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AN INVESTIGATION OF ENGINEERING DECISION-MAKING IN A CALIFORNIA CLEAN WATER GRANT PROJECT

BY

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1979

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

The planning and design of an engineering project can be viewed as a series of decisions. It follows, therefore, that a project is well engineered when good decisions are made in an efficient manner. This investigation seeks to examine engineering decision-making for the general purpose of providing insights which may improve the engineering decision-making process.

The study centers around a project constructed under the Clean Water Grant Program in California. There are two reasons for this: 1) the Clean Water Grant Program is presently (1979) the largest public works program in the United States and is, therefore, significant to the field of civil engineering in general, and 2) the author has worked in the program for several years. Despite the choice of a Clean Water Grant project, the investigation is, in most respects, illustrative of engineering decision-making in general and applicable to other types of projects.

The first part of the investigation is an overview of engineering decision-making. Utilizing the literature, as well as examples from other Clean Water Grant projects, various bases on which decisions are made are explored considering also, some psychological aspects and philosophical implications of engineering decision-making. Also, some special tools and approaches current in the engineering field are discussed. The second part investigates, in detail, the planning and design of wastewater facilities for the

City of Taft, California. Its purposes are: 1) to survey all decisions made in the planning and design of the project; and 2) to identify and discuss the basis of the decisions.

The Taft project was selected for study for several reasons: 1) the limited scope of its design allowed the design decisions to be identified without becoming unwieldy; 2) it is typical of Clean Water Grant projects in many respects; 3) the planning and design were exceptionally well done; and 4) there were interesting and uncommon features to the project, especially in the planning phase. In addition, the project engineer was willing to discuss candidly the basis of the decisions in this project. This is in contrast with engineers on other projects, who, when approached by the author, were very reticent to discuss the true basis of their decisions. Finally, the author's direct involvement in the project, by way of his duties working for the State Water Resources Control Board, greatly facilitated the investigation.

OVERVIEW OF ENGINEERING DECISION-MAKING

Based on a review of the literature and experiences in working with Clean Water Grant projects in California, an overview of the bases on which engineering decisions are made is presented in this section. The major decision-making criteria and methodologies, such as government regulations and economic analysis, are discussed, in addition to some auxiliary tools to decision-making, such as mathematical modeling and value engineering. Psychological aspects of the decision-making process and philosophical implications of engineering decision-making are also briefly considered.

Psychological and Philosophical Considerations

Inasmuch as engineering decisions are made by people, psychological forces and societal values are everpresent in the decisions that are made. It has been observed that decisions are always subjective and that feelings always influence and often control decisions (31). Miles (31) asserted that fear of embarrassment is the prime motivating force in engineering decision-making and he concluded that many actions of designers are made with the intention of minimizing their risk of personal loss.

Decision-making may be blocked because the problem has not been clearly defined. If this is known, then activity can be directed to increase clarity (10). Deferring a decision because of uncertainty or lack of clarity implies the unstated decision to incur higher costs temporarily in order to reserve the privilege of making a second decision when the situation becomes clearer (53).

The "systematic use of conjecture" has been proposed to assist in gaining a clearer understanding of an obscure situation (53). Polya (37) presented a methodology to assist in approaching problems which are entirely new to the decision-maker. Oglesby et al. (in 18) pointed out that "it is essential to make as clear as possible the comparison of the actual points at issue and thus reduce the number of irrational arguments that accompany most controversial decisions."

The right psychological environment is essential when creativity is required. Osborne (in 31) has proposed various methods to accelerate creativity. The presence of judgmental or critical attitudes has been observed to inhibit creativity, and creativity is encouraged by free association of ideas in a group (31). Dickerson and Robertshaw (14) observed that "the key to success in creativity is quantity of ideas," and they identified stages in the creative process.

Radford (45) has identified four criteria for decision-making under uncertainty, that is, when the possible outcomes of a decision are known but the probability of those outcomes occurring is unknown: 1) the criterion of pessimism, in which one seeks to minimize the maximum possible risk; 2) the criterion of optimism, in which one seeks to maximize the maximum possible gain; 3) the criterion of regret, in which one seeks to minimize the maximum possible opportunity cost; and 4) the Laplace criterion, in which one assigns equal probability to all unknown consequences. Radford (45) noted that "one further possible criterion for selection of a course of action is the minimization of uncertainty about the outcome of the decision process." Studies have shown that people subjectively estimate probabilities very poorly and generally very conservatively (58). Various factors will affect this judgment, but people generally show great reluctance to revise an original probability estimate towards a better value (58).

Hendrick et al. (19) claimed that when people are confronted by a decision "regarded as hopelessly complex . . . there may be a tendency to give up trying to compare the alternatives. Instead, a choice may be made compulsively." Pollay (36), however, regarded the same phenomenon in a different light: "It would seem more appropriate to consider the decision-maker implicitly making evaluations of both the difficulty of the analysis required and the potential fruitfulness of that analysis. One could then consider a decision-maker terminating analysis and making an impulsive decision whenever his perception of the task difficulty, that is, his expected cost, exceeded his perception of the potential fruitfulness of analysis, that is, his expected value." Dickerson and Robertshaw (14) argued that such complexity is a good reason to avoid an impulsive decision: ". . . there is a powerful tendency for decision-makers to rely exclusively on intuition, whereas the complexity of the interactions in society is such that intuition is often at variance with reality."

In dealing with decisions involving a large number of factors, it has been observed that people tend to base their subjective decisions on a very limited number of variables and ignore the remaining factors (28). Lifson (28) stated: ". . . there is a considerable body of evidence which indicates that people are not capable of optimally transforming multi-dimensional outcomes into a single utility dimension." Studies have shown that increasing the number of criteria produces a significant increase in errors in decision-making (1, 48).

Even a brief treatment of factors involved in decision-making by groups is beyond the scope of this discussion; however, a few pertinent observations will be stated. A basic factor determining the behavior of a decision-making group is the degree of conflict existing between the individual members (45). Radford (45) has noted that the importance of a dominant member within the group increases as the degree of variation between individual members' solution to the problem increases. He has also observed what he calls the "risky shift" phenomenon: that decisions made by groups are generally more risky than those that would be advocated by individual members of the group prior to group discussion of the problem. Regarding the efficiency of decision-making groups, Old has "reported" in a satirical article (33) that the relationship between the efficiency of output from a committee and the number of persons on the committee reaches a maximum at seven-tenths of a person.

Engineering decisions inherently involve the values of the decision-maker and, therefore, have philosophical implications. As Schumacher (46) observed: "the conclusions and prescriptions of economics change as the underlying picture of man and his purpose on earth changes." Thus, decisions made on the basis of "economics" implicitly incorporate a definite value system, and the engineering planning process attempts to put those economic values into perspective with other aspects of the society's value system. Sporn (49) asserted that economics "provides the analytical mechanism for determining the relative participation of (resources, tools, and labor) and the value of a new technology to society." George T. Lewis (in 15) has remarked that it was "painfully clear" that "the 'intangibles' of pollution, safety, reliability, and other social and consumer values must be considered in decision-making equations." Lewis' statement reveals that the implicit values of engineering decision-making of the past may be in philosophical conflict with societal values of the present. As to the value of engineering decision-making itself, Thuesen and Fabrycky (53) optimistically observed that "design, no matter how poorly done, is predicated on the thought that the effort devoted to it will be outweighed by the results."

Economics

An important, powerful, and widespread tool providing the basis for many engineering decisions is economic analysis. Modern engineering economics compares prospective differences in the consequences of alternatives using the commensurable units of dollars (18). As stated by Grant and Ireson (18): "The fundamental question regarding a proposed investment in capital goods is whether the investment is likely to be recovered plus a return commensurate with the risk and with the return obtainable from other opportunities for the use of limited resources." Economic analysis incorporates the idea of the time value of money, that is, it recognizes the fact that money to be expended now could be invested elsewhere and accumulate interest over time. Therefore, compound interest formulas are used to convert all payments to either an equivalent single payment at some point in time or to an equivalent uniform series of payments, the former being referred to as the present worth, and the latter as the equivalent annual cost (18). This provides a common basis for comparison of alternatives having differing prospective cash flow characteristics.

A critical issue when using economics in engineering decision-making is: Whose point of view is to be used? In the Clean Water Grant Program, federal law requires that economic analyses be performed from the point of view of the entire nation (55). However, there is a strong tendency to disregard that requirement and consider costs from the local point of view. For example, in the study of a proposed sludge-gas utilization system at Davis, California (4), the present worth of capital investments and maintenance costs for a system to utilize digester gas for electrical power generation was $455,000. Energy cost savings over the twenty-year planning period had a present worth of only $255,000. However, since capital costs received an 87.5 percent grant from higher levels of government, from the local point of view the proposed system was economically attractive and it was recommended by the engineer. Again, in the evaluation of proposed sewer-system repair at Richvale, California (8), extensive collection system and interceptor rehabilitation had an estimated capital cost of $100,000, and would save an estimated $5,600 per year in operation and maintenance cost. On an equivalent annual cost basis, the work would increase the total equivalent annual cost by $2,500 per year. However, because the capital outlay received an 87.5 percent grant, it was economically advantageous to the local entity to do the rehabilitation work, which was recommended by the engineer (9).

The selection of an appropriate interest rate is also very important. The use of a low interest rate has the effect of making alternatives requiring higher investments appear desirable even though they show the prospect of yielding a relatively low return (18). According to Grant and Ireson (18), businesses tend to use a relatively high interest rate (10 to 15 percent); regulated utilities are in the middle (6.5 to 10 percent); and government agencies use a low rate (0 to 7 percent). As a result, government projects tend to be overdesigned. The interest rate may be determined by government regulation in some types of projects (55). Grant and Ireson recommended that the controlling interest rate be the return on the investment opportunity foregone or the overall cost of capital (18). If "constant dollars" are used, then inflation need not be considered except in the case of major anticipated differential price changes. The effect of considering inflation is to decrease the effective interest rate used by an amount equal to the assumed inflation rate. Another effect of using a moderate or high interest rate is that comparisons are not as sensitive to changes in estimated distant salvage values (18).

As Grant and Ireson (18) observed: "Engineers' decisions regarding economy must be based on preliminary estimates made in advance of design that necessarily have a considerable danger of large errors." Several methods have been proposed to deal with the problem of uncertainty in estimates. Thuesen and Fabrycky (53) recommended: 1) use of high interest rates; 2) use of conservative values; or 3) use of a shorter planning period. They also proposed using a "fair estimate," "least favorable estimate," and "most favorable estimate," as an aid to judgment, to indicate the consequences of deviation from the "fair estimate." Giffin (17) observed that when one uses the present worth, equivalent annual cost, and rate of return criteria as normally formulated, the decision is really being made on the basis of expected values, and he proposed the use of a range of cost estimates. Kaplan and Barish (27) suggested that the interest rate be regarded as a random variable, and Hillier (21) advocated that net cash flows be treated as random variables. Hertz (20) proposed assigning probability distributions to various cost estimates. Sensitivity analysis is used to determine the "relative magnitude of the change in one or more elements of an engineering economy problem that will reverse a decision among alternatives" (18). When an analyst is aware of which variables are most sensitive, he can put his maximum efforts into the estimates that are most important (18). Regarding the use of probabilities to get a fair comparison of alternatives in the face of uncertainty, Grant and Ireson (18) advised that one should attempt to avoid making "allowances for the <u>same</u> uncertainties at a number of different stages in the process of analysis and decision-making."

Common errors in economic analyses include (18): 1) use of too low an interest rate; 2) assumption of perpetual life for resources; and 3) use of accounting data irrelevant to economic studies (e.g., depreciation). If the effect of income taxes is ignored, it can be shown that present worth is unaffected by the method of depreciation used (16). Another common error is to entangle the economic analysis with consideration of alternative sources of financing. Sporn (49) demonstrated the illogic of considering the method of financing in the economic analysis by citing the example of a federal project in 1965. The "cost" of the project according to the Federal Power Commission was as follows, depending on the source of financing: $4,442,000 if financed by private enterprise,

$1,507,000 if financed by the federal government, and $1,370,000 if financed by REA. Sporn concluded: "Thus, with exactly the same installation, the same use of real resources, and the same benefits, the economic desirability of the project varies not only in the degree of desirability or viability, but even to the extent of changing it to undesirable or non-viable, depending on what choice of ownership is selected."

A variation of the present-worth analysis is the "benefit-cost ratio" analysis, common in government studies. Grant and Ireson (18) noted: "The special useful concept emphasized by a formulation using the word benefits is that it is desirable to examine prospective consequences 'to whomsoever they may accrue.'" In using benefit-cost ratio analysis, careful judgment is required in deciding which consequences are to be counted and which disregarded (18). Also, the benefit-cost comparison is only valid between two alternatives at a time, and the absolute magnitude has no meaning other than whether or not it exceeds unity.

Cost-effective Analysis

Modern engineering projects often involve decisions with social and environmental consequences which cannot be satisfactorily dealt with by ordinary economic analysis. DeGarmo (12) stated: "The tremendous scope of modern engineering projects makes it essential that all factors involved in the economy of an undertaking not only be considered but handled in an accurate, approved manner, in order that the results will be satisfactory from all the viewpoints touched by the project." Grant and Ireson (18) noted the "much greater importance of irreducibles in public works than in private enterprise." The attempt to incorporate these "irreducibles" into engineering decision-making is termed a cost-effective analysis. Lifson (28) observed that if the decision-maker is to identify an optimal alternative, he must be able to relate the various factors to some scalar "measure of goodness" common to all criteria. The relationship between each criterion and the measure of goodness or utility is called a utility function and would generally be non-linear (28).

The Environmental Protection Agency (EPA) (55) has defined the most cost-effective alternative in Clean Water Grant facilities planning to be: "The waste treatment management system determined from the analysis to have the lowest present worth and/or equivalent annual value without overriding adverse non-monetary costs and to realize at least identical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse, and/or land and subsurface disposal." The State of California facilities planning guidelines (5) go beyond the EPA requirements and specify an evaluation procedure involving the following factors: monetary cost, environmental impact, social impact, scarce resources, flexibility and reliability, ability to implement, compatibility with local planning goals, bypass potential, flood protection, land use, and public acceptability. Each factor is assigned a relative weight, the alternatives being considered are ranked quantitatively for each factor, and the products of the rankings and relative weights are summed for each alternative. The alternative having the best total "score" is called the cost-effective alternative. An example of an unusually clear and comprehensive cost-effective analysis, utilizing a somewhat different but similar methodology, has been presented by Bursztynsky and Davis (in 38).

A virtue of the cost-effective analysis is that non-monetary values are considered openly and on an equal footing with monetary values. De Neufville (13) described a water-supply study in New York City in which cost-effective analysis was utilized to relate technical issues to important public-policy objectives so that a decision could be made. In the planning of a wastewater treatment and disposal system at Kettleman City, California (30), a pond treatment-infiltration/percolation disposal alternative was compared to a trickling filter treatment-agricultural reuse design. The pond alternative had a lower capital cost by $180,000 and a lower operation and maintenance cost by $8,000/year. However, due to the differences between the sites of the two proposed alternatives, there was considerable public opposition to the pond option, which, it was feared, would interfere with future development and cause odor nuisances. This public statement was incorporated into the cost-effective analysis by giving "social impacts" and "public acceptability" significant weight compared to "monetary cost" and by assigning a very low rank to the pond alternative within those two categories. As a result, the trickling filter alternative was chosen.

Cost-effective analyses cannot be used properly without great care. By quantifying "irreducibles" into a utility function, a simple judgment of the overall effect of those factors is replaced with a mathematical composite of one's judgments of the effect of each individual factor. To correctly evaluate whether the result is reasonable, the basis of the utility scale for each factor and the basis of the ranking of each alternative must be clearly shown. If not, the system of weighting and ranking can easily obscure the importance of some key factors while making the outcome overly sensitive to trivial differences. Also, since the utility scales of the factors are non-linear, the relative magnitude of the resulting measures of utility of the alternatives can be misleading and should not be considered comparable in a linear sense. Thus, although the purpose of cost-effective analysis is to put the significance of multiple factors into proper perspective in a decision among alternatives, if improperly used it can result in distortion.

Rational and Standard Design Methods

Rational and standard design methods are dealt with extensively in engineering texts, and, ideally, every design decision has some rational technical basis, albeit implicit. Sizing of aeration tanks, aerators, and sludge handling facilities in activated sludge design, pipeline sizing and design of hydraulic structures, sizing of structural members, and numerous other design decisions involve rational or standard design procedures to some extent.

Manufacturers' catalogues often contain "standard" design procedures for use by the engineer in designing with the manufacturer's product. Such procedures may contain biases for the manufacturer's benefit, and in any case may involve design assumptions which are not universally applicable. As a case in point, in the preliminary design of an aerated lagoon system at a facility in Kern County, California (29), the design engineer relied on the Aqua-Aerobic Systems, Inc., design catalogue without careful investigation of the assumptions used and without modification to account for local conditions. This led to a proposed lagoon sizing and aerator capacity approximately half that needed.

Codes, Standards, Regulations, and Other Externally Established Requirements

Codes, standards, and regulations dictate, or at least influence, vast numbers of engineering decisions. Building codes, agency-adopted standard specifications, regulatory agency requirements and guidelines, and technical standards established by professional organizations are included in this category. Such externally established requirements are promulgated with the intention of being of general benefit to the public or the profession. They relieve the decision-maker of having to individually evaluate numerous decisions, while at the same time generally assuring him of satisfactory solutions which are not excessively uneconomic, although they may not be optimal. However, Grant and Ireson (18) have observed: "Many decisions that are of an economic character are, in effect, made by default through the establishment of standards. Certain general statements that may lead to economic decisions in one setting may lead to extremely uneconomic decisions when they are applied in another type of setting."

Cities, counties, or other agencies may adopt construction codes or standard specifications. For example, the County of Sacramento, California, has by ordinance, adopted standard construction specifications, one section of which reads (51): "SS54-03. Joints--Joints between sections of aluminum pipe shall be welded, using aluminum alloy welding rod as specified in ASTM Designation: B285. Transition joints shall be of an approved coupling designed so that the aluminum does not contact dissimilar metal." Design problems covered by these standard specifications would be decided by them, as a matter of county policy.

In the wastewater treatment plant upgrading project at Lake Arrowhead Sanitation District, Californa (40), Cal-OSH (Occupational Safety and Health) requirements dictated various aspects of the design of the laboratory facilities, such as: exhaust stack height, minimum hood ventilation velocities, separation of laboratory ventilation from the rest of the plant, minimum working space requirements, special autoclave venting, special chemical storage requirements, safety equipment, strength of railings, and required locations of various pieces of equipment. Most of the design decisions (and most of the cost) were determined by the Cal-OSH requirements.

Regulations may not predetermine certain decisions yet may dictate how they are to be made. The Environmental Protection Agency's cost-effectiveness guidelines (55) specify the following key elements for all economic analyses made in Clean Water Grant Projects: 1) type of economic analysis, 2) length of planning period, 3) cost elements to be included, 4) price level and method of handling inflation, 5) interest rate, 6) interest during construction, 7) service life of project components, and 8) calculation of salvage value.

Regulatory agency requirements may serve as basic constraints in important design decisions. For example, in the wastewater treatment plant upgrading project at Tranquillity, California (43), the Regional Water Quality Control Board's requirement that 5 feet be maintained between the bottom of the oxidation ponds and the top of the ground-water dictated the engineer's choice of a 4-foot average depth of the ponds. Deeper ponds of smaller area may have been more economical, but they would have violated the external constraint fixed by the Regional Board.

Testing and Experimentation

Many engineering decisions are made on the basis of auxiliary testing and experimentation. Soil characteristics tests for foundation design, corrosivity tests for steel pipeline design, chemical tests for water treatment plant design, and a wide variety of standard materials tests conducted by manufacturing and engineering organizations to aid in material selection are examples of routine testing and experimentation which are integral to most engineering designs.

Planning decisions may also be based on testing and experimentation. Grant and Ireson (18) have observed that "systematic fact-finding on a continuous basis is needed to permit valid economic studies to be made for many types of projects." They draw particular attention to flood-control projects and projects for improvement of highway safety.

Special studies may form the basis of important engineering decisions when unusual conditions exist and there is no adequate theoretical or empirical basis for design, particularly in the case of larger projects in which the expense of the study is small compared to the possible benefit. The City of Trulock, California (7), experiences very high wastewater loadings at certain times of the year due to its canning industries. In planning the upgrading of its sewage treatment plant, on-site pilot studies were conducted to establish basic design criteria for choosing between the major secondary treatment alternatives of pure-oxygen activated sludge, activated-biofilter activated sludge, and roughing-filter activated sludge. In the design of the Sacramento, California regional wastewater treatment plant (41, 42), high grade stainless steel mobile ventilation units using activated carbon absorption were originally specified for odor control. In testing a prototype unit, it was found that the interaction of hydrogen sulfide from the wastewater atmosphere and activated carbon from the ventilation unit had a synergistic effect and severely corroded the stainless steel. As a result, fiberglass reinforced plastic was substituted for many of the parts previously made of stainless steel.

Modeling and Other Mathematical Tools

When design decisions involve systems which can be characterized by physical parameters, whether definite or probabilistic, a number of mathematical tools exist which can greatly assist the decision-maker. Models are abstractions of physical reality which highlight problems of interest, allow economical experimentation, assist in precision of thought, and help solve operational problems (17). De Garmo (12) has noted: "the development of various linear programming techniques, together with computer programming for handling more complex problems . . . has made possible the quantitative treatment of economic problems that hitherto could only be solved by trial and error, and frequently not in an optimum manner." Computer programs are available to solve many problems of optimization involving mathematical investigation with statistical and variational techniques (35). They are particularly useful in analyzing sensitivity to design variations (54). In general, computer-assisted design maximizes some return function while satisfying stated constraints (54).

Linear programming, non-linear programming, Markovian decision processes, and the calculus of variations are some important mathematical optimization tools. Linear programming seeks the optimum value of a linear function when the constraints can be stated as inequalities involving the design variables. Even when the behavior of an object or process cannot be described by linear expressions, linear programming is nonetheless an aid to intuition in conjunction with more advanced techniques (54). In non-linear programming, the inequality constraints and value function are non-linear. It is obviously complex mathematically. Markovian decision models seek to optimize a series of stochastic choices and are useful in such advanced applications as inventory and production problems, control problems, and reliability problems (32). The calculus of variations seeks to find a function which optimizes some criterion, the classical problem being the shape of the path which a frictionless sliding object would follow to move from a first point to a second in the shortest amount of time under the force of gravity (14). It has found application in a wide variety of advanced engineering proglems (54).

In the structural design of the San Francisco Southwest Ocean Outfall, wave effects were determined using mathematical models, and statistical techniques were used to extrapolate existing data to wave heights and return periods (34). Model studies were also used in that San Francisco project in the design of a diffuser for optimum dispersion. The design criteria for the outfall headworks were likewise analyzed by a mathematical model (34). As an example of a simpler and more common application of a mathematical tool, at Tuolumne City, California (50), the designer used a statistical hydrograph in choosing the design flow in the design of a spillway for a proposed effluent storage dam.

It is important to keep in mind that mathematical models always involve assumptions and some compromise with reality. As Giffin (17) pointed out, by abstracting only certain portions of reality, the model builder gains the benefits of economy at the risk of losing validity. Grant and Ireson (18) declared: "The analyst who uses a formula to guide an economic decision ought to understand the assumptions underlying the mathematical model that generated his formula." Ways in which models may be misused include (14): 1) forgetting that the model is only an approximation of the real system; 2) omitting key assumptions or allowing excessive approximations; 3) designing the system to fit the limitations of the model rather than using the model to represent the system; and 4) neglecting "unquantifiables." Models and tools should help put information and design factors into perspective as an aid to human judgment; they should not replace judgment. As one handbook of computer-aided engineering design states (54): "A key challenge to developers of practical computer aids to designers is to take maximum advantage of human judgment in the design process."

Value Engineering

Value Engineering (VE) was originated by Lawrence Miles at General Electric in 1947 and is a tool which can be of benefit to the engineering decision-maker. In 1974, the Environmental Protection Agency introduced a voluntary VE program to the design phase of its construction grant program. Results from the voluntary program showed (57): 1) VE is effective for cost control in water pollution control projects; 2) cost savings have been substantial; 3) quality and reliability of the project are maintained; 4) design techniques are improved and more efficient using VE concepts; and 5) project delays can be prevented when the VE program is properly managed. Consequently, VE was made mandatory for all Clean Water Grant projects having estimated construction costs greater than $10 million, and was encouraged for those under $10 million (57).

Value engineering, in the words of its originator (31), "is an organized, creative approach that has for its purpose the efficient identification of unnecessary cost, i.e., cost that provides neither quality nor use nor life nor appearance nor customer features." VE is performed by a trained, multi-disciplined team having from three to ten members (31, 56), which systematically analyze the _functional_ requirements of the project under consideration and creatively generates and explores alternative methods of achieving the required functions (2). A unique aspect of the VE approach is that all cost is assigned to functions and none to parts (31, 47). After new solutions have been generated, investigated, and refined, they are analyzed by present-worth economic methods, termed in VE literature as "life cycle costs" (2, 31).

In the design of the Sacramento regional wastewater system (3, 41, 42), odor control at various facilities was to be accomplished by twenty mobile ventilation units. These units were originally estimated to cost $35,000 each; however, due to successive piece-meal alterations and additions resulting from tests on a prototype unit, the cost rose to an estimated $95,000 each. At that point it was recommended that a VE study be conducted. Among the recommendations resulting from the VE study were to (3): 1) change the trailer configuration to a "blow-through" arrangement; 2) eliminate internal baffling; 3) provide a perforated blower enclosure and remove insulation; 4) remove the exterior floor covering; 5) simplify the doors; and 6) use "piggy-back" tires (low road use and high weather and time endurance). These changes did not diminish the performance of the units, but resulted in a total estimated present worth savings of $487,000 (3).

The application of VE to a wide variety of engineering problems has produced a number of useful suggestions of general benefit to decision-makers concerned with design problems. These include the following (31, 2): 1) avoid generalities; 2) get all available costs and use information from only the best sources; 3) brainstorm, deferring all judgments; 4) identify and overcome road-blocks to change; 5) use industry specialists to extend specialized knowledge; 6) get a dollar sign on key tolerances; 7) utilize vendors' available functional products, and utilize vendors' skill and knowledge; 8) utilize applicable standards, but do not use standards that do not apply; and 9) use the criterion, "Would I spend money this way?".

Miscellaneous Decision Bases

Undoubtedly, many engineering decisions are made on the basis of such things as company design policy, past experience, political pressure, expediency, intuition and "educated guesses." There is always an element of uncertainty in design; therefore, successful past experience with a particular process or piece of equipment provides a strong incentive to choose it again when the opportunity presents itself, without necessarily making a full investigation of other less certain alternatives. In the design of a wastewater treatment facility at Weaverville, California (6, 52) the design firm chose to use a modified activated sludge process without primary clarification because of their recent success with the same type of system in Dalles, Oregon. That firm subsequently chose the identical process in several other projects (52).

Public works projects are often highly political. Solutions which may be technically sound and economically favorable may be politically infeasible. As a case in point, in the planning of a wastewater treatment project in Nevada County, California (11), it was found after extensive studies that consolidation of wastewater treatment facilities for the cities of Nevada City and Grass Valley was favored by both economic and environmental considerations. However, policial antagonism between the two cities, as well as community resentment towards the state regulatory agency, resulted in a decision to build separate treatment plants (44).

Because of limitations on time during the design process, some decisions are made on the basis of expediency. Thornton (in 47) has observed, concerning the selection of constructional steels: "When only a few components are to be made, and material cost is small, a steel which has properties more than adequate is chosen, because, financially, any more critical selection is just not worthwhile. In the case of critical components, where the consequences of failure would be serious, the best avialable steel is chosen. However, as the weight of steel used increases, and the ratio of fabrication to material cost decreases, choosing a steel just good enough for service and fabrication requirements becomes increasingly important economically." As an illustration of design decision based on expediency, in the design of two wastewater treatment facilities in the San Francisco Bay area by the same engineering firm, the digester design at San Leandro was made essentially identical to that at Hayward because the needed capacity was close and finished design drawings were already available (25, 26).

Some engineering decisions can only be accounted for as based on intuition or "general engineering judgment." Thornton (in 47) stated that there is often no definite criterion for material selection, and that "factory facilities, industry requirements, individual skills, experience, and prejudice, although not easily assessed, play a large role in final selection." Thuesen and Fabrycky (53) concluded that intuition "should be reserved for those areas where facts on which to base a decision are missing." Studies by Fairley (in 58) indicated that people's intuitions are generally quite poor in certain kinds of probability estimating situations. In the field of wastewater treatment plan design, decisions which are commonly made on the basis of intuition or educated guessing include: plant layout, location of units and processes for expansion, certain decisions regarding instrumentation and control systems, and by-pass piping and valving for operational flexibility (52).

PROJECT BACKGROUND AND METHOD OF STUDY

Project Background

The City of Taft, together with the Ford City and Taft Heights Sanitation Districts, is a small urbanized area of about 10,000 people, located near the junction of State Highways 33 and 119 in Kern County, California approximately 40 miles west of the City of Bakersfield (Figures 1 and 2). It is situated at approximately 1,000 feet above sea level in the shallow Midway Valley between Buena Vista Hills to the northeast and the Temblor range to the southwest. Sandy Creek, an intermittent stream which drains approximately 22.0 square miles in Kern and San Luis Obispo Counties, forms the principal watercourse through both Taft and Ford City.

The existing joing sewage treatment plant went on line in 1974, replacing an older facility constructed in 1952. The existing treatment facility has a design flow of 1.2 million gallons per day (mgd) and consists of a bar screen, comminutor, aerated primary and secondary lagoons, and chlorine contact chamber (Figure 3). A small irrigation holding reservoir is also available. The facility discharges on an intermittent basis an average of 0.9 mgd to Sandy Creek. While designated a "water of the United States," Sandy Creek only has natural flow during and after storms. The treatment plant effluent has been used for irrigation of cotton and forage crops from April through October each year.

Figure 1. Location map of Taft, California. (23)

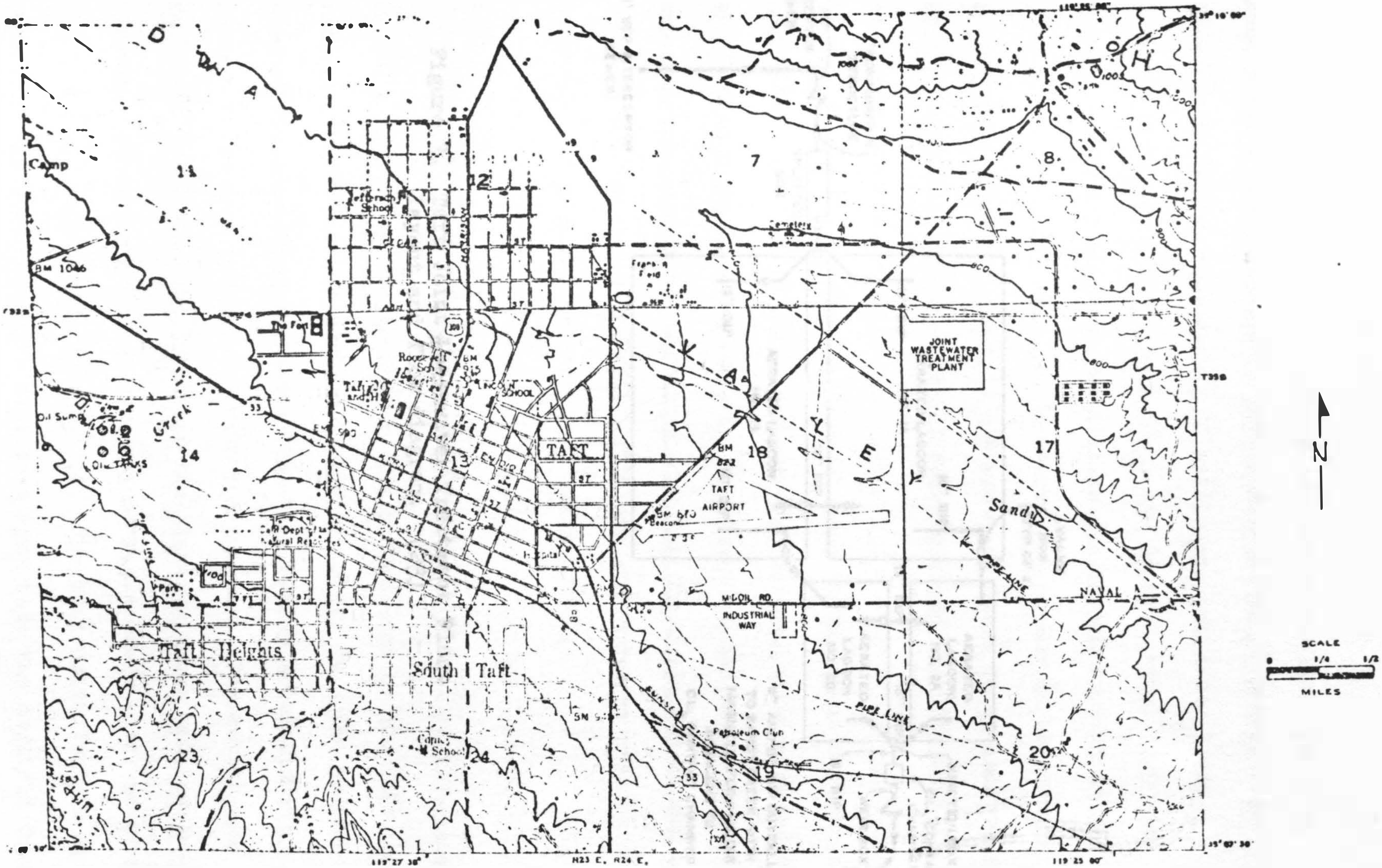

Figure 2. Map of area served by Taft Joint Wastewater Treatment Plant. (23)

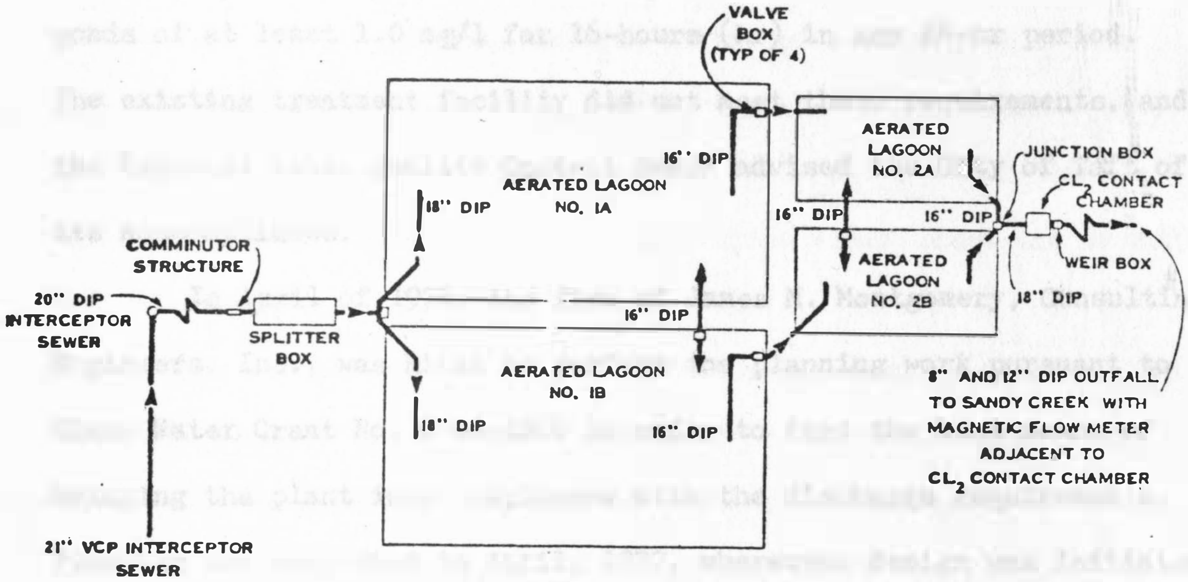

Figure 3. Taft Joint Wastewater Treatment Plant layout and flow diagram. (23)

Effluent limitations set by the Central Valley Regional Water Quality Control Board in 1975 under the NPDES program for discharge to Sandy Creek were: 30 milligrams per liter 5-day biochemical oxygen demand (mg/l BOD_5) and 30 mg/l total suspended solids on a 30-day average, and a dissolved oxygen content in all ponds of at least 1.0 mg/l for 16-hours (hr) in any 24-hr period. The existing treatment facility did not meet these requirements, and the Regional Water Quality Control Board advised the City of Taft of its noncompliance.

In April of 1976, the firm of James M. Montgomery, Consulting Engineers, Inc., was hired to perform the planning work pursuant to Clean Water Grant No. C-06-1200 in order to find the best means of bringing the plant into compliance with the discharge requirements. Planning was completed in April, 1977, whereupon design was initiated. The final design was completed in February, 1978.

Method of Study

The purpose of this study was to identify the decisions made in the planning and design of the Taft project and to identify the basis on which each of those decisions was made, from the point of view of the consulting engineer. This was partly accomplished through first-hand involvement with the project. The author was the state project evaluator during the planning phase and, consequently, either participated directly or was closely involved with all decisions made during that period. The most valuable information regarding the basis on which decisions were made was acquired from many conversations and interviews with Dr. Frank Grant, project engineer, and Ms. Janet Fahey, assistant project engineer, both during and after the planning and design effort. Mr. Joe Rodriguez, the state design reviewer for the project, also provided insight into the basis for certain design changes. Finally, additional information was gleaned from careful review of the Project Report (23), Environmental Impact Report (22), various design reports (39), construction drawings and specifications (24), and related correpondence (39) submitted pursuant to the Clean Water Grant and on file with the State Water Resources Control Board.

Due to the large number of individual decisions studied, the identification of decisions and the basis on which they were made will mostly be presented in either a tabular or outline format. A narrative format will be employed when appropriate to bring out special points of interest. Finally, some consolidation of design decisions, particularly those associated with the specifications, was necessary due to the vast number of such decisions.

SURVEY OF PLANNING DECISIONS

Planning decisions will be identified and the basis of each discussed, in roughly the order in which the decisions were made. In general, it will be possible from the list of decisions to follow the project through various phases from conception to completion of design and agency approval. A decimal numbering system is used to identify major planning decisions and sub-decisions.

1. To Have a Project?

   Having recently completed construction of the existing facilities, there was considerable public opposition to authorizing a new wastewater project, especially on the part of Kern County. The decision to go ahead with the new project was based on the following: 1) new waste discharge requirements posed the threat of legal enforcement action by the Regional Water Quality Control Board; and 2) the project was seen politically as a possible means of establishing an agricultural program at Taft College, largely at state and federal expense.

2. Choice of Design Flows and Wastewater Charateristics.

   Values for these parameters were selected on the basis of: 1) testing and monitoring records; 2) demographic studies and population projections; and 3) grant regulations limiting the eligible design average flow.

3. Choice of Effluent Quality Constraints.

Effluent standards were based on the NPDES Permit for surface water discharge and probable waste discharge requirements for other modes of disposal.

4. Choice of Alternatives to Study.

Selection of possible project alternatives was based on: 1) State planning guidelines; 2) engineer's past experience; 3) engineer's desire to limit alternatives studied to as few as possible for the sake of expediency; and 4) local political interests desiring an agricultural program at Taft College.

5. Recommendation of Upgrading Existing Sewage Treatment Plant Units.

5.1. Provide laboratory improvements, including replacement of BOD bottle incubator and installation of fume hood. Based on request of sewage treatment plant (STP) operator.

5.2. Install additional aerators. Based on testing and analysis of existing ponds.

5.3. Use of five (5) horsepower per million gallons (HP/mg) as a design criterion for sizing aerators. Based on engineering judgment.

5.4. Provide baffling in chlorine contact chamber. Based on suggestion of state project evaluator.

6. Selection of Recommended Alternative.

The recommended alternative was chosen ostensibly on the basis of cost-effective analysis in which multiple criteria were analyzed in a matrix model (Table 1). However, in fact the analysis was

TABLE 3

ALTERNATIVE COMPARISON SUMMARY (23)

Factor	Relative Weight	Alternatives *			
		A	B	C	D
Environmental Effects					
Primary Impacts					
Water Quality	6	4	6	4	6
Air Quality	2	2	1	1.5	1.5
Noise and Traffic	2	2	1	1.5	1.6
Geology and Soils	4	4	2	3	3
Vegetation and Wildlife	8	8	2	6	4
Archaeology	2	2	2	2	2
Odors	4	4	2	3	3
Secondary Impacts					
Population	6	6	6	6	6
Public Health	6	5	4	4	5
Sub Rating	40	37	26	31	32
Social Impacts and Additional Considerations					
Economic Activity	2	0	2	2	2
Institutions	2	0	2	1	2
Land Use	2	2	2	2	2
Flood Protection	2	2	1	2	2
Bypass Analysis	1	1	1	1	1
Public Acceptability	2	0	1	0	2
Implementation Capability	2	0	1	0	2
Compatibility with Planning Goals	2	1	2	2	2
Flexibility	1	0	0	1	1
Reliability	2	2	2	2	2
Power and Chemicals	2	2	2	2	2
Sub Rating	20	10	16	15	20
Monetary Cost					
Total Present Worth	25	15	22	18	25
Capital Cost	15	15	6	8	10
Sub Rating	40	30	28	26	35
Overall Rating	100	77	70	72	87

*See page 40 for description of alternatives.

used to justify a choice already made, which was based principally on: 1) capital cost (Note that the analysis matrix contains a separate "capital cost" factor, based on the imperative need to stay within the budget in order to maintain public acceptance.); and 2) program development interests of Taft College. This major decision involved numerous sub-decisions, if only to prepare an approvable planning report:

6.1. Elimination of domestic reuse from study. Based on economics and State Health Department opposition.

6.2. Elimination of recreational lake reuse from study. Based on lack of public demand, poor soil conditions, and economic considerations.

6.3. Elimination of industrial reuse from study. Based on lack of demand by industry.

6.4. Consideration of irrigation, percolation, and creek disposal options for further study. Based on economic feasibility and engineer's judgment.

6.5. Screening criteria.

  6.5.1. Utilize existing facilities to the maximum extent. Based on avoiding problems with the City and State reviewer.

  6.5.2. Meet discharge requirements. Based on legal and political consequences.

6.5.3. Include water reclamation as a goal. Based on conformance with national, state and local planning goals.

6.5.4. Be cost-effective. Based on grant program requirement.

6.5.5. Be compatible with existing system. Based on concern for public acceptability.

6.6. Specific planning criteria.

6.6.1. Use ultimate oxygen demand. Based on testing which showed an unusually high ultimate oxygen demand compared to BOD.

6.6.2 Maintain dissolved oxygen (DO) of 2 mg/l. Based on engineer's judgment.

6.6.3. Consider using settling ponds for solids removal. Based on the suggestion of the state reviewer.

6.6.4. Consider using irrigation and/or percolation disposal. Based on state facilities planning guidelines as well as local political considerations.

6.7. Choice of irrigation criteria and percolation criteria. Based on engineering judgment and standard practice.

6.8. Choice of cost index. Based on published curves and adaptation to the specific study area.

6.9. Use of Montgomery Engineers cost data. Based on expediency.

6.10. Use of 25 percent for engineering, administrative cost, and contingency. This was the engineer's judgment rather than a matter of company policy. Usually a higher percentage would be used because it would be critical to overshoot rather than undershoot a cost estimate when a bond issue is to go before the voters. However, in this case no bond issue was involved; rather, it was desired that costs appear as low as possible because of public opposition to the project. Finally, 25 percent was used because it was convenient in calculations.

6.11. Choice of interest rate, salvage values, planning period, and non-use of inflation in the economic analysis. Set by federal regulations.

6.12. Choice of factors in cost-effective matrix. Most were set by state guidelines. Use of a "capital cost" factor was based on the importance of keeping within a budget.

6.13. Further screening of alternatives.

    6.13.1. To no longer consider pretreatment of commercial wastes, discontinuation of septage dumping, or elimination of home garbage grinders. Based on assumption that these were socially unacceptable and economically infeasible.

    6.13.2. To not consider add-on treatment units. Based on cost.

6.13.3. To eliminate percolation basins as the sole disposal means but retain them as a part of the system. Elimination of percolation as the sole means of disposal was based on general opposition to loss of the reuse potential of the water (there is no usable groundwater in the area); percolation was retained for consideration as part of a total disposal system because of its apparent low cost.

6.13.4. Landscape irrigation was eliminated based on cost, as was industrial reuse.

Following screening, four final alternatives remained for detailed analysis:

Alternative A--Upgrading for year-round creek discharge.

Alternative B--Agricultural irrigation, and storage during winter (involving minor upgrading).

Alternative C--Agricultural irrigation in the summer and creek discharge in the winter.

Alternative D--Agricultural irrigation in the summer and percolation disposal in the winter.

6.14. Choice of specific process units in each alternative, sizing and other design criteria. Based on engineer's judgment, past experience, and standard practice.

6.15. Use of a total of 250 acres for Alternative D. This size was chosen because it seemed reasonably conservative to the engineer.

6.16. Choice of Alternative D. Justified on the following bases: 1) it had the lowest present-worth cost; 2) it was compatible with local planning (i.e., political) goals; 3) it was compatible with state and federal policy; and 4) it had public acceptability. A major factor in public acceptability was that the proposed plan, by eliminating surface discharge, would minimize future involvement with the state regulator agency which, it was feared, might impose more stringent treatment requirements for surface discharge in the future.

7. Specific Features of the Recommended Project.

7.1. Addition of effluent pump station. Based on physical constraints.

7.2. Sizing of holding basin for three days' storage. This was justified in the planning report as needed to hold flows over a long weekend. In fact, it was a "wild guess" made without any calculations or technical justification.

7.3. Sizing of percolation basins at 10 acres. The sizing was based on laboratory soils tests and on observation of the percolation rate in Sandy Creek. Pilot studies were omitted for the sake of expediency. (Subsequent soils tests showed this to be a mistake. Also, the engineer greatly under-estimated the cost of excavation and basin construction, which affected the recommended sizing.)

7.4. Preliminary selection of piping, booster pumps, and sprinklers. Based on the engineer's judgment and experience.

7.5. Fencing and site preparation. Based on Waste Discharge Requirements' condition that site be isolated and that there be no wastewater runoff.

7.6. Lining of holding basin with soil cement. Based on soil subsidence problems in the area.

7.7. Choice of average design flow. Based on grant-elibible population and per capita flow in order to minimize the local share of the project cost.

7.8. Use of a peaking factor of 2.4 for the effluent pumps. This was based on a mathematical analysis of the damping effects through the treatment ponds on influent peaks. However, to account for uncertainties in the model assumptions, the theoretical peaking factor was adjusted intuitively to give a more conservative figure.

7.9. Choice of possible crops and irrigation practices. Based on recommendation of the area farm advisor.

7.10. Additional specific features of the recommended project, such as addition of surface aerators, baffling in the chlorine contact chamber, and laboratory improvements, have been noted previously.

A significant problem was discovered during planning which would control some major project decisions. The area originally recommended for construction of the irrigation system was found to have many dens of the San Joaquin Kit Fox, a rare species made rarer by the encroachment of agriculture. The U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG) objected both to the new agricultural facilities and to the elimination of wastewater discharge to Sandy Creek, because this discharge was responsible for maintaining a greenbelt for a few miles downstream from the point of discharge. Both agencies threatened to require a Federal Environmental Impact Statement, which would delay the project at least one more year, and meetings were held to negotiate acceptable solutions. A further problem was that the farmer who had been using some of the effluent had a lease from the Navy which was about to expire. The Navy would not sell that land to Taft and was reticent to agree to a lease longer than five years. Standard Oil, the other land owner in the project vicinity, was willing to sell to Taft, but it was on the Standard Oil land that the Kit Fox population was thriving. Through extensive negotiation among the agencies involved, a satisfactory solution was decided.

8. <u>Location of Pumping Facilities, Holding Basin, and Percolation Ponds (Permanent Structures) on Section 17 (Standard Oil), and Location of Irrigated Area in North Half of Section 18 (Navy)</u>. This decision was to minimize the project's impact on the Kit Fox, thereby minimizing implementation problems with regulatory

agencies. Also, it was considered desirable to locate permanent structures on land owned by Taft.

9. Major Environmental Mitigation Measures.

   9.1. Agricultural area to be limited to that recently under cultivation by the previous farmer.

   9.2. Maintenance of an irrigated buffer strip around the agricultural area to provide greenery for wildlife. This strip would be enclosed with a fence to provide protection from sheep and a ditch to keep out tractors and other farm machinery.

   9.3. Percolation basins to be designed to minimize the possibility of waterfowl botulism.

The above measures were the result of negotiations between USFWS, CDFG Taft, Taft College, EPA, and the State Water Resources Control Board and were based on two-agreed-upon criteria: 1) Removal of effluent from Sandy Creek is an environmental loss but is compensated by creating the buffer zone; and 2) Kit Foxes must not be further encroached upon.

10. Construction Impact Mitigation Measures.

    These included such measures as minimizing construction dust by wetting, reduction of noise by muffling equipment and restricting construction activity to normal working hours, posting safety warning signs, traffic control, compliance with Cal-OSH requirements, reseeding and replanting of vegetation. All were standard measures based on expediting EPA approval of the project.

11. Cultural Resources Statement.

This was the requirement that in the event construction activity uncovers items of possible archaeological or cultural importance, work will be stopped and a qualified archaeologist will evaluate the find. This condition was necessary to get approval from the State Historic Preservation Officer.

12. Operational Impact Mitigation Measures.

These include: 1) lining holding pond; 2) maintaining a year-round cover crop; 3) requiring a soil management program; 4) keeping permanent structures out of the flood plain; 5) analyzing soil stability for structures during design; 6) growing boron-tolerant crops; 7) applying gypsum; and 8) maintaining mosquito control. These measures were based on recommendations from Kern County technical staff and were decided during planning in order to expedite approval from EPA and other regulator agencies.

SURVEY OF DESIGN DECISIONS

Design of the facilities proceeded in definite stages: 1) a "ten percent design" submittal; 2) a "fifty percent design" submittal; 3) a "hundred percent design" submittal (hereafter termed the August Plans and Specifications"); and 4) revisions to the design prior to receiving bids. In order to convey a sense of the design decision-making process, the decisions will be grouped and presented accordingly. Owing to the extremely large number of design decisions, no more than the briefest of explanations of the basis of each decision can be presented in most cases. Standard abbreviations are employed, such as "HP" for horesepower; in addition, two abbreviations are used frequently for the design basis: EJ and JMM. EJ is used to mean a decision based on the engineer's judgment and experience without specific additional justification. JMM refers to the company practice or standards of James M. Montgomery Consulting Engineers, Inc. These standards represent a cumulation of past experience and are periodically reviewed by a senior vice-president for quality control. The design engineer simply uses these standards, whenever applicable, without further evaluation. A summary of abbreviations and symbols employed is included in Appendix A.

Ten Percent Design

The decisions made in the ten percent design submittal and the basis on which they were made are shown in Table 2. The ten percent design largely involved refinement and elaboration of decisions made previously. Planning constraints, such as grant eligible flows and waste discharge requirements, were still important considerations. However, engineering judgment began to acquire greater importance in design decision-making than it had during planning. Also, routine design practices began to be employed for some standard details of the design.

TABLE 2

BASES OF TEN PERCENT DESIGN DECISIONS

Decision	Basis
Select combination wheel roll and hand line irrigation system.	Advice of representative of Taft College
Delete large ditch to separate greenbelt from field.	Safety hazard.
Provide 5-strand barbed wire around greenbelt.	EJ
Select two 20-HP aerators in each of two main lagoons.	Rational oxygen transfer and mixing calculations, engineering judgment, increased load due to septage dumping.
Specify 140 acres to be planted, 20 acres fallow.	Largest grant eligible sizing.
Use average flow 1.07 mgd.	From planning.
Use peak flow 2.57 mgd.	From planning.
Replace 8" outlet from chlorine contact tank with 16" gravity line to holding pond.	Headloss calculations.
Size holding pond capacity 3 mg.	Engineer's guess at largest grant eligible size.

TABLE 2--continued

Decision	Basis
Size bottom area of percolation pond 10 acres.	Calculations from preliminary soils tests.
Use two percolation ponds.	EJ
Choose two 750 gpm pumps at 45' TDH for low-lift pump station (PS), one as standby.	Standard practice, pump curves.
Choose three pumps, for high pressure PS, one as standby.	EJ
Variable Speed	EJ
Pressure Controlled	EJ
Each 1100 gpm at 240'	Pump curve selection.
Increase length-to-width ratio of chlorine (Cl_2) contact chamber to 63 to 1 from 5 to 1.	EJ
Use 2" x 12" redwood baffles for Cl_2 contact chamber	EJ
Install new 16" propeller meter at Cl_2 chamber outlet.	NPDES requirement.
Size holding pond bottom 170' x 340'.	What draftsman happened to put on the drawing.
Use 6' holding pond water depth.	EJ
Use 3:1 holding pond side slopes.	Standard practice.
Size percolation basin #2 420' x 520'.	EJ, draftsman.
Size percolation basin #1 360' x 700'.	EJ, draftsman.
Use percolation basin side slopes 3:1.	Standard practice.
Use percolation basin depth 10'.	EJ
Size low lift pump on average flow.	EJ

TABLE 2--continued

Decision	Basis
Control low lift pump by water level in holding pond.	To minimize water to percolation pond and to prevent holding pond from overflowing.
Select acceptable pumps for low-lift PS.	Standard design procedure, EJ.
Divide irrigation field into two zones for larger and smaller feed line.	Engineer's initial concern for pressure differences due to topography.
Use variable-speed pumps for sprinklers.	EJ
Choose pipe sizes for irrigation system.	Standard design procedure.
Locate Cipolletti weir plate after Cl_2 contact chamber.	Engineer could find no better place for flow measurement.

Fifty Percent Design

The decisions made in the fifty percent design submittal and the basis on which they were made are listed in Table 3. Even more than in the ten percent design, the fifty percent design submittal revealed a transition away from planning considerations towards more detailed engineering decisions. Engineering judgment predominated as a decision basis and standard designs of the engineering firm were utilized for some minor details. Also, several decisions were made which relied on the recommendations of equipment manufacturers or other outside advisors.

Two design changes were made in response to the state design reviewer's comments on the ten percent submittal. This indicated continuing concern that the project be fully grant eligible.

Finally, the use of a computer analysis to determine the need for a surge tank demonstrated the more highly technical nature of that phase of the design.

TABLE 3

BASES OF FITY PERCENT DESIGN DECISIONS

Decision	Basis
Specify Cipolletti weir plate details.	JMM
Use 1/4" SS for Cipolletti weir plate.	JMM
Select 4-gpm sprinkler.	EJ
Choose maximum required irrigation rate 0.25" to 0.5" per hour.	Advice of Kern County agricultural advisors.
Choose Rainbird 30W 9/64" nozzle.	EJ, manufacturer's literature.
Space sprinklers at 34'.	Area practice.
Space laterals at 51'.	Area practice.
Select 930' length wheel roll set.	EJ
Specify 31 nozzles per set.	EJ
Use 6 sets.	EJ
Provide enough hand-movable solid sets for 10 acres.	EJ
Use 3" diameter, 30' sections.	Kern County standard.
Use 323 sections.	EJ
Use 7/64" nozzle.	EJ, manufacturer's literature.
Use 30' x 45' spacing for nozzles.	Area practice.
Put fixed sprinklers along fence for greenbelt.	EJ

TABLE 3--continued

Decision	Basis
Use 190 1/8" 7^{o} half-circle impact sprinklers spaced at 50'.	Equipment supplier's recommendations.
Use 80 PVC for main irrigation feed line, no surge tank required.	Surge analysis by computer.
Install anti-erosion plates in lagoons to protect existing diffused aerators and bottom from scouring.	EJ
Change irrigation pump sizing to pump average flow in 12 hours with one standby unit.	Conform to grant eligible sizing.
Change irrigation system to have a single 12" feeder line.	Response to state reviewer's comments.
Change irrigation system to have six 1/4-mile wheel roll sets to cover 100 acres, and hand move lines for remainder.	EJ
Provide each non-wheel area with three hand lines.	To allow lines to be moved without shutting down pumps.

August Plans

Virtually complete construction drawings were submitted to the state reviewing agency in August, 1977. Preparation of those plans involved a large number of decisions the bases of which are summarized in Table 4. The individual decisions and basis of each are tabulated in Appendix B.

In the August Plans, most decisions were made on the basis of the engineer's judgment. No special investigation or analysis was made by the engineer in arriving at these decisions; rather, he principally relied on his training, experience, and general engineering sense.

TABLE 4

SUMMARY OF BASES OF DECISIONS FOR THE AUGUST PLANS

Basis of Decisions*	Number of Decisions
Engineer's judgment	85
James M. Montgomery design standards	59
Manufacturer's standards or equipment supplier information	7
Recommendations of soils consultant or sewage treatment plant operator	4
Constraints on the site	3
Agency or code requirements	2
Standard engineering design procedures	1
TOTAL	161*

*Some decisions have a dual basis; therefore, the total number shown in this table exceeds the actual number of separate identifiable decisions (See Appendix B).

Even the engineer's childhood experiences were involved. For example, the decision to space fence posts at a maximum of 10 feet on center was based on the engineer's experience building fences as a boy. Also included in the category of engineer's judgment were decisions made for purely practical considerations or common sense. For example, raceways were required to be brought into the electrical pull box in order to facilitate pulling the conductors. Similarly, provision was made for salvaging and reusing an existing fence because it seemed common sense to the engineer to utilize existing materials to the greatest extent possible.

Also apparent in the August Plans was a greatly increased reliance on standardized design details of the engineering firm. In making decisions concerning such design elements as anchor bolt details, surface aerator connection details, dimensions of steel supports, and use of high pressure tubing the engineer simply utilized the firm's prepared standards.

For some decisions made in the August Plans, the engineer relied on the judgment and expertise of others. For example, the cement content of the soil cement lining was based on the recommendation of an outside soils consultant, and design of the aerator control ladder diagram was based on the engineering judgment of an electrical engineer from another division of the company. Similarly, details of some equipment, such as the fume hood, exhaust fan, and air supply fan, were based on standards and recommendations of the equipment manufacturers.

Although the decisions included in August Plans were numerous, they individually were of relatively minor importance compared to the decisions of planning and preliminary design. In general, the decisions changed from very site-specific, weighty decisions regarding concepts to very standardized and less consequential decisions regarding details. Only a few decisions were due to site constraints or were otherwise unique to the Taft project. The location of pipes and piping appurtenances was based on trial-and-error attempts to fit the constraints of the topography and existing structures. Similarly, the decision to bury certain exposed active oil pipelines, which crossed the site, with a minimum of three feet of cover was an attempt to locate the pipes below plow depth. Also, the location of equipment within the laboratory was based on consideration of the wishes of the treatment plant operator.

August Specifications

Accompanying the August Plans were construction specifications which also involved a large number of individual decisions. A summary of the bases of those decisions is shown in Table 5, and the individual decisions and basis of each are tabulated in Appendix C.

TABLE 5

SUMMARY OF BASES OF DECISIONS FOR THE AUGUST SPECIFICATIONS

Basis of Decision	Number of Decisions
James M. Montgomery design standards	142
Engineer's judgment	4
City and/or County standards	2
Design of previous project	2
Information--to avoid future claim from contractor	1
EPA and state regulations and policy requirements	Numerous

The August Specifications were characterized by a general reliance on previously prepared standard design specifications of the consulting firm. Decisions such as general requirements for fill materials, safety requirements, performance conditions for floating surface aerators, and handling requirements for piping were apparently so recurrent and routine as to not warrant individual consideration by the design engineer.

Of an even more general nature were numerous requirements such as Federal Wage Determinations, affirmative action requirements, requirements for preservation of cultural resources, and details of the project sign. These requirements came from EPA and state regulations and policies, and the only decision was to insert them in the specifications because they were required by law.

Very few decisions in the August Specifications were unique to the Taft project. Among these were: 1) specification of the time of completion of construction; 2) provision of an aluminum boat and life jackets for pond and aerator maintenance; and 3) replacement of certain existing deteriorated clamps. All of those decisions were based on the engineer's judgment. The engineer also thought it important to specify that a temporary bypass pipeline be installed while work was underway on the chlorine contact chamber, in order to avoid a possible claim by the contractor. The amount of liquidated damages and certain requirements concerning soil cement were taken directly from the specifications of the previous wastewater treatment plant construction project at Taft; these conformed to recommendations made by the City of Taft. Finally, certain contract forms of the County of Kern were included in the specifications.

Subsequent Design Decisions

Following approval of the final design by the state, the engineer revised the design to eliminate percolation ponds entirely and replace them with coarse media, multi-cell pressure filters followed by discharge to Sandy Creek. This drastic change was based on the following: 1) Soils testing during design showed the percolation rate to be much lower than assumed, necessitating deeper ponds (the available area for the ponds was constrained by environmental considerations); and 2) more realistic estimates of the excavation costs showed the percolation ponds to be prohibitively expensive. An interesting facet of this decision was that the engineer, the City, and the County were aware of the problem prior to submittal of the final design for State approval. However, because of a shortage of construction grant funds and an abundance of competing projects in California that year, and because the deadline for award of construction grants was approaching (September 30, 1977), it was deemed expedient to submit construction documents designed according to the original plan for fear that any controversial changes would jeopardize the grant. Decisions required as a result of the decision to use pressure filters are shown in Table 6.

Two other changes were made at the same time as the decision to eliminate the percolation ponds: 1) the specification to replace certain existing deteriorated clamps was deleted; and 2) the provision of an aluminum row boat for maintenance was deleted. The basis for these decisions was the determination by the state that those items would not be eligible for grant funding. Inclusion of any ineligible items in the project was considered undesirable.

TABLE 6

DECISIONS REQUIRED AS A RESULT OF DECISION TO USE PRESSURE FILTER

Decision	Basis
Layout changes.	EJ
Low-lift pump changes.	Standard design procedure.
Choice of layout, valving, piping, and materials of filter.	EJ, JMM
Provision of supports for filter.	EJ
Determination of backwash cycling.	EJ
Piping changes.	EJ
Minor changes in electrical controls.	Experience of electrical engineer.

A second drastic revision to the design was made one month later, which proposed to eliminate the newly-added pressure filters and to discharge plant effluent to Sandy Creek in the winter without additional treatment. The basis of this decision was that EPA and the Regional Water Quality Control Board changed their policy for surface water discharge of pond effluent, relaxing the suspended solids limitation. Inasmuch as the upgraded treatment plant was expected to meet the new requirements, the filters were no longer needed, and the decision to eliminate them was justified on the basis of economics. Modifications to the design which were required as a result of eliminating the pressure filter were: 1) minor changes in layout, valving, piping, and materials; 2) minor electrical changes; and 3) deletion of items associated with the filters. The criterion used by the engineer in making these changes (and not making others) was to minimize the impact on the existing drawings, for the sake of expediency. For example, with elimination of both the percolation basins and the filters, there may have been a better location for the holding pond, but this was not investigated because it would have necessitated a major change in the drawings.

After bid advertisement an addendum to the construction documents made the following changes: 1) update of some federal documents in the specifications; 2) relocation of a fence; and 3) extension of a road. The first change was to conform to legal requirements; the others were needed to conform to previous layout changes.

A second addendum made some additional changes. The designation of excess excavated material for use as fill, and the requirements for such use, were standard construction specifications of Montgomery Engineers which had been inadvertently omitted in the original specification. These were added in the second addendum. The addendum also called for the replacement of an existing deteriorated Chevron Oil Company pipeline which was located in the irrigation area, as well as the relocation of a Chevron gas facility to a site which was to be designated by Chevron during construction. These changes had been demanded by Chevron, and it was considered expedient to accede to them.

SUMMARY DISCUSSION

The most obvious feature which appears from a review of the preceding survey is that the planning stage involved few but important decisions, while the design stage involved many decisions of relatively minor significance. In fact, the truly major decisions made in design, such as abandonment of the percolation basins and changing of the disposal mode were actually planning decisions which were made during design only because new information came to light or important conditions changed. Consistent with this observation is the fact that much greater effort was invested in making the planning decisions. The major planning decisions required information gathering, consultation with various regulatory agencies and other concerned parties, economic analysis, and evaluation of environmental and social factors. By contrast, most design decisions required no evaluation at all by the engineer; rather, they were generally based on company standards, regulatory agency requirements, or general engineering judgment. The specifications were almost entirely standardized.

Political, environmental, and social factors clearly were of much greater concern in this project than were the technical problems. Avoiding further encroachment on the San Joaquin Kit Fox, minimizing conflict with regulatory agencies, starting an agricultural program at Taft College, and trying to avoid antagonizing the local government and citizenry were the criteria shaping the major project decisions. Similarly, official justification for a decision was often different from, and secondary to, the unstated basis. For example, the decision to size the holding basin at 3 million gallons was justified as needed to contain flows over a long weekend, while the true primary basis for that decision was the engineer's guess that 3 million gallons was the largest capacity that would be approved for grant eligibility.

The local point of view was never abandoned. The concerns of state and federal regulatory agencies, such as meeting effluent standards and protecting wildlife, were considered as factors or constraints in the project, but if local constraints and objectives were not met, such as staying within the budget or benefiting the college, there would have been no project. The decision to withhold information from the state on the infeasibility of the percolation ponds until after a construction grant was awarded demonstrates the importance of the local point of view to the consulting engineer. As a corollary, grant eligibility was a key determinant in decision-making. Any project elements which were not grant eligible would have to be paid for entirely at local expense. This was considered politically unacceptable, regardless of technical or economic considerations, and so no ineligible items were included in the project. For example, the boat needed for pond aerator maintenance was deleted from the specifications when it was ruled ineligible for grant funding.

Time and money limitations discouraged in-depth analysis of most design decisons. Thus, reliance on company standards, off-hand engineering judgments, and equipment suppliers' recommendations predominated in design. It is interesting to observe that in contrast to typical engineering training, in which independent work is encouraged, the project engineer needed to make as much use as possible of outside information, other people's judgments, and previously-prepared work. Thus, planning decisions required input from many sources in order to be approvable. Likewise, the Montgomery Engineers' standards, which formed the basis for so many design decisions, are a compilation of judgments made principally by other firms or agencies, and it is on the basis of others' experience that those specifications could be reliably used.

Time and money limitations also constrained the planning effort, but regulatory agency requirements made in-depth analysis of some decisions unavoidable. For example, it is certain that careful evaluation of the disposal alternatives in order to minimize adverse environmental impacts only occurred as a result of regulatory agency requirements. However, in general, the planning process did not serve to make decisions, but rather to justify decisions already made on the basis of local concerns.

It was apparent from this investigation that the most important decisions were site-specific to the project. For example, the wastewater flows and characteristics, the effluent quality constraints, the Kit Fox problem and related environmental considerations, the public interest in reuse of effluent for irrigation, the conditions of land availability and ownership, and the existing treatment plant layout were all conditions unique to the facility. Thus, although many projects in wastewater treatment may be similar in purpose, it is the decisions unique to each project which appear to be the most significant. For this reason, the professional qualities of the project engineer and of the consulting engineering firm are particularly important. In the Taft project, the engineer's judgment reflected training and experience in the use of technical information and engineering principles, and it affected the overall quality of the project decisions more than any other factor.

Finally, the investigation revealed that the engineer's approach to the many decisions of planning and design was not haphazard. Forethought and organization were required to try to optimize the effort expended in the decision-making process. By anticipating key decisions, necessary information was gathered and preliminary work was performed without causing unnecessary project delay. A good example of such forethought was in dealing with the Kit Fox problem. Even before the draft environmental document was released, the engineer set up a meeting with personnel of key regulatory agencies to inform them of the problem and to reach an agreement on the steps needed to make sound decision regarding it. Had the engineer not carefully planned an approach to the Kit Fox decision, the project would have been delayed and greater effort would have been expended. Similarly, the maintaining of prepared standards for design specifications showed planning, on the company level, in the approach to decision-making. It could be concluded, therefore, that if, at the start of planning or design, an engineer outlined all of the anticipated decisions, decided the basis on which each would be made, and organized an approach to the decisions, the engineer's efforts could be optimized and the overall decision-making process would be improved. Further investigation of possible approaches to optimizing the decision-making process is warranted.

CONCLUSIONS

This investigation surveyed all of the decisions which made up the planning and design of a Clean Water Grant project in California. From a review of those decisions, and from the discussion in the preceding section, the following conclusions can be drawn:

1) Few, but relatively important, decisions were involved in the planning stage of the project.
2) A relatively large number of decisions of generally minor importance were made during the design stage.
3) Major planning decisions required extensive data collection, consultation with governmental agencies, economic analysis and consideration of environmental and social factors.
4) Most design decisions required little evaluation by the engineer but instead were based on company policy, governmental requirements or engineering judgment.
5) Political, environmental and social factors were of much greater concern than the technical problems.
6) Official justification for a decision was often different from, and secondary to, the stated basis.
7) Local factors were of more importance to the consulting engineer than concerns with state and federal regulations.
8) Time and money limitations discouraged in-depth analysis prior to many design decisions; use of company standards, prior successful experience, and equipment suppliers' recommendations

seemed to serve as suitable substitutes for detailed study in making minor design decisions.

9) Some design decisions were made only as a result of regulatory agency requirements.

10) The engineers' approach to decision-making was not haphazard; considerable forethought was required to optimize the steps to avoid project delays.

11) In general, the investigation suggested that if an engineer outlined the anticipated decisions, decided on the basis of the decisions, and organized an approach to the decisions at the start of planning or design of a project, the engineer's efforts could be optimized and the decision-making process improved.

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APPENDIX A

SUMMARY OF ABBREVIATIONS AND SYMBOLS USED

Abbreviation or Symbol	Meaning
"	Inches
'	Feet
o	Degrees
%	Percent
AV/AR	Air/vacuum relief (valves)
Cl_2	Chlorine
DIA	Diameter
DIP	Ductile iron pipe
EJ	Engineer's judgment
gpm	Gallons per minute
HP	Horsepower
ID	Internal diameter
JMM	Design standards of James M. Montgomery Consulting Engineers, Inc.
MCC	Main Control Center
mg	Million gallons
mgd	Million gallons per day
mg/l	Milligrams per liter
NPDES	National Pollutant Discharge Elimination System (permit)
O&M	Operation and maintenance

PVC	Polyvinyl chloride
PS	Pump station
RCP	Reinforced concrete pipe
RMS	Root mean square
SS	Stainless steel
TDH	Total dynamic head

APPENDIX B

TABULATION OF DECISIONS AND BASIS FOR DECISIONS IDENTIFIED FROM AUGUST PLANS, CITY OF TAFT WASTEWATER TREATMENT AND RECLAMATION PROJECT, TAFT, CALIFORNIA

Decision	Basis
Use freeboard 3' on holding pond.	EJ
Use 20' top of bank for all ponds.	EJ
Determine exact layout of ponds.	EJ
Use 3:1 internal dike slopes.	EJ
Use 2:1 external dike slopes (toe).	EJ
Use 30' radius of curvature at corners of dikes.	EJ
Determine location of anchor blocks for aerator.	EJ
Provide floats near mooring cable ends.	EJ
Locate drain lines for ponds.	EJ
Locate soil cement paving.	EJ
Use stainless steel for mooring cable.	JMM
Locate piping.	EJ, constraints of site.
Locate 55'-24" RCP culvert with headwall.	EJ
Locate effluent PS.	EJ

Decision	Basis
Size 4" drain line.	EJ
Size culvert, headwall.	EJ
Locate drainage swale.	EJ
Locate 16' access road.	EJ
Sizing piping.	Standard design practice.
Specify pipe materials.	JMM
Locate gate valves.	EJ
Locate check valves.	EJ
Locate 1" water line to PS.	EJ
Provide four 4" guard posts.	JMM
Choose and locate 8' double leaf swing gate.	EJ
Locate fence.	EJ
Choose 6' chain link fence.	EJ
Locate outlet piping for Cl_2 chamber.	EJ
Locate elbows for outlet piping.	EJ
Locate outlet for holding pond.	EJ
Size outlet from holding pond.	EJ
Provide for salvaging and reusing existing fence.	Common sense (in designer's opinion).
Cut existing 4" waterline and realign.	EJ
Locate new 4" waterline alignment	EJ
Require 3' minimum cover on all buried pipe.	JMM
Locate access road.	EJ

Locate plug valves with valve boxes.	EJ
Grade 4:1 in area near holding pond.	EJ
2% slope from center line of bank top.	JMM
Overexcavate 2' for dikes.	JMM
6" soil cement lining and 12" soil cement lining for holding pond.	Recommendation of soils consultant.
10% cement content for soil cement lining.	Recommendation of soils consultant.
Identify anchor bolt details.	JMM
Identify anchor block details.	JMM
Identify headwall details--structural.	JMM
Use 3 lines of 2-strand barbed wire.	EJ
Use 45° angle for barbed wire.	JMM
Space fence posts @ 10' on center maximum.	Based on engineer's experience building fences in his childhood.
Use 2" mesh chain fence.	JMM
Require fence concrete footing to be embedded 3'.	EJ
Use 12" DIA for gate posts, corner posts.	EJ
Use 9" DIA for line posts.	EJ
Identify riser details--typical.	JMM
Provide 5% minimum grading near riser at fence.	JMM
Choose 5-strand barbed wire fence.	EJ

Decision	Basis
Choose 1/8" x 7^{o} half circle impact sprinkler.	Equipment suppliers.
Require 2' cover over main for border strip.	JMM
Locate AV/AR assemblies with guard posts.	EJ
6" thick concrete encasement of pipe crossing drainage channel	JMM
Location of piping and piping details.	Based on trial-and-error attempts to fit the constraints of the site and have a reasonable arrangement according to the engineer's judgment.
Locate 3" pipe along fence.	EJ
Locate 3" gate valve.	EJ
Locate 3" and 4" risers with riser valves.	EJ
Locate reducer.	EJ
Locate trees.	EJ
Remove trees.	EJ
Remove tree and fence.	Site constraints.
Provide 6 pairs of swing gates.	EJ
Each swing gate 15' wide.	EJ
Bury exposed active oil pipelines with 3' cover minimum.	Attempt to get pipe below plow depth.
Remove exposed inactive oil pipeline.	EJ
Require all new irrigation pipeline class 160 PVC, except as noted.	JMM

Decision	Basis
Plow top 2' of soil in irrigation area, adding 5T/ac of 60% gypsum.	Soils consultant's recommendation.
Provide uniform slopes in irrigation areas.	EJ
Grade strip along fence higher than field.	To confine runoff to field, as required by NPDES.
Provide 3 guard rails for each AV/AR valve.	JMM
Provide extension stem and valve box at ground level for each isolation valve.	JMM
Provide wood post for each isolation valve.	Identification purposes.
Determine location of baffles and joists.	EJ
Locate weir plate.	EJ
Require 3/4" fillet of sealant each side of weir.	JMM
5/8" SS Wedge anchors @ 24" on center.	JMM
Use 1/8" thick neoprene gasket.	JMM
Provide connection details for baffles and joists.	JMM
Choose 2" x 14" redwood joist and hanger.	EJ
Weld joist hanger to support angle.	EJ
Provide groove filled with sealant all around pipe opening for Cl_2 contact outflow pipe.	JMM
Use non-shrink, non-metallic grout.	JMM

Decision	Basis
Use 1/4" plate wall flange for Cl_2 outflow pipe.	JMM
Locate fume hood, air fan, exhaust fan, compressor and vacuum pump in laboratory.	Recommendation of STP operator.
Fume hood: size, material, properties, air, gas, water outlets, electrical outlets, remote controls, switches, supporting base cabinet size and configuration.	Manufacturer's standards.
Exhaust fan: type, motor, details, capacity.	Manufacturer's standards.
Air supply fan: type, capacity, motor type and requirements.	Manufacturer's standards.
Compressor and vacuum pump: capacity, motor type and requirements.	Manufacturer's standards.
Require water, gas, air, vacuum lines to be 1/2" copper.	JMM
Require drain line and vents to be 3" duriron.	JMM
Require ducts to be SS.	JMM
Require ducts to have weather louvers and bird screen.	Manufacturer's recommendations.
Coat exhaust fan to protect it from acid fumes.	JMM
Layout effluent PS piping, equipment, and structures.	EJ
Choose concrete pad reinforcing (under pumps).	JMM, EJ
Select pressure gauge, 8" check valve, 8" plug valve location.	EJ
Require 1/2" nipple, drill and tap for electrical.	JMM

Decision	Basis
Locate expansion joints.	JMM
Provide 2" x 6" long unistrut welded to pipe for electrical.	EJ
Locate 4" C.I. drain line, slope 1/4" per foot.	EJ
Provide stilling well details (connections, piping, distances, materials).	EJ, JMM
Use 12" propeller meter for PS effluent.	EJ, equipment supplier's recommendation.
Use 1/2" seal water drain line.	JMM
Choose mechanical coupling for certain connections.	EJ
Choose sleeve-type coupling for certain connections.	EJ
Require 1" mortar coating, 3/4" mortar lining for pump barrel.	EJ
Require 20" ID pump barrel.	EJ
Use 1/4" plate bumped head bulkhead.	JMM
Determine air and vacuum release valve details.	JMM
Determine surface aerator connection details.	JMM
Determine aerator power cable installation details.	JMM
Use liquid-tight flexible raceway with suitable conduit clamp.	JMM
Determine non-metallic J-Box details.	JMM
Use insulated throat, strain relief, water-tight, oil-tight, cable grip hub.	JMM

Decision	Basis
Require heavy-duty, 4-wire submersible power cord for aerator.	JMM
Use 1/8" SS cable and basket weave cable grip.	JMM
Use SS turnbuckle--3 threads internally exposed.	JMM
Use hot dip galvanized mallable iron "LB" fitting and cover plate with neoprene gasket.	JMM
Use 24" x 18" x 34" concrete base for power J-Box at top of bank.	EJ, JMM
Determine J-Box base reinforcement.	Concrete code requirements.
Determine power J-Box details.	JMM
Determine location of electrical units.	EJ
Repair existing soil cement surface.	EJ
Supply loop conductors in pull box.	Prevent strain.
Bring raceways into pull box.	Facilitate pulling conductors.
Determine dimensions and materials of manifold pressure switch J-Box.	EJ, JMM
Weld electrical support strut to manifold.	Arbitrary decision.
Use high pressure tubing.	JMM
Use pressure tap with corporation stop.	JMM
Use strain relief watertight sealing fitting.	JMM

Decision	Basis
Use flexible liquid-tight raceway.	JMM
Clamp raceway on manifold side of angle.	EJ
Use 3-way plug valve.	EJ
Determine dimensions of steel support.	JMM
Provide "test" pushbutton to simulate high-pressure contact closure.	JMM
Locate typical pump connection details.	EJ
Determine dimensions and types of J-Boxes, connection boxes, supports for pump connections.	JMM, EJ
Determine layout of MCC.	EJ
Make flush copper alloy ground connection.	EJ
Use exothermic weld to form loop.	EJ
Brace MCC to withstand 22,000 amps RMS symmetrical fault current.	JMM
Choose wires, switches, circuit-breaker capacities.	JMM
Locate area lights.	EJ
Determine capacity, appearance, materials, etc. of area lights.	JMM
Determine low-lift pump ladder diagram (electrical control scheme).	Experience and judgment of electrical engineer (EE).
Determine high-lift pump ladder diagram.	EJ of EE

Decision	Basis
Determine aerator control ladder diagram.	EJ of EE
Determine control compartment ladder diagram.	EJ of EE

APPENDIX C

TABULATION OF DECISIONS AND BASIS FOR DECISIONS IDENTIFIED FROM AUGUST SPECIFICATIONS, CITY OF TAFT WASTEWATER TREATMENT AND RECLAMATION PROJECT, TAFT, CALIFORNIA

Decision	Basis
Time of completion.	EJ
Amount of liquidated damages.	Use of amount from specifications of previous project, conforming to Taft's recommendations.
Install temporary pipeline for work on Cl_2 contact chamber.	Specified in order to point out need to contractor, in order to avoid possible claim.
Contractor to field-check soil conditions.	JMM
Specify procedure to be followed by contractor regarding utilities.	JMM
Method of earthwork balance.	JMM
Delineate limits of contractor's operations and storage of equipment and materials.	JMM
Compliance with safety requirements.	JMM
Resident engineer's office requirements.	JMM
Provision for maintaining operation of utilities during construction.	JMM

Decision	Basis
Requirements for contractor reporting.	JMM
As-built drawing requirements.	JMM
Procedure if conflict in specifications.	JMM
Contractor to pay sales taxes.	JMM
Site preparation and site requirements.	JMM
Excavation and stockpiling requirements.	JMM
Sheeting, shoring, bracing requirements.	JMM
Requirements for removal or diversion of water.	JMM
Requirements for structure excavation.	JMM
Requirements for pipeline trench excavation.	JMM
Requirements for pond and basin excavation.	JMM
Requirements for disposal of excess material.	JMM
Finish grade precision.	JMM
Requirements for fill materials.	JMM
Requirements for use of fill.	JMM
Protection of structures during backfilling.	JMM
Compaction requirements.	JMM
Procedure for structure, pipeline trench, embankment, and basin bottom backfill.	JMM

Decision	Basis
Miscellaneous requirements for chain-link fence and gates.	JMM
Installation requirements for chain-link fence and gates.	JMM
Requirements for barbed wire fence and gates.	JMM
Materials, thickness, construction, and inspection requirements for soil cement.	Copied from design of previous project.
Composition, reinforcing steel, formwork, placing, finishing, curing requirements for concrete.	JMM
Fume hood requirements.	JMM
Aluminum boat requirements.	EJ
Life jackets requirements.	EJ
Supply clamps.	EJ
Contractor may substitute equal equipment.	JMM
Contractor must show shop drawings.	JMM
Contractors must submit O&M instructions.	JMM
Requirements for O&M instructions.	JMM
Requirements for materials and workmanship on equipment in general.	JMM
Equipment installation requirements.	JMM
Equipment testing requirements.	JMM
Requirement for equipment protection.	JMM

Decision		Basis
Requirements for couplings.	JMM	
Special Safety requirements.	JMM	
Bearing requirements.	JMM	
Lubrication requirements.	JMM	
Nameplates requirements.	JMM	
Equipment bases and bedplates requirements.	JMM	
Jacking screws and anchor bolts requirements.	JMM	
Base and bedplate grouting requirements.	JMM	
Electric motors requirements.	JMM	
Submittals for electric motors.	JMM	
Motor characteristics and horsepower.	JMM	
Construction and standards for electric motors.	JMM	
Floating surface aerators requirements.	JMM	
Performance conditions for floating surface aerators.	JMM	
Material and construction for floating surface aerators.	JMM	
Testing and demonstration for floating surface aerators.	JMM	
Parts guarantee for floating surface aerators.	JMM	
Drive motor and power cable for floating surface aerators.	JMM	

Decision	Basis
Control requirements for floating surface aerators.	JMM
General pump requirements.	JMM
Equipment testing requirements.	JMM
Shop drawings for pumps.	JMM
Plant effluent pumps requirements.	JMM
Pump performance.	JMM
Materials and construction for effluent pumps.	JMM
Motors and controls for effluent pumps.	JMM
Risers and riser valves requirements for irrigation system.	JMM
Side roll sprinklers requirements for irrigation system.	JMM
Hand move sprinklers requirements for irrigation system.	JMM
Fixed sprinklers requirements for irrigation system.	JMM
General piping requirements.	JMM
Handling requirements for piping.	JMM
Cleaning requirements for piping.	JMM
Cutting requirements for piping.	JMM
Installation requirements for piping.	JMM
Gaskets and bolts requirements for piping.	JMM
Price supports requirements for piping.	JMM

Decision		Basis
Connections with existing pipelines (potable water) requirements.	JMM	
Shop drawings requirements for piping.	JMM	
Steel pipes and fitting requirements.	JMM	
Welded steel pipe requirements.	JMM	
Small steel pipe requirements.	JMM	
Cast iron soil pipe requirements.	JMM	
Corrosion-resistant cast iron requirements.	JMM	
Copper tubing requirements.	JMM	
Polyvinyl chloride (PVC) pipe requirements.	JMM	
Mechanical-type (grooved end) couplings requirements.	JMM	
Strainer requirements.	JMM	
Propeller meter requirements.	JMM	
Field testing requirements of pipes.	JMM	
Lever type actuators requirements.	JMM	
Operating nuts requirements.	JMM	
Handwheels and gear operators requirements.	JMM	
Gate valves requirements.	JMM	
Swing check valves requirements.	JMM	
Plug valves requirements.	JMM	

Decision		Basis
Lubricated plug valves requirements.	JMM	
Eccentric plug valves requirements.	JMM	
Miscellaneous valves and items requirements.	JMM	
Combination air release valves requirements.	JMM	
Sewage air release and vacuum valves requirements.	JMM	
Cocks and corporations stops requirements.	JMM	
Pressure gages and appurtenances requirements.	JMM	
Hose bibb and hose valve requirements.	JMM	
Extension stems requirements.	JMM	
Valve boxes requirements.	JMM	
Codes and standards for electrical work and instrumentation.	JMM	
Working drawings requirements for electrical work and instrumentation.	JMM	
As-built drawings requirements for electrical work and instrumentation.	JMM	
Testing requirements for electrical work and instrumentation.	JMM	
Shop drawings and catalog data requirements for electrical work and instrumentation.	JMM	

Decision		Basis
Area designations requirements for electrical work and instrumentation.	JMM	
Utility service facilities requirements for electrical work and instrumentation.	JMM	
Grounding requirements for electrical work and instrumentation.	JMM	
Equipment anchoring requirements for electrical work and instrumentation.	JMM	
Conductor and equipment identification requirements for electric work and instrumentation.	JMM	
Finish requirements for electrical work and instrumentation.	JMM	
Equipment connections requirements for electrical work and instrumentation.	JMM	
Underground distribution requirements for power, lighting and miscellaneous electrical systems.	JMM	
Raceway requirements for power, lighting and miscellaneous electrical systems.	JMM	
Wire and cable requirements for power, lighting and miscellaneous electrical systems.	JMM	
Splices and terminations requirements for power.	JMM	
Conduit fittings requirements for power.	JMM	
Boxes and covers requirements for power.	JMM	

Decision	Basis
Wiring devices requirements for power.	JMM
Motor starters requirements for power.	JMM
Pushbutton stations requirements for power.	JMM
Control devices requirements for power.	JMM
Lighting panels requirements.	
Tests, inspections, clean-up, and spares requirements for lighting.	JMM
Aerator installation electrical requirements.	JMM
Motor control centers requirements.	JMM
Control devices requirements.	JMM
Terminal cabinets and control cabinets requirements.	JMM
Transfer switches requirements.	JMM
Circuit breakers requirements.	JMM
General information requirements.	JMM
Effluent flow measurement system requirements.	JMM
Bidding requirements, including instructions to bidders, proposal format, bid bond format, information requirements, and requirement for breakdown of total bid.	JMM

Decision	Basis
Contract forms, including agreement, performance bond, payment bond, guarantee bond, workman's compensation insurance, builder's "all risk" insurance, general liability insurance, and shop drawing submittal forms.	JMM, Kern County standards.
Numerous requirements concerning general conditions, including: contract documents, owner-engineer-contractor relations, quality of materials and workmanship, legal responsibility, and public safety bonds and insurance, and progress payments.	JMM
Numerous requirements complying with state and federal regulations, such as: Federal Wage Determinations, project sign requirements, affirmative action requirements, preservation of cultural resources, etc.	EPA and state regulations and policy requirements.