecosystem (1921-83)" by M. Rozengurt, M. Herz and S. Feld.

This report was presented by Dr. Rozengurt on July 13, 1987 at the D-1415 Hearings of the State Water Resources Control Board in Sacramento. It was funded by the San Francisco Foundation and Buck Trust, presently the Marin Community Foundation.

Sincerely,

Patricia S. Briggs

Patricia S. Briggs
Administrative Secretary

Enc.



Luna B. Leopold
Consulting Engineer

California must take heed of well documented experience in the Soviet Union where diversion of fresh water from the natural supply to an estuary has resulted in immense economic loss and the near destruction of an important estuary. Regulation of the Don River has resulted in an increase of salinity of the Azov Sea by a mere 7 percent and the result was to reduce total fish production from about 15 to 3 thousand tonnes annually. This has been documented in detail by Volovik (1986) and reviewed in the Tiburon report here being discussed. x)

The Tiburon report as it will here be called is a detailed study of the water situation in the Sacramento Delta. The reference is:

Rozengurt, M., Herz, M.J., and Feld, S., 1987, Analysis of the influence of water withdrawals on runoff to the Delta-San Francisco Bay ecosystem (1921-1983): Paul F. Romberg Tiburon Center for Environmental Studies, Tech. Rept. No 87-7.

This voluminous study cannot be either read or taken lightly for it is statistical, detailed, and in many places less than clear. Nevertheless the more one studies it the more impressive is the informational content. The present review deals only with the discussion and data dealing with annual flow data whereas the Tiburon report analyses both annual and monthly data.

The present discussion is an attempt to bring out those points that seem most significant and to present some reanalysis to clarify and emphasize some of the important conclusions.

The data base is reviewed in some detail. It appears that during the planning and construction stages of water development and diversion in the Sacramento system, two somewhat shortcut data compilations were used. The "Four River Index" is a data base that includes runoff from only 75 % of the total drainage area. A "modified method" had previously been employed also selecting less than the full runoff. Finally a compilation was made that estimated the runoff not only from the major rivers but included runoff from the foothill areas and is thought to represent a good approximation of the full runoff volume of 100% of the basin area. The Tiburon report shows that the planning done in the early years based on these less than full runoff volumes have given an over-optimistic picture of the water available for diversion from the Delta system.

x: emphasis added

Then using the most up-to-date data base that most realistically describes what water is really available, the report introduces a statistical analysis of this water supply. Generally this analysis is couched in the form of deviations above and below the mean or average value of the runoff series, and expressed among other ways as probability of occurrence. When values of deviation from the mean are plotted as the probability of being equalled or exceeded, the differences in actual runoff quantities among different data sets can be eliminated so that the particular length of the record becomes unimportant.

The method of analysis will be demonstrated below to help explain and support the major conclusions in the report. First, however, it would be desirable to summarize the major findings of the study.

First, the role of fresh water runoff is of highest importance in controlling salinity and the functioning of the "nutrient trap", that zone of an estuary where fresh water with its load of sediment and nutrients interacts with the saline water from the ocean. This is the area richest in plankton production where many fish species thrive as juveniles (see pp. I.3, I.6, and Fig. I.2). In the Delta area, this is between Chipps Island and Benicia. Reduction of fresh water reaching the Bay has made the saline zone move upstream and is the cause of the historic increase in salinity. The loss of fish populations, a well documented fact, is related to these complex changes. Salinity in the Delta has increased in the present century from an original value of .01-2.0 grams per liter to a present value of 1.0-14. The increase in salinity experienced in the Sea of Azov of the Soviet Union was less than two-fold whereas the increase in the Delta has been ten-fold. Even with the modest increase in the Sea of Azov the result has demonstrably been disastrous in that country.

Second, the Tiburon report shows that use of an unsatisfactory data set to describe the available water has in the planning and construction stages of water development seriously underestimated the probability of critically dry conditions in the estuary. Further, the use of frequency curve analysis is necessary to evaluate properly the effect of the already operative water diversions that deplete the fresh water supply so essential to the continued functioning of the ecosystem.

Third, the report shows what should be an obvious fact, that continued diversion of the same magnitude of fresh water in dry years as well as wet years makes a much larger percentage change in available water in a dry period than in a wet one. Yet there is no attempt to adjust the amount of diversion in response to the available supply.

Fourth, the amount of water diverted has continued to increase with time despite the data on biologic populations and salinity that have given ample warning that even the present amount of diversion is impacting the ecosystem .

Both to check quantitatively the results presented on annual flows in the Tiburon report, and to explain in new words its findings, I have reanalysed some of the data. My results are in qualitative agreement with those in the report though my numbers are not as exact. One reason for this is that I have generally rounded the data to three significant figures, for my work was done by hand whereas the Tiburon computations were made on a computer.

Four sets of data were used in my analysis. They are a) the list of annual flows representing natural, unimpaired inflows to the delta; b) the regulated annual inflow to the Delta; c) the natural or unimpaired outflows from the Delta, and d) the regulated or altered outflow annual values. These tabulations of basic data are included as printed tables in this study. The annual natural inflow data are those representing the flow from all or 100% of the drainage area as previously stated as being necessary for a correct analysis.

The method of analysis is similar to that used in the Tiburon report. The data array was retabulated in order of magnitude of the values. For each the recurrence interval was calculated as $n+1/m$ where n is the number of years of record, and m is the rank order of the value or runoff quantity. The reciprocal of recurrence interval is the probability of occurrence, that is $m/n+1$ is the probability. For example, the value of probability of 0.10, that is 10 chances out of 100, means that in 100 years, it is probable that 10 years will experience a flow less than the quantity specified.

To make this more specific consider Figure 1. of the present study. Four graphs are plotted. They show the probability that any value of annual flow will be equalled or exceeded. The four graphs describe the annual natural inflow to the Delta, the regulated inflow, the natural outflow, and the regulated outflow.

Consider first, the graph of natural inflow, plotted as the symbol x . There is a 50 percent probability that the annual natural inflow will be equal to or less than 25,000,000 acre feet. This is the median value of the array, that is half the annual values are larger and half smaller. The arithmetic mean is somewhat larger, about 28.1 million. Now look at the value 25% on the bottom scale. At a probability of 25% the annual runoff value is about 37 million acre feet. This says that there is a 25% chance, one in four, that the annual value of natural inflow will be equal to or larger than 37 million. By the same token, the

upper scale says that there is a 75% chance, 3 out of 4, that the annual value will be equal to or less than 37 million. In other words it is less than likely that any given year will have as large a flow as 37 million.

Now look at the lower part of the curve which is the significant part from the standpoint of the estuarine ecosystem. Where the lower scale reads 90, the graph reads 13 million acre feet. Thus 9 years out of 10 or 90 years out of 100 it is probable that the natural inflow would equal or exceed 13 million. Or from the upper scale, 10 years out of 100 can be expected to have a natural inflow less than 13 million.

The average natural inflow to the delta is about 28.1 million acre feet. It should be obvious that this average value has but little significance. Of interest is the year of short supply and the frequency with which it might be expected. This is the reason both the Tiburon report and the present analysis concentrate on frequency curves.

Consider now the comparison of the curves for the natural inflow and the natural outflow to the Delta. In Fig. 1 the former is the crosses x, and the latter is the solid circle. The two curves are nearly identical. To the extent they are the same the data show that under natural conditions water coming into the Delta was nearly the same as that amount leaving the Delta. At the scale of this graph the amount of loss by seepage or evapotranspiration cannot be seen.

But now consider the comparison of natural inflow to the regulated inflow shown on the graph by open circles. Regulated inflow is the water allowed to flow into the Delta after diversion and after the construction of upstream dams. Diversions to southern California are the primary cause of depletion. The average regulated or man-influenced inflow is about 22.8 million acre feet. This is an average reduction of 28.1-22.8 or 5.3 million or 19 percent of the natural. Again this average reduction is not very informative. Compare the curves on the lower scale at 75 percent probability. The natural inflow expected to be equalled or exceeded 75 percent of the time or 75 years out of 100 is about 18 million acre feet. But the regulated flow will only produce 13 million, a depletion of 5 million out of the naturally expected 18 million, a reduction of nearly 30 percent.

Now consider that low flow expected 10 percent of the years or once every ten years. At this frequency the natural inflow was 12 million acre feet. The expected regulated outflow once in ten years is only 7.5 million. At this frequency the depletion of the flow into the Bay is nearly 40 percent.

experiencing any given quantity and do not mean to apply to any particular year. However, when one looks at the probability of one in ten, it means that next year or any given year in the future has a one in ten chance of experiencing an outflow to the Bay of less than 7.5 million acre feet. Like tossing a coin, each toss has the same chance of coming up heads.

Note also that the regulated outflow to the Bay is considerably less than the regulated inflow to the Delta. This means that after regulation the losses or depletions within the Delta have increased. Before regulation the losses within the Delta were negligible as previously stated.

The Tiburon report wisely makes an important issue of the number of dry and critical years under natural as compared with regulated conditions. To check and extend those findings I have prepared Figure 2. I have used the same definitions of wet, abnormal, subnormal, dry, critically dry, and drought as used by the Dept. of Resources Bulletins 23-62 and 130-70s (see Tiburon report Table I-9 p I.45). I have added a category of very dry so that all years may be described. The definitions are given in Figure 2.

In my tables with the annual flows arranged in order of magnitude it is easy to count the number of years in each category. As Figure 2 shows, regulation and diversion of water have increased the number of years in the dry categories and reduced the number of years in the wet categories. The Figure refers to annual values of inflow to the Delta.

Years in which the inflow is considered wet have decreased from natural conditions from 17 to 9, or from 30 percent of all years to 15 percent of years.

Subnormal years have changed from 11 to 7 or from 19 percent of all years to 12 percent.

The important change is in the number of critically dry years, an increase from 8 to 23 in the period of record or from 14 percent of all years to 39 percent. Thus the amount of diversion and depletion under present conditions has doubled the number of years considered critically dry.

Further, the increase in depletion has been continuous over time. A measure of depletion is the difference between natural and regulated values of outflow from the Delta. The depletion by periods of time is shown below.

Natural outflow less Regulated Outflow
average values in millions of acre feet

| Time Period | Depletion |
|-------------|-----------|
| 1921-1929 | 3.77 |
| 1930-1939 | 3.79 |
| 1940-1949 | 4.73 |
| 1950-1959 | 6.64 |
| 1960-1969 | 8.74 |
| 1970- 1979 | 10.94 |
| 1980-1982 | 12.70 |

In conclusion, my studies confirm the general conclusions in the Tiburon report. The depletions have been massive and continue to increase. They have greatly increased the percentage of years of critical drought in the Delta and the Bay.

It is my professional opinion that no set of standards of water quality can be written that can have the practical effect of protecting the ecosystem from further degradation if diversions increase over the present level. Because forecasts of runoff are imperfect the effect of diversions in a year that turns out to be dry will already have taken its toll on the ecosystem before water quality measurements can compare the condition with the standards.

The logical and in my opinion the imperative step is to preclude henceforth any additional diversions of water from the Delta system.