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Assessment of Present Phosphate Mining and Beneficiation Practice and the Evaluation of Alternative Technology

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FLORIDA INSTITUTE OF PHOSPHATE RESEARCH

ASSESSMENT OF PRESENT PHOSPHATE MINING AND BENEFICIATION PRACTICE AND THE EVALUATION OF ALTERNATIVE TECHNOLOGY

FIPR PROJECT #86-04-031

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PERSPECTIVE

Robert S. Akins

Florida Institute of Phosphate Research

On May 5, 1987, the Zellars-Williams Company was awarded a grant by the Institute to perform a study entitled "An Assessment of Present Phosphate Mining and Beneficiation Practice and the Evaluation of Alternative Technology."

The goal of the project was to study the challenges faced by the phosphate industry in areas of continued economic viability, environmental concerns, resource conservation, and generally lower yield and quality of ore reserves. Although it was recognized that traditional systems still serve the industry well, an assessment of these practices and technology was desirable in light of the future needs of the industry in order to provide a constructive evaluation of alternatives and to identify the industries requirements for new technology.

Operations used for mining, beneficiation, waste disposal, water recovery and reclamation are reasonably straightforward; however, interdependence of the various operations results in a complex total system. This is the main reason that major changes in technology have been difficult to develop and implement. The history of new developments in phosphate technology is littered with failures which have been expensive, causing most producers to be conservative. This conservatism is dramatically depicted in new mine design. The risks associated with approaches which represent wide deviation from conventional practices have not been acceptable to most producers. With new mine capital investment reportedly exceeding $100 per annual ton of product, risk/reward analysis becomes a serious consideration. Conversely, the dramatic increase in capital and other costs for new mines threatens the future economic viability of the industry.

What the Zellars-Williams Company proposed to do was to make a paper study of how present technology would perform over the next 20 years in response to changes in characteristics of ore reserves and then evaluate the impact of applying new technologies.

It was recognized that constructive evaluation of present technology with consideration of future ores could also provide early identification of economic, environmental and resource conservation problems. This would allow time for the industry to react to meet these challenges in an orderly and systematic manner.

The major tasks associated with the program were as follows:

-- Assess the adequacy of present industry technology and practice to meet future technical and economic needs.

-- Assess alternate available technology, compare alternatives to present practice and select systems offering prospective technical or economic benefits.

-- Identify the industry needs for new technology to meet the technical and economic demands of the future.

-- Evaluate the risk factors involved in implementation of alternative technology and develop strategies to reduce these risks.

In order to accomplish these tasks, Zellars-Williams set up four groups -- Mining, Beneficiation, Waste Disposal and Reclamation, and Product Management. Representatives from the mining industry, regulatory agencies and associated and service industries participated in a series of three workshop meetings for each of the four subjects. A fifth group, the Advisory Panel served in a like manner representing the interests of those not directly involved in production of phosphate products. In all, 55 individuals participated in the workshops. The results are contained in the ensuing report.

From the perspective of the Institute, this study provides a broad-based consensus of highly experienced and knowledgeable people as to what are the new technologies that can benefit the industry today and in the future as the mining activities shift to the South. Further, and perhaps more importantly, the study quantifies those benefits in dollars and cents. This, in turn, underscores the significance to the industry, and to the public impacted by the industry, of research programs aimed at reducing the risks in these new technologies. For this reason the study will assist the Institute in setting its priorities for future research in the areas covered by this study.

The Institute wishes to thank the participants in the workshops for their time and effort, the organizations to which these people belong for making their time available and to the Zellars-Williams Company for their contribution to the successful completion of the project.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

EXECUTIVE SUMMARY

Traditionally, the Florida phosphate industry has effectively responded to the competitive pressures of the market place by implementing technological improvements to mining and beneficiation methods.

Although there has been some relief recently from the most severe economic recession in industry history, it has come at the expense of painful retrenchment and restructuring for the Florida producers.

With further expansion of fertilizer production capacity worldwide, and depletion of Florida's higher grade deposits domestically, the competitive pressures are expected to continue rather than abate. If Florida is to remain the world leader, it is important to continue seeking out technological improvements to mining and beneficiation as well as chemical processing.

It is with these objectives in mind that FIPR funded this project, "Assessment of Present Phosphate Mining and Beneficiation Practices and Evaluation of Alternative Technology". The study concentrated on identifying alternative technology which offers the opportunity for near-term reductions in the cash cost of producing wet phosphate rock, without considering long-term or more capital-intensive improvements.

A series of workshops with industry participation were held to identify those activities in a typical mine-beneficiation operation which most contribute to cost, and to brainstorm ideas that can reduce these costs.

Twenty-nine alternative technology ideas, each representing an opportunity for improving the way industry operates, were identified by the four work area category workshops. Preliminary evaluation of some of these indicate the potential of reduction in production cost near-term, without major capital investment, at minimum technical and economic risk.

The contribution of each workshop to the findings of this study is summarized below:

Work Area Category Workshop	Alternative Technology Ideas
1. Mining	3
2. Beneficiation	17
3. Waste Disposal, Land Reclamation and Water Re-Use	4
4. Product Management and Mineral Resource Conservation	5
Total, Identified Opportunities	29

Seven of the most promising concepts were "implemented" in the unit operation modules of previously established state-of-the-art (SOTA) cost cases to determine the overall cost reduction potential. A case was developed and cost reduction features applied to two mining scenario cases. One case, referred to as "present", is based on hypothetical characteristics of most orebodies located in the central district. The second, or "future" case, is characteristic of conditions south of the "Bone Valley". The results of implementing seven alternative technology concepts are shown below.

	Cost-dollars per Short Ton			
	SOTA "present" orebodies file 6r	Alt.Tech. "present" orebodies file 7r	SOTA "future" orebodies file 8	Alt.Tech. "future" orebodies file 9
1. Mining	2.45	2.06	4.24	3.48
2. Beneficiation	3.30	3.16	5.27	4.94
3. Waste Disposal, Land Reclamation and Water Re-use	2.44	1.84	4.53	3.35
4. Product Management	.46	.46	.46	.46
5. Administrative, clerical, technical	1.30	1.30	1.30	1.30
Total Cash Cost (Wet rock)	$ 9.95	$ 8.82	$15.80	$13.53

Alternative Technology Cost Case	Cost Reduction $/ton	%
"Present" orebodies (File 7r)	1.13	11%
"Future" orebodies (File 9)	2.27	14%

The reader will recognize that since no two orebodies or mine-beneficiation plants are exactly alike, the estimated cost reductions shown may not reflect any specific operation. The cost reductions shown should be viewed as indicative of the opportunity to be realized by in-depth study and implementation of the alternative technology suggested or other concepts. True cost reduction can be determined only by testing alternative technology on site-specific orebody mine-beneficiation situations.

The study provides a prioritized list of ideas which survived workshop critique and screening, and are characterized in terms of; problem statement, study objective, possible problem solution scenarios, potential study results, cost analysis and risk evaluation.

Small capital expenditures, low risk, reasonably short-term payback, and attractive economic benefits appear likely if implementation of some of the proposed alternative technology is pursued.

A separate group of individuals, not directly employed by operating companies, met three times as an Advisory Panel to provide an independent overview of the study. This group expressed great concern over the startling view, believed to be held by a large segment of the general public, media, and government, that the phosphate industry is in a state of irreversible decline, heading to extinction in the near-term.

The real picture of a viable industry which owns or controls resources containing enough phosphate to permit mining, at today's annual rates, well into the next century needs to be promoted. Action is indicated to do whatever is required to correct the perception that the Florida phosphate industry is going to disappear in the near future.

Independent studies are recommended of several of the many alternative technology concepts presented. These are concepts which appear to offer the best opportunity for significant savings at least risk.

In the mining area it is recommended that parallel studies be undertaken. One, to improve on the way matrix is handled between the dragline bucket and the slurry pump-pipeline; a second, to look at the potential of equipment development which would permit separating the dragline from the matrix transportation system.

Conditioning of flotation feed is a topic of study having universal and enthusiastic support of workshop participants. The suggestions made in this report should be adopted as the basis for undertaking a comprehensive study.

The areas of blending rock to storage to suit chemical plant and overseas market specification requirements, and of working to reduce traditional inventory levels, offer much opportunity. A study to examine the application of state-of-the-art computer program-driven blending technology to assist in solving the problems addressed should also be of high priority.

Many other of the ideas and alternative technology concepts presented offer a basis for operating companies to conduct in-house programs designed to meet specific objectives.

A study of this kind, with the results presented, would have been meaningless, if not impossible, without the support of operating companies by the active participation of their representatives.

SECTION 1

INTRODUCTION

1.1 TODAY'S CHALLENGES

Today, Florida's phosphate industry faces serious challenges to continued economic viability due to world oversupply and intense foreign competition, exacerbated by environmental concerns, the trend toward orebodies whose yield and quality are lower, increased local taxes, and higher transportation costs.

1.2 COMPETITIVE STATUS

The current excess capacity of world-wide producers, brought about by reduced phosphate fertilizer consumption associated with disasterous economic conditions in international agriculture, and the fact that foreign producers have become more competitive, poses serious threats to the continued economic viability of the industry. The long-established dominance of Florida phosphate fertilizer producers in export markets has been successfully challenged by the state-controlled phosphate producers of North Africa and the Middle East. The erosion of Florida's share of total world markets by these producers became evident as domestic consumption peaked in 1980-81, and since contracted. Global P_2O_5 fertilizer consumption appears to have leveled off and the most confident forecasters suggest future growth at no more than 2-3% per year. However, current adverse export and domestic market conditions for Florida phosphate fertilizer producers will be further aggravated by new mines, fertilizer plants and port facilities of international competitors; such as Morroco's fertilizer complex and new port at Jorf Lasfar, and Jordan's new high grade phosphate rock mine.

The gap between world-wide supply and demand will be further widened by additional new production scheduled to come on-stream by state-controlled producers whose principal objective is to substitute imported products with domestic production, without regard to project profitability. The long-term trend, therefore, appears to be that government-owned producers will dominate the export market.

Florida's share of world wide markets was 32% in 1980, but is predicted to be less than 20% by 1995. This is likely to occur unless some remarkable changes are made to benefit Florida producer's status relative to international competitors who receive government subsidies.

The mining, beneficiation, chemical conversion, and industrial infrastructure facilities which exist today in Florida represent a mature industry. The current replacement cost of these capital improvements is estimated to be about 9 billion dollars. The Florida phosphate industry makes a significant economic contribution to the State and to the nation today, and will continue to do so far into the future.

The economic health and vitality of the Florida phosphate industry is of national interest. Florida supplies about 80% of the agricultural phosphate fertilizer requirements of the United States. The remaining 20% has been supplied by other U.S. producers except that Morocco is now supplying about a half-million tons of special high quality rock to one U.S. producer of liquid fertilizer products. The United States, the leading world producer of phosphate fertilizers, with Florida's dominant contribution, supplies about 30% of world consumption.

1.3 ADVERSE FACTORS

The phosphate industry in Florida during the past decade has been adversely impacted by several factors which have aggravated its competitive economics more severely than its international competitors.

Environmental Concerns

A major factor with considerable effect on Florida producer's costs relates to environmental concerns, now being expressed in the form of statutory constraints. Government regulations promulgated to address environmental safeguards have, to date, resulted in increased production cost and loss of resource. Adoption by industry of environmentally acceptable methods for deposition of waste materials, and of effecting reclamation after mining, have resulted in increased cost. Some mineable areas, including certain wetlands and water courses classified as environmentally sensitive, now require preservation and the underlying phosphate resource lost forever. In those instances where regulations permit wetlands mining, the prohibitive cost of restoration, or of in-kind construction of equivalent features, dictates the economic choice made by producers to by-pass these sensitive areas. The amount of resource thus lost is not known, but is broadly estimated at 10-15% of total estimated reserves. Losses of reserves have also increased because of greater set-backs required by government regulations to further safeguard interests of neighboring property owners. This reflects population increase in otherwise mineable areas.

Future application of phosphate fertilizers at the rates traditionally employed is being challenged by environmental pressure groups who seek to curb fertilizer usage because of its alleged detrimental effect on ground water through leaching, and on surface water through run-off.

Grade and Quality

Many of Florida's producers have mined out their high grade phosphate ore reserves in the central or Bone Valley area. Deeper ore, having lower phosphate value and more contaminants (especially MgO), located at greater distances from existing beneficiation plants, is being mined. These factors tend to increase cost and make less product available whose grade and quality is uniform and otherwise competitive in the export market. More difficulties lie ahead as mining moves south in the next decade. Economic beneficiation of high carbonate ore has received much attention, but has not been needed on a broad basis to date. This will be a major consideration in the future as the costs of these carbonate rejection processes are higher.

Technological solutions to this and other mining-beneficiation problems are a challenge which must be met to ensure survivability of Florida's phosphate industry into the next century.

Taxes

Florida severance tax, initially imposed in 1971 at $0.10 per ton, escalated to $2.26 by 1986. The law was amended in 1987 to reduce the tax to $1.35 in 1988. The tax is imposed uniformly on all tons of phosphate severed regardless of mineral value. This has the effect of reducing the incentive to produce lower grade products, and may result in less revenue to the State as the industry mines out of high grade reserves.

In addition, ad valorem property taxes on unmined reserves lands and on mining and processing facilities have increased materially in past years.

Transportation and Port Costs

During past years transportation cost, by the single public railroad, of wet rock from various mines to central drying locations has increased from $1.76 per ton in 1981 to $2.16 in 1987. Similarly, charges for shipping and receiving rock in rail cars at Tampa ports and for loading vessels has escalated from $4.61 per ton in 1981 to $5.59 in 1987.

Depletion of High Grade Reserves

Historically, Florida producers have been capable of selecting high grade phosphate rock for long distance shipment to consumers and utilizing their lower grade production to supply local consumers. As the higher grade reserves are depleted and mining proceeds to lower grade reserves, two problems are magnified. The highest grade rock available for long distance shipment is inferior to grades available from foreign producers, and the lower grades for local consumption are below former specifications.

In order to utilize the lower grade reserves, given the diminishing proportion of high grade rock competitive with that from foreign sources, Florida's producers are finding it necessary to convert more rock locally to high grade fertilizers for long distance shipment to consumers. Furthermore, to optimally recover the maximum phosphorus content from the lower grade reserves, the rock of lower quality available for local conversion makes it increasingly difficult to meet specifications of high analysis fertilizers historically manufactured. New technology is being developed for conversion of lower grade rock to phosphoric acid and fertilizer derivatives. In addition, fertilizer specifications are being modified to accommodate the rock quality, although greater progress is necessary to retard Florida's loss of market share.

1.4 MEETING THE CHALLENGES - NEAR TERM

Traditionally, the Florida phosphate industry has effectively responded to the challenges by implementing technological improvements to the methods by which rock is mined and beneficiated. Improvements in mining by the introduction of large electric-powered walking draglines, and in ore transportation by the development of large capacity slurry pipeline pumping systems, have made possible the extraction of ore under deep overburden at distances far from beneficiation plants. Beneficiation technology has dramatically increased the phosphorus content of all orebodies by the introduction and refinement of physical particle separation and flotation technology. Florida has been and continues to be the world leader in developing technology for converting rock to fertilizer products.

Phosphate-bearing zones and areas heretofore not mined because they were not economic, have been reclassified and are today being routinely extracted for efficient and economic recovery of the mineral value. More of this non-replaceable natural resource is being extracted and upgraded per unit of land surface area disturbed than ever before. These gains in resource recovery are offset to some extent by the restrictions placed on mining in environmentally sensitive areas.

The Florida phosphate industry has, to date, successfully overcome many of the additional costs none of its competitors have had to bear. Severance taxes levied by state government have been reduced; however, this gain is offset by the increased cost of compliance with environmental regulations imposed by federal, state, local governments, and special districts.

Against the backdrop of more intense environmental responsibilities and increasing difficulty of beating competition, the industry is recovering from the most severe recession of its history.

Improvement in economic viability is necessary and requires a renewed effort toward cost reduction from new technology. Although traditional methods and techniques, as employed today, serve the industry well, an assessment of present practice and technology is needed. Such an assessment needs to look to identifying areas of high cost where constructive improvements can be made to effect significant cost reduction. Near-term cost improvements by application of proven alternative technology to present practice is the immediate objective. Long-term benefits are necessary to cope with future lower grade reserves and increased foreign competition. New technology must be separately examined for application to new mine construction and/or to major modifications of existing facilities.

1.5 MEETING THE CHALLENGES - LONG TERM

Ultimately, direct conversion of most, if not all, of Florida's phosphate rock into intermediate and final chemical fertilizer products appears to be the most effective means to ensure highest recovery of the in-situ resource. Meanwhile, the die is cast and the trend irreversible ... less Florida phosphate rock will continue to move into export markets and to lower U.S. Gulf Coast fertilizer plants and more will be converted at local plants. Most of these are captive, and their production process trains are adjusted to accommodate the rock their sisters produce.

Florida can continue to be a major player in world fertilizer supply by producing and marketing chemical fertilizers. In the near-term, owing to the fixation of buyers and sellers, the preferred product is DAP. In the long-term, however, it may be in Florida's best interest to mount a campaign to educate buyers and sellers, and to a lesser extent the users, in the merits of other chemical fertilizers, such as MAP. This is especially true if chemical conversion technology to effectively and economically utilize future phosphate rock concentrates as feedstock to produce "buyer's and seller's choice" fertilizer products is not developed. Meanwhile, present chemical plants will be pressed to use feedstocks of lower grade and higher contaminant levels to produce market-oriented fertilizer products.

1.6 STUDY OF NEAR TERM SOLUTIONS

Florida phosphate rock contribution at an annual production rate of about 30 million tons per year can be sustained well into the next century. The industry will respond, at it has in the past, with significant new technological developments and the investments required to sustain this production.

Meanwhile, it is necessary to maximize the utilization of existing facilities and to reduce production cost without making major capital investments. It has been suggested that this can be accomplished by adapting, on an industry-wide basis, alternative technology to state-of-the-art practice.

The report presented herein following is the result of a study undertaken to explore possibilities. This is accomplished by identifying and describing problems, and then conceptually estimating economic benefit which can result from solution and implementation of alternative technology.

SECTION 2

OBJECTIVES, SCOPE AND METHODOLOGY

2.1 BACKGROUND

The Florida Institute of Phosphate Research (FIPR), in recognizing its role to assist the industry in meeting the challenge to improve economic viability, responded by awarding to Zellars-Williams Company (ZW), a member of Jacobs Engineering Group Inc., the undertaking of a study project entitled "An Assessment of Present Phosphate Mining and Beneficiation Practice and the Evaluation of Alternative Technology". A brief description of the background and chronology of events leading to this study is given below.

ZW submitted for the consideration of FIPR, on April 10, 1986, an unsolicited proposal describing the scope, objectives and methodology of a study it proposed, to assess the adequacy of present Florida mining practice to meet future needs.

Responding to comments generated from technical reviews by FIPR staff, and the Mining Technical Advisory Committee, this proposal was revised and later resubmitted. ZW, on August 6, 1986, and again on November 12, 1986, made an oral presentation of the proposed modifications proposed. The revised scope specifically excluded future technology for application to new "grass-roots plants" and focused on retrofitting technologies to existing operations to reduce costs.

Based on comments by reviewers and members of the Mining Technical Advisory Committee, FIPR staff, recommended funding of the proposal on December 9, 1986, subject to certain conditions, as follows:

(1) ZW would obtain support from industry management to perform the study.

(2) The study should focus on technologies that can be retrofitted to existing operations.

(3) ZW should form a committee of industry specialists to nominate those new technologies to be reviewed and evaluated.

(4) The study should be divided into two phases: the first phase to identify the areas to be evaluated; with FIPR approval, the second phase to actually perform the evaluation.

James M. Williams responded to the conditions in a letter dated December 16, 1986 which confirmed that management of the Florida phosphate industry would support the project and assign technical personnel to participate in a series of Workshops. This industry support was evidenced by letters from local managers.

A contract was approved for funding at a regular FIPR board meeting on February 5, 1987, and awarded on February 16, 1987. This contract was officially approved on March 18, 1987, and executed on May 1, 1987. The study commenced with ZW's presentation of the proposed scope and methodology, as revised, at a Mining Technical Advisory Committee meeting on May 13, 1987.

2.2 STUDY OBJECTIVES

Owing to the economically depressed state of the industry in recent years, local producers have been unable to support, as in the past, research and study programs to develop improved technology. A principal goal of this study is to help fill the research void created over the last 4-5 years, so that the local phosphate industry can maintain its technological advantage over off-shore producers.

The primary objectives of the study required to accomplish this goal as they have been set forth are to:

1. Evaluate the adequacy of present practice to meet near-term future industry needs.
2. Evaluate available alternative technology and compare it to present practice for identification of possible improvements.
3. Identify new technology required to meet future industry needs.
4. Address risk factors involved with implementation of alternative and/or new technology.

Serving as guidelines in the conduct of the study, corollary goals as they have evolved were to: (1) avoid disclosure of proprietary technology and/or production cost information, (2) demonstrate order-of-magnitude estimated cost reduction possibilities, (3) encourage all ideas and concepts offered with the constructive intent of benefiting the industry, recognize these inputs and, if appropriate, evaluate them, and (4) provide a "blueprint" for successor study/research efforts.

The study focus is on technologies that can be retrofitted. Emphasis, in assessing alternative technology, is placed on those areas which can best serve existing operations. Individual unit operations were broken down into their basic components for examination and evaluation of alternative technology to permit retrofitting into existing operations.

The combined goals and objectives of the study, when condensed, are simply to identify and evaluate methods of improving on the cost of the best current technology. The "blueprint" concept is intended to provide the information base from which the specific technical study-research efforts can be undertaken to refine and implement these methods. The identification, definition, and economic benefit of problem solution possibilities and the series of such possibilities resulting from the study presented in this report is a "blueprint"-guide for conducting specific studies and/or research development programs.

2.3 SCOPE AND METHODOLOGY

The study examines unit operations in typical Florida phosphate mining and beneficiation plants as practiced today. In-situ characteristics of an orebody which typify those currently encountered by producers were created for the purpose of developing a basis for comparison. Technology as applied to present practice by operating companies is the starting point. Mine-beneficiation plant operations for production of phosphate rock concentrate is divided into four work areas, to identify relative costs of major areas, from site preparation and mining through beneficiation, to wet concentrate product load-out.

The four work areas are: (1) Mining, (2) Beneficiation, (3) Waste Disposal, Land Reclamation and Water Re-Use, and (4) Product Management. Each work area is divided into a number of unit process modules to describe discrete operations for which unit consumptions and cost have been calculated. A base case "typical-average" consumption and cost estimate was prepared for use as a guide in identifying elements and operations which contribute most to cost and to establish a basis of comparison which permits evaluation of alternatives.

o <u>Workshops</u>

A series of workshops, each focusing on one work area, were organized and scheduled. Three series of half-day workshops, each having one of the four work areas as its subject, were conducted as indicated below.

Workshop	#1	#2	#3
1) Mining	July 28	August 25	October 15
2) Beneficiation	July 29	August 26	October 16
3) Waste Disposal, Land Reclamation & Water Re-Use	July 30	August 28	October 28
4) Product Management and Mineral Resource Conservation	July 31	August 27	October 21

Participants in the workshops were recruited from the technical-operating personnel of the eleven active Florida operating companies. Workshop attendees are named in each Work Area, Sections 4, 5, 6, and 7. Cooperation was excellent and representatives with specific expertise in each "work area" participated, from the following companies.

IMC Fertilizers, Inc.	W.R. Grace & Co.
Agrico Chemical Company	Mobil Mining and Minerals Company
Gardinier Inc.	CF Industries, Inc.
Estech, Inc.	U.S. Agri-Chemicals

One of the early objectives of the workshop was to acquaint participants with the objectives, and the methodology proposed.

A "typical-average" orebody and mine-beneficiation plant base case (file 5rr) computer printout cost display was circulated to all attendees prior to the first workshop meeting.

File 5rr represents a base case constructed from ZW in-house data for the purpose of:

1) familiarizing workshop participants with methodology and defining of "battery limits",
2) obtaining a consensus as to the coponents of a "typical" mine-beneficiation facility,
3) establishing units which describe important operating cost contributors, and
4) creating a consensus representing state-of-the-art (SOTA).

This cost file was published as part of the Interim Report and is not included in this document.

The base case operating cost displays unit consumption, unit prices, and production costs, in terms of each discrete unit operation module and identifies by percent the contribution overall of each working area, and of each unit process module. Major cost contributors were thus identified.

The workshop participants responded with inputs reflecting their own experience, adjusted for applicability to the "typical average" orebody. These inputs served to create a state-of-the-art (SOTA) operating cost case (file 6r) which was to be the basis of proceeding to identify areas offering opportunity for cost improvement. The orebody characteristics described represent current mine orebodies and this case is sub-titled "present".

General consensus of participants was that production factors, unit consumptions, and costs displayed in the base case are acceptable for currently mined orebodies. However, concern was expressed that the "typical average" orebody characteristics described do not reflect the trend toward the more difficult conditions and leaner matrix to be encountered as mining moves out of traditionally high pebble, high grade reserve areas. Some producers have mined out of the high grade reserves and are now encountering the more difficult conditions associated with lower grade reserves.

In response to this concern, another orebody was created to represent conditions of the near future which require more material handling and result in lower yield. Production factors, recoveries, unit consumptions, and unit costs developed for the "present" SOTA case (file 6r) were applied to this orebody to create a "future" SOTA case (file 8). These are presented in Section 3 of this report.

Preparatory to the Workshops, ZW prepared an agenda for each work area subject which proposed new, innovative, or alternative technology for consideration by the participants. The proposed concepts were discussed and additional ideas offering the potential for cost improvement were introduced and discussed. Specific concepts were examined and, based on cost of implementation, potential benefit and risk associated with success/failure, were discarded or retained and prioritized for further consideration during the final phase of the study.

Alternative technology for this study is defined as improvement by modification of current practice by the adaptation of proven technology to traditional unit operations and processes. This includes new and innovative applications of proven technology, but is not intended to include totally new or undeveloped technology.

Cost comparison of new, innovative, or alternative technology to the SOTA cases identified candidates worthy of further consideration. The rationale of SOTA is that it represents the best cost achievable (for the described orebody) if all state-of-the-art techniques were employed at this one hypothetical mine.

The measurement of the effect of alternative technology was, therefore, compared to a composite of the best available industry-wide practice.

New concepts (alternative technology) of economic merit were prioritized as to benefit and further evaluated.

The common technique employed to measure and estimate comparative improvement is the computer-generated estimating routine presented in the six-page format. Potential improvements are measured by applying appropriate efficiencies, consumptions and other factors to this routine.

This was the procedure employed to identify and evaluate methods of improving on the cost of the best current technology industry has to offer as applied and expressed in the SOTA case models.

The Product and Mineral Resource Management Workshop group expressed concern that a large part of the cost of supplying phosphate rock for export was not considered in the base case, or

SOTA case, cost displays. Since this area of cost is not related to direct production, i.e., mining and beneficiation, technological alternates or improvements are not applicable. However, in order to properly emphasize the incurred cost magnitude, this area was examined and a separate estimate was prepared to display the unit consumptions and cost involved in getting wet rock FOB mine converted to dry rock on board vessel for export from a Tampa Bay port. These costs are summarized in Section 7 of this report.

- Advisory Panel

In order to ensure a broad based analysis of the industry which includes all possible considerations, a special Advisory Panel, chaired by J.M. Williams and R.S. Akins, was formed. This panel was composed of people who have interest in the phosphate industry, but are not directly involved in operations. The overview function of this panel was to provide perspective to the assessment of present practice and also to generate new ideas and concepts which will lead to an improved industry as a whole.

Members of the panel were selected from government agencies such as the Florida DNR and DER, academia, private consultants with special phosphate expertise, and trade organizations and industry support group experts such as transportation and utilities.

This panel was assembled for half-day meetings on August 18, September 11, and again on November 3, to review study activities, to comment on and to offer possible solutions to industry problems.

Participants to one or more Advisory Panel meetings are named in Section 8 of the report.

The final product is, therefore, a series of alternative technology concepts, each supported by preliminary evaluation of potential economic benefit and associated risk, and presented as study projects to be considered for future funding. These concepts are presented in Sections 3 through 8 of this report.

Some of the concepts advanced during the conduct of workshops could not be evaluated in terms of economic benefit within the scope of this study. Several of these, however, have the support of workshop participants and merit further consideration. These are included in the listings and descriptions of alternative technology.

SECTION 3

PRESENT PRACTICE AND ALTERNATIVE TECHNOLOGY

3.1 STATE-OF-THE-ART - SOTA

The expression SOTA, as used in this study, is intended to describe in a computer printout format the hypothetical Florida phosphate orebody and mine-beneficiation plant which embodies all of the currently employed technology in a single operation, having a nominal capacity of 3 million short tons of wet rock per year.

The following comments and observations pertaining to the SOTA cases used in this study are necessary to understanding the direction taken by the study team in identifying, examining, and evaluating alternative technology.

- o Operating cost is defined as the direct cash cost, FOB mine, wet per short ton of phosphate rock product.

- o Production is divided into four major work areas; (1) Mining, (2) Beneficiation, (3) Waste Disposal, Land Reclamation and Water Re-use, and (4) Product Management.

- o Total direct cash cost includes electricity, operating labor, operating supplies, maintenance labor, maintenance supplies, fuel, reagents, contract services, replacement pipe, and for alternative technology an item for amortization of capital.

- o Total direct cash cost includes an additional item identified as administrative, clerical, technical, and general services, in the same amount of $1.30 for all cases. Since this cost is an arbitrary constant for all cases, it was not considered a candidate for improvement.

- Total direct cash cost excludes sales expenses, all taxes, insurance, exploration, depletion, depreciation, amortization and home office, headquarters, parent company, or corporate expenses.

A base case, in computer printout format, was developed by ZW from in-house data and deliberately designed to represent characteristics of most mines, but not to describe any one particular mine.

The base case (file 5rr) operating cost displays unit consumption, unit prices, and production costs, in terms of each discrete unit operation module and identifies by percent the contribution overall of each working area, and of each unit process module. Major cost contributors were thus identified.

The workshop participants responded with inputs reflecting their own experience, adjusted for applicability to the base case or "typical average" orebody. These inputs served to create a state-of-the art (SOTA) "present" orebody operating cost case (file 6r) which was to be the basis of proceeding to identify areas offering opportunity for cost improvement.

Cost comparison of new, innovative, or alternative technology to the SOTA case would identify candidates worthy of further consideration. The rationale of SOTA is that it represents the best cost achievable (for the described orebody) if all state-of-the-art techniques were employed at this one hypothetical mine. The measurement of the effect of alternative technology would, therefore, be compared to a composite of the best available industry-wide practice.

General consensus of participants was that production factors, unit consumptions, and costs displayed in the base case are acceptable for currently mined orebodies. However, concern was expressed that the "typical average" orebody characteristics described do not reflect the trend toward the more difficult conditions and leaner matrix to be encountered as mining moves out of traditionally high pebble, high grade reserve areas. Some producers have mined out of the high grade reserves and are now encountering the more difficult conditions associated with lower grade reserves.

In response to this concern, another orebody was created to represent conditions of the near future which require more material handling and result in lower yield.

The computer cost display provides the details underlying the cost of each module in terms of consumables and the units to which these are applied. These data are presented on page 2 of each six-page cost case printout. Cost case printouts are included at the end of the text in this section.

3.2 ASSESSMENT OF PRESENT PRACTICE

A reliable indicator of the effectiveness of present practice in dealing with today's industry challenges is the spread between sales revenue and production cost. Sales revenue based on the price obtained for the product in a free market is the result of the meeting of supply and demand. Today's market for phosphatic fertilizer products is over-supplied. Prices are, therefore, set by producers having the lowest cost of production.

This is an obvious oversimplification as it does not consider dissimilarity in product, governmental intervention, or subsidization of production cost.

Since little or no control can be exercised over the market, survival of Florida's producers depends on the profit derived by maintaining an acceptable spread (margin) between sales revenue and production cost.

Assessment of present practice is, therefore, an exercise in examining production factors, unit consumptions, and cost for each operating work area and each production module.

The cases developed as a result of the examination and critique by the workshops of each work area and production module is an assessment of state-of-the-art (SOTA) technology as currently practiced by industry as a whole. The assessment is represented by the SOTA case displays, which incorporate in one theoretical mine-beneficiation facility all of the currently practiced technology, as it is applicable to "present" and "future" orebody characteristics.

Application of the "assessed" production factors and unit consumptions from the "present" orebody to the orebody of the near "future" resulted in the second SOTA case (file 8). This case also reflects the impact of increased distance between mine and beneficiation plant of one mile to each pipeline transportation module.

Production (concentrate and pebble) from SOTA "present" cost case (file 6r) is 3.29 MMTPY, and from SOTA "future" cost case (file 8) is 2.71 MMTPY

Assessment of present practice as described in the production cost case displays is summarized below.

Cash Cost $ per Short Ton of Wet Rock

Work Area	SOTA Present File 6r	SOTA Future File 8
1. Mining	2.45	4.24
2. Beneficiation	3.30	5.27
3. Waste R&W	2.44	4.53
4. Product Mgmt.	0.46	0.46
5. Admin/Cler/Tech.	1.30	1.30
Total Cash Cost	$ 9.95	$15.80

A copy of the six-page print-out for each case follows the text of this section.

This basis of assessing present practice permits identification and quantification of high cost contributors which, in turn, focuses attention on those offering the most opportunity for improvement. Percent contribution of work areas to total cash cost and of production modules to work area cost is shown on pages 5 and 6 of each case display printout. The percent relationships by work area are summarized below and graphically illustrated for the "present" case on Figure 3.1.

Percent Contribution of Cash Cost

Production Work Area	SOTA Present File 6r	SOTA Future File 8
1. Mining	25	27
2. Beneficiation	33	33
3. Waste R&W	24	29
4. Product Mgmt.	05	03
5. Admin/Cler/Tech.	13	08
Total Cash Cost	100.00%	100.00%

3.3 ALTERNATIVE TECHNOLOGY

The technical Workshops, with the guidance of Workshop leaders and assistant leaders working from prepared agendas containing a number of alternative technology ideas, generated a number of additional subjects. Some of these warrant consideration as possible candidates for specific study programs, but have not been evaluated to quantify economic benefit. All of the alternative technology topics having the support of workshop participants and the prospect of economic benefit have been retained and are presented herein. The alternatives which afford the most opportunity for reducing cost have been evaluated and the potential benefit estimated. Others are simply described and rated as to priority and risk. These are presented in a general order of priority in each Section 4, 5, 6 and 7, by Work Area.

Alternative technology ideas which survived the open-forum interchange among Workshop participants which, if properly developed, offer real opportunity for cost reduction, are

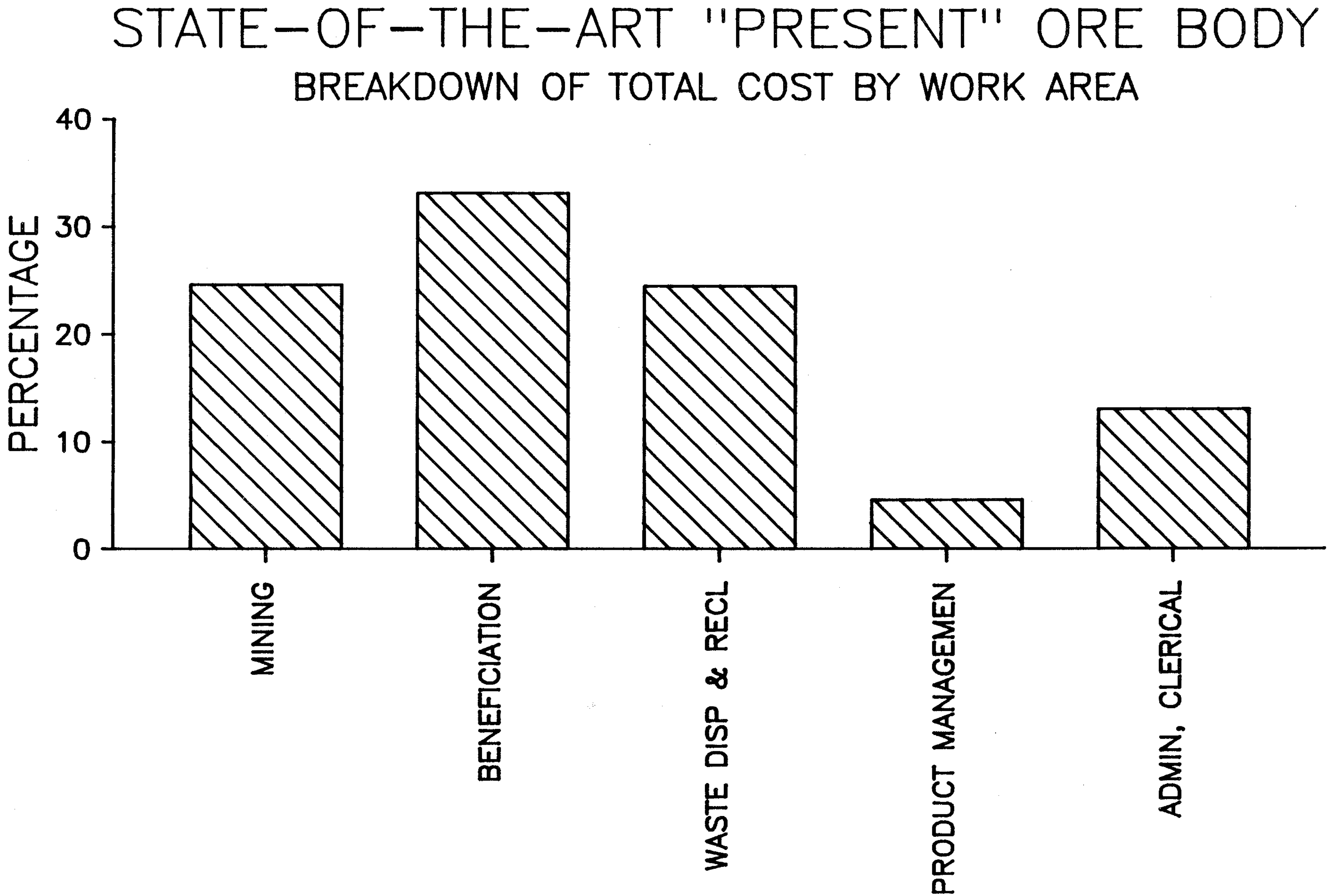

STATE-OF-THE-ART "PRESENT" ORE BODY
BREAKDOWN OF TOTAL COST BY WORK AREA
PERCENTAGE
40
30
20
10
0
MINING
BENEFICIATION
WASTE DISP & RECL
PRODUCT MANAGEMEN
ADMIN, CLERICAL

Figure 3-1

described. Cost analyses have been performed to demonstrate potential for those ideas offering the most promise. Cost analysis summaries follow the itemization and description in each Work Area section.

The standard operating procedure of conducting a cost analysis and for making comparisons of SOTA cost cases (file 6r and 7r) with applied alternative technology is by comparing a module or line item cost, SOTA cost case to the new scheme. The capital cost to equip and install the new scheme is estimated ($\pm$30-40% accuracy) and amortized over a 10-year life at 10% interest. The annual charge is then converted to a unit cost which is comparable to the SOTA module unit expression. The capital amortization charge unit cost added to computed operating cost units for the new scheme is to be the basis of comparison with the SOTA base case module. This procedure is used in the cost estimates included in each Work Area section.

In order to rank the significance and priority of alternative technology, new or innovative concepts, etc., and the potential these ideas may offer to the reduction of operating cost in the near term, the following general format has been adopted for each Work Area section.

1. Problem Statement/Definition

   Current practice, as defined by SOTA cost cases for "present" and "future" orebodies, is described to define a typical problem in the subject area of operation causing excessive cost which if corrected can increase recovery or otherwise result in economic benefit to the operator.

2. Study Objective

   The first objective of most studies is to confirm problem definition. This is followed by setting forth the other objectives and stating what the study will produce and how this product will be applied to problem solution. This general scope and objective description is essential to gaining an appreciation of the magnitude of the study, investigation, or research program in terms of time and cost.

3. Problem Analysis/Solution Scenarios

The conceptualization of solutions is often necessary to an analysis of a problem. In describing problems, and studies to specifically define problems, alternate solutions are often conceptualized. These solution scenarios are, in some instances, presented as ideas for further consideration. Each Work Area section treats this topic a little differently, but each includes a detailed discussion of the specific problem analysis steps proposed, or of ideas for problem solution.

It is important to recognize that no attempt is made to solve the problem but simply to suggest a solution scenario as one of many possibilities, and thus to demonstrate the potential benefit of solution. Properly conducted study will undoubtedly yield more favorable results than shown in this report.

4. Potential Results

Potential results are expressed in several ways. One is an itemization and description of what the results of a study might be. Another is a description and estimate of the potential economic benefit which might result. Generally the narrative given under this general heading describes the improvements or changes, and how these have the potential to favorably impact operating cost.

The most likely scenario for problem solution envisaged is described in terms of technology changes, capital investment, cost savings, increased recovery, upstream or downstream impacts, and other factors influencing economic or technical feasibility.

5. Cost Analysis

This is a summary, in economic terms, of potential benefits if the problem as here defined would be solved by this conceptual application of new technology. These economics are expressed in terms compatible with the SOTA cost cases for "present" and "future" orebodies, i.e., how the items of consumption in affected operating modules are changed by introducing the new technology. Reduction in the unit costs of administrative, technical clerical, etc., services and of other annualized cost items resulting from increased production are not considered. No credit is taken for the additional revenue realized from the increment of increased production. The resulting operating cost savings indicated are, therefore, a very conservative way of expressing economic benefits. This method is used to permit effects of ideas generated in the workshops to be incorporated in the same cost module to define the cumulative impacts of potential improvements.

6. Risk Analysis

Consideration of risk is important in deciding which ideas should have highest priority for commitment of resources. Answers to the following question are necessary for evaluating risk.

- Is the problem accurately defined and quantified?
- Is the envisaged study sufficiently defined?
- Does the selected solution scenario technically solve the problem?
- How are the potential benefits effected by changes in estimated new capital, operating cost, incremental recovery?
- Are potential technological solutions constrained by public opinion and political factors?

Risk is usually related to investment, and return on investment. Risk varies widely with proposed undertakings, and the acceptability of rates of return varies accordingly.

Risk may be defined as the degree of probability of failure to achieve desired rates of return. Risk is the degree of probability of loss owing to failure. Risk, for the purpose of evaluating new, innovative or alternative technology or concepts differs. These kinds of undertakings incur exposure to the hazards of investing resources without return or of failure accompanied by a reduction in revenue .. or worse, by loss of revenue. This definition is the most severe characterization of risk related to the concepts advanced by this study.

The major risks , i.e., of investing without return, stem from; (1) the cost of developing the proposed concept(s) in scientific-engineering studies and/or by laboratory and pilot plant scale testing, and (2) the cost of implementation at commercial scale in existing operations.

Well designed and systematically executed studies/test programs will mitigate the risk of failure upon implementation.

The types of risk which might apply are:

- technological risk,
- reserve risk,
- production/operating risk,
- cost overrun risk,
- marketing risk

Most of these risks are generally dependent on one another, and may not be applicable to the concepts proposed.

The scope of this study limits the consideration given types of risk to subjective evaluation. The risk types are considered, first for applicability, and then subjectively as to level. Applicable risk types are rated high, moderate, or low level risks. Workshop participant consensus of rating levels is the basis of the final risk assigned.

3.4 POTENTIAL ECONOMIC BENEFIT OF ALTERNATIVE TECHNOLOGY

Examples of the potential benefit of applying alternative technology concepts to state-of-the-art "present" and "future" orebody mine-benficiation cost scenarios are given below.

The alternative technology concepts used were selected from those developed in the workshop format studies. These are described in detail in the following sections by work area. Two concepts were adopted from Section 4, Mining, and three from Section 5, Beneficiation. These are not intended to represent predictions of cost reduction, but are conceptual estimates of possible benefits. Section 6, Waste Disposal, Land Reclamation, and Water Re-Use, describes opportunities for alternative methods/technology and conceptualizes the potential of 25% reductions in the major cost contributing unit operation modules. None of the benefits from cost savings concepts described in Section 7, Product Management and Mineral Resource Conservation, have been included in the alternative technology cost cases. Estimates of improvements by adopting alternative technology in each work area module affect other areas-modules. Total effect is illustrated when the improvements are applied to the total cost estimate computation. The results from applying selected alternative technology to each, "present" and "future" orebodies, are summarized in the two tables which follow.

Production (concentrate and pebble) from alternative technology "present" cost case (file 7r) is 3.44 MMTPY, and from "future" cost case (file 9) is 2.86 MMTPY.

Cash Cost $ Per Short Ton of Wet Rock

Work Area	Alt.Tech. Present File 7r	Alt.Tech. Future File 9
1. Mining	$ 2.06	$ 3.48
2. Beneficiation	3.16	4.94
3. Waste R&W	1.84	3.35
4. Product Management	0.46	0.46
5. Admin/Cler/Tech.	1.30	1.30
Total Cash Cost	$ 8.82	$ 13.53

Percent Contribution to Cash Cost

Work Area	Alt.Tech. Present File 7r	Alt.Tech. Future File 9
1. Mining	23	26
2. Beneficiation	36	36
3. Waste R&W	21	25
4. Product Management	05	03
5. Admin/Cler/Tech.	15	10
Total	100%	100%

The four 6-page cost printout files are included at the end of this section. These contain, in addition, bar charts which graphically illustrate the contribution of work areas, and modules to the total cost of each.

3.5 DESCRIPTION OF COST PRINTOUT FILES

Page 1 of the cost printout displays input factors and unit cost data used to generate consumptions and module operating costs. These data describe orebody characteristics and quantify components of matrix mined and delivered to the beneficiation plant. Finished products, intermediate products, and waste-reject products are itemized. Quantities are stated in universally accepted units. Ratio of concentration is the ratio of flotation feed to flotation concentrate. Pumping distances are expressed in miles. Additional description of these data is given in Section 3.6 following.

Page 2 of the cost printout shows consumption quantified by units applied to each module within each of the four work areas. Some of the consumption quantities are unfamiliar. Others are readily recognized units and quantities. Each of these, however, offers the opportunity to look for the high cost contributors. For example, it is revealing to note the electric energy consumed by the hydraulic monitor.

Page 3 expresses the same consumptions in dollars per unit, and displays the extended total unit cost for each module.

Page 4 presents the detail and summary by module, horizontally, and by consumption item vertically, of the total cash operating cost (as defined elsewhere) of each cost case. These costs are summarized by work area. SOTA case (file 6r and 8) and alternative technology case (files 7r and 9) costs are summarized in this section.

Pages 5 and 6 of the cost printouts deal with percent contributions. Page 5 treats each work area as an entity (100%) and displays the percent contribution of each module and of each consumable component. For example, in file 6r, the hydraulic monitor module represents almost 25% of total mine cost, and the electric energy component of that contribution is almost 9%.

Page 6 presents the percent contribution of each module, each work area, and each consumable component to the total mine-beneficiation case cost. This page shows, for example, in the case of file 6r, a total percent contribution of electric energy to total cost of about 25%. The summary of percent cost contribution by work area presented in the followng text is taken from this page.

The operating cost case file printouts provide the basis to seek out opportunities for improvement and to evaluate the potential cost benefit which can result from applying alternative technology.

3.6 COST MODULE DESCRIPTION

The following modules are used to represent a typical Florida phosphate mine. Each module description consists of equipment, process elements, engineering criteria, and battery limits. The unit consumptions and corresponding cost units are also listed for each module. Since the cost unit is related to module consumption, not "per ton product", it applies equally to present mine conditions and to future mine conditions. Unit consumptions represent state-of-the-art (SOTA) present practices in the phosphate industry. SOTA includes available technology which is currently used in the industry. These module factors are the base from which improvements are compared.

a) Site Preparation

This module is to perform the work required to prepare the site for mining. The cost includes the removal and disposal of 0.5 feet of surface soil. Also included are costs for clearing, grubbing, normal ditching and dewatering. Not included is "wetland" type dewatering, rough terrain considerations, and the stringing of high power or overhead aerial electric lines and and construction of substations. The module calculates mobile equipment fuel, operating and maintenance labor, and operating and maintenance supplies. The cost of equipment ownership is not included (as this is covered in replacement or sustaining capital which is not considered in this study). Site preparation cost developed by this module is expected to be less than that of contract services. Costs under difficult conditions are about 50% higher than for normal conditions.

COST UNIT: Acres

UNIT CONSUMPTION:

Operating Labor	11 manhours
Operating supplies	$44
Maintenance labor	11.11 manhours
Maintenance supplies	$267
Fuel	150 gallons

b) Dragline

The dragline excavates overburden and matrix. Overburden is wasted in the mine cut. Matrix is mined and dumped in a well or pump pit. This pit is also excavated by the dragline. This module is based on normal operating conditions of an electric powered walking dragline, sized between 35 and 65 cubic yards bucket capacity. The module includes costs of preparing pad sites, moving power cables and field transformers and miscellaneous support equipment.

COST UNIT: Cubic yards handled

UNIT CONSUMPTION:

Electricity	.52 KWH
Operating labor	.0012 manhours
Operating supplies	$.00300
Maintenance labor	.00121 manhours
Maintenance supplies	$.02909

c) Hydraulic Monitor

This module includes the cost of the system supplying mine supply water used in matrix disaggregation by the hydraulic monitors (water cannons). The monitors direct high pressure water against the matrix dumped in the pit to slurry the solids and direct the mixture to a slurry pump. This module cost includes the pumps and pipelines required to supply and boost pressure to the hydraulic monitors, the hydraulic monitor operation, the pit car, and the moving of the entire system as mining advances. Module cost starts with matrix dumped by the dragline and ends with slurry about to enter the pit slurry pump. The cost of pumping matrix is not included. The gunning water supply system is based on 9,500 gpm of water pumped one mile to monitor nozzles at 200 psi, and on a matrix disaggregation and feed rate of 1000 tph (dry).

COST UNIT: Dry tons matrix

UNIT CONSUMPTION:

Electricity	1.32 KWH
Operating labor	.00496 manhours
Operating supplies	$.00184
Maintenance labor	.00046 manhours
Maintenance supplies	$.01115

d) <u>Slurry Pumping of Matrix</u>

This module covers the cost of pumping matrix slurry from the slurry well (pit) at the mine cut near the dragline to the washer, the first production unit in the beneficiation plant. Cost includes all the slurry pumps, pipeline, electric power supply, switchgear, control systems, and all appurtenances required for the matrix pumping system. All components are skid mounted. Cost includes seal water supply systems. Pit pump operation is included except for moving cost, which is a part of hydraulic monitor cost. Cost developed by this module is a function of distance based on transporting 1,000 tph of matrix (dry basis) at 30% solids average (by weight) and a pipeline velocity of 15 fps.

COST UNIT: Dry ton-miles matrix

UNIT CONSUMPTION:

Electricity	1.08 KWH
Operating labor	.00046 manhours
Operating supplies	$.00184
Maintenance labor	.00046 manhours
Maintenance supplies	$.01115

e) <u>Washer</u>

This module consists of ore disaggregation, and separation and washing of pebble. A common washer includes a trommel, static screens, vibrating screens, and log washers. Its battery limits are from the matrix pumping system discharge to the feed distributor for the primary cyclones and the pebble transfer conveyor.

COST UNIT: Tons Matrix

UNIT CONSUMPTION:

Electricity	2.25 KWH
Operating labor	.00195 manhours
Operating supplies	$.00094
Maintenance labor	.00199 manhours
Maintenance supply	$.04774

f) Feed Preparation

This module represented two stages of desliming and includes feed sizing and in-process storage of feed. Its battery limits are from primary desliming cyclone feed distributor to the flotation feed dewatering or conditioning.

COST UNIT: Tons Flotation Feed

UNIT CONSUMPTION:

Electricity	3.00 KWH
Operating labor	.00148 manhours
Operating supplies	$.00003
Maintenance labor	.00151 manhours
Maintenance supplies	$.03623

g) Flotation

This module includes anionic rougher flotation for two size fractions, deoiling, and cationic cleaner flotation. Battery limits are from discharge of flotation feed prep to the tails discharge point and the flotation concentrate discharge point.

COST UNIT: Ton Flotation Feed

UNIT CONSUMPTION:

Electricity	3.50 KWH
Operating labor	.00594 manhours
Operating supplies	$.00001
Maintenance labor	.00606 manhours
Maintenance supplies	$1.4541

Reagents:

Fatty Acid	1.0 lb
Fuel Oil	1.25 lb
$NaOH/NH_3$	.4 lb
H_2SO_4	1.3 lb
Amines	.17 lb
Kerosene	.1 lb

h) <u>In-Process Storage</u> (Product Bins)

This module is for wet bin storage and retrieval of product. Battery limits are between product discharge from the washer and flotation plant to the product conveyor.

COST UNIT: Tons Product (as derived from flotation feed tons)

UNIT CONSUMPTION:

Electricity	.18 KWH
Operating labor	.00074 manhours
Operating supplies	$.00036
Maintenance labor	.00075 manhours
Maintenance supplies	$.01812

i) <u>Hydraulic Station</u>

This module is for operation of a plant hydraulic station. The basis is 15,000 gpm at 90 psi head and 35,000 gpm at 50 psi. Battery limits are from the water collection points of recycled water from other modules, to the make-up water supply points in other modules.

COST UNIT: 1,000,000 gallons

UNIT CONSUMPTION:

Electricity	700 KWH
Operating labor	.30140 manhours
Operating supplies	$.54252
Maintenance labor	.30441 manhours
Maintenance supplies	$5.48

j) <u>Slurry Pumping of Tailings</u>

This module is for hydraulic transport of tailings as a function of pumping distance to the disposal site. The basis is 1,000 tph, dry, at 30 percent solids with a velocity of 13 fps. Tails are fed directly from the flotation plant. Battery limits are from the tails slurry pump to discharge from the tails pipeline at the tailings disposal site. Dozing or other mechanical leveling of tailing is not included. Stringing, repositioning, and replacement of pipe is included.

COST UNIT: Ton-Miles Tailings

UNIT CONSUMPTION:

Electricity	.76 KWH
Operating labor	.00046 manhours
Operating supplies	$.0011
Maintenance labor	.00046 manhours
Maintenance supplies	$.01115
Replacement pipe	$.0015/ft.

k) Slurry Pumping of Slimes

This module accounts for hydraulic transport of slimes as a function of distance to the disposal site. No credit is implicit in this module for gravity flow. Therefore, unit consumptions should be estimated on the basis of actual pumping distance. The module basis is 400 tph, dry, at 4 percent solids with velocity of 8 fps. Lift of about 55 to 60 feet for slime ponds is required. Battery limits are from slimes discharge points of other modules to the slimes pipe discharge at the clay settling area disposal site.

COST UNIT: Ton-Miles Slimes

UNIT CONSUMPTION:

Electricity KWH	1.15
Operating labor	.00141 manhours
Operating supplies	$.00564
Maintenance labor	.00142 manhours
Maintenance supplies	$.0418
Pipe replacement	$.00016/ft.

l) Make-up Water

This module accounts for fresh water pumped from deep wells as the source of supply to make up for system losses. The basis is 7,500 gpm pumped a distance of one mile from a water level of 150 feet below the center line of discharge. The battery limits are from the deep aquifer water level surface to the hydraulic station.

COST UNIT: 1,000,000 Gallons

UNIT CONSUMPTION:

Electricity	850 KWH
Operating labor	.301 manhours
Operating supplies	$.48160
Maintenance labor	.30401 manhours
Maintenance supplies	$7.30

m) Waste Disposal for Slimes

The cost of dike construction is the primary expense in this area. Since costs are strongly dependent upon the particular dike-building plan employed in any given case, and since the work is typically performed on contract, making cost breakdown less meaningful than for other modules, expenses in this area are manually calculated based upon a general waste disposal plan that is prepared to meet disposal needs. Relevant assumptions concerning dike cross-section and settling area size, and pertinent calculations appear in the Appendix to Section 6. Long-term waste disposal volume requirements are based on waste clays at 25% solids and sand tailings deposited at a density of 100 pcf.

n) Land Reclamation

Two types of pre-reclamation landforms are contemplated: clay settling areas and mined-out areas not subjected to clay disposal; these are reclaimed by sand-fill or as land-and-lakes for mined-out areas and by crust-development for settling areas. Land reclamation requirements are intimately linked to the waste disposal plan which governs the relative amounts of different pre-reclamation land-forms. Since the work is commonly done on contract, making cost breakdown less meaningful that for other modules, overall expenses in this area are calculated manually. See Appendix to Section 6.

o) Conveyor

This module accounts for transportation by conveyor belt a distance of 600 feet with a 50 foot rise in elevation. The battery limits are from the product bin discharges to the conveyor belt discharge above the stockpiles.

COST UNITS: Tons of Product

UNIT CONSUMPTION:

Electricity KWH	.05 KWH
Operating labor	.00011 manhours
Operating supplies	$.0023
Maintenance labor	.00011 manhours
Maintenance supplies	$.00267

p) Storage

This module accounts for open pile storage of phosphate pebble and concentrate. Stacker and reclaimer factors are included. Battery limits are from the end of the transportation conveyor to the storage pile by stacker or tripper.

COST UNIT: Ton Product

UNIT CONSUMPTION:

Electricity	.22 KWH
Operating labor	.00351 manhours
Operating supplies	$.02022
Maintenance labor	.00355 manhours
Maintenance supplies	$.08508

q) Loadout

This module covers getting product from storage to the rail car. Battery limits are from the reclaimer which retrieves material from the wet rock pile to placement into the rail car.

COST UNIT: Ton Product

UNIT CONSUMPTION:

Electricity	.20 KWH
Operating labor	.00351 manhours

Operating supplies	$.01123
Maintenance labor	.00355 manhours
Maintenance supplies	$.08508

Labor Costs

Labor costs are based on hours consumed for actual production functions. To this, a factor of 26% is added to allow for extra men, foreman, supervisors and managers. The factors for each division follow:

Additional men	5%
Foremen	16%
Supervisors	3%
Managers	2%
Total	26%

The average rate used for labor is $16.00 per hour, and includes all fringe benefits.

Administrative Costs

A figure of $1.30 was used. This value remains constant for all cases as these costs are not affected by proposed alternative technology. This includes clerical, engineering support, planning, accounting, personnel, payroll, safety, legal, and all other local administrative, technical, and laboratory services. This does not include sales expense, taxes, insurance, exploration drilling, depletion, depreciation, or amortization.

3.7 OPERATING COST DETAILS

The SOTA cases developed in this study are, of necessity, generalized representations of the many processes and components which make up the modern Florida phosphate mine-beneficiation facility.

The intent of the SOTA cases is to identify the major contributors to the cash operating cost as defined for purposes of the study. No attempt has been made to define a specific flowsheet or process. The generalized format of the cost breakdown by work area is to provide a basis for evaluating the potential economic benefits of any proposed improvement.

Costs are arranged by work areas and basic process or production modules in a computer model developed by ZW to allow for a quick, accurate method of comparing production costs based on orebody characteristics.

Many factors affect operating costs. Among those factors, matrix "X" (the cubic yards of matrix that must be moved to yield a short ton of pebble and/or concentrate product) is the most significant. In the analysis of comparative costs for mining operations, matrix "X" is used as a key parameter.

Another cost related factor is total "X", which refers to the total yards, i.e., overburden plus matrix, that must be handled to produce one ton of product. The total "X" factor is not nearly as significant as matrix "X" since the common method of overburden removal in Florida is by large electric walking draglines which move large volumes of overburden inexpensively.

Typical Bone Valley "present" orebodies in central Florida have traditionally yielded large amounts of pebble, with the minor product being flotation concentrates. This favorable pebble to concentrate ratio greatly affects operating costs since the cost to produce pebble is significantly less than the cost to produce a flotation concentrate. Therefore, the concentrate to pebble ratio is a major cost factor. "Future" orebodies yield much lower pebble and rely principally on flotation concentrate for product.

The clay content of the matrix is important since it directly affects costs in the areas of waste disposal and land reclamation. As less favorable orebodies are mined and the application of more stringent environmental regulations are applied, the cost of waste disposal and land reclamation increases significantly. These factors are incorporated into the cost model.

The BPL grade of the flotation feed is related to achievable product recovery and reagent costs. The recovery effectiveness of flotation and the amount of flotation required dictates operating costs for reagents, power, labor, etc., and impacts capital costs significantly. In SOTA case (file 8) production is from "future" orebodies (relatively low in pebble content), the amount of concentrate that must be produced is significantly higher, resulting in higher operating costs. In addition, generally lower total phosphate BPL recovery is achieved. Pebble recovery normally is greater than 95 percent, whereas flotation frequently recovers less than 80 percent of the BPL in the feed. Thus, the model considers the material balance and recovery of the various product size fractions.

Production rate is a major factor affecting production costs. In these studies the base case mine-beneficiation plant is retained. Effects of orebody characteristics and applied alternative technology result in differing recoveries and consequently different annual production capacity. For simplicity, cost reductions resulting from increased production are not reflected in all unit costs reported.

The base case "typical-average" orebody (file 5rr) was designed as a mine-beneficiation production facility having a nominal capacity of 3.0 million short tons per year (pebble and concentrate products) based on 12 million tons of matrix throughput. SOTA "present" orebody case (file 6r) results in total annual production of 3.29 million tons with the same matrix throughput.

SOTA "future" orebody case (file 8) requires 14.7 million tons of matrix to produce 2.71 million tons of product.

Throughput, or matrix mined and delivered to the plant, remains the same for the cases developed to evaluate and compare alternative technology, for each, "present" and "future" orebody characteristics.

The amount of overburden and matrix to be mined in order to accomplish a desired production is determined. The cost components are segregated into the categories: electricity, operating labor, operating supplies, maintenance labor, maintenance supplies, fuel, reagents, replacement pipe, work contracted for, and in the cases of alternative technology, an amortization cost. Amortization cost is based on capital improvement cost recovery and interest at 10% per year over a 10 year period. This annual cost is divided by the annual production tonnage and applied as cost per ton to each applicable work area.

Mine recovery refers to the percentage of the ore recovered from the mining pit. The application of mine recovery to the cost model is basically through application of consistent factors of recovery as a function of overburden to matrix ratio and total mining depth of the specific operation.

The unit train approach is used to define certain process costs not directly related to tonnage. Examples of process trains are listed following:

1. Prime mover units
2. Ore transportation units
3. Ore washing train consisting of screens, log washers, pumps, etc.
4. Feed desliming unit
5. Feed storage and/or sizing units
6. Flotation units
7. Waste and water units

Once matrix is delivered to the washer and divided into its major components, cost estimation of the major components such as power, labor, maintenance, etc., is based on the tonnage of materials handled by the process units. The unit train concept, as applied, is based on the assumption that a conventional set of beneficiation equipment of optimum size will process a known tonnage.

Waste disposal and water requirements for the process are estimated on the basis of tons of material handled, volumes of water used, and distances involved in transportation, recycling, etc. Included in waste disposal costs are pumping of tailings used in reclamation of mined land.

Reclamation costs are assigned an average value based on an average distribution of types of land reclamation normally encountered. These costs do not include cost of holding land prior to release following reclamation.

Severance and local taxes are not considered nor included.

Depreciation of capital improvements required for alternative technology is presented as a 10-year straight line factor for the initial investment. Depreciation of existing mine-beneficiation facilities is not considered.

Depletion or holding cost of the orebody based on the recoverable tonnage estimated for the orebody is not included as a cost.

There is no allowance for interest on working capital as a real cost in the cost estimation method. Working capital is not included as a cost.

Mine investment costs normally include items such as depreciation, depletion, and interest on working capital. These items are specifically "excluded" so that relative "controllable" operating costs can be identified.

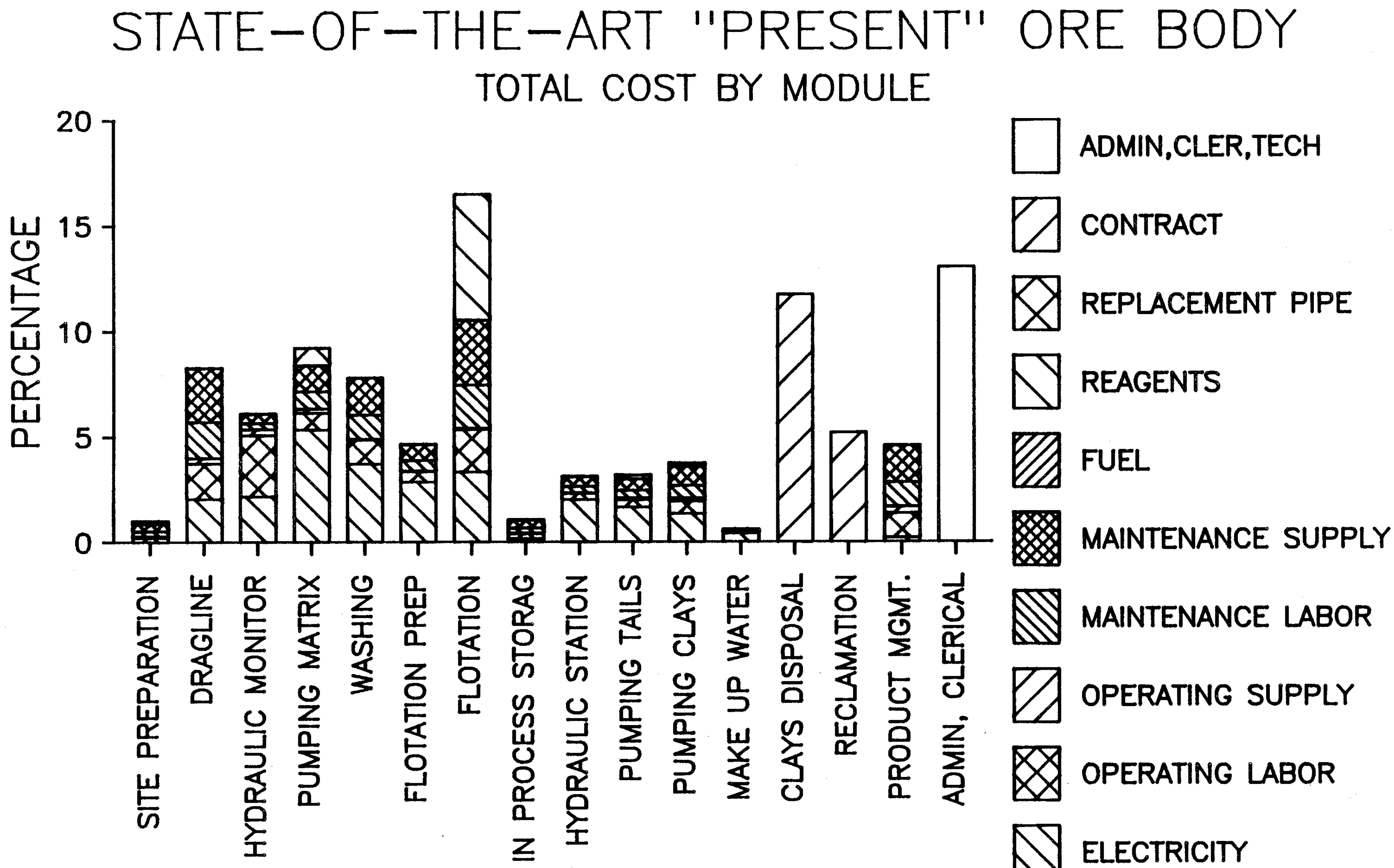
3.8 SOTA CASE "PRESENT" OREBODY CHARACTERISTICS

Summarized from Following 6-Page Cost File 6r

Production (concentrate & pebble)	3.29 million tons per year
Matrix throughput	12.0 million tons per year

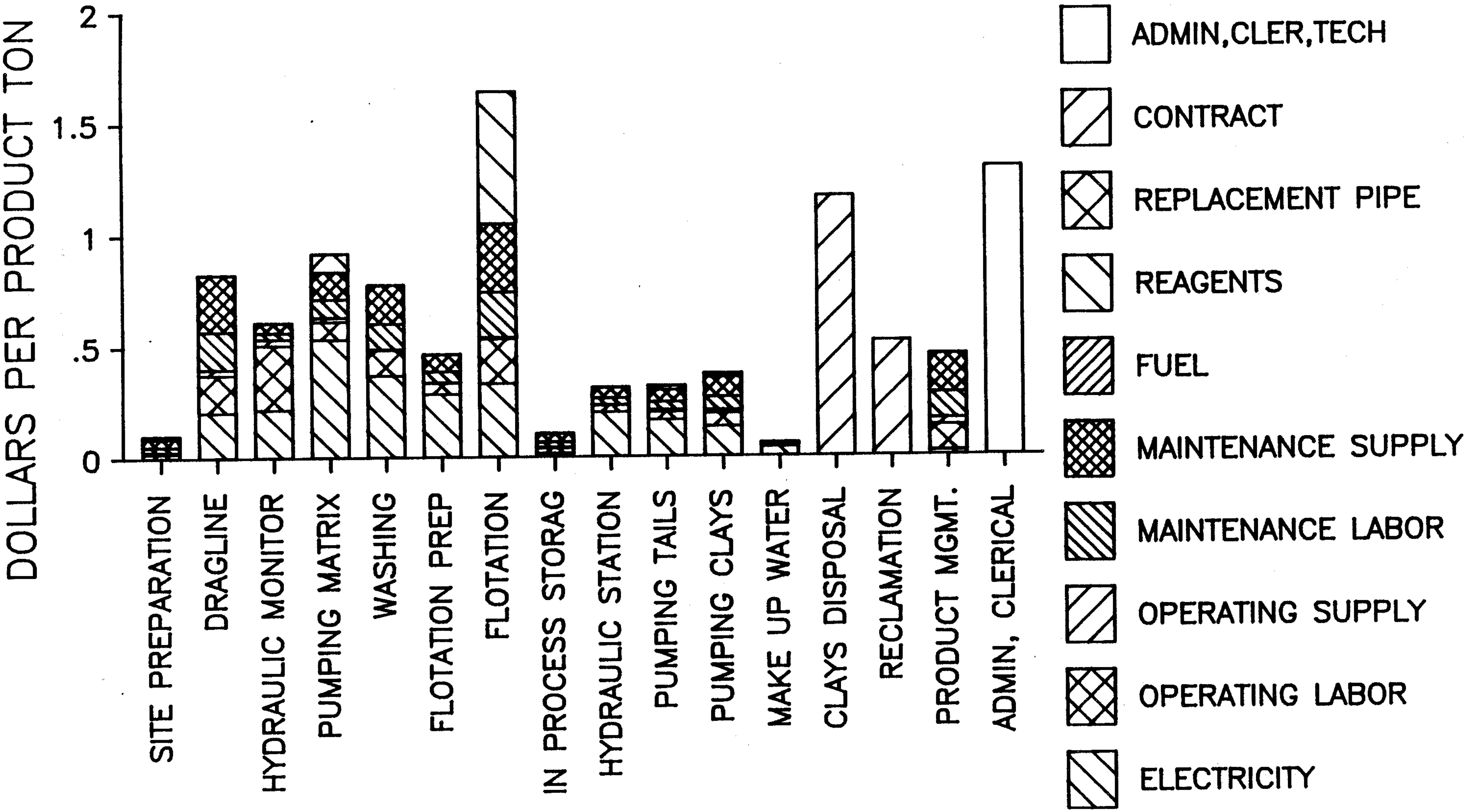
Cash Cost, FOB Mine, Wet Rock $/Short Ton

1. Mining	2.45
2. Beneficiation	3.30
3. Waste disposal, land reclamation and water re-use	2.44
4. Product management	0.46
5. Admin., Clerical, Tech.	1.30
Total Cash Cost	$9.95


STATE-OF-THE-ART "PRESENT" ORE BODY
TOTAL COST BY MODULE
PERCENTAGE
0
5
10
15
20
SITE PREPARATION
DRAGLINE
HYDRAULIC MONITOR
PUMPING MATRIX
WASHING
FLOTATION PREP
FLOTATION
IN PROCESS STORAG
HYDRAULIC STATION
PUMPING TAILS
PUMPING CLAYS
MAKE UP WATER
CLAYS DISPOSAL
RECLAMATION
PRODUCT MGMT.
ADMIN, CLERICAL
ADMIN,CLER,TECH
CONTRACT
REPLACEMENT PIPE
REAGENTS
FUEL
MAINTENANCE SUPPLY
MAINTENANCE LABOR
OPERATING SUPPLY
OPERATING LABOR
ELECTRICITY

STATE-OF-THE-ART "PRESENT" ORE BODY

TOTAL COST BY MODULE



12/18/1987 29-A366

REVISED INPUTS RESULTING FROM WORKSHOPS IN JULY, AUGUST, & OCTOBER, 1987

STATE-OF-THE-ART CASE "PRESENT" ORE BODY CHARACTERISTICS

FILE # 6R

INPUT FACTORS:		ITEM	UNIT COST $
MATRIX X	2.83	KWH	.045
TOTAL X	8.76	OPERATING LABOR MH	16.000
TONS OF PRODUCT/YEAR	3.29	DIESEL FUEL GAL.	.600
% OF SLIMES IN MATRIX	28.60	A-FATTY ACID #	.080
% OF PEBBLE IN MATRIX	13.60	B-FUEL OIL #	.071
% OF SAND TAILS IN MATRIX	44.00	C-NAOH/NH3 #	.075
% OF FLOT. CON. IN MATRIX	13.80	D-H2SO4 #	.025
MATRIX DRY DENSITY	1.29	E-AMINES #	.240
MATRIX PUMPING DISTANCE	3.00	F-KEROSENE #	.091
SLIMES PUMPING DISTANCE	2.50	18" PIPE FT	
TAILS PUMPING DISTANCE	3.00	(TAILS & MATRIX)	25.000
THICKNESS OF MATRIX	14.50	24" SLIME PIPE FT	38.800
MM GALLONS/YR HYDR.STA.	21000		
MM GALLONS/YR MAKE UP	3570		
MM CYD OVERBURDEN	19.50		
MM CYD MATRIX	9.30		
MM TONS MATRIX	12.00		
MM TONS SLIMES	3.43		
MM TONS SANDS	5.28		
MM TONS PEBBLE	1.63		
MM TONS FLOT CON	1.66		
ORE DENSITY WET	1.61		
RATIO OF CONCENTRATION	4.19		
FEET OVERBURDEN	33.78		
ACRES/YEAR	442		
TONS/ACRE	7442		
ACRE FT SLIMES/YEAR	8509		
FLOTATION RECOVERY %	87		
MINE RECOVERY %	90		
PROD.PEBBLE GRADE %BPL	67		
PROD.CON GRADE %BPL	69		
COMP.PROD. GRADE %BPL	68		
FLOT FEED % BPL	19.00		

UNIT CONSUMPTION

MINING (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(a) SITE PREPARATION	ACRE		11.00000	44.00000	11.11000	266.64000	150.00000			
(b) DRAGLINE	CY MOVED	.52000	.00120	.00300	.00121	.02909				
(c) HYDRAULIC MONITOR	TONS MATRIX	1.32000	.00496	.00794	.00050	.01200				
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	1.08000	.00046	.00184	.00046	.01115				.00030

BENEFICIATION (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT (TON FLT FD	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(e) WASHER	TONS MATRIX	2.25000	.00195	.00094	.00199	.04774		A- 1.00000		
(f) FLOTATION PREP	TONS FLOAT FEED	3.00000	.00148	.00071	.00151	.03623		B- 1.25000		
(g) FLOTATION	TONS FLOAT FEED	3.50000	.00594	.00285	.00606	.14541		C- .40000		
(h) IN PROCESS STORAGE	TONS FLOAT FEED	.18000	.00074	.00036	.00075	.01812		D- 1.30000		
(i) HYDRAULIC STATION	1,000,000 GALLONS	700.00000	.30140	.14467	.30743	7.37827		E- .17000		
								F- .10000		

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	.76400	.00046	.00184	.00046	.01115				.00015
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	1.15000	.00141	.00564	.00142	.03418				.00016
(l) MAKE UP WATER	1,000,000 GALLONS	850.00000	.30100	.48160	.30401	7.29624				
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES								452.00000	
(n) LAND RECLAMATION	ACRES MINED								3860.00000	

PRODUCT MANAGEMENT (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(o) CONVEYOR	TONS PRODUCT WET	.05350	.00011	.00023	.00011	.00267				
(p) STORAGE	TONS PRODUCT	.22000	.00351	.02022	.00355	.08508				
(q) LOADOUT	TONS PRODUCT	.20000	.00351	.01123	.00355	.08508				

UNIT COST

MINING (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(a) SITE PREPARATION	ACRE	$.000	$176.000	$44.000	$177.760	$266.640	$90.000				$754.400
(b) DRAGLINE	CY MOVED	$.023	$.019	$.003	$.019	$.029					$.094
(c) HYDRAULIC MONITOR	TONS MATRIX	$.059	$.079	$.008	$.008	$.012					$.167
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	$.049	$.007	$.002	$.007	$.011				$.008	$.076

BENEFICIATION (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(e) WASHER	TONS MATRIX	$.101	$.031	$.001	$.032	$.048					$.213
(f) FLOTATION PREP	TONS FLOAT FEED	$.135	$.024	$.001	$.024	$.036					$.220
(g) FLOTATION	TONS FLOAT FEED	$.158	$.095	$.003	$.097	$.145		$.281			$.779
(h) IN PROCESS STORAGE	TONS FLOAT FEED	$.008	$.012	$.000	$.012	$.018					$.050
(i) HYDRAULIC STATION	1,000,000 GALLONS	$31.500	$4.822	$.145	$4.919	$7.378					$48.764

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	$.034	$.007	$.002	$.007	$.011				$.004	$.066
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	$.052	$.023	$.006	$.023	$.034				$.006	$.143
(l) MAKE UP WATER	1,000,000 GALLONS	$38.250	$4.816	$.482	$4.864	$7.296					$55.708
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES	$.000	$.000	$.000	$.000	$.000		$.000	$452.000	$.000	$452.000
(n) LAND RECLAMATION	ACRES MINED	$.000	$.000	$.000	$.000	$.000		$.000	$3860.000	$.000	$3860.000

PRODUCT MANAGEMENT (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(o) CONVEYOR	TONS PRODUCT WET	$.002	$.002	$.000	$.002	$.003					$.009
(p) STORAGE	TONS PRODUCT	$.010	$.056	$.020	$.057	$.085					$.228
(q) LOADOUT	TONS PRODUCT	$.009	$.056	$.011	$.057	$.085					$.218

TOTAL OPERATING COST $ PER SHORT TONS

$ PER SHORT TON OF PRODUCT

(WORK AREA)	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN LABOR	MAIN SUPPLY	FUEL	REAGENT	REPL. PIPE	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
MINING	$.954	$.562	$.081	$.304	$.457	$.012	$.000	$.083			$.000	$2.453
BENEFICIATION	$1.205	$.420	$.013	$.428	$.643	$.000	$.593	$.000			$.000	$3.302
WASTE, RECLAIM AND WATER	$.342	$.100	$.024	$.101	$.151	$.000	$.000	$.034	$1.689			$2.440
PROD MANAGEMENT	$.022	$.114	$.032	$.116	$.173	$.000	$.000	$.000				$.457
ADMIN, CLER, TECH										$1.300		$1.300
TOTAL	$2.523	$1.196	$.150	$.949	$1.423	$.012	$.593	$.117	$1.689	$1.300	$.000	$9.952

% OF (WORK AREA) COST BY MODULE

MINING (WORK AREA) % OF TOTAL

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS
(a) SITE PREPARATION	.00	.96	.24	.97	1.46	.49	.00	.00	4.13
(b) DRAGLINE	8.36	6.86	1.07	6.93	10.39	.00	.00	.00	33.60
(c) HYDRAULIC MONITOR	8.84	11.81	1.18	1.19	1.79	.00	.00	.00	24.80
(d) SLURRY PUMPING MATRIX	21.69	3.29	.82	3.32	4.98	.00	.00	3.37	37.46
TOTAL	38.89	22.91	3.31	12.41	18.61	.49	.00	3.37	100.00

BENEFICIATION (WORK AREA) % OF TOTAL

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST
(e) WASHER	11.19	3.45	.10	3.52	5.28	.00	.00	.00	23.54
(f) FLOTATION PREP	8.62	1.51	.05	1.54	2.31	.00	.00	.00	14.04
(g) FLOTATION	10.06	6.07	.18	6.19	9.29	.00	17.96	.00	49.76
(h) IN PROCESS STORAGE	.52	.76	.02	.77	1.16	.00	.00	.00	3.23
(i) HYDRAULIC STATION	6.09	.93	.03	.95	1.43	.00	.00	.00	9.43
TOTAL	36.49	12.72	.38	12.98	19.47	.00	17.96	.00	100.00

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	CONTRACT	TOTAL
MODULE	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R.	% W.D.,W.R. COST
(j) SLURRY PUMPING TAILS	6.788	1.453	.363	1.468	2.201	.000	.000	.745		13.019
(k) SLURRY PUMPING SLIMES	5.53	2.41	.60	2.44	3.66	.00	.00	.65		15.29
(l) MAKE UP WATER	1.70	.21	.02	.22	.32	.00	.00	.00		2.48
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	47.95	47.95
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	21.26	21.26
TOTAL	14.02	4.08	.99	4.12	6.18	.00	.00	1.40	69.21	100.00

PRODUCT MANAGEMENT (WORK AREA) % OF TOTAL COST

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRO.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST
(o) CONVEYOR	.62	.45	.06	.46	.69	.00	.00	.00	2.28
(p) STORAGE	2.17	12.30	4.43	12.42	18.63	.00	.00	.00	49.94
(q) LOADOUT	1.97	12.30	2.46	12.42	18.63	.00	.00	.00	47.78
TOTAL	4.76	25.05	6.95	25.30	37.95	.00	.00	.00	100.00

% OF TOTAL COST BY (WORK AREA)

	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
(a) SITE PREPARATION	.00	.24	.06	.24	.36	.12	.00	.00				1.02
(b) DRAGLINE	2.06	1.69	.26	1.71	2.56	.00	.00	.00				8.28
(c) HYDRAULIC MONITOR	2.18	2.91	.29	.29	.44	.00	.00	.00				6.11
(d) SLURRY PUMPING MATRIX	5.35	.81	.20	.82	1.23	.00	.00	.83				9.23
SUBTOTAL MINING	9.59	5.65	.82	3.06	4.59	.12	.00	.83			.00	24.65
(e) WASHER	3.71	1.14	.03	1.17	1.75	.00	.00	.00				7.81
(f) FLOTATION PREP	2.86	.50	.02	.51	.77	.00	.00	.00				4.66
(g) FLOTATION	3.34	2.01	.06	2.05	3.08	.00	5.96	.00				16.51
(h) IN PROCESS STORAGE	.17	.25	.01	.26	.38	.00	.00	.00				1.07
(i) HYDRAULIC STATION	2.02	.31	.01	.32	.47	.00	.00	.00				3.13
SUBTOTAL BENEFICIATION	12.11	4.22	.13	4.31	6.46	.00	5.96	.00			.00	33.18
(j) SLURRY PUMPING TAILS	1.65	.36	.09	.36	.54	.00	.00	.18				3.19
(k) SLURRY PUMPING SLIMES	1.36	.59	.15	.60	.90	.00	.00	.16				3.75
(l) MAKE UP WATER	.42	.05	.01	.05	.08	.00	.00	.00				.61
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	11.76			11.76
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	5.21			5.21
SUBTOTAL W.D., L.R. & W.R.	3.44	1.00	.24	1.01	1.52	.00	.00	.34	16.97			24.52
(o) CONVEYOR	.03	.02	.00	.02	.03	.00	.00	.00				.10
(p) STORAGE	.10	.56	.20	.57	.85	.00	.00	.00				2.29
(q) LOADOUT	.09	.56	.11	.57	.85	.00	.00	.00				2.19
SUBTOTAL PRODUCT MAN.	.22	1.15	.32	1.16	1.74	.00	.00	.00				4.59
ADMIN, CLER, TECH										13.06		13.06
TOTAL	25.35	12.02	1.50	9.54	14.30	.12	5.96	1.17	16.97	13.06	.00	100.00

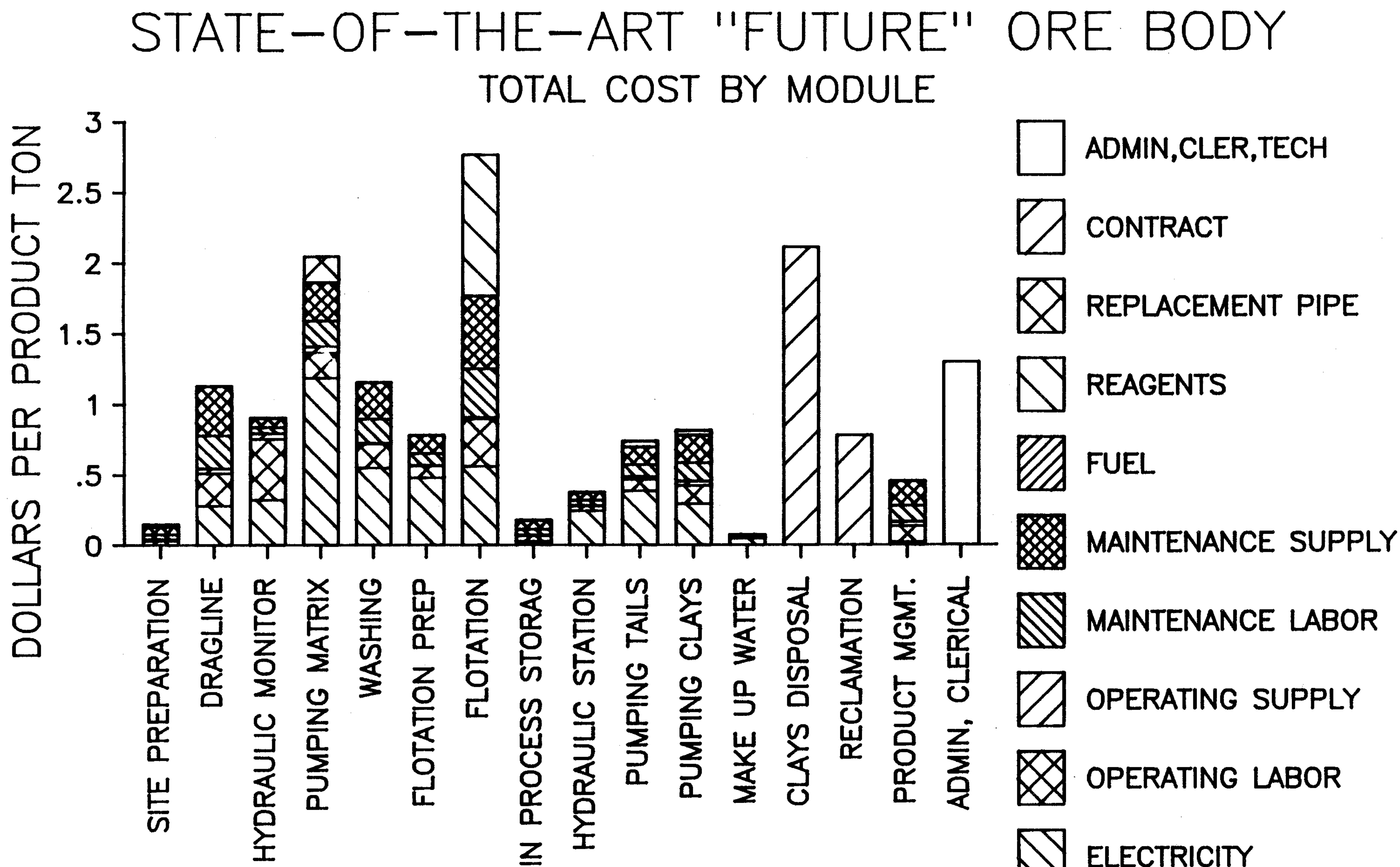
3.9 SOTA CASE "FUTURE" OREBODY CHARACTERISTICS

Summarized from Following Cost File 8

Production (concentrate & pebble)	2.71 million tons per year
Matrix throughput	14.7 million tons per year

Cash Cost, FOB Mine, Wet Rock $/Short Ton

1. Mining	$4.24
2. Beneficiation	5.27
3. Waste disposal, land reclamation and water re-use	4.53
4. Product management	0.46
5. Admin., Clerical, Tech.	1.30
Total Cash Cost	$15.80


STATE-OF-THE-ART "FUTURE" ORE BODY
TOTAL COST BY MODULE
DOLLARS PER PRODUCT TON
3
2.5
2
1.5
1
.5
0
SITE PREPARATION
DRAGLINE
HYDRAULIC MONITOR
PUMPING MATRIX
WASHING
FLOTATION PREP
FLOTATION
IN PROCESS STORAG
HYDRAULIC STATION
PUMPING TAILS
PUMPING CLAYS
MAKE UP WATER
CLAYS DISPOSAL
RECLAMATION
PRODUCT MGMT.
ADMIN, CLERICAL
ADMIN,CLER,TECH
CONTRACT
REPLACEMENT PIPE
REAGENTS
FUEL
MAINTENANCE SUPPLY
MAINTENANCE LABOR
OPERATING SUPPLY
OPERATING LABOR
ELECTRICITY

12/18/1987 29-A366

REVISED INPUTS RESULTING FROM WORKSHOPS IN JULY, AUGUST & OCTOBER, 1987

REPRESENTS FUTURE ORE BODIES & LONGER PUMPING DISTANCES (1 MILE)

STATE-OF-THE-ART CASE "FUTURE" ORE BODY CHARACTERISTICS

FILE # 8

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INPUT FACTORS:		ITEM	UNIT COST $
MATRIX X	4.21	KWH	.045
TOTAL X	12.01	OPERATING LABOR MH	16.000
TONS OF PRODUCT/YEAR	2.71	DIESEL FUEL GAL.	.600
% OF SLIMES IN MATRIX	30.00	A-FATTY ACID #	.080
% OF PEBBLE IN MATRIX	4.60	B-FUEL OIL #	.071
% OF SAND TAILS IN MATRIX	51.60	C-NAOH/NH3 #	.075
% OF FLOT. CON. IN MATRIX	13.80	D-H2SO4 #	.025
MATRIX DRY DENSITY	1.29	E-AMINES #	.240
MATRIX PUMPING DISTANCE	4.50	F-KEROSENE #	.091
SLIMES PUMPING DISTANCE	3.50	18" PIPE FT	
TAILS PUMPING DISTANCE	4.00	(TAILS & MATRIX)	25.000
THICKNESS OF MATRIX	14.50	24" SLIME PIPE FT	38.800
MM GALLONS/YR HYDR.STA.	21000		
MM GALLONS/YR MAKE UP	3570		
MM CYD OVERBURDEN	21.10		
MM CYD MATRIX	11.40		
MM TONS MATRIX	14.71		
MM TONS SLIMES	4.41		
MM TONS SANDS	7.59		
MM TONS PEBBLE	.68		
MM TONS FLOT CON	2.03		
ORE DENSITY WET	1.61		
RATIO OF CONCENTRATION	4.74		
FEET OVERBURDEN	29.82		
ACRES/YEAR	541		
TONS/ACRE	4997		
ACRE FT SLIMES/YEAR	10941		
FLOTATION RECOVERY %	86		
MINE RECOVERY %	90		
PROD.PEBBLE GRADE %BPL	65		
PROD.CON GRADE %BPL	69		
COMP.PROD. GRADE %BPL	68		
FLOT FEED % BPL	17.00		

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UNIT CONSUMPTION

MINING (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(a) SITE PREPARATION	ACRE		11.00000	44.00000	11.11000	266.64000	150.00000			
(b) DRAGLINE	CY MOVED	.52000	.00120	.00300	.00121	.02909				
(c) HYDRAULIC MONITOR	TONS MATRIX	1.32000	.00496	.00794	.00050	.01200				
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	1.08000	.00046	.00184	.00046	.01115				.00030

BENEFICIATION (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT (TON FLT FD	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(e) WASHER	TONS MATRIX	2.25000	.00195	.00094	.00199	.04774		A- 1.00000		
(f) FLOTATION PREP	TONS FLOAT FEED	3.00000	.00148	.00071	.00151	.03623		B- 1.25000		
(g) FLOTATION	TONS FLOAT FEED	3.50000	.00594	.00285	.00606	.14541		C- .40000		
(h) IN PROCESS STORAGE	TONS FLOAT FEED	.18000	.00074	.00036	.00075	.01812		D- 1.30000		
(i) HYDRAULIC STATION	1,000,000 GALLONS	700.00000	.30140	.14467	.30743	7.37827		E- .17000		
								F- .10000		

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	.76400	.00046	.00184	.00046	.01115				.00015
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	1.15000	.00141	.00564	.00142	.03418				.00016
(l) MAKE UP WATER	1,000,000 GALLONS	850.00000	.30100	.48160	.30401	7.29624				
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES								523.00000	
(n) LAND RECLAMATION	ACRES MINED								3905.00000	

PRODUCT MANAGEMENT (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(o) CONVEYOR	TONS PRODUCT WET	.05350	.00011	.00023	.00011	.00267				
(p) STORAGE	TONS PRODUCT	.22000	.00351	.02022	.00355	.08508				
(q) LOADOUT	TONS PRODUCT	.20000	.00351	.01123	.00355	.08508				

UNIT COST

MINING (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(a) SITE PREPARATION	ACRE	$.000	$176.000	$44.000	$177.760	$266.640	$90.000				$754.400
(b) DRAGLINE	CY MOVED	$.023	$.019	$.003	$.019	$.029					$.094
(c) HYDRAULIC MONITOR	TONS MATRIX	$.059	$.079	$.008	$.008	$.012					$.167
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	$.049	$.007	$.002	$.007	$.011				$.008	$.076

BENEFICIATION (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(e) WASHER	TONS MATRIX	$.101	$.031	$.001	$.032	$.048					$.213
(f) FLOTATION PREP	TONS FLOAT FEED	$.135	$.024	$.001	$.024	$.036					$.220
(g) FLOTATION	TONS FLOAT FEED	$.158	$.095	$.003	$.097	$.145		$.281			$.779
(h) IN PROCESS STORAGE	TONS FLOAT FEED	$.008	$.012	$.000	$.012	$.018					$.050
(i) HYDRAULIC STATION	1,000,000 GALLONS	$31.500	$4.822	$.145	$4.919	$7.378					$48.764

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	$.034	$.007	$.002	$.007	$.011				$.004	$.066
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	$.052	$.023	$.006	$.023	$.034				$.006	$.143
(l) MAKE UP WATER	1,000,000 GALLONS	$38.250	$4.816	$.482	$4.864	$7.296					$55.708
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES	$.000	$.000	$.000	$.000	$.000		$.000	$523.000	$.000	$523.000
(n) LAND RECLAMATION	ACRES MINED	$.000	$.000	$.000	$.000	$.000		$.000	$3905.000	$.000	$3905.000

PRODUCT MANAGEMENT (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(o) CONVEYOR	TONS PRODUCT WET	$.002	$.002	$.000	$.002	$.003					$.009
(p) STORAGE	TONS PRODUCT	$.010	$.056	$.020	$.057	$.085					$.228
(q) LOADOUT	TONS PRODUCT	$.009	$.056	$.011	$.057	$.085					$.218

TOTAL OPERATING COST $ PER SHORT TONS

$ PER SHORT TON OF PRODUCT

(WORK AREA)	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN LABOR	MAIN SUPPLY	FUEL	REAGENT	REPL. PIPE	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
MINING	$1.792	$.877	$.133	$.494	$.741	$.018	$.000	$.185			$.000	$4.240
BENEFICIATION	$1.863	$.671	$.020	$.684	$1.027	$.000	$.999	$.000			$.000	$5.265
WASTE, RECLAIM AND WATER	$.731	$.218	$.053	$.220	$.330	$.000	$.000	$.077	$2.896			$4.525
PROD MANAGEMENT	$.022	$.114	$.032	$.116	$.173	$.000	$.000	$.000				$.457
ADMIN, CLER, TECH										$1.300		$1.300
TOTAL	$4.409	$1.880	$.238	$1.514	$2.270	$.018	$.999	$.262	$2.896	$1.300	$.000	$15.786

% OF (WORK AREA) COST BY MODULE

MINING (WORK AREA) % OF TOTAL

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS
(a) SITE PREPARATION	.00	.83	.21	.84	1.26	.42	.00	.00	3.56
(b) DRAGLINE	6.63	5.44	.85	5.19	8.24	.00	.00	.00	26.65
(c) HYDRAULIC MONITOR	7.61	10.17	1.02	1.03	1.54	.00	.00	.00	21.37
(d) SLURRY PUMPING MATRIX	28.04	4.25	1.06	4.29	6.43	.00	.00	4.36	48.42
TOTAL	42.28	20.69	3.14	11.65	17.47	.42	.00	4.36	100.00

BENEFICIATION (WORK AREA) % OF TOTAL

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST
(e) WASHER	10.45	3.22	.10	3.29	4.93	.00	.00	.00	21.98
(f) FLOTATION PREP	9.11	1.60	.05	1.63	2.45	.00	.00	.00	14.84
(g) FLOTATION	10.63	6.42	.19	6.54	9.82	.00	18.98	.00	52.58
(h) IN PROCESS STORAGE	.55	.80	.02	.82	1.22	.00	.00	.00	3.41
(i) HYDRAULIC STATION	4.64	.71	.02	.73	1.09	.00	.00	.00	7.19
TOTAL	35.39	12.75	.38	13.00	19.50	.00	18.98	.00	100.00

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	CONTRACT	TOTAL
MODULE	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R.	% W.D.,W.R. COST
(j) SLURRY PUMPING TAILS	8.52	1.82	.46	1.84	2.76	.00	.00	.94		16.35
(k) SLURRY PUMPING SLIMES	6.53	2.84	.71	2.87	4.31	.00	.00	.77		18.03
(l) MAKE UP WATER	1.12	.14	.01	.14	.21	.00	.00	.00		1.62
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	46.73	46.73
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	17.27	17.27
TOTAL	16.16	4.81	1.18	4.86	7.29	.00	.00	1.70	64.00	100.00

PRODUCT MANAGEMENT (WORK AREA) % OF TOTAL COST

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST
(o) CONVEYOR	.62	.45	.06	.46	.69	.00	.00	.00	2.28
(p) STORAGE	2.17	12.30	4.43	12.42	18.63	.00	.00	.00	49.94
(q) LOADOUT	1.97	12.30	2.46	12.42	18.63	.00	.00	.00	47.78
TOTAL	4.76	25.05	6.95	25.30	37.95	.00	.00	.00	100.00

% OF TOTAL COST BY (WORK AREA)

	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
(a) SITE PREPARATION	.00	.22	.06	.23	.34	.11	.00	.00				.96
(b) DRAGLINE	1.78	1.46	.23	1.48	2.21	.00	.00	.00				7.16
(c) HYDRAULIC MONITOR	2.04	2.73	.27	.28	.41	.00	.00	.00				5.74
(d) SLURRY PUMPING MATRIX	7.53	1.14	.29	1.15	1.73	.00	.00	1.17				13.00
SUBTOTAL MINING	11.35	5.56	.84	3.13	4.69	.11	.00	1.17			.00	26.86
(e) WASHER	3.49	1.07	.03	1.10	1.64	.00	.00	.00				7.33
(f) FLOTATION PREP	3.04	.53	.02	.54	.82	.00	.00	.00				4.95
(g) FLOTATION	3.55	2.14	.06	2.18	3.27	.00	6.33	.00				17.54
(h) IN PROCESS STORAGE	.18	.27	.01	.27	.41	.00	.00	.00				1.14
(i) HYDRAULIC STATION	1.55	.24	.01	.24	.36	.00	.00	.00				2.40
SUBTOTAL BENEFICIATION	11.80	4.25	.13	4.34	6.50	.00	6.33	.00			.00	33.35
(j) SLURRY PUMPING TAILS	2.44	.52	.13	.53	.79	.00	.00	.27				4.69
(k) SLURRY PUMPING SLIMES	1.87	.82	.20	.82	1.24	.00	.00	.22				5.17
(l) MAKE UP WATER	.32	.04	.00	.04	.06	.00	.00	.00				.47
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	13.40			13.40
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	4.95			4.95
SUBTOTAL W.D., L.R. & W.R.	4.63	1.38	.34	1.39	2.09	.00	.00	.49	18.35			28.67
(o) CONVEYOR	.02	.01	.00	.01	.02	.00	.00	.00				.07
(p) STORAGE	.06	.36	.13	.36	.54	.00	.00	.00				1.44
(q) LOADOUT	.06	.36	.07	.36	.54	.00	.00	.00				1.38
SUBTOTAL PRODUCT MAN.	.14	.72	.20	.73	1.10	.00	.00	.00				2.89
ADMIN, CLER, TECH										8.23		8.23
TOTAL	27.93	11.91	1.51	9.59	14.38	.11	6.33	1.66	18.35	8.23	.00	100.00

3.10 ALTERNATIVE TECHNOLOGY "PRESENT" OREBODY CHARACTERISTICS

Summarized from Following Cost File 7r

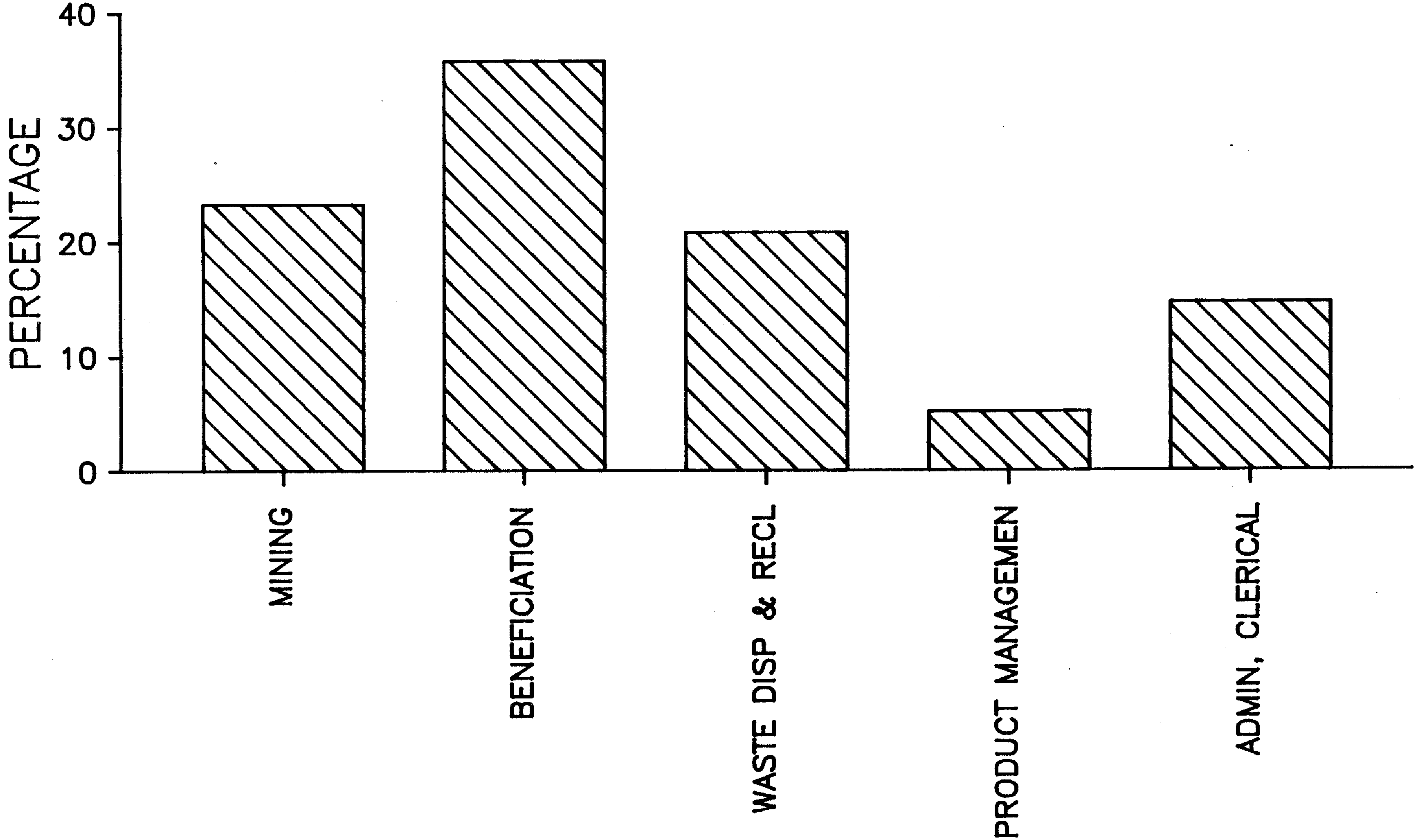
Production (concentrate & pebble)	3.44 million tons per year
Matrix throughput	12.00 million tons per year

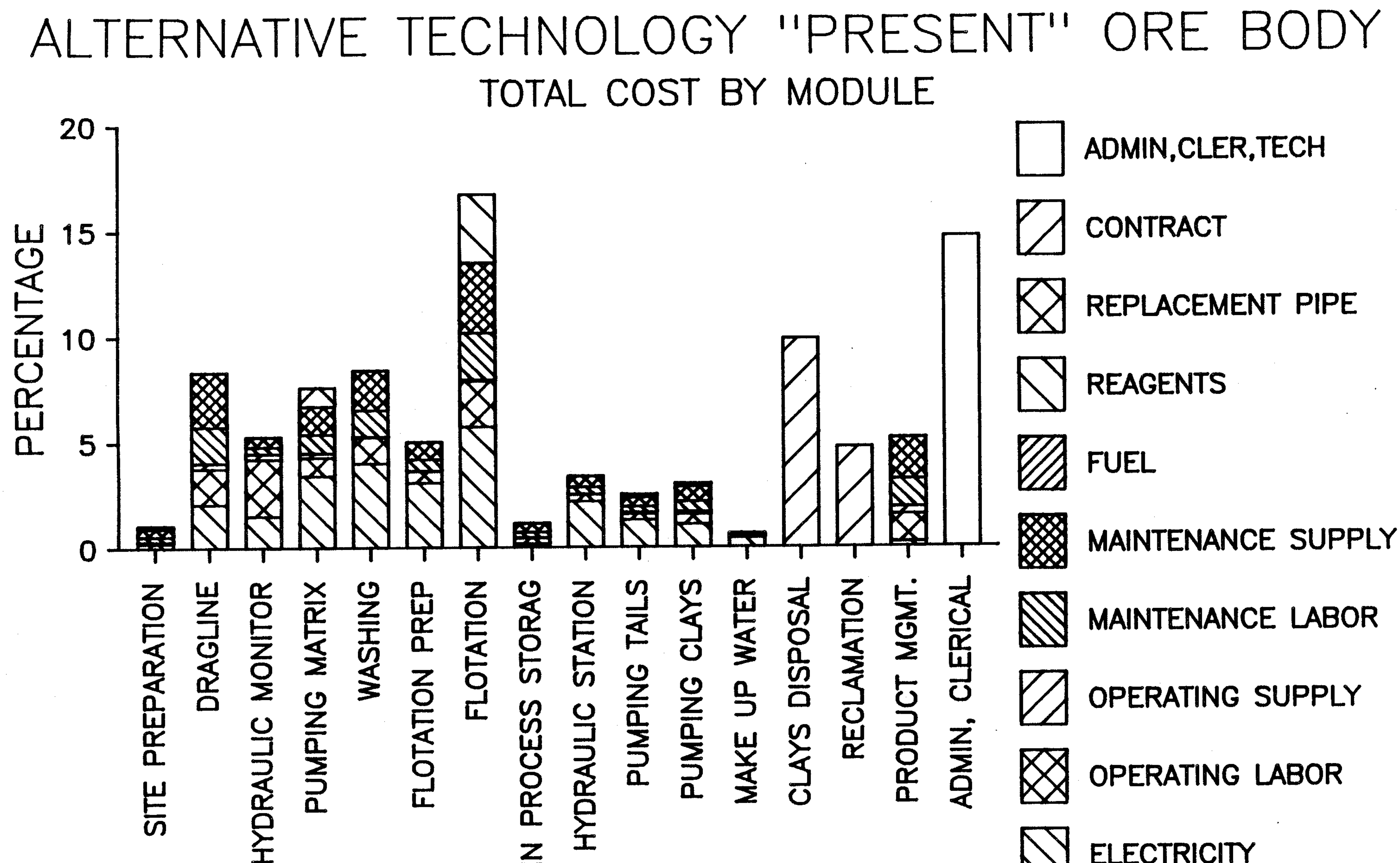
Cash Cost, FOB Mine, Wet Rock $/Short Ton

1. Mining	$2.06
2. Beneficiation	3.16
3. Waste disposal, land reclamation and water re-use	1.84
4. Product management	0.46
5. Admin., Clerical, Tech.	1.30
Total Cash Cost	$8.82

ALTERNATIVE TECHNOLOGY "PRESENT" ORE BODY

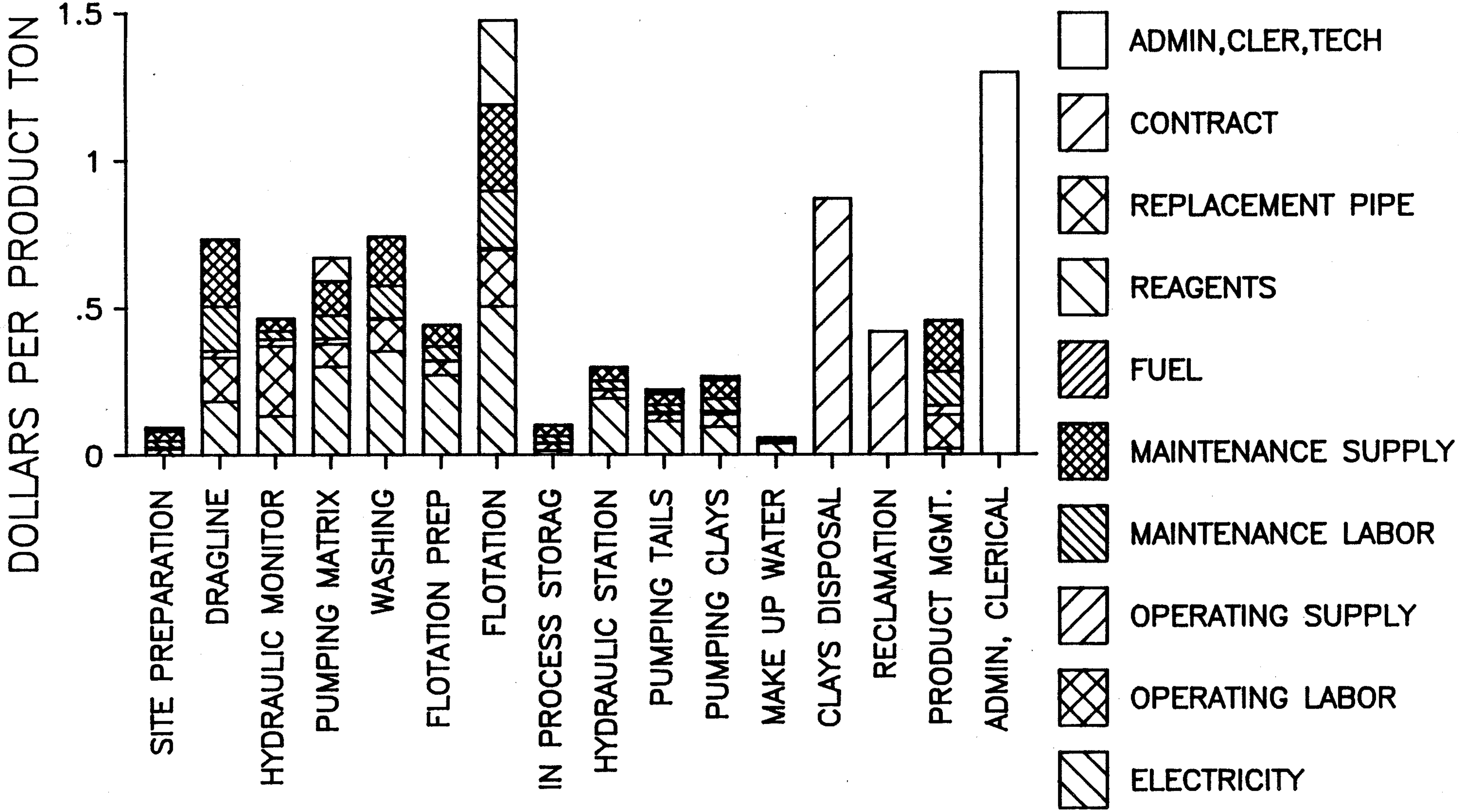
BREAKDOWN OF TOTAL COST BY WORK AREA




ALTERNATIVE TECHNOLOGY "PRESENT" ORE BODY
TOTAL COST BY MODULE
PERCENTAGE
0
5
10
15
20
SITE PREPARATION
DRAGLINE
HYDRAULIC MONITOR
PUMPING MATRIX
WASHING
FLOTATION PREP
FLOTATION
IN PROCESS STORAG
HYDRAULIC STATION
PUMPING TAILS
PUMPING CLAYS
MAKE UP WATER
CLAYS DISPOSAL
RECLAMATION
PRODUCT MGMT.
ADMIN, CLERICAL
ADMIN,CLER,TECH
CONTRACT
REPLACEMENT PIPE
REAGENTS
FUEL
MAINTENANCE SUPPLY
MAINTENANCE LABOR
OPERATING SUPPLY
OPERATING LABOR
ELECTRICITY

ALTERNATIVE TECHNOLOGY "PRESENT" ORE BODY

TOTAL COST BY MODULE



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NEW COST SAVING PROJECTS

ALTERNATIVE TECHNOLOGY"PRESENT" ORE BODY CHARACTERISTICS

FILE # 7R

INPUT FACTORS:		ITEM	UNIT COST $
MATRIX X	2.706	KWH	.045
TOTAL X	7.81	OPERATING LABOR MH	16.000
TONS OF PRODUCT/YEAR	3.44	DIESEL FUEL GAL.	.600
% OF SLIMES IN MATRIX	28.45	A-FATTY ACID #	.080
% OF PEBBLE IN MATRIX	13.87	B-FUEL OIL #	.071
% OF SAND TAILS IN MATRIX	42.90	C-NAOH/NH3 #	.075
% OF FLOT. CON. IN MATRIX	14.78	D-H2SO4 #	.025
MATRIX DRY DENSITY	1.29	E-AMINES #	.240
MATRIX PUMPING DISTANCE	3.00	F-KEROSENE #	.091
SLIMES PUMPING DISTANCE	2.50	18" PIPE FT	
TAILS PUMPING DISTANCE	3.00	(TAILS & MATRIX)	25.000
THICKNESS OF MATRIX	14.50	24" SLIME PIPE FT	38.800
MM GALLONS/YR HYDR.STA.	21000		
MM GALLONS/YR MAKE UP	3570		
MM CYD OVERBURDEN	17.55		
MM CYD MATRIX	9.30		
MM TONS MATRIX	12.00		
MM TONS SLIMES	3.41		
MM TONS SANDS	5.15		
MM TONS PEBBLE	1.66		
MM TONS FLOT CON	1.77		
ORE DENSITY WET	1.61		
RATIO OF CONCENTRATION	3.90		
FEET OVERBURDEN	29.74		
ACRES/YEAR	432		
TONS/ACRE	7955		
ACRE FT SLIMES/YEAR	8465		
FLOTATION RECOVERY %	91		
MINE RECOVERY %	92		
PROD.PEBBLE GRADE %BPL	67		
PROD.CON GRADE %BPL	69		
COMP.PROD. GRADE %BPL	68		
FLOT FEED % BPL	19.38		

UNIT CONSUMPTION

MINING (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(a) SITE PREPARATION	ACRE		11.00000	44.00000	11.11000	266.64000	150.00000			
(b) DRAGLINE	CY MOVED	.52000	.00120	.00300	.00121	.02909				
(c) HYDRAULIC MONITOR	TONS MATRIX	.85000	.00427	.00683	.00050	.01200				
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	.64000	.00046	.00184	.00046	.01115				.00030

BENEFICIATION (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT (TON FLT FD	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(e) WASHER	TONS MATRIX	2.25000	.00195	.00094	.00199	.04774		A- .30000		
(f) FLOTATION PREP	TONS FLOAT FEED	3.00000	.00148	.00071	.00151	.03623		B- .37500		
(g) FLOTATION	TONS FLOAT FEED	5.58000	.00594	.00285	.00606	.14541		C- .12000		
(h) IN PROCESS STORAGE	TONS FLOAT FEED	.18000	.00074	.00036	.00075	.01812		D- 1.30000		
(i) HYDRAULIC STATION	1,000,000 GALLONS	700.00000	.30140	.14467	.30743	7.37827		E- .17000		
								F- .10000		

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	.57000	.00035	.00138	.00035	.00836				.00011
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	.86000	.00106	.00424	.00107	.02569				.00012
(l) MAKE UP WATER	1,000,000 GALLONS	850.00000	.30100	.48160	.30401	7.29624				
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES								354.00000	
(n) LAND RECLAMATION	ACRES MINED								3339.00000	

PRODUCT MANAGEMENT (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS $/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(o) CONVEYOR	TONS PRODUCT WET	.05350	.00011	.00023	.00011	.00267				
(p) STORAGE	TONS PRODUCT	.22000	.00351	.02022	.00355	.08508				
(q) LOADOUT	TONS PRODUCT	.20000	.00351	.01123	.00355	.08508				

UNIT COST

MINING (WORK AREA) COST

	CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN. LABOR	MAIN. SUPPLIES	FUEL	REAGENTS	CONTRACT	REPLACEMENT PIPE	TOTAL
MODULE	UNITS	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$/UNIT		$ PER UNIT
(a) SITE PREPARATION	ACRE	$.000	$176.000	$44.000	$177.760	$266.640	$90.000				$754.400
(b) DRAGLINE	CY MOVED	$.023	$.019	$.003	$.019	$.029					$.094
(c) HYDRAULIC MONITOR	TONS MATRIX	$.038	$.068	$.007	$.008	$.012					$.133
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	$.029	$.007	$.002	$.007	$.011				$.008	$.064

BENEFICIATION (WORK AREA) COST

	CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN. LABOR	MAIN. SUPPLIES	FUEL	REAGENTS	CONTRACT	REPLACEMENT PIPE	TOTAL
MODULE	UNITS	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$/UNIT		$ PER UNIT
(e) WASHER	TONS MATRIX	$.101	$.031	$.001	$.032	$.048					$.213
(f) FLOTATION PREP	TONS FLOAT FEED	$.135	$.024	$.001	$.024	$.036					$.220
(g) FLOTATION	TONS FLOAT FEED	$.251	$.095	$.003	$.097	$.145		$.142			$.733
(h) IN PROCESS STORAGE	TONS FLOAT FEED	$.008	$.012	$.000	$.012	$.018					$.050
(i) HYDRAULIC STATION	1,000,000 GALLONS	$31.500	$4.822	$.145	$4.919	$7.378					$48.764

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

	CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN. LABOR	MAIN. SUPPLIES	FUEL	REAGENTS	CONTRACT	REPLACEMENT PIPE	TOTAL
MODULE	UNITS	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$/UNIT		$ PER UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	$.026	$.006	$.001	$.006	$.008				$.003	$.049
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	$.039	$.017	$.004	$.017	$.026				$.005	$.107
(l) MAKE UP WATER	1,000,000 GALLONS	$38.250	$4.816	$.482	$4.864	$7.296					$55.708
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES	$.000	$.000	$.000	$.000	$.000		$.000	$354.000	$.000	$354.000
(n) LAND RECLAMATION	ACRES MINED	$.000	$.000	$.000	$.000	$.000		$.000	$3339.000	$.000	$3339.000

PRODUCT MANAGEMENT (WORK AREA) COST

	CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN. LABOR	MAIN. SUPPLIES	FUEL	REAGENTS	CONTRACT	REPLACEMENT PIPE	TOTAL
MODULE	UNITS	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$ PER UNIT	$/UNIT		$ PER UNIT
(o) CONVEYOR	TONS PRODUCT WET	$.002	$.002	$.000	$.002	$.003					$.009
(p) STORAGE	TONS PRODUCT	$.010	$.056	$.020	$.057	$.085					$.228
(q) LOADOUT	TONS PRODUCT	$.009	$.056	$.011	$.057	$.085					$.218

TOTAL OPERATING COST $ PER SHORT TONS

$ PER SHORT TON OF PRODUCT

(WORK AREA)	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN LABOR	MAIN SUPPLY	FUEL	REAGENT	REPL. PIPE	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
MINING	$.618	$.488	$.072	$.280	$.419	$.011	$.000	$.079			$.089	$2.056
BENEFICIATION	$1.339	$.401	$.012	$.409	$.614	$.000	$.286	$.000			$.095	$3.157
WASTE, RECLAIM AND WATER	$.251	$.072	$.017	$.073	$.109	$.000	$.000	$.024	$1.292			$1.837
PROD MANAGEMENT	$.022	$.114	$.032	$.116	$.173	$.000	$.000	$.000				$.457
ADMIN, CLER, TECH										$1.300		$1.300
TOTAL	$2.230	$1.075	$.133	$.877	$1.315	$.011	$.286	$.103	$1.292	$1.300	$.184	$8.806

% OF (WORK AREA) COST BY MODULE

MINING (WORK AREA) % OF TOTAL

CONSUMABLES / MODULE	ELECTRICITY % MINE COSTS	OPERATING LABOR % MINE COSTS	OPERATING SUPPLY % MINE COSTS	MAINTENANCE LABOR % MINE COSTS	MAINTENANCE SUPPLY % MINE COSTS	FUEL % MINE COSTS	REAGENTS % MINE COSTS	REPLACEMENT PIPE % MINE COSTS	TOTAL % MINE COSTS
(a) SITE PREPARATION	.00	1.12	.28	1.14	1.70	.58	.00	.00	4.82
(b) DRAGLINE	9.29	7.63	1.19	7.70	11.55	.00	.00	.00	37.36
(c) HYDRAULIC MONITOR	6.79	12.12	1.21	1.42	2.13	.00	.00	.00	23.67
(d) SLURRY PUMPING MATRIX	15.33	3.92	.78	3.96	5.94	.00	.00	4.02	34.14
TOTAL	31.41	24.79	3.66	14.21	21.32	.58	.00	4.02	100.00

BENEFICIATION (WORK AREA)

CONSUMABLES / MODULE	ELECTRICITY % BENEF. COST	OPERATING LABOR % BENEF. COST	OPERATING SUPPLY % BENEF. COST	MAINTENANCE LABOR % BENEF. COST	MAINTENANCE SUPPLY % BENEF. COST	FUEL % BENEF. COST	REAGENTS % BENEF. COST	REPLACEMENT PIPE % BENEF. COST	TOTAL % BENEF. COST
(e) WASHER	11.54	3.56	.11	3.63	5.44	.00	.00	.00	24.28
(f) FLOTATION PREP	8.88	1.56	.05	1.59	2.38	.00	.00	.00	14.45
(g) FLOTATION	16.51	6.25	.19	6.37	9.56	.00	9.34	.00	48.22
(h) IN PROCESS STORAGE	.53	.78	.02	.79	1.19	.00	.00	.00	3.32
(i) HYDRAULIC STATION	6.29	.96	.03	.98	1.47	.00	.00	.00	9.73
TOTAL	43.75	13.10	.39	13.37	20.05	.00	9.34	.00	100.00

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

CONSUMABLES / MODULE	ELECTRICITY % W.D.,W.R. COST	OPERATING LABOR % W.D.,W.R. COST	OPERATING SUPPLY % W.D.,W.R. COST	MAINTENANCE LABOR % W.D.,W.R. COST	MAINTENANCE SUPPLY % W.D.,W.R. COST	FUEL % W.D.,W.R. COST	REAGENTS % W.D.,W.R. COST	REPLACEMENT PIPE % W.D.,W.R. COST	CONTRACT % W.D.,W.R.	TOTAL % W.D.,W.R. COST
(j) SLURRY PUMPING TAILS	6.27	1.35	.34	1.36	2.04	.00	.00	.69		12.06
(k) SLURRY PUMPING SLIMES	5.23	2.29	.57	2.31	3.47	.00	.00	.62		14.50
(l) MAKE UP WATER	2.16	.27	.03	.27	.41	.00	.00	.00		3.15
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	47.45	47.45
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	22.85	22.85
TOTAL	13.66	3.91	.94	3.95	5.93	.00	.00	1.31	70.30	100.00

PRODUCT MANAGEMENT (WORK AREA) % OF TOTAL COST

CONSUMABLES / MODULE	ELECTRICITY % PRD.MAN. COST	OPERATING LABOR % PRD.MAN. COST	OPERATING SUPPLY % PRD.MAN. COST	MAINTENANCE LABOR % PRD.MAN. COST	MAINTENANCE SUPPLY % PRD.MAN. COST	FUEL % PRD.MAN. COST	REAGENTS % PRD.MAN. COST	REPLACEMENT PIPE % PRD.MAN. COST	TOTAL % PRD.MAN. COST
(o) CONVEYOR	.62	.45	.06	.46	.69	.00	.00	.00	2.28
(p) STORAGE	2.17	12.30	4.43	12.42	18.63	.00	.00	.00	49.94
(q) LOADOUT	1.97	12.30	2.46	12.42	18.63	.00	.00	.00	47.78
TOTAL	4.76	25.05	6.95	25.30	37.95	.00	.00	.00	100.00

% OF TOTAL COST BY (WORK AREA)

	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
(a) SITE PREPARATION	.00	.25	.06	.25	.38	.13	.00	.00				1.08
(b) DRAGLINE	2.08	1.70	.27	1.72	2.58	.00	.00	.00				8.34
(c) HYDRAULIC MONITOR	1.52	2.71	.27	.32	.48	.00	.00	.00				5.29
(d) SLURRY PUMPING MATRIX	3.42	.88	.22	.88	1.33	.00	.00	.90				7.63
SUBTOTAL MINING	7.02	5.54	.82	3.17	4.76	.13	.00	.90			1.01	23.34
(e) WASHER	4.01	1.24	.04	1.26	1.89	.00	.00	.00				8.44
(f) FLOTATION PREP	3.09	.54	.02	.55	.83	.00	.00	.00				5.02
(g) FLOTATION	5.74	2.17	.07	2.22	3.32	.00	3.25	.00				16.76
(h) IN PROCESS STORAGE	.19	.27	.01	.28	.41	.00	.00	.00				1.15
(i) HYDRAULIC STATION	2.19	.33	.01	.34	.51	.00	.00	.00				3.38
SUBTOTAL BENEFICIATION	15.21	4.56	.14	4.65	6.97	.00	3.25	.00			1.08	35.84
(j) SLURRY PUMPING TAILS	1.31	.28	.07	.28	.43	.00	.00	.14				2.52
(k) SLURRY PUMPING SLIMES	1.09	.48	.12	.48	.72	.00	.00	.13				3.02
(l) MAKE UP WATER	.45	.06	.01	.06	.09	.00	.00	.00				.66
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	9.90			9.90
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	4.77			4.77
SUBTOTAL W.D., L.R. & W.R.	2.85	.82	.20	.82	1.24	.00	.00	.27	14.67			20.86
(o) CONVEYOR	.03	.02	.00	.02	.04	.00	.00	.00				.12
(p) STORAGE	.11	.64	.23	.64	.97	.00	.00	.00				2.59
(q) LOADOUT	.10	.64	.13	.64	.97	.00	.00	.00				2.48
SUBTOTAL PRODUCT MAN.	.25	1.30	.36	1.31	1.97	.00	.00	.00				5.19
ADMIN, CLER, TECH										14.76		14.76
TOTAL	25.32	12.21	1.51	9.96	14.94	.13	3.25	1.17	14.67	14.76	2.09	100.00

3.11 ALTERNATIVE TECHNOLOGY "FUTURE" OREBODY CHARACTERISTICS

Summarized from Following Cost File 9

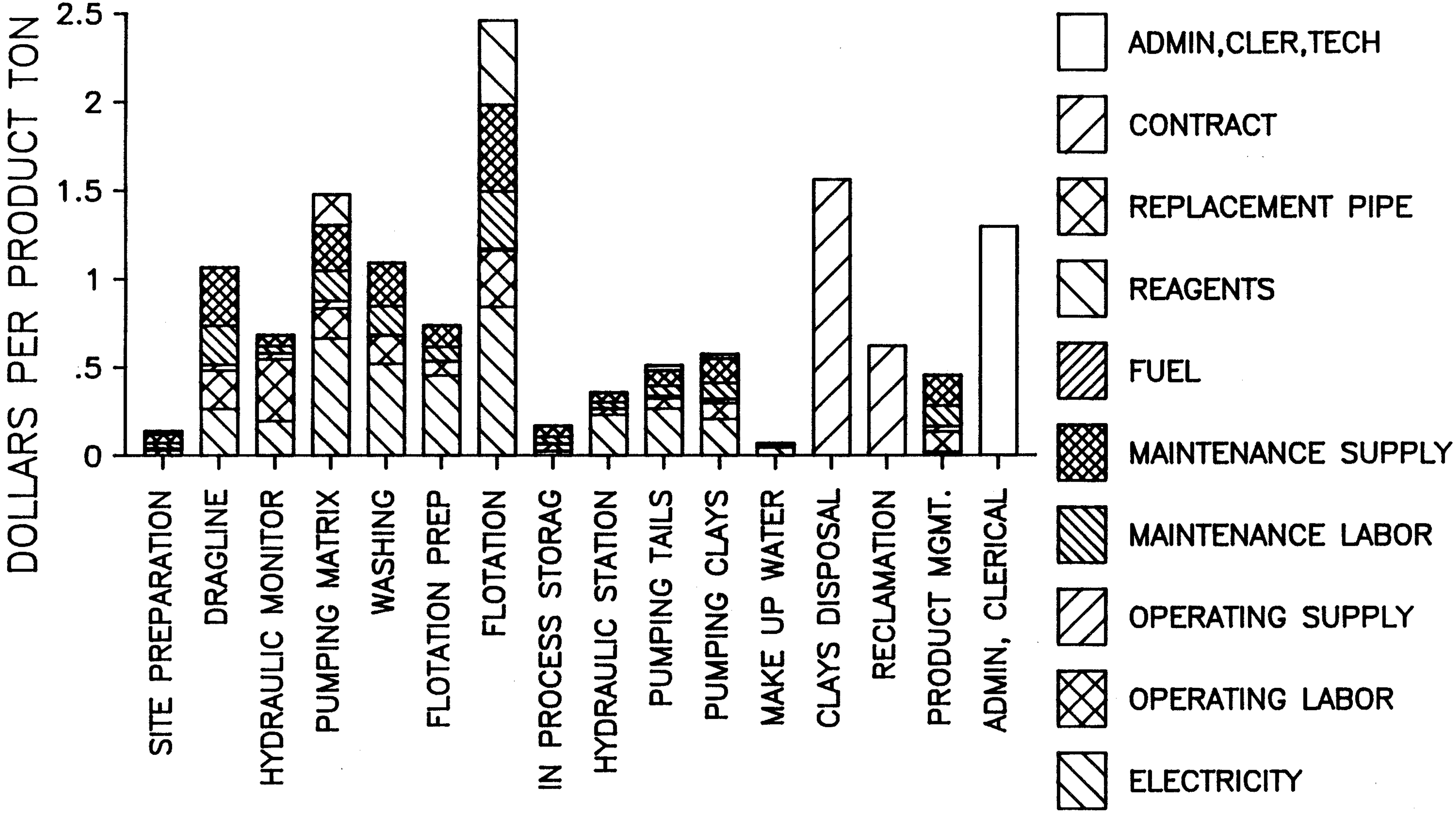
Production (concentrate & pebble)	2.86 million tons per year
Matrix throughput	14.70 million tons per year

Cash Cost, FOB Mine, Wet Rock $/Short Ton

1. Mining	$3.48
2. Beneficiation	4.94
3. Waste disposal, land reclamation and water re-use	3.35
4. Product management	0.46
5. Admin., Clerical, Tech.	1.30
Total Cash Cost	$13.53

ALTERNATIVE TECHNOLOGY "FUTURE" ORE BODY

TOTAL COST BY MODULE



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NEW COST SAVING PROJECTS

REFRSENTS FUTURE ORE BODY

PAGE 1 OF 1

ALTERNATIVE TECHNOLOGY "FUTURE" ORE BODY CHARACTERISTICS

FILE # 9

INPUT FACTORS:		ITEM	UNIT COST $
MATRIX X	3.98	KWH	.045
TOTAL X	11.34	OPERATING LABOR MH	16.000
TONS OF PRODUCT/YEAR	2.86	DIESEL FUEL GAL.	.600
% OF SLIMES IN MATRIX	29.86	A-FATTY ACID #	.080
% OF PEBBLE IN MATRIX	4.70	B-FUEL OIL #	.071
% OF SAND TAILS IN MATRIX	50.66	C-NAOH/NH3 #	.075
% OF FLOT. CON. IN MATRIX	14.78	D-H2SO4 #	.025
MATRIX DRY DENSITY	1.29	E-AMINES #	.240
MATRIX PUMPING DISTANCE	4.50	F-KEROSENE #	.091
SLIMES PUMPING DISTANCE	3.50	18" PIPE FT	
TAILS PUMPING DISTANCE	4.00	(TAILS & MATRIX)	25.000
THICKNESS OF MATRIX	14.50	24" SLIME PIPE FT	38.800
MM GALLONS/YR HYDR.STA.	21000		
MM GALLONS/YR MAKE UP	3570		
MM CYD OVERBURDEN	21.10		
MM CYD MATRIX	11.40		
MM TONS MATRIX	14.71		
MM TONS SLIMES	4.39		
MM TONS SANDS	7.45		
MM TONS PEBBLE	.69		
MM TONS FLOT CON	2.17		
ORE DENSITY WET	1.61		
RATIO OF CONCENTRATION	4.43		
FEET OVERBURDEN	29.17		
ACRES/YEAR	530		
TONS/ACRE	5408		
ACRE FT SLIMES/YEAR	10890		
FLOTATION RECOVERY %	90		
MINE RECOVERY %	92		
PROD.PEBBLE GRADE %BPL	65		
PROD.CON GRADE %BPL	69		
COMP.PROD. GRADE %BPL	68		
FLOT FEED % BPL	17.34		

UNIT CONSUMPTION

MINING (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(a) SITE PREPARATION	ACRE		11.00000	44.00000	11.11000	266.64000	150.00000			
(b) DRAGLINE	CY MOVED	.52000	.00120	.00300	.00121	.02909				
(c) HYDRAULIC MONITOR	TONS MATRIX	.85000	.00427	.00683	.00050	.01200				
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	.64000	.00046	.00184	.00046	.01115				.00030

BENEFICIATION (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT (TON	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(e) WASHER	TONS MATRIX	2.25000	.00195	.00094	.00199	.04774	A-	.30000		
(f) FLOTATION PREP	TONS FLOAT FEED	3.00000	.00148	.00071	.00151	.03623	B-	.37500		
(g) FLOTATION	TONS FLOAT FEED	5.58000	.00594	.00285	.00606	.14541	C-	.12000		
(h) IN PROCESS STORAGE	TONS FLOAT FEED	.18000	.00074	.00036	.00075	.01812	D-	1.30000		
(i) HYDRAULIC STATION	1,000,000 GALLONS	700.00000	.30140	.14467	.30743	7.37827	E-	.17000		
							F-	.10000		

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	.57000	.00035	.00138	.00035	.00836				.00011
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	.86000	.00106	.00424	.00107	.02569				.00012
(l) MAKE UP WATER	1,000,000 GALLONS	850.00000	.30100	.48160	.30401	7.29624				
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES								412.00000	
(n) LAND RECLAMATION	ACRES MINED								3368.00000	

PRODUCT MANAGEMENT (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY KWH/UNIT	OPERATING LABOR MH/UNIT	OPERATING SUPPLY $/UNIT	MAINTENANCE LABOR MH/UNIT	MAINTENANCE SUPPLY $/UNIT	FUEL GALLONS/UNIT	REAGENTS #/UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE FT/UNIT
(o) CONVEYOR	TONS PRODUCT WET	.05350	.00011	.00023	.00011	.00267				
(p) STORAGE	TONS PRODUCT	.22000	.00351	.02022	.00355	.08508				
(q) LOADOUT	TONS PRODUCT	.20000	.00351	.01123	.00355	.08508				

UNIT COST

MINING (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(a) SITE PREPARATION	ACRE		$176,000	$44.000	$177.760	$266.640	$90.000				$754.400
(b) DRAGLINE	CY MOVED	$.023	$.019	$.003	$.019	$.029					$.094
(c) HYDRAULIC MONITOR	TONS MATRIX	$.038	$.068	$.007	$.008	$.012					$.133
(d) SLURRY PUMPING MATRIX	MATRIX TONS-MILE	$.029	$.007	$.002	$.007	$.011				$.008	$.057

BENEFICIATION (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(e) WASHER	TONS MATRIX	$.101	$.031	$.001	$.032	$.048					$.213
(f) FLOTATION PREP	TONS FLOAT FEED	$.135	$.024	$.001	$.024	$.036					$.220
(g) FLOTATION	TONS FLOAT FEED	$.251	$.095	$.003	$.097	$.145		$.142			$.733
(h) IN PROCESS STORAGE	TONS FLOAT FEED	$.008	$.012	$.000	$.012	$.018					$.050
(i) HYDRAULIC STATION	1,000,000 GALLONS	$31.500	$4.822	$.145	$4.919	$7.378					$48.764

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(j) SLURRY PUMPING TAILS	TAILS TON MILE	$.026	$.006	$.001	$.006	$.008				$.003	$.049
(k) SLURRY PUMPING SLIMES	SLIMES TON MILE	$.039	$.017	$.004	$.017	$.026				$.005	$.107
(l) MAKE UP WATER	1,000,000 GALLONS	$38.250	$4.816	$.482	$4.864	$7.296					$55.708
(m) WASTE DISPOSAL SLIMES	ACRE FT SLIMES	$.000	$.000	$.000	$.000	$.000		$.000	$412.000	$.000	$412.000
(n) LAND RECLAMATION	ACRES MINED	$.000	$.000	$.000	$.000	$.000		$.000	$3368.000	$.000	$3368.000

PRODUCT MANAGEMENT (WORK AREA) COST

MODULE	CONSUMABLES UNITS	ELECTRICITY $ PER UNIT	OPERATING LABOR $ PER UNIT	OPERATING SUPPLY $ PER UNIT	MAIN. LABOR $ PER UNIT	MAIN. SUPPLIES $ PER UNIT	FUEL $ PER UNIT	REAGENTS $ PER UNIT	CONTRACT $/UNIT	REPLACEMENT PIPE	TOTAL $ PER UNIT
(o) CONVEYOR	TONS PRODUCT WET	$.002	$.002	$.000	$.002	$.003					$.009
(p) STORAGE	TONS PRODUCT	$.010	$.056	$.020	$.057	$.085					$.228
(q) LOADOUT	TONS PRODUCT	$.009	$.056	$.011	$.057	$.085					$.218

TOTAL OPERATING COST $ PER SHORT TONS

$ PER SHORT TON OF PRODUCT

(WORK AREA)	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAIN LABOR	MAIN SUPPLY	FUEL	REAGENT	REPL. PIPE	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
MINING	$1.127	$.771	$.120	$.466	$.698	$.017	$.000	$.174			$.107	$3.480
BENEFICIATION	$2.075	$.634	$.019	$.647	$.970	$.000	$.477	$.000			$.114	$4.936
WASTE, RECLAIM AND WATER	$.522	$.154	$.038	$.156	$.234	$.000	$.000	$.054	$2.189			$3.347
PROD MANAGEMENT	$.022	$.114	$.032	$.116	$.173	$.000	$.000	$.000				$.457
ADMIN, CLER, TECH										$1.300		$1.300
TOTAL	$3.746	$1.674	$.208	$1.384	$2.076	$.017	$.477	$.228	$2.189	$1.300	$.221	$13.520

% OF (WORK AREA) COST BY MODULE

MINING (WORK AREA) % OF TOTAL

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS	% MINE COSTS
(a) SITE PREPARATION	.00	.96	.24	.97	1.46	.49	.00	.00	4.14
(b) DRAGLINE	7.87	6.46	1.01	6.52	9.78	.00	.00	.00	31.64
(c) HYDRAULIC MONITOR	5.82	10.40	1.04	1.22	1.83	.00	.00	.00	20.30
(d) SLURRY PUMPING MATRIX	19.72	5.04	1.26	5.09	7.64	.00	.00	5.17	43.92
TOTAL	33.41	22.86	3.55	13.80	20.71	.49	.00	5.17	100.00

BENEFICIATION (WORK AREA) % OF TOTAL

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST	% BENEF. COST
(e) WASHER	10.78	3.32	.10	3.39	5.08	.00	.00	.00	22.67
(f) FLOTATION PREP	9.40	1.65	.05	1.68	2.52	.00	.00	.00	15.31
(g) FLOTATION	17.49	6.62	.20	6.75	10.13	.00	9.89	.00	51.09
(h) IN PROCESS STORAGE	.56	.82	.02	.84	1.26	.00	.00	.00	3.52
(i) HYDRAULIC STATION	4.79	.73	.02	.75	1.12	.00	.00	.00	7.41
TOTAL	43.03	13.15	.39	13.41	20.12	.00	9.89	.00	100.00

WASTE DISPOSAL, LAND RECLAMATION AND WATER RE-USE (WORK AREA)

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT	CONTRACT	TOTAL
MODULE	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R. COST	% W.D.,W.R.	% W.D.,W.R.	% W.D.,W.R. COST
(j) SLURRY PUMPING TAILS	7.97	1.72	.43	1.73	2.60	.00	.00	.88		15.33
(k) SLURRY PUMPING SLIMES	6.20	2.72	.68	2.75	4.12	.00	.00	.73		17.20
(l) MAKE UP WATER	1.42	.18	.02	.18	.27	.00	.00	.00		2.07
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	46.79	46.79
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	18.61	18.61
TOTAL	15.60	4.61	1.13	4.66	6.99	.00	.00	1.61	65.40	100.00

PRODUCT MANAGEMENT (WORK AREA) % OF TOTAL COST

CONSUMABLES	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT PIPE	TOTAL
MODULE	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST	% PRD.MAN. COST
(o) CONVEYOR	.62	.45	.06	.46	.69	.00	.00	.00	2.28
(p) STORAGE	2.17	12.30	4.43	12.42	18.63	.00	.00	.00	49.94
(q) LOADOUT	1.97	12.30	2.46	12.42	18.63	.00	.00	.00	47.78
TOTAL	4.76	25.05	6.95	25.30	37.95	.00	.00	.00	100.00

% OF TOTAL COST BY (WORK AREA)

	ELECTRICITY	OPERATING LABOR	OPERATING SUPPLY	MAINTENANCE LABOR	MAINTENANCE SUPPLY	FUEL	REAGENTS	REPLACEMENT	CONTRACT	ADMIN,CLER,TECH	CAP-AMORT	TOTAL
(a) SITE PREPARATION	.00	.24	.06	.24	.36	.12	.00	.00				1.03
(b) DRAGLINE	1.96	1.61	.25	1.63	2.44	.00	.00	.00				7.89
(c) HYDRAULIC MONITOR	1.45	2.59	.26	.30	.46	.00	.00	.00				5.07
(d) SLURRY PUMPING MATRIX	4.92	1.26	.31	1.27	1.91	.00	.00	1.29				10.96
SUBTOTAL MINING	8.34	5.70	.89	3.44	5.17	.12	.00	1.29			.79	25.74
(e) WASHER	3.84	1.18	.04	1.21	1.81	.00	.00	.00				8.09
(f) FLOTATION PREP	3.35	.59	.02	.60	.90	.00	.00	.00				5.46
(g) FLOTATION	6.24	2.36	.07	2.41	3.61	.00	3.53	.00				18.22
(h) IN PROCESS STORAGE	.20	.29	.01	.30	.45	.00	.00	.00				1.25
(i) HYDRAULIC STATION	1.71	.26	.01	.27	.40	.00	.00	.00				2.64
SUBTOTAL BENEFICIATION	15.35	4.69	.14	4.78	7.18	.00	3.53	.00			.84	36.51
(j) SLURRY PUMPING TAILS	1.97	.42	.11	.43	.64	.00	.00	.22				3.79
(k) SLURRY PUMPING SLIMES	1.54	.67	.17	.68	1.02	.00	.00	.18				4.26
(l) MAKE UP WATER	.35	.04	.00	.04	.07	.00	.00	.00				.51
(m) WASTE DISPOSAL SLIMES	.00	.00	.00	.00	.00	.00	.00	.00	11.58			11.58
(n) LAND RECLAMATION	.00	.00	.00	.00	.00	.00	.00	.00	4.61			4.61
SUBTOTAL W.D., L.R. & W.R.	3.86	1.14	.28	1.15	1.73	.00	.00	.40	16.19			24.76
(o) CONVEYOR	.02	.02	.00	.02	.02	.00	.00	.00				.08
(p) STORAGE	.07	.42	.15	.42	.63	.00	.00	.00				1.69
(q) LOADOUT	.07	.42	.08	.42	.63	.00	.00	.00				1.61
SUBTOTAL PRODUCT MAN.	.16	.85	.23	.85	1.28	.00	.00	.00				3.38
												.00
ADMIN, CLER, TECH										9.62		9.62
TOTAL	27.71	12.38	1.54	10.24	15.35	.12	3.53	1.69	16.19	9.62	1.63	100.00

SECTION 4

MINING

4.1 INTRODUCTION

Technology workshop meetings in the area of Mining were held in FIPR's office at Bartow, Florida on July 28, August 25, and October 15, 1987. Meetings commenced at 8:00 a.m. and adjourned at about noon. Each meeting was conducted by the designated ZW Workshop Leader, J.D. Raulerson, assisted by John W. Hughes. Agendas were circulated to attendees to assist in guiding the conduct of each workshop and to stimulate active participation and discussion of all issues.

Participation of workshop attendees was sponsored by respective employers. The following named persons and companies were represented in the Mining Workshops.

Bonnie Dodson, Agrico
Chuck Hammill, Agrico
Al Propp, Mobil
Terry Atchley, Gardinier
Frank Buzzanca, CF Industries
John Previte, Estech
Dave Barnett, Estech
Phong Vo, U.S. Agri-Chemicals
Ed Hafferly, U.S. Agri-Chemicals
Jim Schmidt, IMC
M. L. Hutchins, IMC
Gene Armbrister, W.R. Grace

For purposes of economic evaluation, the mining work area is divided into four modules or unit operations. These are: Site Preparation, Dragline, Hydraulic Monitor, and Matrix Slurry Pumping. Each of these modules is described in Section 3. The unit consumptions used for each are also given.

The tasks of the workshops were to examine the cost components of each module and to suggest ways these costs might be reduced. These suggestions were then transformed into study ideas which were reviewed and modified in following workshops.

The SOTA present orebody case (file 6r) was developed by modifying a Base Case (file 5rr) prepared by ZW prior to the first mining workshop. The modifications to the base case were based on inputs from workshop participants and are intended to represent the best of current practice taken from several mines, as applied to the base case "typical-average" orebody. SOTA "future" orebody case (file 8) was developed in response to workshop participant concern that "present" orebody characteristics did not represent orebodies of the near-term future.

SOTA cases "present" and "future", therefore, are used as the basis to evaluate and measure the economic benefit which can result from the alternative technology concepts proposed for further study. The first two of these were applied to the SOTA cases to generate Alternative Technology cost cases (files 7r and 9).

After candidate studies were screened and ranked, three topics survived and are recommended for further development. The first of these is a study of the hydraulic monitor - matrix pumping system. The second is a study of matrix losses and dilution. The third is separation of dragline from well.

4.2 ANALYSIS OF OPERATING COSTS BY MODULE

Based on the cost module descriptions and the use of indicated factors, items of operating cost for the two SOTA case were calculated. Each of these were examined in the workshops with the following results.

The percent contribution of mining for SOTA "present" orebody characteristics (file 6r) as related to total cost is graphically illustrated on Figure 3.1. The percentage which each module contributes to the Mining Area cost is graphically illustrated on Figure 4.1.

SOTA mining costs for "present" and "future" orebody characteristics are given below in dollars per short ton of product.

Mining Area Modules	SOTA "present" File 6r	SOTA "future" File 8
a) Site preparation	0.10	0.15
b) Dragline	0.82	1.13
c) Hydraulic monitor	0.61	0.91
d) Matrix pumping	0.92	2.05
Total Mining Cost	$2.45	$4.24

According to SOTA cost estimates, mining accounts for 25% of "present" orebody total production cost, and 27% of "future" orebody total production cost.

Alternative Technology mining costs for "present" and "future" orebody characteristics are given below in dollars per short ton of product. These cases were generated to indicate the possible potential for cost improvement of applied alternative technology. The first two of three alternative technology concepts developed in this section were applied to obtain the following costs. Cost reduction potential indicated is the result of alternative technology concepts applied to (1) the hydraulic monitor and matrix pumping system, and (2) reduction of matrix loss and dilution in mining.

Mining Area Modules	Alt.Tech. "present" File 7r	Alt.Tech. "future" File 9
a) Site preparation	0.10	0.14
b) Dragline	0.77	1.10
c) Hydraulic monitor	0.49	0.71
d) Matrix pumping	0.70	1.53
Total Mining Cost	$2.06	$3.48

STATE-OF-THE-ART "PRESENT" ORE BODY

MINING AREA COST BY MODULE

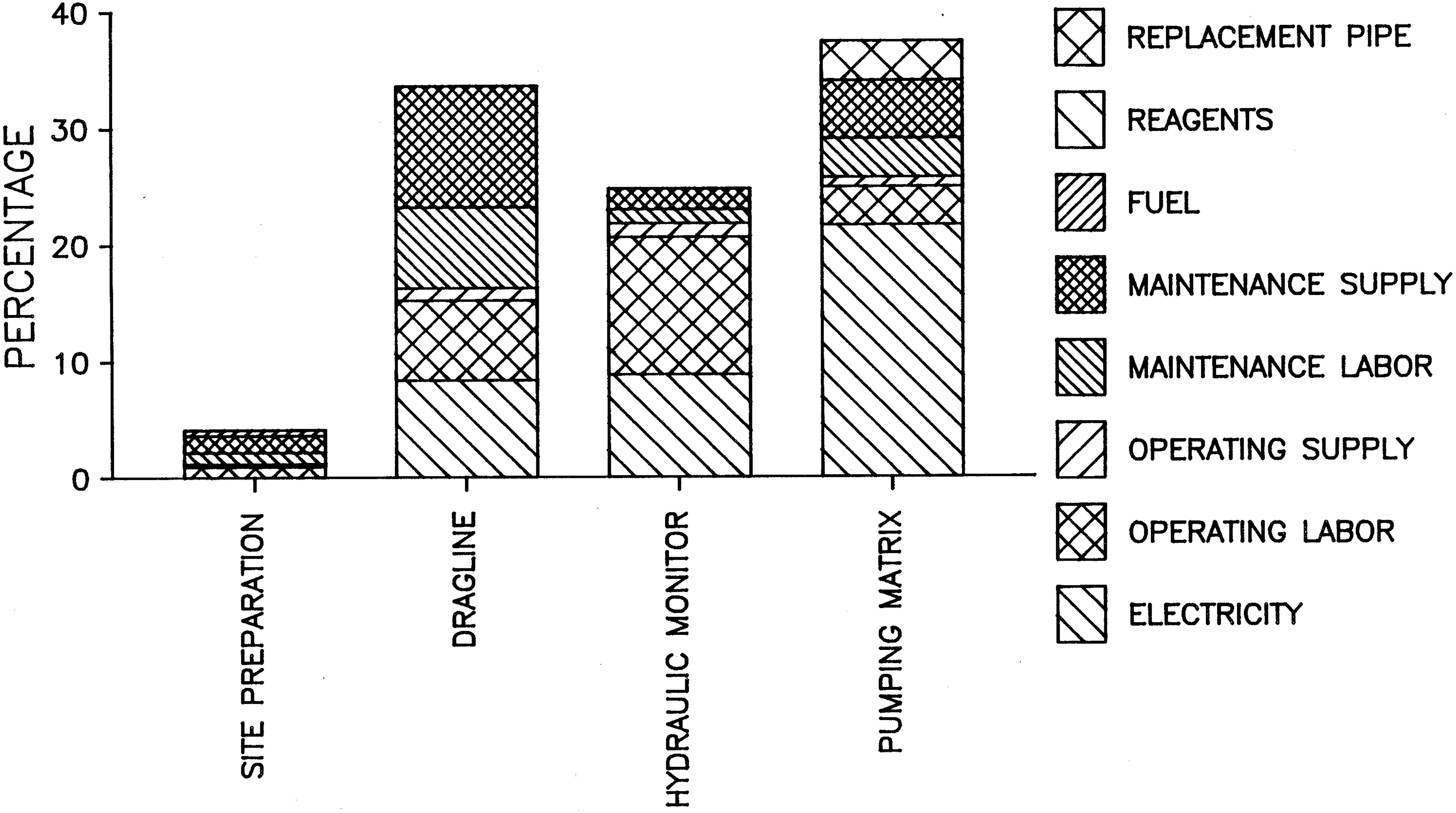


Figure 4-1

The improvements in cost resulting from applying the two alternative technology concepts are not intended to be predictions of costs, but simply to indicate the potential.

According to Alternative Technology production cost cases (files 7r and 9), mining accounts for 23% of "present" prebody total production costs, and 26% of "future" orebody total production cost.

The comparative savings in mining by applying two alternative technology concepts to "present" and "future" orebodies is shown below.

	"Present" Orebody	"Future" Orebody
SOTA (files 6r and 8)	2.45	4.24
Alternative Technology (files 7r and 9)	2.06	3.48
Potential Improvement ($/ton product)	$0.39	$0.76
Percent Improvement	15.9%	17.9%

4.2.1 Site Preparation

While this module shows that its total cost impact is small, there was considerable discussion in the workshop concerning the special case of wetlands dewatering. Dewatering of wetlands is expensive. Methods discussed for dewatering include well point pumping, ditching, and recharge wells. The workshop particpants agreed that wetlands dewatering is a site specific activity and as such a general study would not be useful to most operators. For this reason no attempt was made to formulate a study to make cost improvements in this module's activities.

4.2.2 Dragline

The largest component of dragline operating cost is maintenance supplies. A number of cost saving possibilities were mentioned in the workshops. One was to install a computer-aided system to monitor equipment performance and maintenance history. By facilitating the scheduling of preventive maintenance and component replacement, this computer application offers the possibility for reducing maintenance cost and increasing the operating factor. Computer systems with these capabilities are already being marketed for installation in new draglines. They could probably be adapted to existing machines for some functions.

Another way to reduce cost of maintenance and at the same time improve bucket-load efficiency is by lining the bucket with HDPE or polyurethane. This lining has greater wear resistance and a lower friction factor than steel. The result is lower drag energy, less bucket maintenance and faster, more complete unloading of the bucket. Bucket lining of this type is being used by several Florida operators. While both of these are excellent suggestions, neither requires further development through study.

The next largest dragline cost is electricity. The consensus of the workshop members was that proper planning, management, and operator training could favorably influence energy consumption. However, the dragline is already so efficient that a study would have little potential for improvement of dragline energy cost and is, therefore, not justified.

4.2.3 Hydraulic Monitor

The largest items of hydraulic monitor (water cannon) operating costs are labor and electricity. Most of the labor is used in pit gunning. The thought was expressed in the workshop that operators are expected to make an almost unworkable system perform. If the system can be improved and automated so the operator can concentrate on the primary task of disaggregation, then efficiency can be improved, thereby reducing costs.

Electric energy cost is primarily associated with pumping to supply high pressure gun water. If disaggregation of the matrix can be made more efficient so it uses less and/or lower pressure water, energy needs can be reduced in proportion. Operation of the hydraulic monitor offers much opportunity for improvement and by consensus of workshop participants was selected for study development. The hydraulic monitor is covered in greater detail later in this report.

4.2.4 Pumping Matrix

The largest single item in matrix pumping is the electric energy required to drive slurry pumps. A large reduction is possible if the pit gunning operation can be improved so as to feed the pit pump more uniformly. Since the hydraulic monitor and the matrix pumping units operate as a single interactive system, it was concluded that they should be combined into one study.

4.2.5 Separation of Well from Dragline

Present practice of feeding the well with the dragline makes for a single mining-ore transportation system. Dragline performance, matrix disaggregation, pit pump feeding, and pipeline transportation are interdependent functions. The system is either dragline limited, or pump limited, depending on mining conditions and matrix pumping characteristics. The concept of separating the mining function from the transportation function was the subject of some workshop discussion. Agrico employed this concept in its rail-head matrix transport system with favorable results. Dragline separation was reduced from three shifts (24 hours/day) to two shifts (16 hours/day), while the independent ore transportation function operated three shifts. This concept, if successfully employed, can reduce cost. Cost reduction potential is particularly significant for future orebodies more distant from beneficiation plants. Since this concept has been successfully employed and since the potential for savings is large, it was decided that "separation of well from dragline" be recommended as a topic for further study.

4.3 OTHER SUGGESTIONS FROM WORKSHOPS

4.3.1 Wetlands Mining

A need was expressed for clear regulations which would allow a more rational decision process to determine if wetlands would or would not be profitable to mine. This process would require a more exact definition of wetlands and clear-cut specifications for restoration. Since this concept cuts across the areas being investigated by other workshops the subject is considered under Section 7, Product Management and Mineral Resource Conservation.

4.3.2 Bulldozer Maintenance

It was brought out by certain participants in the second workshop that dozer maintenance is very expensive. Since a large number of dozers are used, this is a major cost item. This expense, as a discrete cost, was not identified.

For both the dragline and dozers, the potential exists to decrease maintenance costs greatly through better planning and management procedures. A study should be done to analyze past expenditures and past maintenance planning procedures. Then, working with suppliers and operating companies, develop a manual for monitoring equipment, maintenance techniques, and maintenance planning. It is difficult to predict possible savings since the effectiveness of present practice has not been evaluated. However, maintenance represents about one-third of total operating cost. Therefore, maintenance study has high potential for success and the risk factor is low.

The control of these kinds of costs is peculiar to each operating company, and such studies are best undertaken by individual operators.

4.3.3 Mechanical Grizzly

The idea of a mechanical powered grizzly has been considered for many years, but never successfully adopted. That, however, does not necessarily mean the idea should be discarded. Improvements in hydraulic drives and other mechanisms may have improved its chance for successful development. Rather than becoming an independent study it appeared to be more reasonable to include its consideration in the scope of the monitor study which is being recommended.

4.3.4 Dragline Modification

A comment from one of the dragline manufacturers and presented at a workshop meeting is that many draglines being used in Florida are no longer well matched with the new conditions under which they are required to operate. In some cases their efficiency could be improved by field modifications such as lengthening the boom or increasing the power of certain functions. Dragline modification could be a helpful idea for some operators, but is so specific it does not meet the criteria for industry-wide study.

4.3.5 Matrix Losses and Dilution

This item of "hidden cost" was discussed during the first workshop. While matrix loss and dilution do not appear as line items in the cost model, detailed analysis revealed them to be significant factors in the overall cost of processing. Since the potential savings were so large and several members of the workshop felt matrix loss and dilution might be controlled if better measured and understood, this item was recommended for study and will be discussed in detail later in the report.

4.4 SCREENING OF SUGGESTIONS

At several levels during the workshop, preliminary cost estimates were prepared and reported. The potential cost savings associated with each of the suggestions, along with other factors, were used to screen the ideas that merited further consideration. The following criteria were used in the screening process:

- Is the concept applicable to most operations?
- Is the concept too expensive to expect a single operator to fund?
- Is the concept in the general area of research and development?
- Is the concept consistent with the FIPR mission?
- What is the risk? How likely is a beneficial result likely to come from the study?

It should be emphasized that because a suggestion might not pass this screening, does not mean it is a "bad" idea. It might be very useful to an individual operator.

As a final result of the workshop effort and this screening process, the following three concepts were selected to be recommended for further studies.

1. Hydraulic Monitor and Matrix Pumping.
2. Matrix Losses and Dilution
3. Separation of Well from Dragline.

4.5 PROPOSED ALTERNATIVE TECHNOLOGY STUDIES

4.5.1 Hydraulic Monitor and Matrix Pumping

The hydraulic monitor and matrix pumping are interrelated and form one potential study.

1) Problem Definition

The two major cost components of the hydraulic monitor are operating labor and electricity. Most of the electric energy is used to pump water at high pressure to the pit guns. This energy is not used very effeciently to break-up matrix into a slurry due to the nature of the system.

The primary need for high pressure water is to disaggregate the matrix. However, the gunning operation, in doing this, uses hydraulic energy very inefficiently.

Water from the hydraulic monitor is used to:

- o disaggregate the matrix,
- o convey matrix by drift to the pit pump suction,
- o help clear the grizzly of rocks and roots,
- o dilute the slurry for pumping,
- o feed matrix to the pit pump suction.

- o In the most generally used well configuration the low angle of the gun stream does not allow the matrix on the pile to be effectively contained. Since it has no back stop to hold it in place while the jet impacts the matrix, a large part of the energy is wasted rolling lumps and stirring material.

- o Hydraulic energy is dissipated striking water pooled at the point of impact.

- o As the distance from the gun to impact increases, the jet feathers, and its velocity decreases with loss in useful energy.

- o The amount of energy required for disaggregation varies widely with the type of matrix, but the system energy is constant regardless of need.

In well type I (see Figure 4.2) transport of the matrix slurry to the pit pump suction is by gravity flow over a wide area with a low slope. Therefore, slurry transport velocities in the well are low and inefficient. These conditions also result in other problems:

- The guns are frequently required to keep the matrix moving uniformly. The gun jet is in a direction opposite to slurry drift. This operation wastes hydraulic energy and reduces the availability of gun water for use in disaggregation.

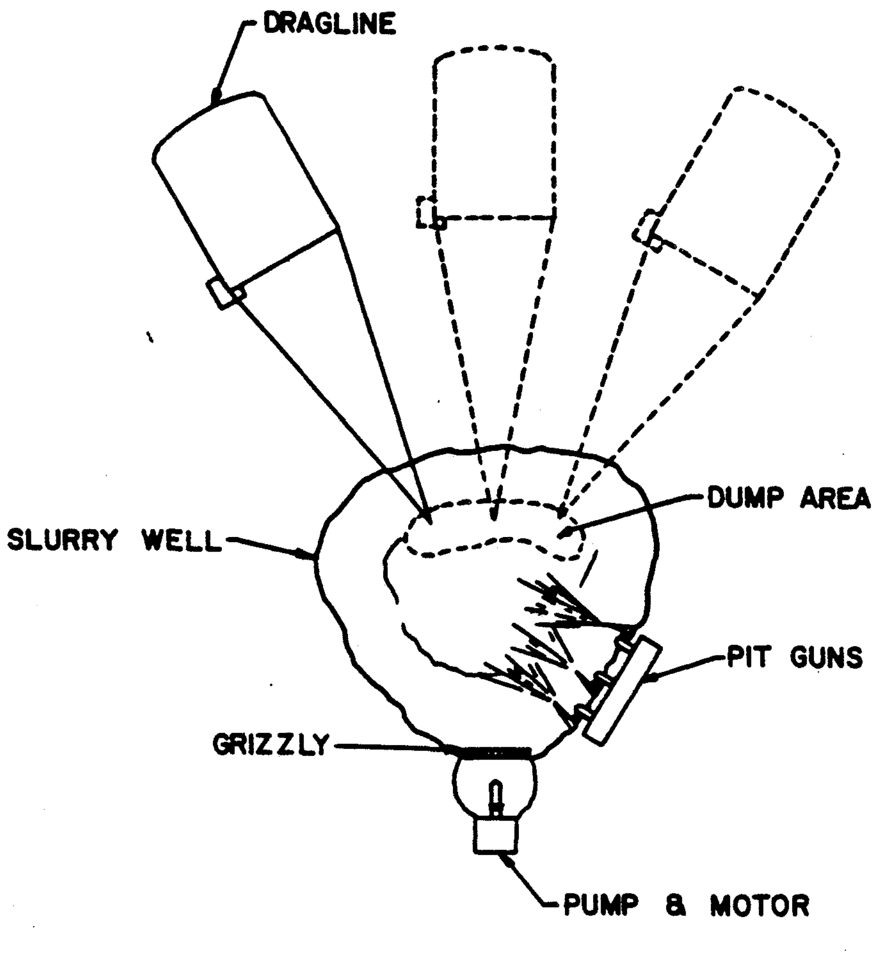
- Since the drift velocity is low, larger solid particles settle out rapidly. The result is a highly variable feed to the pit pump, both in mass flow and size distribution.

The type II slurry well shown on figure 4.3 is used at one mining operation. This configuration, while effective at one mine, is not a good application at other mines.

The single large disadvantage of the type II well is that the dragline dump target is smaller, which limits the dragline freedom. A secondary disadvantage is that a small dragline must be made available occasionally to remove rocks from the grizzly.

- Extreme variations in the pump feed density makes it necessary to pump at a higher than optimum line velocity in order to prevent pump cavitation and choking of the line. This excess safety factor is a large contributor to the electrical cost of matrix pumping.

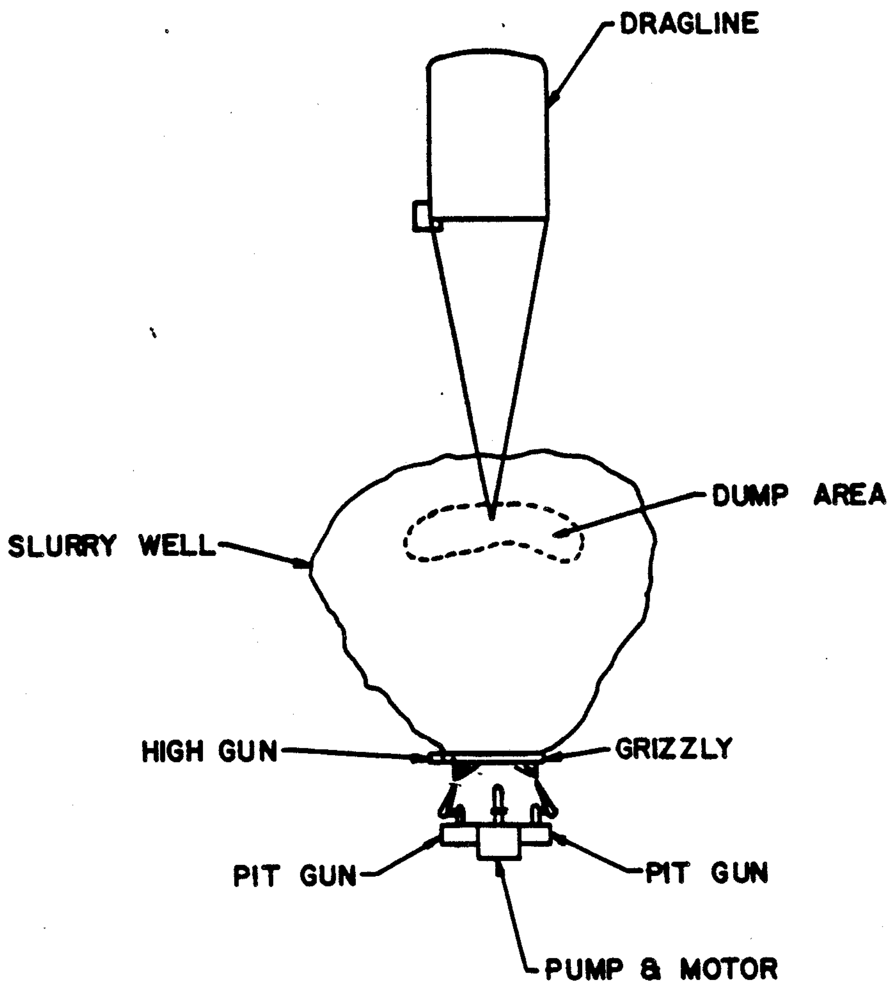
The obvious way to reduce energy use in a slurry pumping system is to optimize the slurry density and line velocity. Pumping conditions are determined by the limited ability of the operator to feed the pump uniformly. The other limiting factor is the low NPSH on the pit pump suction. Together they limit the pumping variables to values that have been found to safely avoid choking the matrix line.



PLAN OF SLURRY WELL

TYPE I

Figure 4-2



PLAN OF SLURRY WELL

TYPE II

Figure 4-3

2) Study Objective

Reduction of cost in the operation of the system which transports matrix from the mine to the beneficiation plant is a simplified statement of the objective of any study of this subject.

It is recognized that the functions which make up this sytem have been the subject of considerable investigation and trial and error field modification by phosphate rock producers. A relatively efficient system has evolved. The cost of these functions, however, remain a significant part of mining cost, and therefore offer opportunity for improvement. The hydraulic monitor and matrix pumping systems together represent about 65% of mining cost.

Current practice results in pumping at about 35% solids (30% average) at 16-18 feet per second pipeline velocity. If optimum conditions could be attained, pumping power would be cut to about 40% of current practice. In order to move toward a more efficient system, the monitor and pit pump will have to be modified to:

- o Improve the disaggregation efficiency so the matrix can be slurried with about half the water used for 35% pumping.
- o Decrease drift distance and increase slope.
- o Provide real time information for the gun operator so the pit pump can be fed consistently.
- o Provide a higher NSPH to the pit pump suction.
- o Change the pit pump to a lower head pump with better suction characteristics.

With this system the matrix can be disaggregated and fed uniformly enough so that an average of 45% solids can be pumped with a corresponding 10% reduction in pipeline velocity.

A FIPR-funded study by GIW Industries, Inc. is in progress. One result from this study will be the development of design factors for pumping several different classes of matrix at higher solids and lower velocity. This information should demonstrate an optimum pumping density and solids for each class of matrix. These optimums ought to become the goal of any future study. The current pit monitor design, if modified, might be able to deliver 50%-55% solids by weight to the pump suction. If densities greater than 55% are required, a whole new system for feeding matrix to the pit pump suction will have to be developed.

3) Problem Analysis/Solution Scenarios

- o Observe well operation at several existing mines to determine the factors that influence operating results.
- o Develop an improved monitor and well configuration.
- o Field test the improved monitor and well configuration and optimize the overall system, including the dragline and pumping systems.
- o Determine how the pumping system should be modified to gain maximum savings in the light of improved well operation.

The monitor and well operation is a complex system which must accomplish several interrelated functions.

- o Disaggregation of the matrix.
- o Drifting of matrix to pit pump suction.
- o Separation and removal of tramp rocks and other material.
- o Feeding pit pump with slurry at constant rate and density.

The first phase is field observation of several pits to evaluate how each of the above functions is accomplished and how they interact. This observation should also lead to a better understanding of the overall system operation and the relative importance of the factors that influence each function. In addition, the interaction of the well operations with the dragline and matrix pumping system will be observed and analyzed.

From the information collected, it should be possible to arrange a more efficient well configuration and operation. This may include new instrumentation and mechanisms. Among the factors to be considered are well orientation and shape, placement and height of guns, drift slope and channel, depth of suction well, elevation of pit pump, type of pit pump, grizzly design (including a powered grizzly) and location, and possible use of double side well.

In order to estimate the economic potential and risk, an assumed configuration or system has to be developed from the best available knowledge, suggestions, and experience.

Field tests will be run with the improved configuration which can be modified as required to achieve optimum layout and operating conditions. The effects on dragline operation and matrix pumping are a highly important consideration in this optimization.

As improved pit pump suction feed density and more uniform flow rate are accomplished, then the matrix pumping system can be redesigned to reduce pumping energy and manpower while maintaining an adequate factor of safety to prevent line choking. Improved instrumentation and controls will be required to accomplish these results. Information being developed in the current FIPR-GIW study should be highly useful in arriving at the optimum pumping conditions at a higher density and lower velocity than is currently practiced. This study will investigate pumping at up to 55% solids.

The condition of providing the pit operator with real time information can be accommodated with a slurry density measuring instrument located close to the pit car. Pipeline booster pump power levels can be transmitted to the gun car for control of the pump system with the assistance of a micro-processor.

4) Potential Results

Hydraulic monitor system performance could be improved if one or more of the following changes could be applied:

- Increase disaggregation efficiency by reducing the gunning distance.

- o Provide a back-up to contain the matrix at point of impact.
- o Provide for rapid removal of water and slurry from the impact point.
- o Decrease the drift distance.
- o Increase the drift slope.
- o Decrease the width of the drift area to increase velocity.
- o Reduce the drift channel drag.
- o Improve the gunning angle to impact the pile 90 degrees from the pile slope in both horizontal and vertical direction.
- o Provide the monitor operators with real time information on their performance.
- o Improve the pit pump suction conditions and the pump suction characteristics.

In discussing the type II well, it became obvious that if one or two alternate guns were mounted high above the grizzly, a high bank of matrix could be deposited over a wider area by the dragline and could be cut down into the grizzly by intermittent use of the high mounted guns. This arrangement would allow the dragline more freedom while the matrix could still be made available to the grizzly face. Final clean up of the well would be done by dozer pushing the matrix into range of the guns. In effect, this assumed layout would be something between the type I and type II wells with most of the advantages of both.

Improvement of the pit pump suction condition can be accomplished by using a lower head, lower profile pit pump mounted low in a car with metal sides to keep water out. The pit pump suction would be at ground elevation. A further improvement could be an automatic control on the pit pump suction pipe height to maintain a constant pumping density.

5) Cost Analysis

The final result should be a much better understanding of a very old and important, but little studied system. This enhanced understanding has the potential to result in an improved system which will achieve a large saving in pumping costs. As matrix lines are extended more than three miles from the washer, savings will be even greater. See Appendix 4-1, page 4-35, for discussion and calculation details.

Capital Cost	$ 550,000
Savings - Annual	1,103,000
Added Operating Cost	90,000
Net Annual Savings	1,013,000
Risk Low	

(Based on SOTA "present" case.")

6) Risk Analysis

The assumed configuration is so close to the commonly employed type II well that there is very little risk. CF is using this type well and reports an average of 40% solids. With improvements in instrumentation and the high guns, pumping 45% is not a high risk assumption. The only question is how much the high, alternate guns will increase the dragline dump area. During times when production is dragline limited, there will be some loss in production. If, for a particular operation, this is a serious problem, then the assumed configuration may not be suitable. The study need not be limited to the assumed solution, so it is possible that a better configuration could be developed.

The assumed condition represents almost no risk. With improved suction conditions, complete automatic control, and more uniform feeding from an improved monitor, pumping at 45% solids and 10% lower velocity can be accomplished with very low risk.

Considering the monitor and matrix pumping together as a single study, the assumed system still has an overall low risk of not being able to attain the expected cost reduction. After more prolonged investigation and field trials, and with the results of the FIPR-GIW matrix pumping study available, there is reason to believe an even better end result may be attained.

4.5.2 Losses and Dilution

1) Problem Definition

In the usual Florida operation a large dragline removes the overburden and casts it across to the other side of the cut. This leaves the matrix exposed so it can be mined up by the same dragline and deposited in the "well" on the bank away from the cut.

The primary problem is that the interface between the overburden and matrix is not clearly defined. In addition, the elevation of the interface changes as the cut progresses. To complicate the problem, the dragline operator is sitting in a cab 40 to 100 feed from the bucket lip as he tries to detect and follow the overburden-matrix interface. He may have clues from some differences in color, or texture, but these are not usually clear cut and many times are unreliable. Operation at night under artificial light becomes even more difficult.

Secondary problems are excessive overburden depth for the dragline being used. This condition makes it impossible for the operator to cast the overburden far enough to keep it clear of the matrix toe. Excess water in the pit or at the interface is common and can cause matrix losses, or dilution, from sloughing of overburden onto the exposed matrix.

2) Study Objectives

- o Determine how to measure matrix losses and dilution.
- o Measure the magnitude of losses and dilution in several operating mines. Isolate the factors that influence losses and dilution.
- o Investigate means for reducing losses. Search for new equipment and methods that might improve operations.

- o Conduct field trials of new procedures and equipment.
- o Develop a comprehensive program for reduction of losses which could be applied to any pit operation.

3) Problem Analysis/Solution Scenarios

Matrix losses and dilution can be directly interrelated. If the overburden is not cut deep, losses will be reduced, but dilution is increased. The optimum cut-off point requires careful physical and economic analysis and many times is difficult to determine even for an experienced geologist. To expect a dragline operator to make this determination in the middle of the night is simply not reasonable.

The problem then becomes, how to to obtain the information necessary for an evaluation? Who is to make the evaluation? How to transmit this information to the dragline operator? How can he use this information to position the bucket at the optimum elevation?

The workshop examined each of these questions. Suggestions included additional prospecting, better correlation of prospect and pit conditions, a computerized range finder to determine the pit elevation, better lighting, and a laser light marker for the top of matrix. The suggestion with the most support was to have an experienced, properly equipped geologist at the pit on all shifts.

There was agreement that since matrix losses and dilution do not appear as a readily identifiable cost, their importance is underestimated. In addition, these losses are difficult to measure and the true cost of dilution may not be appreciated because it carries over into beneficiation and processing. The workshop concluded that the subject of matrix losses and dilution should be recommended for further study.

In order to estimate the economic potential and risk, an assumed configuration or system has to be developed from the best available knowledge, suggestions and experience. The assumed conditions for matrix losses and dilution are not as easily defined in detail as are conditions for the monitor and pumping study. Since, for matrix losses and dilution, the problem is not clearly defined, this study will investigate the true nature and magnitude of the problem. Only then can the direction and form of the improvements be defined.

From workshop discussion and suggestions, the assumed solution evolved around additional, experienced geologists at the pit. These people could accumulate useful information, evaluate its significance and communicate the results to the dragline operator at a time and in a form which would allow him to position the dragline bucket at the optimum level of the overburden matrix interface.

4) Potential Study Results

Since matrix losses and dilution are largely hidden costs, little has been done to adopt standard methods to measure them. Therefore, the first, rather complex task, will be to develop effective ways to measure the magnitude of these losses. A first approach to this would be to collect, analyze, and correlate data from prospecting, production, geological observation, field sampling, dragline operation, and plant feed.

- After a workable procedure for measurement has been developed, it can be used to determine the actual magnitude of losses and dilution in operating mines. At the same time, it should be possible to isolate the primary factors that influence these losses.

- Having measured the extent of losses, and isolated the factors that influence them, it should be possible to develop methods and equipment which will effect some degree of reduction of losses. Dilution is such a large contributor to cost that even a small percentage reduction would have a major impact on mining and beneficiation costs.

A number of activities will have to be included in this investigation. Among these are; the use of geologists and their training of other operating personnel, the evaluation of current prospecting techniques and practice, possible modification of prospect frequency; processing ahead of dragline operation, and finally, the interpretation and communication of prospect data and actual bank information to the dragline operators in a timely and useful form.

- o The newly developed procedures will have to be field tested over an extended period of time to evaluate and improve their ability to reduce costs. See Appendix 4.2, page 4-36, for discussion and calculation details.

- o The final product will be a comprehensive set of recommendations which will allow operating mines to institute better practices that can result in major savings.

5) Cost Analysis

Capital Cost	$250,000
Savings - Annual	685,000
Added Operating Cost	166,000
Net Annual Savings	519,000
Risk	Moderate

6) Risk Analysis

The potential savings from a study of matrix losses and dilution are not easily quantified. However, the risk is one of degree rather than total success or failure. To date, mining losses and dilution have not been well defined or measured. The reason is that the associated costs are so "hidden" and spread through the process that over the years they have simply come to be accepted as not subject to control, and hence ignored.

Better information can be developed by more extensive geological and economic investigation and analysis. This information can be made available to the dragline operator ahead of and during actual excavation. However, there are limits to the dragline operator's ability to make a sharp separation of the components, but this may also be subject to improvement. The assumption that the dragline operator can effect a 20% reduction in matrix losses and dilution is assigned a somewhat arbitrary intermediate degree of risk. However, even if only a 10% reduction occurs, the effort would be cost effective.

4.5.3 Separation of Dragline and Well

1) Problem Definition

The SOTA "present" orebody characteristics (file 6r) cost model shows that electrical energy is 39% of mining costs, and 10% of total phosphate rock operating costs. Electrical energy is by far the largest mining cost. With this target area defined, separation of the dragline and well was suggested as a potential alternative system.

2) Study Objectives:

Obviously the incentives must be economic. Economic incentives from dragline/well separation are:

- o lower operating costs,
- o improved operating efficiency,
- o improved systems efficiency.

3) Problem Analysis

Mining starts with site preparation and is followed by overburden removal. These functions are identical for the SOTA cases and for the dragline/well separation system.

Functional analysis reveals 4 distinct matrix mining operations:

- o dig matrix,
- o unload matrix,
- o disaggregate matrix/separate from rocks
- o transport matrix.

Dig matrix and unload matrix

Presently matrix is mined with a dragline which operates from a level spot above the pit bank. Matrix from the mine pit cut is mined by the dragline bucket and hoisted to the matrix well where it is dumped. The dragline boom reverses direction, swings over the pit cut and the bucket is lowered onto the matrix in one continuous motion. The mining cycle is now complete and the dragline begins digging again.

Matrix well locations determine dragline bucket dumping points. Operators minimize well movement because moves interrupt production, and therefore are costly. Moves are necessary when dragline reach is insufficient to unload matrix at the well.

Figure 4.4 shows a typical dragline pit. Swing angle averages 77° to the matrix well, with a minimum of 45° and a maximum of 130°. With the dragline and well separated, the digging matrix operation is identical, but matrix is unloaded in windrows near the slope crest on top of the bank at grade. The swing angle is 52° and varies only slightly.

Separation of dragline/well results in a smaller swing angle and higher operating factor. A smaller swing angle means less distance moving matrix, which results in lower electricity consumption. A smaller swing angle also results in a lower cycle time. A lower cycle time results in one or a combination of four possibilities:

- o greater matrix production from dragline,
- o less dragline operating hours,
- o dragline used for reclamation,
- o smaller size dragline required.

A higher operating factor results from separating the inter-related dependence of dragline, slurry well and hydraulic transportation. For example, if the dragline is available 85% of the time and

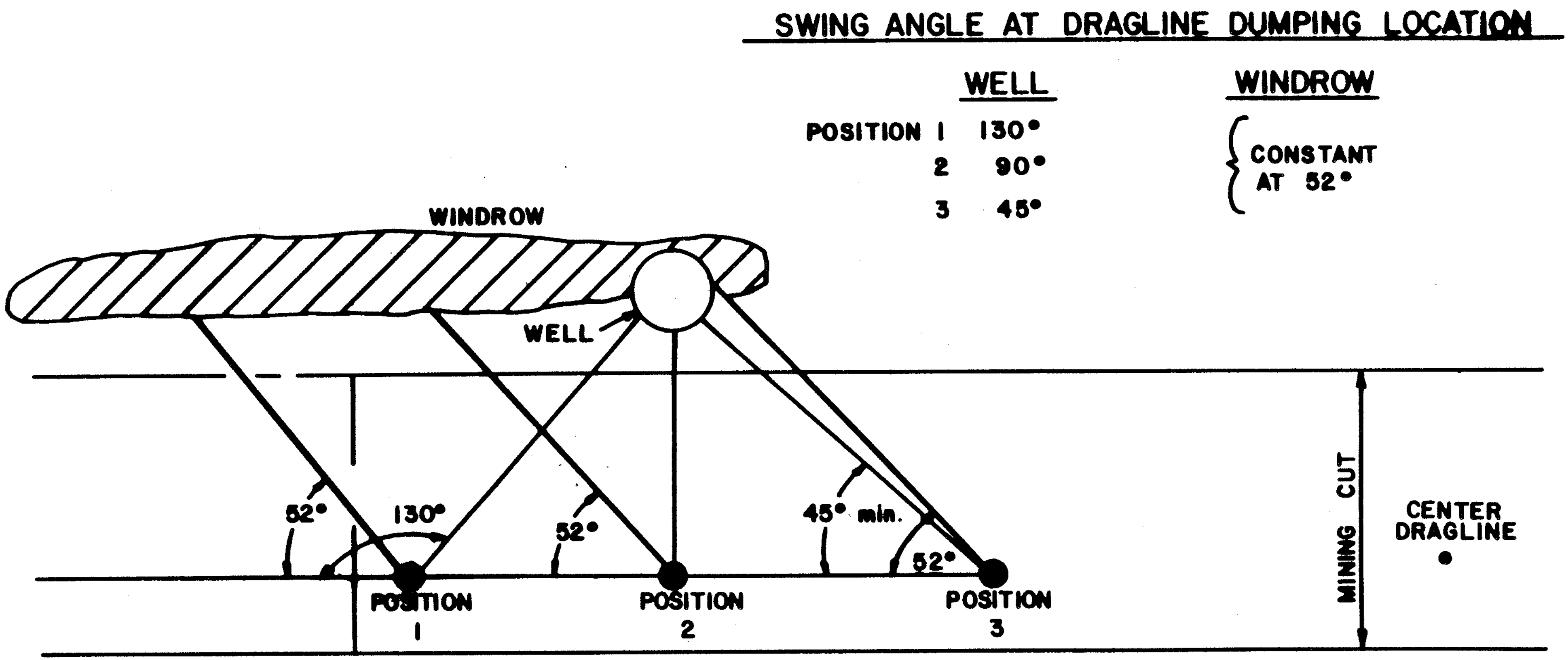


FIGURE 4-4

COMPARISON OF DRAGLINE SWING ANGLES, TO WELL, WINDROW typical pumping systems operate only 70% of the time, some time is wasted. By removing dependence, a 9% higher operating factor is possible. The results are:

- o greater matrix production from dragline,
- o dragline used for reclamation,
- o smaller size dragline required.

Disaggregation

Disaggregation currently takes place in the well. When the dragline unloads matrix in windrows, that matrix must be reloaded and hauled to a place where disaggregation and separation of rocks can occur. Several concepts for accomplishing this are possible. Detailed analysis is beyond the scope of this project. One possibility is a Holland-type loader with a built-in mechanical feeder/breaker. This unit can be mounted on a mobile crawler track-mounted type machine which is powered by two diesel engines. Matrix would be loaded onto a feeder by a mechanical device using arms, a plow scraper, bucket wheels, or a bucket mechanism of some type. The feeder portion of this machine feeds a mechanical crushing device. This device would be shaft driven with picks mounted on a rotary driven cylinder. Spacing and angle of these picks would be designed to break mud balls. Large "unbreakable" rocks would be forced downward over a mechanical grizzly device to retain smaller material. Larger unbreakable rocks would pass through a chute and be rejected. The size openings and pressure release of the cylinder would be calibrated to permit clayballs to be compressed, but would open for higher strength rocks allowing them to be rejected. Several stages of size breaking may be required.

This device does not exist as described at present. Development work will be required. One manufacturer of feed-breakers employed in similar applications has expressed interest in participating in such development work.

A second possibility is to use a standard feeder breaker to screen material and break up materials. A vibrating grizzly installed in front of the feeder breaker can control oversize rocks and pass undersize. This feeder breaker will be fed by a choice of loading equipment. Possibilities are front end wheel loaders, front end crawler loaders, front end hydraulic shovels, bucket wheel and dozers.

The feeder breaker replaces the hydraulic pit monitors presently in use. Currently the hydraulic monitor uses high pressure water to disaggregate matrix and to move (drift) it into the pumping intake well.

The results of dragline/well separation for matrix disaggregation are:

- o additional capital cost, plus operating cost for loading-transport equipment from windrow to breaker,
- o additional capital, plus operating cost of the breaker,
- o savings in capital and operating cost for high pressure monitors and pumping systems,
- o separating the disaggregation unit from the matrix loading unit means the disaggregation unit is not down when the dragline is down, resulting in a higher operating factor.

<u>Transportation of matrix</u>

Presently the pit monitor drifts matrix to a well that serves as an intake for matrix pumping. Matrix is pumped at about 30% solids depending upon the toughness of the matrix. A typical system consists of a 18-inch pipeline and 1200 HP pumps moving matrix at about 15 fps. Booster pumps are added along the pipeline as required.

Most slurries can be efficiently pumped at 45% solids and above. The reason slurry is not pumped at 45% solid today is that the need to disaggregate and drift matrix requires more water than matrix pumping does. By disaggregating the matrix before placing it in the well, the well's only function is matrix pumping. Low pressure water can be added to obtain a 45% average solid content for pumping. The following table shows the theoretical energy required to pump 1 ton of matrix one mile level at different percent solids.

Theoretical Energy for One Mile Slurry Transport

% Solids	Tons Matrix	Tons H_2O	Total Ton	KWH Pump Effic. 65%	KWH Pump Effic. 70%
20	1.00	4.00	5.00	1.59	1.48
25	1.00	3.00	4.00	1.27	1.18
30	1.00	2.33	3.33	1.06	.99
35	1.00	1.86	2.86	.91	.84
40	1.00	1.50	2.50	.79	.74
45	1.00	1.22	2.22	.71	.64
50	1.00	1.00	2.00	.64	.59

In addition, the efficiency is further increased since with a more predictable system a higher pump/motor efficiency is achieved. The table above shows the KWH for each percent solids with each pump efficiency of a 65% and 70%.

Another advantage is that with a higher percent solids and the same velocity, a smaller pipe is required. The table below shows the pipe size required for percent solids based on 1000 tph at 15 fps (solids density of 168 lbs/ft^3, spec.grav. 2.7).

Pipe Size for 1000 TPH @ 15 FPS for Different % Solids

% Solids	Volume Solids ft^3	Volume H_2O	Total Volume	Nominal Dia.
20	11,900	128,000	139,000	22"
25	11,900	96,000	115,000	20"
30	11,900	75,000	87,000	17"
35	11,900	60,000	72,000	16"
40	11,900	48,000	60,000	14"
45	11,900	39,000	51,000	13"
50	11,900	32,000	43,000	12"

Matrix need not be transported by pipeline. Alternate transportation systems that could be considered include conveyor belt, railroad, scrapers, and trucks.

Railroad systems have been considered for several phosphate operations. One such railroad system was successfully employed by a Florida operator for transporting matrix. Generally, railroads are more suited for long regular mining cuts of a duration of two months or more. After each cut the dragline is deadheaded. Matrix is mined by dragline and stacked on the bank as described earlier. Front end loaders load rail cars which are transported to a dump station where disaggregation and separation of rocks occurs. Either the conventional pit or new equipment described here can be used for breaking. Problems associated with rail are weather, good footing conditions, operating in non-uniform cuts or in swampy areas, and operating in non-level terrain. These, however, can be overcome by good planning and site preparation work.

Rubber tired trucks can also be used for transportation. Weather problems, non-uniform cuts and background conditions must also be overcome, but the trucks are more flexible than railroads. The same comment applies to scrapers. At longer distances, over 3 miles, scrapers historically are much higher cost than loader/trucks.

The conveyor belt system could also be used in connection with any of the loading equipment mentioned earlier. Hoppers above the conveyor belts with apron feeder could load the conveyor belt. Hoppers could be moved as required along the feeder belts. Conveyors show cost cutting potential since the electrical consumption in kwh/ton mile is about .28 compared with 1.08 for slurry pumping.

Success of this system depends as much on the ability of the loading machine to feed the conveyor as with the conveyor itself. Wet material, poor ground conditions and irregular cuts are factors that may limit applicability.

Figure 4.5 shows the functions and how they are performed by the present system and by the proposed system. The results of the proposed system leading to beneficial cost or production effects is also listed. Possible equipment is listed, but this is not meant to be an all-inclusive list. For example, dozers may be used to push matrix to a well location. A well with a mechanical grizzly might also be considered instead of a feeder breaker. Other solutions to solve the disaggregation/transportation problem may also exist.

4) Potential Study Results

A more detailed analysis must be done to determine which possible systems have the best chance of technical and economic success. After a system has been selected, field testing is necessary. Savings of $1,765,000 in operating cost and $4,000,000 in new capital costs are possible. The new capital cost savings result from a 27% smaller bucket dragline doing equivalent production as the larger dragline. Estimated calculations are given in Appendix 4-3.

5) Cost Analysis

To get an idea of the potential savings, a system was selected and briefly studied. This system uses front end wheel loaders to load matrix from windrows to feeder breakers, then low pressure water to prepare a high percent solids slurry for pumping to the beneficiation plant.

Results of this study show a potential annual savings of $1,052,000 for a three-mile matrix transportation distance applicable to the SOTA "present" orebodies case. For a six-mile matrix transportation distance the annual savings potential increase to $1,765,000

In addition to these savings, the dragline requires 27% less operating time - 18% from reduced swing angle and 9% from increased availability.

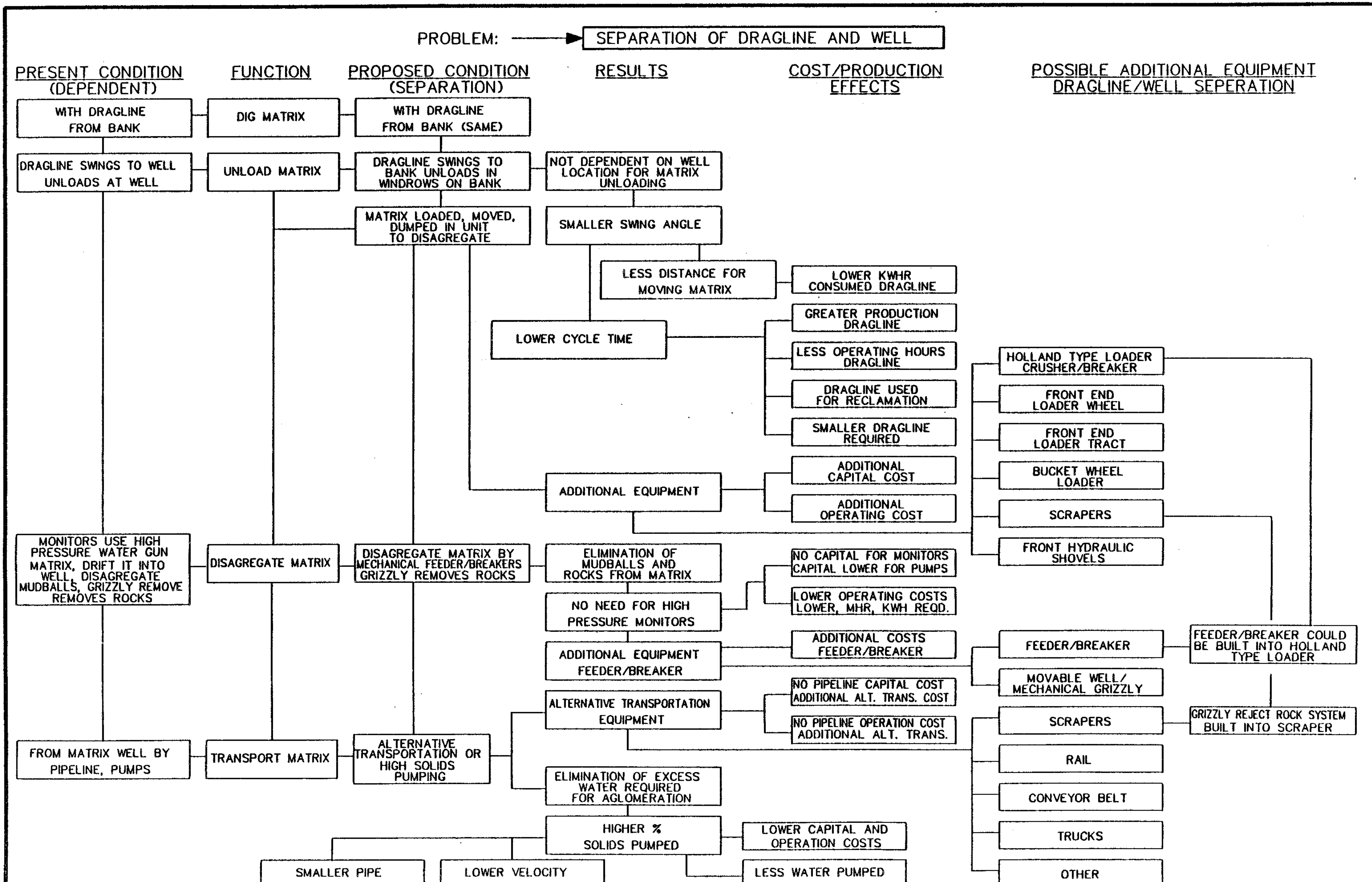

PROBLEM:
SEPARATION OF DRAGLINE AND WELL
PRESENT CONDITION (DEPENDENT)
FUNCTION
PROPOSED CONDITION (SEPARATION)
RESULTS
COST/PRODUCTION EFFECTS
POSSIBLE ADDITIONAL EQUIPMENT DRAGLINE/WELL SEPERATION
WITH DRAGLINE FROM BANK
DIG MATRIX
WITH DRAGLINE FROM BANK (SAME)
DRAGLINE SWINGS TO WELL UNLOADS AT WELL
UNLOAD MATRIX
DRAGLINE SWINGS TO BANK UNLOADS IN WINDROWS ON BANK
NOT DEPENDENT ON WELL LOCATION FOR MATRIX UNLOADING
MATRIX LOADED, MOVED, DUMPED IN UNIT TO DISAGREGATE
SMALLER SWING ANGLE
LESS DISTANCE FOR MOVING MATRIX
LOWER KWHR CONSUMED DRAGLINE
LOWER CYCLE TIME
GREATER PRODUCTION DRAGLINE
LESS OPERATING HOURS DRAGLINE
DRAGLINE USED FOR RECLAMATION
SMALLER DRAGLINE REQUIRED
HOLLAND TYPE LOADER CRUSHER/BREAKER
FRONT END LOADER WHEEL
FRONT END LOADER TRACT
BUCKET WHEEL LOADER
SCRAPERS
FRONT HYDRAULIC SHOVELS
ADDITIONAL EQUIPMENT
ADDITIONAL CAPITAL COST
ADDITIONAL OPERATING COST
MONITORS USE HIGH PRESSURE WATER GUN MATRIX, DRIFT IT INTO WELL, DISAGREGATE MUDBALLS, GRIZZLY REMOVE REMOVES ROCKS
DISAGREGATE MATRIX
DISAGREGATE MATRIX BY MECHANICAL FEEDER/BREAKERS GRIZZLY REMOVES ROCKS
ELIMINATION OF MUDBALLS AND ROCKS FROM MATRIX
NO CAPITAL FOR MONITORS CAPITAL LOWER FOR PUMPS
NO NEED FOR HIGH PRESSURE MONITORS
LOWER OPERATING COSTS LOWER, MHR, KWH REQD.
ADDITIONAL EQUIPMENT FEEDER/BREAKER
ADDITIONAL COSTS FEEDER/BREAKER
FEEDER/BREAKER
FEEDER/BREAKER COULD BE BUILT INTO HOLLAND TYPE LOADER
MOVABLE WELL/ MECHANICAL GRIZZLY
ALTERNATIVE TRANSPORTATION EQUIPMENT
NO PIPELINE CAPITAL COST ADDITIONAL ALT. TRANS. COST
NO PIPELINE OPERATION COST ADDITIONAL ALT. TRANS.
SCRAPERS
GRIZZLY REJECT ROCK SYSTEM BUILT INTO SCRAPER
FROM MATRIX WELL BY PIPELINE, PUMPS
TRANSPORT MATRIX
ALTERNATIVE TRANSPORTATION OR HIGH SOLIDS PUMPING
RAIL
ELIMINATION OF EXCESS WATER REQUIRED FOR AGLOMERATION
CONVEYOR BELT
HIGHER % SOLIDS PUMPED
LOWER CAPITAL AND OPERATION COSTS
TRUCKS
SMALLER PIPE
LOWER VELOCITY
LESS WATER PUMPED
OTHER

Figure 4-5

The following economic gains can be realized:

- o 27% more matrix production from dragline with the same equipment, or deeper overburden stripping with the same equipment,
- o 27% less dragline operating hours,
- o 27% of dragline time can be spent for reclamation,
- o a 27% smaller bucket can be used. In new mines this means a 45 cy dragline could be purchased instead of a 60 cy bucket, or existing draglines could be equipped with longer booms. Substantial savings will result.

6) Risk Analysis

The mine situation has a lot to do with determining the risks. This system is more rewarding for new mines, although for new areas with long pumping distances, or where dragline productivity is important, it could also be successful.

More study to define the operational problems, and a certain amount of research and development by manufacturers is necessary. Test cases will be necessary to prove design. Following this procedure the risk for an individual company is reduced, although still high.

APPENDIX 4-1

HYDRAULIC MONITOR AND MATRIX PUMPING ECONOMIC CALCULATIONS

HYDRAULIC MONITOR SAVINGS

	SOTA			NEW	
	$/unit(t)	$/year	Savings	$/unit	$/year
Electricity	.059	708,000	35% *	.038	460,000
Labor	.079	948,000	1 man	.068	813,000
Total		1,656,000			1,273,000
Annual Savings					$ 383,000

* Saving is from reduction in water volume required for 35% slurry vs 45%

SLURRY PUMPING MATRIX SAVINGS

	SOTA			NEW	
	$/unit(t)	$/year	Savings	$/unit	$/year
Electricity	.049	1,764,000	40% **	.029	1,044,000
Annual Savings					$ 720,000

Added Operating Cost

Capital recovery $550,000 x 0.1627	$ 90,000	
Added Maintenance	--	
Total Annual Net Savings		$1,013,000

** Basis for Saving	SOTA	STUDY CASE	SAVING
Slurry Density	35%	45%	25%
Line Velocity	16.6 fps	15 fps	15%
Total Energy Saving			40%

This applies to both "present" and "future" orebody cases.

APPENDIX 4-1

MONITOR AND PUMPING ENERGY REDUCTION CALCULATIONS

Monitor- Reduction in water required for slurry make-up (35% - 45% solids)

35% water factor	7.43	(gpm water/ton solids/hour)
45%	4.87	

(7.43 - 4.87) ÷ 7.43 = 35% reduction

Slurry Pumping - 35% vs 45% slurry solids

Saving from volume reduction corrected for change in density:

35% slurry factor	8.94	(gpm slurry/ton solids/hr)
45% " "	6.35	

$$\frac{8.94 - 6.35}{8.94} \times \frac{1.28 \text{ Sg}}{1.40 \text{ Sg}} \quad 26\%$$

Saving from 10% lower velocity

Velocity	Head loss Hf (ft/100 ft.)	
16.6 fps	7.18	(approximately)
15.0	6.03	
13.8	5.12	

$$\frac{7.18 - 6.03}{7.18} = 16\%$$

Total 26 + 16 = 42% (use 40%)

APPENDIX 4-2

MATRIX LOSSES AND DILUTION CALCULATIONS

Assume that dilution is about 10% and recovery loss is about 10%, for the base case.

A 2% improvement in dilution, (8% total) is proposed.

A 2% improvement in recovery, (8% recovery loss) is proposed.

It is assumed that all dilution is from overburden and all recovery loss is at matrix and overburden contact. It is also assumed that the dilutant has no phosphate value and the matrix loss is the same value as the average matrix value.

Under these assumptions, the matrix and overburden tonnage and cubic yard are identical to the base case. Dilution reduction reduces the matrix mined by 2%, but increased recovery increases the matrix mined by 2%. The overburden increases by 2% by dilution reduction, and decreases by 2% with an increase in recovery. The net result and exchange of 2% dilutant (no phosphate value), leaving the matrix and 2% material (phosphate value), entering the matrix mined from the overburden.

To account for this gain, 2% greater matrix phosphate grade was calculated and an assumption of 2% more tons was made.

Savings per ton approximates 2% of base case, since there are no additional costs, and 2% more tonnage.

Annual savings approximates:

$9.95/ton x .02 x 3,440,000 ton product/year or $684,560/yr

Cost: 2 geologists @ $50,000/year = $100,000
Maintenance $ 25,000

Capital cost $250,000 (computers sensor lights)

at 10%, 10 years (.1627) = $ 41,000

Total Annual Cost $166,000

Approximate Net Savings $518,560

APPENDIX 4-3
SEPARATION OF DRAGLINE AND WELL

SEPARATION OF DRAGLINE AND WELL

MINING METHOD-

1 -Dragline Mines matrix and dumps ton in windrow on highwall bank

2 - Frontend Wheel Loader loads matrix from bank into feeder breaker type machine

3 - Feeder Breaker rejects hard rocks breaks up mudballs conveys feed to sump

4 - Sump and Matrix Pump low pressure water added to makeup slurry - pump to plant

PRODUCTION PARAMETERS

present mining	method proposed	mining method
% slimes	28.6	28.6
% pebble	13.6	13.6
% sands	44.0	44.0
% flotation conc.	13.8	13.8
Tons matrix	12,000,000	12,000,000
yd3 overburden	19,500,000	19,500,000
yd3 matrix	9,500,000	9,500,000
dragline $/yd3	0.094	0.081
operating hours	7,000	7,000
matrix pumping % solids	30%	45%

Costs for present system are from spread sheets

CALCULATIONS

1 - Dragline present cost/yr. 0.094 x 12,000,000 = $2,707,000
Dragline proposed system has less swing will figure from detailed charts, diagrams - cycle estimate at 82% of present, therefore
2,707,000(0.82) = $2,220,000
In addition the dragline if free and extra 18% of the time due to shorter swing angle

2 - Loader needed only for proposed system feeder breaker moves only every 200 feet average haul 100 feet

	cycle time sec	min	
dump load	38		
haul	9		or 67 cycles/hour
return	7		
total	54	0.9	

base case requires 2 dragline:
2 loaders are required

Hourly production required per loader (2):

$\frac{9,300,000}{(2)\quad(7000)}$ 664 cy/hr

Loader production 992 13.5 x 58 = 971 cy/hr
Hours required 992 $\frac{9,300,000}{971}$ 9,577 hr

$ hour operation

	fuel 20 gal.	12.00
	repair	14.00
	operator	16.00
	tires	5.60
$4,200/tire 3000 hr/tire	total	47.60

Loader cost 9,577 x 47.60 = 456,000/yr

Loader = 3 (1 spare)

Cost Loader = 3 x 540,000 = $1,620,000

3 - Feeder Breaker - needed to disagregate material feed to well slurry

Operating costs estimated at $0.06/yd3 (9,300,000) $558,000

Rock are rejected but clayballs pass or and are broken in breaker action

2 needed at 783 yd3/hr
cost 2 x 400,000 $800,000

4 - Pump (Matrix) and well the wells required for mixing only may be

Present cost

Hydraulic monitor 0.167(12,000,000) $2,004,000
Pumping $0.084 (3 miles) (12,000,000) $3,024,000

Proposed cost

engineering calculations assume 1,000 tph
45% solids
1000/0.45 = 2222 tons per hour slurry
1222 + water, 1000 + matrix

water gpm tph (2222 - 1000)(2000)#/t   4884
#/gal 8.34(60) m/hr

matrix gpm tph (1000)7.48 gal/ft3 (2000) #/t 1480
62.4 #/ft3 (2.7) sq. (60) m/hr

total
slurry gpm   6364

All costs other than electricity assumed the same. This is not entirely true since pipe would be less, but this is relatively minor cost in relation to electricity

Electric cost assumed to be proportional to gallon/min of slurry pumped E = 1.08 at 30% solids 10,805 gpm pumped, E = at 45% solids 6,364 gpm pumped

10,804 = 1.08
6,365 = x
x = 0.64

Saving in electric per ton 1.08 - 64 = 0.44 kw

$ Savings is +12,000,000 (0.045 $/kwh m) 0.44 kwh/t 3m
$713,000

Cost is $3,024,000 (present) - $713,000 (savings) = $2,311,000   cmiles extra $713,000

Water for mixing slurry 12,000,000
(1 system)   7,000 (2 systems)

	856	tons/hr
at 45% water	1,046	tons/hr water
at 2000 #/ton	2,092,444	#/hr water
at 62.4 #/ft3	33,532	ft3/hr water
at 7.48 gal/ft3	250,825	gal/hr water
at 60 min/hr	4,180	gal/min

By chart 2.5 ft loss/1000 ft

for 1 mile	loss	130 ft
by chart	200 hp required pump	
by estimate	100 hp mixer	
total	300 hp x 0.748 = 224 kwhr	

224 kw x 7000 hr x 2 = 3,136,000 kwhr/yr

2(units)(kwh/y) 3,136,000 x 0.045($/kwh) = $282,000

maintenance 50,000(2) $100,000
1 man per shift x 2 units
or 8 men yr @ 16 $/hr x 2080 $266,000

COSTS

	Present	Proposed	(Proposed) Capital
Dragline	$2,707,000	2,220,000	-
Pit Monitor	$2,004,000	None	-
Loader	None	$456,000	$1,620,000
Feeder/Breaker	None	$558,000	$800,000
Pit mixer (water supply)	None	$648,000	-
Pipeline	$3,024,000	$2,311,000	-
Total Matrix Mine to Plant	$7,735,000	$6,193,000	$2,520,000

Capital $800,000 @ 0.167(10 yr. @ 10%) = $130,000
1,620,000 @ 0.222(6 yr. @ 10%) = $360,000
Total $490,000

3 mile savings $7,735,000 - $6,193,000 - $490,000 = $1,052,000
6 mile $1,052,000 + 713,000 = $1,765,000

In addition to these savings, the dragline requires 27% less time - (reduced swing angle) plus (9% operating factor not down when well or is down).

The following economic gains can be realized

1) - 27% more matrix production with same equipment or deeper overburden with some equipment

2) - 27% less operating hours are saving in calculations

3) - Dragline used 27% of time for reclamation

4) - A 27% smaller bucket used in new mine this could be a 45 yd3 instead of a 60 yd3 bucket. Possible savings are around 4 million dollars.

SECTION 5

BENEFICIATION

This project is a review of the current operating practices employed in the production of phosphate rock. The measure of effectiveness of these practices is economic, and the motivation behind this examination is to find ways and means of producing rock at lower cost.

The point of departure for the entire study was the construction of a yardstick, which would define the upper limits of economic performance of current technology. This was done to ensure that our project would not identify areas for improvement and consequent studies which were merely a reiteration of existing practice. The SOTA cost model, described in Section 3, was developed expressly for the purpose of providng a tool to measure the impact of individual cost areas and the potential of candidate studies to improve the overall mine cost for the industry.

The objective of the beneficiation portion of this study can be stated as two main goals:

- Identification of categories having high operating cost with subsequent analysis of these categories to define problems and to direct problem-solvers toward the areas of greatest potential benefit.

- Formulation of prototype study ideas to define actual projects, fundable by FIPR, which are practical and useful in the near term.

Beneficiation technology workshop meetings were held in FIPR's office at Bartow, Florida on July 29, August 26, and October 16, 1987. Meetings commenced at 8:00 a.m. and adjourned at about noon. Each meeting was conducted by the designated ZW Workshop Leader, F.S. Hicks and his assistant J.D. Raulerson. Agendas were circulated to attendees to assist in guiding the conduct of each workshop and to stimulate active participation and discussion of all issues.

Participation of workshop attendees was sponsored by respective employers. The following named persons and companies were represented in the Beneficiation Workshops.

Bud Staniek, Agrico
Howard Wyncoop, Mobil
Parker Keene, CF Industries
Herschel Morris, CF Industries
Dave Barnett, Estech
John Previte, Estech
Ed Hafferley, U.S. Agri-Chemicals
Phong Vo, U.S. Agri-Chemicals
Glen Oswald, IMC
Ron Weigel, IMC
John Kraus, W.R. Grace
Gene Armbrister, W.R. Grace

5.1 SUMMARY AND CONCLUSIONS

An examination of file 6r, state-of-the-art cost for "present" orebody, using the methodology described in Section 3, shows beneficiation to be a significant portion of the overall mine cost.

The comparison of SOTA beneficiation costs for "present" and "future" orebodies is given below. Although the costs of beneficiation increase significantly, the contribution of beneficiation cost to total cost does not change appreciably, Dollars per Product Ton

Beneficiation Work Area Modules	SOTA "Present" File 6r	SOTA "Future" File 8
(e) Washer	0.78	1.16
(f) Flotation Prep	0.46	0.78
(g) Flotation	1.64	2.77
(h) In-Process Storage	0.11	0.18
(i) Hydraulic Station	0.31	0.38
Total Beneficiation Cost	$3.30	$5.27
Contribution to Total Cost	33.2%	33.4%

The application of the Alternative Technology, which was identified during the course of this study, is demonstrated using files 7r and 9. The beneficiation portion of the same "present" and "future" orebodies that were used above is shown below using the alternative technology.

Dollars per Product Ton

Beneficiation Work Area Modules	SOTA "Present" File 7r	SOTA "Future" File 9
(e) Washer	0.74	1.09
(f) Flotation Prep	0.44	0.74
(g) Flotation	1.48	2.46
(h) In-Process Storage	0.10	0.17
(i) Hydraulic Station	0.30	0.36
Total Beneficiation Cost	$3.06	$4.82
Contribution to Total Cost	34.7%	35.6%

The cost imnprovements resulting from the application of alternative technology to the two orebodies are only intended to indicate the potential of these studies. The more rigorous estimation of cost and benefit will come when these concepts are studied in detail.

The comparative savings in beneficiation by applying alternative technology concepts to "present" and "future" orebodies are shown below.

	"Present" Orebody	"Future" Orebody
SOTA	$3.30	$5.27
Alternative Technology	3.06	4.82
Potential Improvement ($ per ton product)	$0.24	$0.45
Percent Improvement	7.3%	8.5%

The cost improvements resulting from the application of alternative technology to the two orebodies are only intended to indicate the potential of these studies. The more rigorous estimation of cost and benefit will come when these concepts are studied in detail.

Figure 5-1 illustrates that beneficiation is 33 percent of the total operating cost for the present orebody.

The beneficiation study consisted of the following steps:

- o Step 1 - Identification of high cost categories which is contained in Section 5.3.
- o Step 2 - Analysis of costs by category given in Section 5.4.
- o Step 3 - Suggestions from workshops which are enumerated in Section 5.5.
- o Step 4 - Formulation and screening of candidate studies which are discussed in Section 5.6.
- o Step 5 - Recommendation of projects for FIPR discussed in detail in Section 5.7

The areas having the greatest potential for cost improvement are described below. Although both electricity and maintenance costs are large expenditures, they did not show correspondingly high potential for improvement. The estimated savings percentages given below identify maximum potential savings in each area.

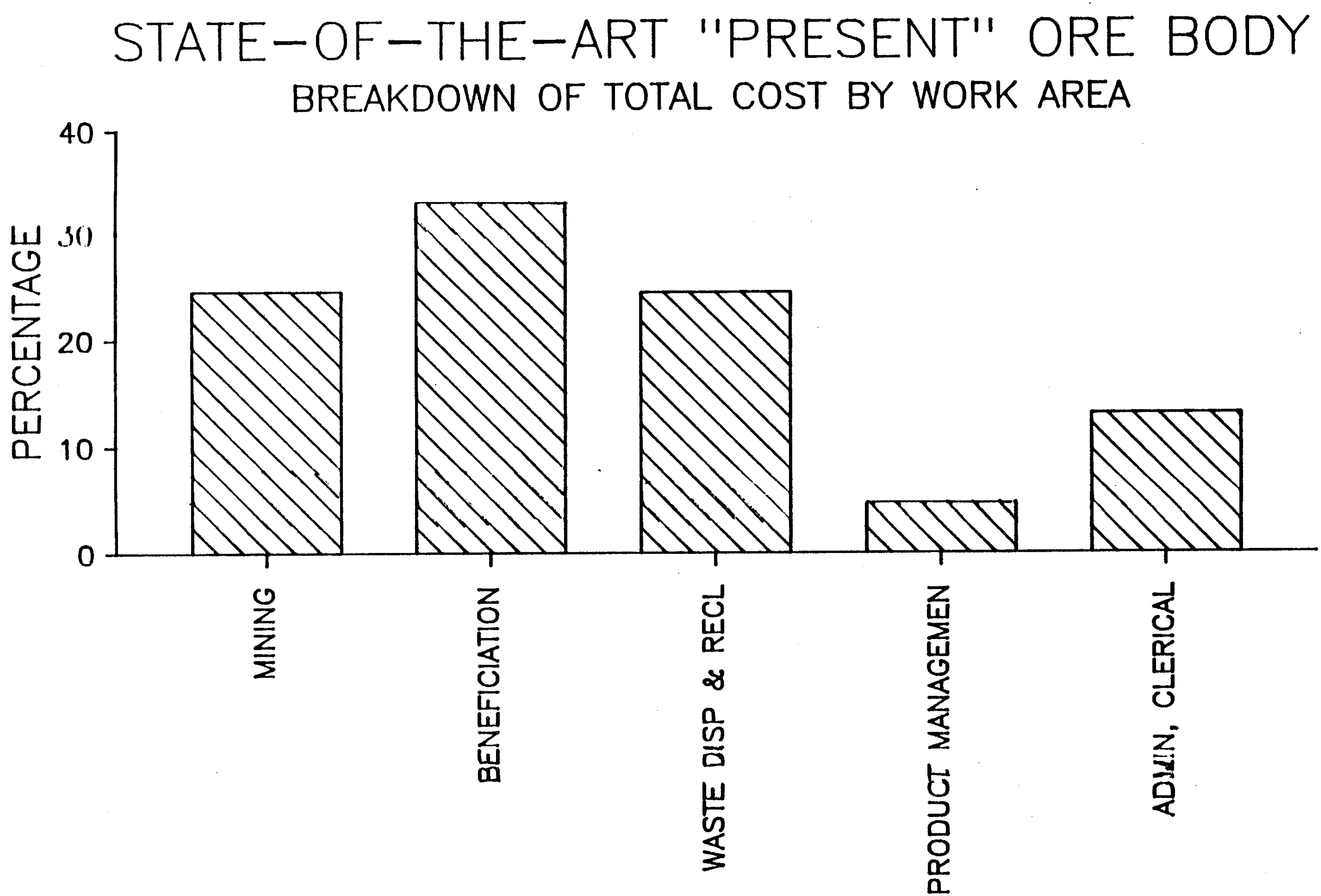

STATE-OF-THE-ART "PRESENT" ORE BODY
BREAKDOWN OF TOTAL COST BY WORK AREA
PERCENTAGE
40
30
20
10
0
MINING
BENEFICIATION
WASTE DISP & RECL
PRODUCT MANAGEMEN
ADMIN, CLERICAL

Figure 5-1

Summary of Cost Improvements
(M $ Per Year)

Category	SOTA "Present" Benefit	Estimated Savings	Potential Savings	Net Savings Identified By Studies*
Electricity	$3,960	10%	$ 400	$ ---
Maintenance	3,520	10%	350	---
Flotation Performance				
Recovery	2,310	65%	1,500	1,000
Reagents	1,960	50%	980	750
Operating Labor and Supplies	1,420	15%	210	---

* Priority #1, 2 and 3 studies only.

During the course of the project, many ideas were discussed and examined in detail. The five highest (numbers 1 through 5) priority projects listed in Section 5.2 are those which demonstrated the greatest potential savings and least technical risk. The screening process carried on in the workshops evaluated technical merit, risk, and cost savings.

Net cost savings of $0.53 per ton were identified for these three projects. Many areas for future studies are identified by the specific problems discussed in Sections 5.4 and 5.5.

5.2 RECOMMENDATIONS

There were five recommended beneficiation area studies which survived the screening process. Each of these projects is discussed in detail in Section 5.7 They are summarized below in descending order of importance.

o Priority 1 - ANIONIC CONDITIONING STUDY
  This study has been assigned a low-moderate risk and shows a potential cost savings of $940,000 per year as compared to the SOTA "present" case for the hypothetical mine. The problem

addressed by this study is the inability to scale-up laboratory conditioning results into the full-scale plant, combined with a general lack of definitive data on the subject of phosphate conditioning.

The study will address the basic parameters of conditioning, optimization of conditioner design, investigation of scale-up factors, and development of a control strategy for conditioning.

- Priority 2 - VARIABILITY OF PLANT FLOTATION FEED

  This study was designated as having a moderate risk and a potential net annual payout of $230,000 for the hypothetical plant. This study was formulated because flotation feed characteristics vary widely over short time periods in an operating plant.

  The study would quantify the extent of the savings and look at the cost to the operator of these changes in feed. Additional study would be directed toward mitigating the effects of these deviations including studies of alternative blending practices.

- Priority 3 - REAGENT RECOVERY

  This project has a moderate risk and could save $260,000 per year over the SOTA "present" case cost in our hypothetical mine. The technology to recover anionic flotation reagents already exists. The proposed study would determine the most economical way to reconstitute and use these spent reagents. The study would focus on the various technologies to purify the reagents and then determine the most cost-effective way in which to use the end product.

- Priority 4 - OPTIMIZE MINE/CHEMICAL PLANT SYSTEM

  This project has been assigned a high risk, but shows a potential payout of $840,000 per year. The study was formulated to address the problem of decreasing plant feed grades and the impact on overall production costs to make 28 percent phosphoric acid.

The study would investigate the economics of the production of phosphate rock, transportation of that rock and subsequent manufacture of phosphoric acid. This would be done by varying the phosphate rock grades and examining impact on total cost. Sensitivity analyses would be performed for the major process parameters for the various feed grades.

- Priority 5 - IMPROVE ROUGHER SELECTIVITY
  This project has been assessed as a high risk venture with a potential payout of $300,000 per year over the SOTA (file 6r) case for the hypothetical mine. This project was formulated to counteract the problems of diminishing feed grade. As the feed grade is reduced, reagent selectivity becomes increasingly important, due to the very large ratios of concentration.

  The study would take an "Edisonian" approach to the problem, in which numerous categories of compounds would be screened in search of a reagent suite which exhibited significantly improved selectivity over the current anionic reagents.

5.3 IDENTIFICATION OF HIGH COST CATEGORIES

In order to focus the study on to the areas of maximum benefit, the first task in the study was to define the areas of highest cost, and then to examine these areas for cost saving opportunities. Figure 5.2 shows the percent contribution of each module to beneficiation area costs based on SOTA "present" case (file 6r). Flotation by far is the largest cost, accounting for about 50% of beneficiation cost.

The breakdown of beneficiation costs into cost areas according to the SOTA case (file 6r) is given below.

STATE-OF-THE-ART "PRESENT" ORE BODY

BENEFICIATION AREA COST BY MODULE

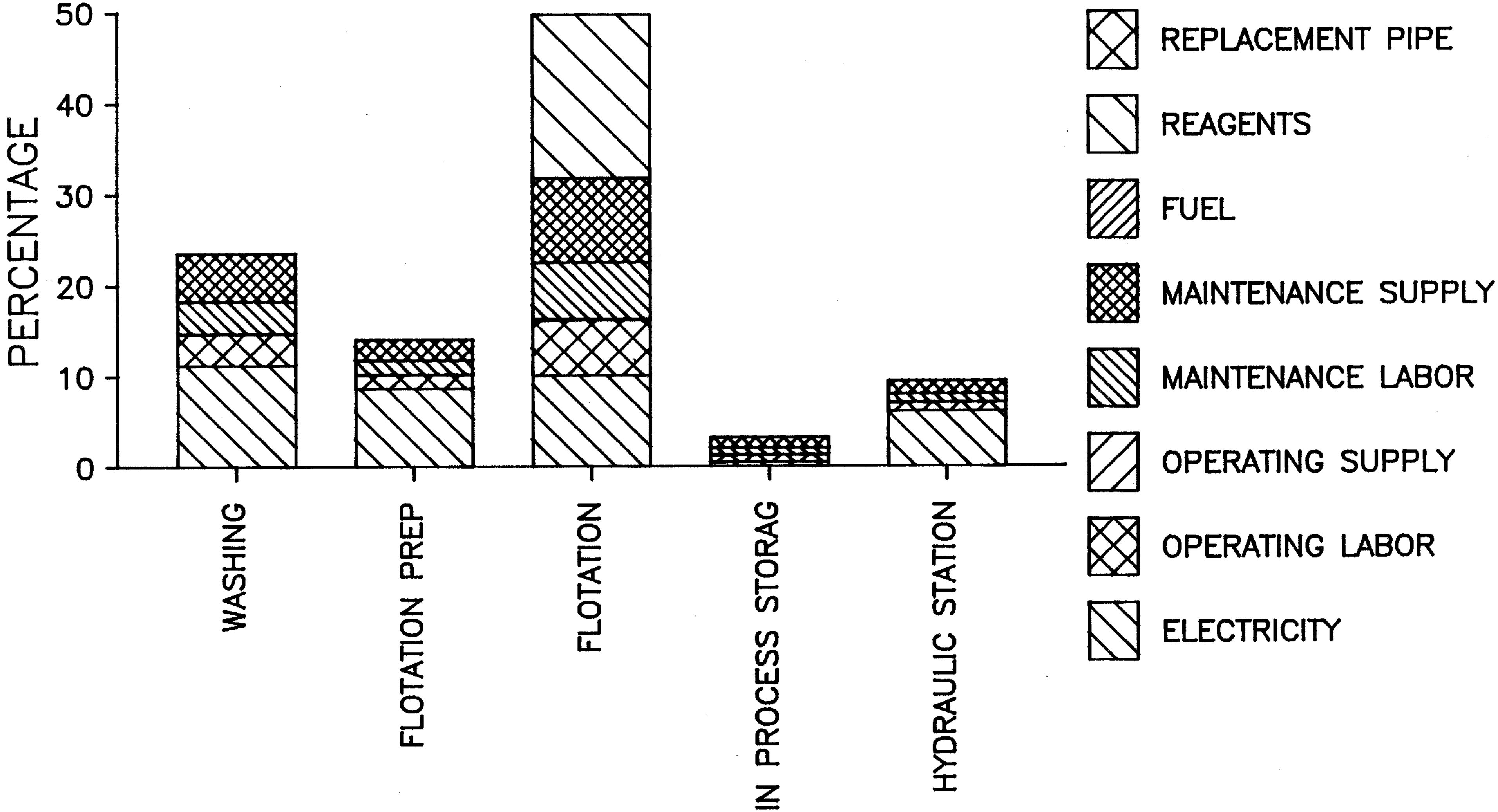


Figure 5-2

Beneficiation Cost Areas	Percentage of Beneficiation Cost	Cost M $ Per Year
o Electricity	36.5	3,960
o Maintenance	32.4	3,520
o Flotation Reagents	18.0	1,960
o Operating Labor and Supplies	13.1	1,420
	100.0	10,860

The basic operating costs given above are based on a constant 87% flotation recovery. Therefore, these costs can not reflect the effect of changes in flotation recovery.

In order to properly evaluate beneficiation, the cost effects of variations in flotation recovery must be examined. By maintaining the concentrate grade at 69 BPL and feed at 19 BPL, there would be 1,910,000 tons of concentrate produced at 100 percent recovery. When combined with the pebble produced, this would give the maximum possible yield of 3,540,000 tons of product, and if no additional costs were incurred the following potential cost improvement:

$$\frac{\text{SOTA total mine cost}}{\text{Tons @ 100\% flotation recovery}} \quad \frac{\$32,742,000}{3,540,000} = \$9.249/\text{ton}$$

SOTA "present" case cost per ton	$9.952
100% recovery cost per ton	$9.249
Max. theoretical improvement per ton	$0.703 = $2,310,000/year

The cost improvement associated with additional recovery is a further incentive to investigate projects in the flotation area. The breakdown of savings in the beneficiation area is given below.

For the purposes of this report, projects dealing with flotation recovery and reagents will be grouped together under the heading of flotation performance, but the recovery and reagent costs and benefits will be calculated separately.

5.4 ANALYSIS OF COSTS BY CATEGORY

The categories which were identified in the Section 5.3 have been analyzed in this section to determine the potential for cost improvement by delineating the individual cost elements within each category. An additional category called "New Technology" has been added at the end of this section to incorporate potential improvements which were not readily classified within the existing structure.

- Electricity Costs

  Electricity costs in the beneficiation area result principally from the energy required to transport slurries. Most of the connected horsepower within beneficiation area battery limits is used for pumping.

  Pumping costs are a function of the slurry percent solids; therefore, lower solids content results in higher power use. The judicious use of water within the plant can reduce power costs, but careful design is required to ensure adequate removal of clays. Improved methods of clay removal could lead to water conservation and to lower power consumption.

  More efficient pumps and electric motors, as well as water conservation procedures, could be advantageously employed. It is also possible to reduce electricity costs by incorporating new process equipment that requires less water, or is more energy efficient in its own right. The factors which influence electricity costs are as follow:

  - Unit cost of power

    The subject of the unit cost of power is outside the scope of this study. However, more favorable electric rates, whether obtained through negotiation or by peak demand management could be a significant factor in reducing overall costs.

- oo Motor efficiency

  Use of modern high efficiency motors could decrease electric costs by approximately 2 percent. Since replacement cost is high, a long-term upgrading program may be required.

- oo Pumping efficiency

  The conventional slurry pumps that are used within the battery limits of most plants have efficiencies of 65 to 75 percent. There is potential for improvement in this area, as the use of high efficiency slurry pumps could yield a 10% efficiency improvement. This could mean as much as a 5% savings in beneficiation electrical costs, depending upon the pumps currently in service.

- oo Process equipment

  Process equipment such as hydrocyclones, mechanical flotation cells, conditioners, scrubbers, and log washers consume considerable horsepower. Alternative process equipment such as hydroseparators, Flotaire cells, and static mixers could be employed to reduce energy costs, but overall cost impacts of these changes must be considered. Research on more energy efficient separation devices is strongly indicated.

- oo Water use

  Water use patterns within a plant can significantly impact the pumping cost within the plant itself, as well as the costs of external water return and disposal.

- oo Information and control

  Closer monitoring of plant systems could minimize the costs associated with the operation of equipment and pumps during periods of shutdown, interruption, or reduced operating rate.

- Maintenance Costs

  Plant maintenance costs were difficult to establish, but a few suggestions were made in the Workshops for improving this very large cost item. Maintenance cost is a complicated issue which is greatly affected by the philosophy of the individual company. The factors which influence maintenance costs include:

  - Materials of construction

    Since the unit operations in beneficiation consist of handling highly abrasive materials, the materials of construction for pipe, launders, chutes, and process equipment are very important with regard to wear and frequency of replacement.

  - Operating philosophy

    The choice made by an individual company to operate equipment at rates in excess of design capacity can also lead to premature wear and higher maintenance costs. However, these costs may be more than offset by the production of higher tonnages, making more efficient use of existing capital equipment.

  - Scheduling and planning

    The use of preventive maintenance and the scheduled replacement of equipment before destruction is also a means of mitigating the costs of maintenance.

  - Skill level of personnel

    The skill of the individual maintenance personnel is an important factor in achieving less downtime and more effective, longer lasting repairs.

- Flotation Performance

  The largest cost item which appeared to be controllable was flotation performance, consisting of reagent costs and recovery improvement. Most of the ideas for improvement in beneficiation cost were from the area of flotation performance. Factors which affect flotation performance are:

- oo Feed characteristics

  The type of feed that is being floated, both from the standpoint of size distribution, mineralogy and the presence of contaminants, is critical to the performance of flotation.

- oo Conditioning

  The conditioning of feed prior to anionic flotation may be the most important unit process within the entire beneficiation area, and according to the Workshop, deserves the highest priority for study.

- oo Process flowsheet/equipment

  Although the basic process is similar from one plant to another, there are considerable variations, especially with respect to the method of treatment of coarse particle flotation within the phosphate industry. There are potential efficiency improvements within other unit operations, especially deoiling and slimes separation.

- oo Product specifications

  There is potential economic benefit from altering the product specifications for concentrate, which could yield an overall improvement in cost when considering the flotation and acidulation process together. There was considerable interest by the beneficiation Workshop participants in this concept.

- oo Reagent selection

  The suite of reagents that is selected for a given plant can considerably affect the performance of that plant. Within the Workshops several ideas were put forth on different reagents and reagent suites, including evaluation of some radically different technology, such as xanthate flotation.

oo Water quality
The impact of water quality on flotation performance is an area which has not been thoroughly studied. There are many instances when changes in water use patterns have produced marked changes in flotation.

oo Process control and analysis
Process control schemes within the industry vary from hand sampling and manual control to on-line analysis and computerized control. The potential benefit from the more sophisticated schemes is great; however, their success is not assured without additional development and management commitment.

o Operating Labor
Other than the recommendation for training of operators and maintenance personnel, there were no suggestions in the beneficiation Workshops for items which might reduce the number of operators within the beneficiation plant. The industry has responded to the current competitive situation and has reduced personnel to a reasonable minimum. This can be seen by examining the current employee structure of the beneficiation area described in our SOTA case (file 6r), which leaves very little room for subsequent reduction. The factors which affect the operating labor costs are:

oo Hourly salary rate, which is based on individual company policy and therefore not a subject for FIPR's study.

oo Plant design, which in the case of existing plants is not amenable to changes, although radical changes in plant design could reduce the number of employees.

- oo Degree of automation and control provides another means to reduce the number of employees. However, based solely on the sheer size of the operation, there is a basic need for intervention and supervision of the process by the operators and management, which leads to some irreducible minimum of persons involved in the operation.

- oo Skill level of personnel has become increasingly important with the introduction of new technology and the ever-increasing pressure of competition.

- o New Technology

  There are several new technologies which are sufficiently different from current practice so that a new category was required in order to describe these changes. This category includes the use of novel equipment, recovery of phosphate currently ignored by the industry and recovery of by-product or accessory minerals, which would also encompass uses for waste products from the beneficiation process.

5.5 SUGGESTIONS FROM WORKSHOPS

The Workshop in the beneficiation area produced a great number of ideas as participation was at a very high level. These suggestions have been grouped into the same categories used in the previous sections, so that the reader can see the ideas which were generated in response to the various cost categories.

Those suggestions which could be formulated into studies will be expanded upon in the succeeding sections.

- o Electricity Costs
  - oo Process Equipment
    - Improve energy efficiency in desliming

- oo Optimize Water Use
  - Evaluate plant water use on an energy basis.
  - In-plant recycle of reagentized water
- oo Awareness and Control
  - Meaningful energy monitoring.

o Maintenance Costs

- oo Materials of Construction
  - Evaluate alternative materials of construction
- oo Skill Level of Personnel
  - Training of personnel.

o Flotation Performance

- oo Feed Characteristics
  - Optimized feed sizing
  - Variability of plant flotation feed
- oo Conditioning
  - Understand basics of conditioning
  - Empirical conditioning studies
  - Pretreatment of reagents
  - Measurement and control of conditioning
- oo Process Flowsheet and Equipment Used
  - Coarse rougher flotation
  - Locate a more selective phosphate collector
  - Coarse silica flotation
  - Basics of flotation
  - Deoiling studies
  - Xanthate flotation via sulfidization
  - Scavenging of amine tailings
- oo Reagent Cost
  - Optimize deoiling circuit
  - Characterize non-floatable phosphate and activated silica
  - Reagent recovery

oo Process Control and Analysis

- Investigate late float of rougher tailings
- On-line BPL analysis and plant control
- Use of mesh-by-mesh data in plant

o Operating Labor

oo Skill Level of Personnel

- Training of Personnel
- Washer Operating Principles and Practice

o New Technology

oo New Processes

- Optimize mine/chemical plant system
- Alternative process flowsheets
- Direct acidulation of matrix
- Determine effects of electrochemical potential on phosphate flotation

oo Novel Equipment

- Attrition device for low pebble matrix

oo Recovery of Currently Unexploited Size Ranges and Grades

- Upgrading of pebble without grinding
- Recovery of phosphate values from -150 mesh
- Alternative fertilizer products to maximize resource use

oo Use of Co-products

- Use of byproducts and accessory minerals

5.6 FORMULATION OF CANDIDATE STUDIES

Once the initial concepts were advanced in response to the various cost categories, candidates for further study were formulated in conjunction with the Workshop group and thoroughly reviewed by them in order to ensure that the concepts were properly incorporated into the study.

In the second Workshop the various candidate studies were screened to determine which would be carried forward. The studies which were carried forward were thoroughly evaluated and have been condensed into five recommended studies which are reported in Section 5.7 The items which were formulated into studies are discussed in the following format:

- o Need for study
- o Proposed study
- o Projected result
- o Disposition

Each study is discussed below in the order in which they were presented in Section 5.5.

o In-plant recycle of reagentized water.

oo Need for study - Power costs incurred in waste disposal, water return and fresh water pumping can be directly reduced by improved re-use of water in-plant. In order to re-use waste water, the quality of the waste stream must be compatible with the needs of the water user. This led to the suggestion to examine the physical and chemical characteristics of the various reagentized water streams within the battery limits of the plant to determine their suitability for use in various circuits. The study should examine ways to minimize energy consumed in the pumping of fresh water, and potential advantages that could be gained from re-using the reagents remaining in the water.

oo Proposed study - Investigate both positive and negative aspects of recycle of reagentized water. Include flotation studies which evaluate the effect of the following items on flotation:

- Residual reagent level
- Presence of particulate, including clays
- Effect of recycle on water hardness

- oo <u>Projected Result</u> - Provide technical and economic evaluation of systems which recycle reagentized water.

- oo <u>Disposition</u> - Small study, low priority. Water quality aspects are important.

o Variability of plant flotation feed

- oo <u>Need for study</u> - The degree of control that can be exercised over the flotation process is inversely related to the variability of the feed. Continual short-term changes in feed grade, tonnage rate, and size distribution lead to wasted reagents and lower flotation recoveries. In response to these comments concerning the operational problems that are encountered with transient changes in the character of flotation feed, it was suggested that a study be developed to quantify the effects of the major variables. Subsequently, there would be a determination of the impact that those particular changes would have on the process.
- oo <u>Proposed study</u> - Study short-term variations in flotation feed by characterizing grade and size variation in the real time, in-plant environment, and determine the extent of variation and the associated economic impact of the grade and size variations found.

  Investigate the dynamic response of the plant to variations in feed, and establish control strategies to react to feed changes.

- oo <u>Projected Result</u> - Economic impact study of feed variability, and large scale in-plant feed storage and blending.

- oo <u>Disposition</u> - This important study, which should follow conditioning study for maximum benefit, has been recommended as the second highest priority project.

- Understanding the basics of anionic conditioning
  - oo <u>Need for study</u> - The two greatest opportunities for improvement identified in beneficiation are reagent cost and flotation recovery. The key unit process that affects these variables is anionic conditioning. Potential savings in these areas amount to over $2,000,000 per year. There is a real need for definitive data concerning the basic mechanism of the conditioning process and its associated parameters - whether or not the reagent attachment was physical or chemical in nature - how much energy is really required to effect good conditioning.

  - oo <u>Proposed study</u> - Perform industry survey to establish current industry practices and amount of variation. Develop bench scale designed experiments for rougher flotation using several feed samples of high, low and medium grade from different plants.

  - oo <u>Projected Result</u> - - A better understanding of the mechanism of conditioning and its associated parameters as they relate to feed variability.

  - oo <u>Disposition</u> - Has been grouped with the following three items to form a study of conditioning, with the highest priority recommendation.

- Empirical reagent conditioning studies
  - oo <u>Need for study</u> - There has been considerable variance in scale-up between laboratory conditioners and plant conditioners. The focus of this project would address the notion that the higher recovery and lower reagent consumption that is seen in the laboratory could be extrapolated into the plant. The ability to achieve laboratory recoveries and reagent levels in the plant could result in reagent reductions of 40% and recovery improvement of 4%.

oo Proposed study - Set up side-by-side laboratory continuous and batch conditioning and laboratory flotation in existing plants. Replicate all plant variables in lab conditioners and compare float plant conditioned feed and lab conditioned plant feed in the laboratory flotation cell. Take simultaneous samples around the plant flotation circuit for comparison. The project would consist of testing all industry circuits from companies who would volunteer to be a part of the program. Data would be provided to participants for their plants and would be coded in the study presentations to prevent identification of individual participants by others.

oo Projected Result - - A quantification of lab/plant scale-up and the significance of the major parameters involved.

oo Disposition - Part of conditioning study above.

o Pretreatment of reagents

oo Need for study - The importance of anionic conditioning has been cited in previous examples. This is another possible avenue of improvement. Pre-saponifcation and emulsification of tall oil fatty acid have been tried by various operators, but could not be made to work well on the plant scale basis, although they appeared to work in the laboratory. It is felt that if the laboratory results could be translated into plant performance, there would be a significant improvement in reagent consumption and recovery.

oo Proposed study - The first step would be a literature survey and discussions with experienced researchers to discover what problems have been encountered in earlier efforts.

Develop a bench scale test program to establish the preliminary feasibility of reagent emulsification, pre-saponification, and elevated temperatures, on the conditioning and subsequent flotation of phosphate. Proceed to a pilot scale test and continue to a full scale implementation, if warranted.

oo Projected Result - Recommendation concerning reagent pretreatment based on cost effectiveness studies.

oo Disposition - Part of conditioning study above.

o Measurement and control of conditioning

oo Need for study - Currently the only measure for the effectiveness of conditioning is flotation recovery. If there were an independent measure of degree of conditioning, it would be easier to control this particular unit process on a real time basis. The large potential for savings in reagent costs and recovery benefits addressed earlier suggest a study on this topic.

oo Proposed study - Set up a series of experiments to correlate plant flotation performance with measureable variables from conditioning. Establish optimum conditioning as determined by flotation and look for corresponding measurable parameters.

At the same time, perform basic research with conditioned particles, to find a means of measurement of degree of conditioning and translate that knowledge into the development of a control scheme. This measurement would be a real time indication of plant conditioner performance, which would serve as an indirect measure of flotation.

oo Projected Result - A means for measuring and controlling conditioning in-plant.

oo Disposition - Part of conditioning study above.

- Evaluate coarse rougher flotation technology
  - oo <u>Need for study</u> - The metallurgically efficient flotation of phosphate coarser than 28 mesh is both reagent and labor intensive and requires greater capital and operating cost than fine flotation. Because there are many different technologies in the field to deal with particles coarser than 28 mesh in the rougher float, the question asked was "which of these methods is really the best?" This suggested a study to quantify the various flotation schemes currently in practice.

  - oo <u>Proposed study</u> - Conduct a detailed in-plant sampling and testing program with appropriate experimental control to establish mesh-by-mesh recovery/grade data for various types of flotation equipment currently used in coarse phosphate service.

    The recovery and reagent use data would then be evaluated to demonstrate the cost effectiveness of each of these systems, by relating the mesh fraction recovery, reagent use, and cost of each device.

  - oo <u>Projected Result</u> - Clear comparison of the available coarse flotation schemes on a consistent basis, using mesh-by-mesh recovery.

  - oo <u>Disposition</u> - Will be carried forward as small project with low priority.

- Locate a more selective phosphate collector
  - oo <u>Need for study</u> - The impact of anionic reagent selectivity will become greater as the flotation feed grades decline. Although much effort has been expended in this area, we still see a need for a more selective anionic reagent system.

- oo Proposed study - Review previous research to focus on the most productive compounds or systems to achieve better selectivity. Start with a bench scale screening program to define candidates for further study. Improved selectivity across a range of concentrate grades should be the main criterion at this stage.

  Set up designed experiments to define optimum performance on bench scale for reagents identified as having potential. Proceed to pilot plant and production testing, if warranted by bench scale results.

- oo Projected Result - Location of a more selective rougher reagent to improve recovery and cost.

- oo Disposition - Changed to "Improve Rougher Selectivity" and will look at collectors and related chemicals. Will be carried forward with priority of five.

o Coarse silica flotation

- oo Need for study - In many plants the grade of the 14x28 mesh fraction is very high in comparison to the +28 mesh material, but is not high enough to be a saleable product by itself. If reagents were found which could float this coarse silica in a one-step flotation, high recovery and acceptable grade could be achieved at the same time, offering significant relief for this very difficult to handle fraction.

- oo Proposed study - Perform screening tests to locate a silica reagent system capable of floating +28 mesh silica in the presence of phosphate.

  Set up designed experiments to optimize bench scale performance for reagents identified as having potential in the screening tests.

Determine cost effectiveness using bench scale results and proceed to pilot scale and plant implementation as warranted.

oo Projected Result - Single reagent system for upgrading coarse phosphate or improved coarse recovery in conventional process.

oo Disposition - Carry forward with low priority.

o Basics of flotation

oo Need for study - As in conditioning, it was suggested that many of the basic aspects of flotation were not clearly understood for phosphate. Therefore, there is a need for a research study to understand the important parameters for control and optimization of the flotation process, such as: feed BPL vs residence time and cell density; froth removal rate; air rate and bubble formation.

oo Proposed study - The first step in the study would be to conduct a survey of industry practice, including an in-depth sampling program to include column flotation as well as mechanical flotation cells. Variables to be studied include:

- Machine Design, Size, and Modifications
- Operating Practices
- Cell Loading
- Mesh-by-Mesh Flotation Recovery and Kinetics
- Use of Frothing Agents and Aeration Rate

Evaluate data collected in the survey in light of flotation theory and practices in other industries, and produce a research plan. Suggest a workshop format to include industry, consultants, and academics.

oo Projected Result - A detailed research plan including suggested research areas and priorities in the area of phosphate flotation.

oo Disposition - Maintain as a possibility for future study.

o Deoiling studies

oo Need for study - Thirty percent of the reagent cost is involved in deoiling and subsequent amine flotation. Operator practices in deoiling and washing of the rougher concentrate vary from mine to mine in terms of equipment, pH, and amount of water and power consumed. Optimization of this process is a good candidate for further study.

oo Proposed study - None.

oo Disposition - No study recommendation was promulgated in this area.

o Sulfidization of Phosphate Particle and Subsequent Flotation with Xanthate Collector

oo Need for study - Reagent selectivity in phosphate flotation has been previously addressed. This study would investigate a very different reagent which is successful with other minerals. This project centers on the application of a sulfide coating on the surface of the phosphate particle which is then floated with xanthates. TVA had been doing research on this, but has abandoned it in the recent past.

oo Proposed study - Review literature, especially recent TVA work, to establish viability of the concept, and determine cost effectiveness based on laboratory results and reagent costs. If project appears viable, proceed to bench scale testing with subsequent scale-up as warranted by testing.

oo Projected Result - A determination of the economic and technical viability of this process in phosphate beneficiation.

oo Disposition - Project will not be carried forward as TVA has discontinued their work due to poor results.

- o Reagent recovery
  - oo Need for study - The anionic reagents account for 70% of the total reagent cost. Recovery and re-use of these reagents would be of significant benefit. The technology exists to recover reagents from the waste streams in the plant, particularly the rougher reagents. However, concern was shown in the Workshop that the recovered reagents effectiveness varies in flotation. A cost effective use for recovered reagents would both improve the quality of the water throughout the mine, and yield additional revenue to the producer.

  - oo Proposed study - Investigate potential for upgrading recovered flotation reagents by either reconstituting them for re-use in flotation; or alternatively to process them for some other end use.

    Examine the properties of the reagents recovered by presently available technology, with the purpose of determining their suitability as feedstocks to a proposed reagent upgrading facility.

    Investigate separation processes and demonstrate reagent recovery and efficacy using recovered reagents on a laboratory scale.

  - oo Projected Result - Identification of cost improvements from use of recovered reagents, either as recycled reagents or some alternative end use.

  - oo Disposition - Carry forward, with emphasis on finding an economic use for spent reagents. Priority is three.

- o Optimize mine/chemical plant system
  - oo Need for study - From the standpoint of the mine operator, it is becoming increasingly difficult to produce rock grades which were easily achieved ten years ago. The present flotation technology cannot continue to produce 3-4 percent insoluble levels in the concentrate, while maintaining 85 percent recovery; when feed grades of 10 or less are encountered. The question was asked during the Workshops "is the grade of phosphate rock produced the optimum grade from the standpoint of a chemical plant feed, and are the other characteristics about the phosphate rock, which when considered as a chemical plant feed, rather than as an end product, could be changed to improve the profitability of the overall process?" Since there are many operators with captive plants, and still others who have relationships with acid producers in the area, there is a significant opportunity for an improved process that could yield the 28% acid at a minimum cost.

  - oo Proposed study - Perform an economic feasibility study to optimize overall cost of mine and chemical plant by evaluating impacts of varying levels of contaminants (particularly silica). Investigate possibility of flotation/grinding scheme to eliminate chemical plant grinding. Include segregation of fine feed to prevent grinding of this fraction.

  - oo Projected Result - Overall cost optimization study.

  - oo Disposition - Carry forward, with a priority of four.

- o Determine effects of electrochemical potential on phosphate flotation
  - oo Need for study - The observation was made that the application of an electromotive potential during conditioning or flotation is employed in other flotation processes to enhance the selectivity of the separation process, and

consequently would it have any effect on phosphate/silica separation? The importance of reagent selectivity has been previously discussed, and this is another potential avenue to explore.

- oo Proposed study - Perform bench scale experiments on both rougher and amine flotation to determine if an electromotive potential applied during conditioning can alter the selectivity of either the anionic or cationic flotation process.

- oo Projected Result - A determination of the potential value of this technology in phosphate beneficiation.

- oo Disposition - Will not be carried forward in this study, but it is recommended that FIPR do some preliminary tests in-house to explore this idea.

- o Recovery of phosphate values from the -150 mesh fraction
  - oo Need for study - This project was suggested to evaluate the potential of recovering phosphatic values useful in fertilizer manufacture from slimes waste stream. It was estimated that 400,000 tons per year of +400 mesh material was being lost to slimes. This material, if recoverable, would increase production by over 10%.

  - oo Proposed study - Characterize the 150 x 400 mineral species after concentration to assure that the aluminum and iron levels do not preclude its use. Also determine quantity of 150 x 400 mesh material available. Once character is determined, flotation testing of samples from several producers will be performed to obtain product and evaluate recovery and cost.

If recovery and grade seem reasonable, pilot plant beneficiation and acidulation studies would be performed to determine overall operating performance and cost. Economic studies which would include cost of special handling and new equipment requirements would be performed.

oo <u>Projected Result</u> - Economic analysis to improve utilization of the resource.

oo <u>Disposition</u> - This study, as originally outlined, has been given a low priority because a preliminary evaluation indicated costs greater than the value of the recovered product. Other proposed studies of slimes beneficiation should be evaluated on their own merits, with careful consideration of product value and process economics.

o Alternative fertilizer products to maximize resource use

oo <u>Need for study</u> - This study was suggested by the notion that today's high-analysis fertilizer products might be replaced by products which could be made more economically, and thus permit the mining of certain materials which could not presently be mined economically. This would amount to 240,000 new tons per year of mineable product, which will become even greater as ore grades decrease. Is it possible to produce on an overall basis a cheaper, perhaps better fertilizer product while using more of the resource?

oo <u>Proposed study</u> - Evaluate resource utilization associated with varying grades of finished fertilizer. Adjust ore reserve criteria to investigate impact of lower quality products. Conduct agronomic/marketing studies to investigate the feasibility of marketing lower grade fertilizers and educate the consumer to any advantages of same.

Investigate costs of producing and distributing lower grade fertilizer.

- Pilot Scale Beneficiation and Acidulation of Marginal Quality Ores
- Identification of End Products from Acid Produced from Low Grade Ores
- Economic Studies
- Marketing and Distribution Costs and Opportunities

oo Projected Result - Identification of the potential in resource increase and cost reduction by marketing lower grade fertilizer.

oo Disposition - High priority project for product handling area.

5.7 SURVIVING STUDY PROPOSALS

The five most promising of the individual studies that were developed during the beneficiation workshops are discussed in detail in this section.

5.7.1 Anionic Conditioning Study

o Problem definition - In the beneficiation area, the category of flotation performance, which embraces flotation recovery and reagent cost, has been shown to have a potential improvement of $2.5 million per year. The unit process of anionic conditioning, in which the reagents are applied to the flotation feed, is critical to achieving these savings. This operation affects both flotation recovery and reagent consumption. The inability to achieve laboratory recoveries and reagent consumptions in the full scale plant provides incentive to study this topic.

The members of the workshop felt strongly that the unit process of anionic conditioning was not well understood for phosphate flotation, and that there was a very real opportunity for cost improvement in this area.

- Study Objective - Investigate the anionic conditioning of phosphate rock prior to flotation. The investigation should be performed using commercial reagents and standard phosphate laboratory practice at a scale which permits extrapolation to production scale. The goals of this test program include:

  - oo Better understanding of the basic parameters of conditioning.
  - oo Optimize conditioner design.
  - oo Determine scale-up factors for conditioners.
  - oo Develop a means of measuring and controlling conditioning.

- Problem Analysis - This study was configured into four sequential steps, so that the knowledge gained in each step could be applied to the succeeding steps. These steps directly address the goals enumerated above.

  - oo Basics of Conditioning - Collect operating and mechanical design information from several plants to provide background for the study. The next step would be the investigation of the mechanism of phosphate collection in a series of tests, which would measure physical and chemical adsorption of the reagent by the phosphate particles while varying energy input and conditioner type. This will help us to understand the nature of reagent attachment. The construction and testing of a batch pilot scale vertical conditioner would then be performed to replicate several existing plants in order to pin down mechanical scale-up and provide equipment suitable to be used in the optimization studies.

  - oo Optimization Studies - Optimize the mechanical and operational variables involved in conditioning. The mechanical studies will include construction and testing of a continuous conditioner circuit, comparisons with the batch unit, and optimization of mechanical parameters, such as agitator impeller configuration, agitator impeller tip speed, and energy input in terms of flotation response. The operational tests would be a series of designed experiments using several feeds and investigating the impact and interaction of mechanical, operational, and plant variables.

oo Plant Correlation - After the pilot scale conditioners have been optimized, a series of in-plant comparisons will be performed. These tests will compare the mesh-by-mesh recovery from lab flotation by conditioning plant feed with plant reagents, and plant water using:

- Full Scale Conditioners
- Pilot scale conditioners (configured like plant)
- Pilot scale conditioners (optimized configuration)

oo Measurement and Control of Conditioning - An integral part of the previous steps will be the search for a measurable parameter which can be correlated to flotation performance. If such a variable is found, then a strategy of measurement and control will be developed and tested.

- Potential Result - Laboratory and plant scale study of the parameters of rougher conditioning with recommendations for plant implementation of study results.

- Cost Analysis - Laboratory to plant comparisons indicate that plant feed may be over-reagentized by 40% and recovery could be improved by 4% if laboratory conditioning could be extrapolated into plant practice.

Annual Savings	$1,320,000
Annual Costs	$ -380,000
NET ANNUAL SAVINGS	$ 940,000

See Appendix 5, page 5-44.

- Risk Assessment - (Low-medium). The general feeling during the workshop was that there was a high probability of obtaining some improvements in flotation performance from a thorough study of conditioning. The consensus of opinion in the workshop was that the knowledge obtained from this study would be useful to all companies involved in phosphate flotation, and that conditioning of phosphate rock has been neglected as an area of research. The risk of obtaining no benefit from this study is low, while the risks of achieving the benefits shown in the cost analysis is medium.

5.7.2 Variability of Plant Flotation Feed

- Problem Definition - During the course of collecting data to evaluate flotation performance, it has become apparent that there are significant short term variations in the grade and size distribution of feed, product, and tailings in phosphate flotation plants. This observation has led to the conclusion that sophisticated plant control schemes based on BPL analysis may be difficult to implement in a process subject to transient swings in feed properties. A conventional process which lacks feed analysis capability would be likely to over-reagentize the feed one minute and have an excess of reagents the next minute. This may be adversely affecting the industry both in terms of reagent cost and recovery. The stabilization of feed grade and size would improve plant performance and allow for longer term control and optimization strategies.

- Study Objective - The study will identify the extent of variation within actual operating plants, and determine the cost to the operator of these variations. Armed with this information, solutions to the variability program, including process control and blended storage schemes, would be developed.

- Problem Analysis - The scope will include quantification of variability, assessment of economic impact and development of solutions for implementation.

- oo Study short-term variations in flotation feed by using in-plant measurement to characterize grade and size variation in the real time plant environment.

- oo Determine the extent of variation found in the plants, replicate these conditions in laboratory tests to determine the associated economic impact of the grade and size variations found in step "A".

- oo Using a pilot plant, impose variations found in "A" and "B" to investigate the dynamic response of the process to variations in feed, and determine the feasibility of establishing control strategies to react to feed changes, including the use of on-line analysis.

- oo Study in-plant blending and storage of feed, as well as the potential for segregating and storing feed.

- o Potential Result - Study of the economic impacts of feed variability, develop methods to reduce variability or counteract it;, and investigate economics of improved in-plant feed storage and blending.

- o Cost Analysis - Some over-reagentization may be due to lack of measurement and control of plant feed. Assume 10% reagent reduction and 1% recovery improvement by controlling feed.

  Potential Savings:

Annual Savings	\$ 390,000
Annual Cost (Capital x .1627)	\$ 160,000
NET ANNUAL SAVINGS	\$ 230,000

  See Appendix 5, page 5-46.

- o Risk Assessment - (Moderate). The short-term variability of feed has already been identified. The quantification of the extent of variability can be achieved. It is certain that the industry as a whole can learn from this project. However, there is a possibility that the problem of variability cannot be solved economically.

5.7.3 Reagent Recovery

- o Problem Definition - The technology for recovery of more than fifty percent of the anionic flotation reagents has already been demonstrated. However, the reagent is recovered in a form that is not always as effective in phosphate flotation as virgin reagents. With the cost of anionic flotation reagents at 4 percent of the overall mine cost, there is a real incentive to recover and re-use these reagents.

- o Study Objective - Determine the potential for reconstituting recovered flotation reagents, so that they could be re-used effectively in flotation. The economics of alternative uses for the recovered reagents, such as chemical feedstock and fuel, should also be evaluated.

- o Problem Analysis - The study of this problem would include assessment of current reagent recovery technology, investigation of upgrading proceses, and an economic evaluation of alternative end uses for the recovered reagents.

  - oo Ascertain the quality of reagents, which could be recovered, using present reagent recovery technology.

  - oo Investigate separation processes and demonstrate reconstitution of recovered reagents and their efficacy in laboratory flotation, including bench tests and pilot plant evaluation. Potential methods for upgrading recovered reagents include:

    1. Physical separation
    2. Solvent extraction
    3. Distillation

Provide economic comparisons including environmental impact, as well as processing costs and benefits.

- Potential Result - Identification of actual cost reduction from use of recycled reagents, or some alternative end use which would be economically attractive.

- Cost Analysis - Previous testwork indicates that 50% of rougher reagents can be recovered. Additional processing may be necessary to reconstitute the reagent to achieve acceptable selectivity.

  Potential Savings:

Annual Savings	$ 690,000
Annual Costs	430,000
NET SAVINGS	$ 260,000

  See Appendix 5, page 5-46.

- Risk Assessment - (Moderate) - Although the technology for reagent recovery from plant streams exists, it is not known at this time whether the recovered reagents can be economically reconstituted into a useful form. The relatively low unit cost of reagents will preclude high cost recovery schemes.

5.7.4 Optimize Mine/Chemical Plant System

- Problem Definition - There is a long-term trend toward the production of high analysis fertilizers within the state of Florida, and a decrease in the percentage of rock exported without upgrading. The overall process economics associated with mining rock and processing it into phosphoric acid should be optimized for local production. There may be significant overall cost savings and increased resource recovery by considering the mine output as chemical plant feed and adjusting the rock specifications to optimize the overall economics. As feed grades are reduced below 10 BPL, the processing costs to maintain low silica levels in phosphate concentrate become increasingly higher and recoveries must drop if concentrate insol levels are maintained.

- Study Objective - To determine least cost paths to the manufacture of phosphoric acid starting at the mine and ending with 28 percent P_2O_5 acid, under varying external conditions. The study shall include sensitivity to rock grade, impurity levels in the rock, raw materials pricing, and transportation costs.

- Problem Analysis - This study would be configured to examine current practice and compare it to alternatives. If alternatives of positive economic consequence emerge from the study, then laboratory and pilot plant testing would be performed.

  - Establish baseline economics for current operating practice. Costs would be modelled for mining, beneficiation, product transport and acid manufacture.

  - Sensitivity analyses would be performed to investigate the overall economic impact of:

    - Rock grade versus recovery.
    - Varying impurity levels in rock.
    - Alternative transportation.
    - Changes in severance tax.
    - Changes in raw materials cost.
    - Mining lower grade reserves.

  - Consider flowsheet changes, such as selectively bypassing rock grinding with fine flotation concentrate.

  - Discuss feasibility of least cost alternatives in comparison with current practice in an overall feasibility analysis.

oo If ideas of having economic merit emerge from the study, then laboratory and pilot plant verification will be performed.

o Potential Results - Overall cost optimization study and pilot plant scale verification.

o Cost Analysis - Produce a concentrate product with maximum recovery (95%) at an insol of 10. This could entail a major process change.

Potential Savings:

Annual Savings	$1,650,000
Annual Costs	810,000
NET ANNUAL SAVINGS	$ 840,000

See Appendix 5, pages 5-47 and 5-48.

o Risk Assessment - (High). This is not a new problem and there are known constraints to the use of lower grade rock, including transportation costs and the current tax structure. However, there are significant positive benefits to the industry from such a study. It could provide a basis for change of the above constraints, and there is a real opportunity to improve recovery and cost by analyzing the overall process rather than focusing on a single aspect. In the long term, with lower grade feeds and serious foreign competition, it is studies such as this that will help the industry to survive in times of low demand.

5.7.5 IMPROVE ROUGHER SELECTIVITY

o Problem Definition - The anionic reagents traditionally used for phosphate rougher flotation are strong phosphate collectors; however, they have the inherent characteristics of also floating fine silica. As the feed grades decrease in leaner orebodies, the problem of the selectivity of the rougher reagents currently used in the phosphate industry becomes more pronounced. The current reagents have nearly reached the limits of their ability to separate phosphate from silica. As the feed grades decrease the ratio of silica to phosphate increases, which makes it impossible to continue to maintain recovery and grade simultaneously. This can be illustrated kinetically. Improvement in rougher reagent selectivity would offset this trend and possibly reduce present cost.

- Study Objective - To locate reagents or reagent systems which would improve selectivity in the rougher float and improve the economics of the flotation process.

- Problem Analysis - The proposed effort would involve an Edisonian approach, in which a multitude of compounds would be screened in order to locate an effective system.

  - Review previous research and get input from retired and current researchers to focus on the most productive compounds or systems to achieve better selectivity. Look at the entire suite of rougher reagents.

  - Start with a "rough cut" bench scale screening program to define candidates for further study. Improved selectivity across a range of concentrate grades should be the main criterion at this stage. A five point grade/recovery curve would be used for each reagent evaluated.

  - Set up designed experiments to define optimum performance on bench scale for reagents or reagent systems identified as having potential in step "B".

  - Proceed to pilot plant and production testing, if warranted by bench scale results. If reagents are found with high selectivity, but also high cost, investigate products with similar chain lengths and functional groups which may be less expensive.

  End Product: - Prioritized list of selective reagents for subsequent plant testing and evaluation.

- Cost Analysis - Potential to improve overall recovery by 3% (87% - 90%) at same concentrate grade.

  Potential Savings:

Annual Savings	$ 580,000
Annual Costs	280,000
NET ANNUAL SAVINGS	$ 300,000

  See Appendix 5, page 5-49

- Risk Assessment - (High). Although the payout could be very attractive if this project were successful, there have been many efforts made by all of the operating companies to locate a reagent system which would be a panacea for phosphate flotation. The large effort that has already been directed at this aspect of the problem makes it a very high risk.

BASIS FOR ANALYSIS OF IMPROVEMENTS

(SOTA "Present" Cost Case - FILE #6R)

Rougher Reagent Cost = $\frac{1,379,000}{3,290,000}$ = $0.420/T

Deoiling Cost = $\frac{225,000}{3,290,000}$ = $0.068/T

Amine Cost = $\frac{346,000}{3,290,000}$ = $0.105/T

$0.593/T

Product Tons =	3,290,000 @ 68 BPL
Pebble Tons =	1,633,000 @ 67 BPL
Concentrate Tons =	1,657,000 @ 69 BPL
Flot. Feed Tons =	6,936,000 @ 19 BPL
Flotation Recovery =	87%
Operating Cost =	$9.952/Product Ton

CALCULATIONS

I. ANIONIC CONDITIONING STUDY

A. ANIONIC REAGENT SAVINGS - Laboratory to plant comparisons indicate potential savings of forty percent (40%) of the anionic reagent cost.

$0.420/ton-product x 0.40 = $0.168 savings

SOTA Cost = $9.952
Improvement = 0.168

$9.784/ton

B. RECOVERY IMPROVEMENT = A potential recovery improvement from 87 to 91 percent has been identified with this study.

1) Concentrate Tons at 91% Recovery

$$\frac{6,936,000 \times .19 \times .91}{.69} = 1,740,000$$

2) Product Tons

1,740,000 Concentrate tons
+1,630,000 Pebble tons

3,370,000 Product tons

3) New Cost

$$\frac{9.784 \times 3,290,000}{3,370,000} = \$9.552/\text{ton}$$

4) Cost Improvement

SOTA Cost = $9.952
9.552

$0.400/ton

C. ANNUAL SAVINGS

$0.400/ton x 3,290,000 tons = $1,320,000

D. ANNUAL COST - Amortize $500,000 Capital

$500,000 x .1627 = 80,000
$300,000 operating cost = 300,000
380,000

II VARIABILITY OF PLANT FLOTATION FEED

A. REAGENT SAVINGS - A ten percent (10%) reduction in total reagent cost was estimated for this project.

$0.593 x 0.10 = $0.059/ton

SOTA Cost	=	$9.952/ton
Improvement	=	0.059/ton
		$9.893

B. RECOVERY IMPROVEMENT - A potential recovery improvement of 1% was identified for this project.

1) Concentrate Tons at 88% Recovery

$$\frac{6{,}936{,}000 \times .19 \times .88}{.69} = 1{,}680{,}000$$

2) New Product Tons

Concentrate tons	1,680,000
Pebble tons	1,630,000
Product tons	3,310,000

3) New Cost

$$\frac{9.893 \times 3{,}290{,}000}{3{,}310{,}000} = \$9.833$$

4) Cost Improvement

SOTA Cost	$9.952
New Cost	9.833
	$0.119/ton

C. ANNUAL SAVINGS

3,290,000 x $0.119 = $390,000

D. ADDITIONAL COST - Amortize $1,000,000 Capital

$1,000,000 x .1627 = $160,000/year

III REAGENT RECOVERY

A. ANNUAL SAVINGS

The savings for this project are predicated on a fifty percent (50%) reduction in anionic reagent cost.

SOTA ANIONIC COST = $0.420/ton

SAVINGS = $0.420 x 0.5 = $0.210/ton

ANNUAL SAVINGS $0.210/ton x 3,290,000 tons = $690,000

B. COST OF RECOVERY (treat 5,000 gpm water) (Vendor estimate)

ANNUAL COST = $200,000 including capital recovery for $500,000 investment.

C. COST OF PROCESSING - Processing costs were estimated at $0.03 per pound of recovered reagent.

2.25 #/ton-feed x 0.50 x $0.03 x 6,936,000 = $230,000

D. ANNUAL COST

Recovery	$200,000
Processing	230,000
Total	$430,000

IV OPTIMIZE MINE/CHEMICAL PLANT

A. RECOVERY IMPROVEMENT - The potential recovery was set at 95% to produce a 10 insol concentrate.

1) Recovery Improvement

$$\frac{6{,}936{,}000 \times .19 \times .95}{.65} = 1{,}930{,}000 \text{ tons}$$

2) New Tonnage (grade lowered from 68% to 66%)

Concentrate	1,930,000
Pebble	1,630,000
Total	3,560,000

3) Reagent Cost - Use 20 percent reduction in reagents

$0.593 x .20 = $0.119/ton

SOTA	$9.952
	-0.119
	$9.833

$$\frac{9.833 \times 3{,}290{,}000}{3{,}560{,}000} = \$9.087/\text{ton}$$

B ADDED PROCESSING COSTS

1) Acidulation Costs (-2% BPL)

$0.10 per ton of P_2O_5

$$\$0.10 \times \frac{.66}{2.185} = \$0.030/\text{ton-product}$$

2) Severance Tax

New tons	3,560,000
SOTA tons	3,290,000
	270,000

$$\$1.79/\text{ton} \times \frac{270{,}000}{3{,}290{,}000} = \$0.147/\text{ton-product}$$

3) In-State Transit Costs

$$\$2.27/\text{ton} \times \frac{270{,}000}{3{,}290{,}000} = \$0.186/\text{ton-product}$$

4) Total Added Costs

Acidulation	$0.030
Sev. Tax	$0.147
Transit	$0.186
	$0.363/ton

C. ANNUAL NET SAVINGS

1) $9.087 Reduced Cost
+0.363 New Charges
$9.450 New Cost

2) $9.952 SOTA
9.450 Net Cost
$0.502 Savings

$0.502 x 3,290,000 = $1,650,000

D. ADDED COST - Amortize $5,000,000 Capital

$5,000,000 x 0.1627 = $810,000/year

V. IMPROVE ROUGHER SELECTIVITY

A. RECOVERY IMPROVEMENT - A potential recovery improvement of 3% was used for this study.

$$\frac{6,936,000 \times .19 \times .90}{.69} = 1,720,000 \text{ tons}$$

1,720,000	Concentrate Tons
1,630,000	Pebble Tons
3,350,000	Total Tons

B. COST SAVINGS

$$\$9.952 \times \frac{3,290,000}{3,350,000} = \$9.774/\text{ton}$$

SOTA Cost	$9.952
	9.774
	$0.178/ton

ANNUAL SAVINGS - 3,290,000 x $0.178 = $580,000

C. ADDITIONAL COST - Increased rougher reagent cost by 20%.

$0.420/ton x 0.20 = $0.084/ton

ANNUAL COST $0.084 x 3,290,000 = $280,000

SECTION 6

WASTE DISPOSAL, LAND RECLAMATION, AND WATER RE-USE

6.1 INTRODUCTION

Technology workshop meetings in the area of Waste Disposal, Land Reclamation, and Water Re-Use were held in FIPR's office at Bartow, Florida on July 30, August 28, and October 28, 1987. Meetings commenced at 8:00 a.m. and adjourned at about noon. Each meeting was conducted by the designated ZW Workshop Leader, Tom Oxford. Agendas were circulated to attendees to assist in guiding the conduct of each workshop and to stimulate active participation and discussion of all issues.

Participation of workshop attendees was sponsored by respective employers. The following named persons and companies were represented in the Waste Disposal, Land Reclamation, and Water Re-Use Workshops.

George Weinman, Agrico
Bill Hawkins, Mobil
Richard Hunter, Gardinier
Tom Myers, Gardinier
Parker Keene, CF Industries
Dave Barnett, Estech
Ed Hafferley, USSAC
Mark Brendenmuhl, USSAC
Bob Goodrich, IMC
Dee Smith, IMC
John Kraus, W.R. Grace

The sections following present four problem areas deemed by the workshop attendees to be significant. The highest priority concern is presented first.

For purposes of evaluation, the Waste Disposal, Land Reclamation, and Water Re-use Work Area is divided into five modules or unit operations. These are: Slurry Pumping Tails, Slurry Pumping Slimes, Make-up Water, Waste Disposal Slimes, and Land Reclamation. Each of these modules is described in Section 3.

State-of-the-art (SOTA) costs developed for each, "present" and "future" orebodies and mining-beneficiation scenarios itemized for each module in this Work Area are given below in dollars per short ton of product.

Waste Disposal, Land Reclamation and Water Re-Use Work Area Modules	SOTA "Present" File 6r	SOTA "Future" File 8
(j) Slurry Pumping Tails	0.32	0.74
(k) Slurry Pumping Slimes	0.37	0.82
(l) Make-Up Water	0.06	0.07
(m) Waste Disposal Slimes	1.17	2.12
(n) Land Reclamation	0.52	0.78
Total Work Area Cost	$2.44	$4.53

The percent contribution of this Work Area, in the SOTA "present" orebody cost case (file 6r), as related to total cost is graphically illustrated in Figure 3.1. The percentage which each module contributes to the Work Area cost is shown on Figure 6.1. This figure indicates those activities making the most contribution to cost and which, therefore, offer the most opportunity for cost reduction.

The Waste Disposal, Land Reclamation, and Water Re-use Work Area accounts for about 24% of "present" SOTA orebody total production cost, and about 29% of "future" SOTA orebody total production cost.

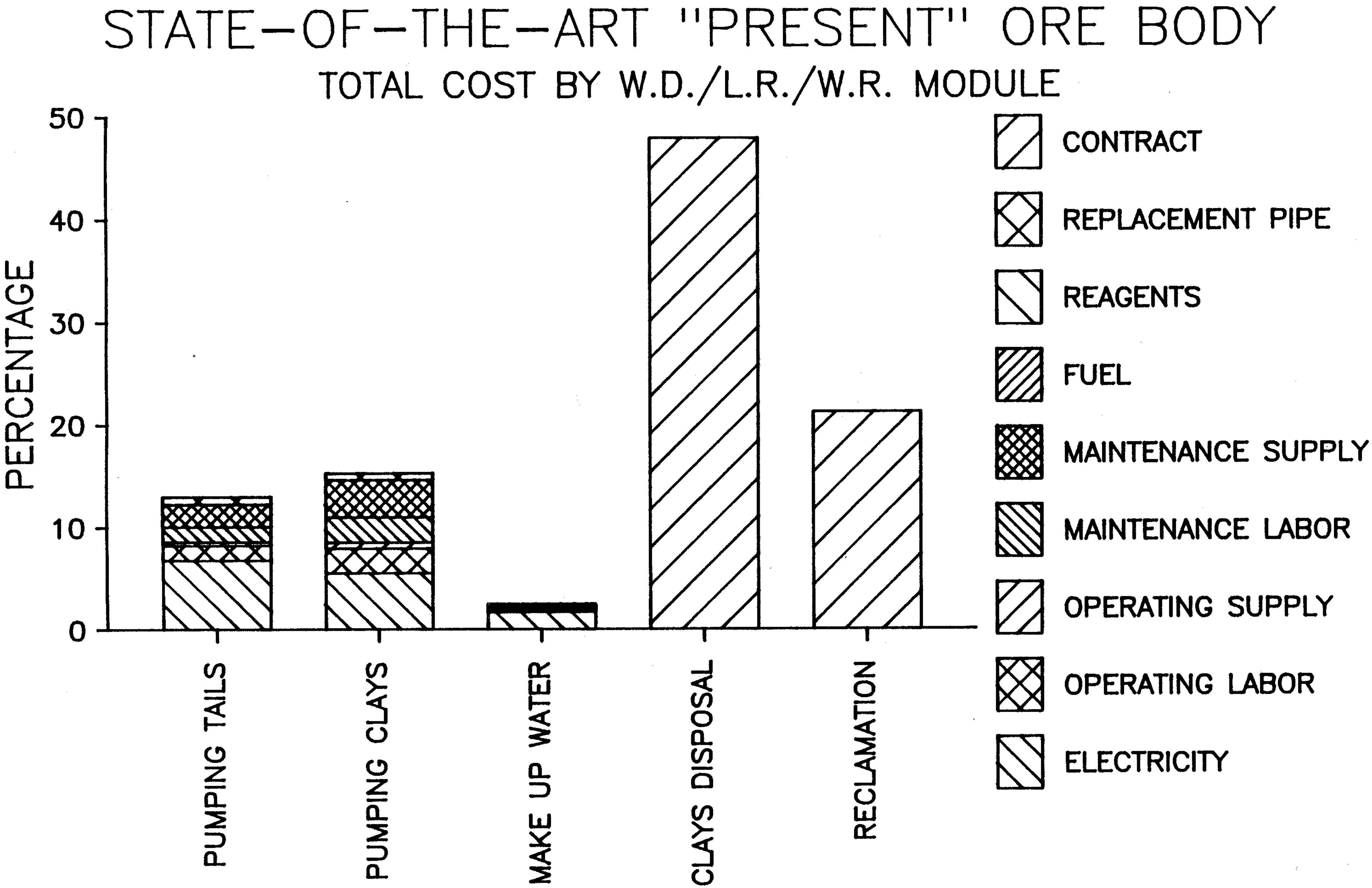

STATE-OF-THE-ART "PRESENT" ORE BODY
TOTAL COST BY W.D./L.R./W.R. MODULE
PERCENTAGE
50
40
30
20
10
0
PUMPING TAILS
PUMPING CLAYS
MAKE UP WATER
CLAYS DISPOSAL
RECLAMATION
CONTRACT
REPLACEMENT PIPE
REAGENTS
FUEL
MAINTENANCE SUPPLY
MAINTENANCE LABOR
OPERATING SUPPLY
OPERATING LABOR
ELECTRICITY

Figure 6-1

6.2 ALTERNATIVE EARTHMOVING METHODS FOR LAND RECLAMATION AND DIKE CONSTRUCTION

6.2.1 Problem Statement

The major cost element in land reclamation for mined-out areas is earthmoving. The most significant expense associated with waste clay disposal is the construction of earthen dikes. Incremental improvement in the unit cost of moving overburden or other mining wastes offers significant potential for $/acre improvements in reclamation expense and $/acre-foot improvements in waste clay storage expense. Fleets of self-loading and dozer-assisted scrapers have proven efficient in many reclamation and waste disposal applications. However, viable alternatives may exist for short-distance or unusually long-distance earthmoving, for high-volume, high-rate movements, and even for the mid-distance applications to which scrapers are suited.

6.2.2 Study Objective

The aim of a study of non-mining earthmoving costs would be to identify equipment and practices with potential to improve waste disposal and land reclamation economics and to understand the mining conditions under which such methods were applicable.

6.2.3 Ideas for Problem Solution

A variety of alternative earthmoving techniques may be defined for evaluation. The proposed studies must separately address land reclamation and dike construction. They must also consider, separately, approaches that may be applied during mining and those that are applicable only after mining is completed in a particular area. The proposed study scope follows:

1. Reclamation activities concurrent with mining. Devise a set of representative mining scenarios and particular reclamation objectives. Conduct the engineering analyses indicated below.

- o Use of dragline for earthmoving - Based on the timing of activities for the mining configuration under consideration, determine the extent to which the mining dragline can be employed to move spoil for reclamation purposes. Determine the extent to which it is technically feasible and estimate the volume of spoil that may be so handled; organize these findings for comparison with earthmoving estimates calculated for other methods.

- o Use of slurry well for earthmoving - Based on typical timing, calculate the production rate and earthmoving cost for removal of overburden by adding water under pressure in a well and pumping the slurry to a remote location (or a nearby location if technically feasible and appropriate for comparison to other approaches).

- o Use of conveyor for earthmoving - Based on typical timing, determine the feasibility of using the mining dragline to feed overburden to a cross-pit conveyor belt system.

2. Reclamation following mining - Devise a set of post-mining land configurations and corresponding reclamation objectives. In a hypothetical engineering analysis, compare earthmoving cost and technical feasibility of each of the approaches indicated below.

   - o Scraper
   - o Hydraulic undercutting of spoil banks, supported by dozer and/or scraper as required to meet reclamation objectives
   - o Establishment of an excavator/reclaimer system with cross-pit conveyor belts for high-volume transfer of spoil
   - o For the sake of comparison, evaluate a truck and loader system.

3. Dike construction during mining - For the basic set of mining scenarios and for particular dike construction requirements, perform the following engineering analysis.

- o Based on the mining configuration under consideration, determine the extent to which the mining dragline can double-spoil or otherwise be used to optimize spoil placement along the dike alignment. Determine the extent to which it is technically feasible and estimate the volume of spoil that may be so handled; organize these findings for comparison with earthmoving estimates calculated for other methods.

- o Based on typical timing of dragline operations, calculate the production rate and earthmoving cost for removal of overburden by slurrification in the well and pumping to a remote dike alignment location.

- o Based on typical timing, evaluate the feasibility of using the mining dragline to feed overburden to a conveyor belt system for distribution to a remote dike alignment.

4. Dike construction after mining - For the set of post-mining land configurations and dike construction requirements considered above, conduct a hypothetical engineering analysis, comparing earthmoving cost and technical feasibility of each of the approaches indicated below.

   - o Scraper
   - o Establishment of an excavator/reclaimer system with cross-pit conveyor belts for high-volume transfer of spoil
   - o Use of the Sauerman bucket for overburden scraping.

6.2.4 Potential Study Results

The study will provide several useful end products.

1. Generalized report comparing overburden transport by scraper, pipeline, conveyor, and truck/loader in land reclamation applications.

2. Generalized report comparing transport by scraper, conveyor, and Sauerman bucket in dike construction applications.

3. Specific evaluation of opportunities for dragline use in land reclamation and dike construction.

6.2.5 Cost Analysis

An evaluation of the cost components of waste clay disposal and land reclamation is presented in Appendix 6-1. For the scenario represented by the SOTA case for a present-day mine, it may be shown that each 10% reduction in earthmoving unit costs corresponds to approximately $0.12/ton product improvement in dike construction expense, and $0.03/ton product savings in land reclamation cost. Thus, a major gain, say 25% reduction, could improve operating costs by $0.37/ton. A similar reduction applied to conditions of a future mine, operating under SOTA practice, could improve operating costs by $0.65/ton.

6.2.6 Risk Analysis

A variety of alternatives to present earthmoving practice will be under evaluation in the present study. The various alternatives are characterized by different levels and types of risk.

The options associated with incorporating non-mining earthmoving procedures into the process of mining are characterized by the highest levels of risk to production operations. Using the mining dragline to provide extra spoil along a dike alignment or to chop-down spoil banks to minimize later earthwork for land reclamation presents the potential for production loss. On the other hand, abandonment of such a practice on recognition of failure presents negligible technological risk since no new equipment investment was involved.

A combined system of dragline and cross-pit conveyor designed to distribute overburden to more remote dike alignments or to the voids between spoil rows would present both a production risk and a technological risk. The production risk would be high if, in fact, the mining dragline were significantly dependent on the conveyor system to remove overburden from the area. That might be the case if waste-disposal/land-reclamation were not the sole justification for the system; rather, the conveyor might be employed to allow production from a high overburden-matrix ratio area that the mining dragline might otherwise not exploit. Under such circumstances, the potential for system failure also presents a risk of reserves loss.

The options associated with earthmoving in areas that have already been mined do not have an impact on production operations. Since outside contractors are available for dike construction and land reclamation, failure of a system need not have an adverse impact on operations, although contractor costs would be expected to exceed the operating costs associated with the alternative system, had it been successful. The chief risk is technological and the level of risk is associated with the alternative equipment investment that is made. Risk is minimized by initiating operations, whether with conveyors, the Sauerman system, or some other method, at a modest scale and increasing system capacity as field success is proven.

6.3 DEVELOPMENT OF A REGIONAL RECLAMATION CONCEPT

6.3.1 Problem Statement

Numerous issues arose in the workshop sessions related to apparent arbitrariness on the part of regulatory authorities in certain aspects of reclamation plan review and approval. It is conceivable that this perceived or actual arbitrariness stems from the lack of a common planning base for decision-making.

Perhaps the industry-regulatory interaction could proceed in a more efficient, less adversarial, and more logical fashion if there were a mutually-accepted framework for decision-making. Industry water use and its relation to regional needs may provide a meaningful focus for a planning study that would establish the framework. The phosphate industry has been effective not only controlling water use, but also in making the fact of high re-use rate broadly known. Consumptive use is seldom a substantive issue in the permit acquisition process. However, the significant quantity of water available from phosphate tracts at any given time is not widely understood by downstream water users; and the relatively high quality of that water (both on an absolute basis and by comparison to receiving waters) is not generally recognized.

Development of a means of calculating aggregate industry water discharge, basin-by-basin, under a range of conditions (at least wet season vs. dry season, typical conditions) would provide a display of the importance of the industry to downstream users. Moreover, it would provide a backdrop for decision-making as regulatory questions arise about allowed quantities of discharge water. Finally, the concept is consistent with current industry and regulatory interest in attempting to forecast the hydrologic characteristics of reclaimed parcels. The latter are microcosmic considerations, whereas the proposed industry-wide water use estimation technique would provide a macro-framework that could serve to guide individual-parcel modeling and reclamation design to contribute to the industry-wide concept.

6.3.2 Study Objective

The published reclamation concept would represent a vehicle for increasing public awareness of the active role the industry plays in regional development and improvement. The chief aim of the study would be to provide a common basis for decision-making in which statutory reclamation requirements might be interpreted in light of the industry-accepted reclamation concept.

6.3.3 Ideas for Solution

Prepare a regional study that identifies the near-term and long-term water use needs of the entire area expected to be affected by phosphate mining in Florida. This would represent the first step of a limited regional planning process. Next, industry acting in a unified fashion would determine its capability through reclamation planning to contribute to those regional needs. How much open water can the regional beneficially use? What other water resource features are significant? How much can the industry reasonably provide? Next, based on the capability so determined, industry would make a statement of its reclamation goals designed to support regional needs; this would represent an industry-wide reclamation concept relevant to regional water resources.

6.3.4 Potential Study Result

The end product would be a detailed evaluation of regional water resource needs, developed from the phosphate industry perspective, and appraisal of industry's ability to support those needs with a well-directed, economical land reclamation program.

6.3.5 Cost Analysis

It is not possible at this stage to evaluate the savings in operating cost potentially associated with the existence of a regional reclamation concept. However, it should be possible to devise a plan characterized by reclamation economics that is no worse than presently experienced.

6.3.6 Risk Analysis

There is not an investment risk associated with developing and implementing a regional reclamation concept, except to the extent that funds are expended for research in support of plan development.

The risk that is associated with undertaking a program of the sort proposed is that it might ultimately lead to requirements for reclamation expenditures well in excess of those presently contemplated. The proposed program has precisely the opposite intent, viz., to maintain or reduce expenses, but an industry-endorsed concept could under certain circumstances be perverted in order to enforce more costly regulatory standards than are currently in place. Such conditions could arise either through regulatory pressure or through lack of forethought on the part of any of the parties to the planning process.

On the other hand, whether or not industry plays an active and positive role, the regional planning process is on the march. There is an ill-defined risk associted with not keeping up with the progress of that activity, and there will be a penalty if the industry view is not incorporated into the planning process. In the Appendix 6-2 is an annotated excerpt from the Central Florida Comprehensive Regional Policy Plan, "Mining" section, regional issue #1, "Reclamation of Mined Areas". Annotation, showing text changes made between the November 1986 draft and the post-public-hearings July 1987 version, permits the reader to assess the extent to which participation in the planning process may have advanced the industry view.

6.4 COMPARATIVE WASTE PUMPING EVALUATION

6.4.1 Problem Statement

Numerous test-loop and field investigations have been conducted over the past decade to evaluate the cost of pumping mine and beneficiation wastes and the technical and economic feasibility of pumping mixed waste streams to disposal sites. It will be useful to mining and waste disposal planners to have available a guidebook showing estimated cost factors for various waste disposal configurations placed in a variety of typical mining scenarios with all calculations performed on a common, comparable basis.

6.4.2 Study Objective

The intent of the study is to consolidate existing data into a single reference for a variety of purposes:

- to identify fruitful areas for future research,
- to provide a standardized framework for reporting of future research findings,
- to provide a useful guidebook for waste disposal planners and engineers.

6.4.3 Ideas for Solution

The proposed study will contribute to pumping system design. This study would identify and place on a common basis all head loss data concerning pumping of tails, waste clays, or mixtures of tails and waste clays and apply them to several typical mining scenarios for the purpose of quantifying cost benefits that might be derived from non-conventional operations. Changes in electricity cost, rate of pipe replacement and its associated labor, and other factors would be calculated.

The study would address a range of commonly observed Florida mining situations (two-dragline operations with various orebody characteristics), as well as dredge-mining and mixed dragline-dredge, non-conventional mining arrangements. Pumping of overburden, as well as tailings and waste clay, would be taken into consideration.

6.4.4 Potential Study Result

The end product would be a guidebook consisting of ready-reference tabular and graphical data showing comparative costs, overall and by cost element, for waste pumping in a wide range of situations, using conventional and non-conventional approaches. The data displays would be supplemented with text describing scenarios, systems, and calculation methods. Incidental to the compilation of data would be identification of data gaps and high-prospect areas for future research.

6.4.5 Cost Analysis

The principal area of potential savings in waste pumping is electricity cost. Using as an example the characteristics of the SOTA case for a present-day mine, the possible reduction in production costs that could result from improved pumping may be calculated. Let "R" represent this operating cost reduction in \$/ton product and let "r" be the fractional reduction in waste pumping cost resulting from reduced electricity consumption. See Appendix 6-1 for details.

For sand tails,

$R = r \times 0.065$ \$/ton-mi $\times 5.28(10^6)$ tpy $\times 3.0$ mi $\div 3.29(10^6)$ tpy-product $= 0.31\ r$

For waste clays,

$R = r \times 0.143$ \$/ton-mi $\times 3.43(10^6)$ tpy $\times 2.5$ mi $\div 3.29(10^6)$ tpy-product $= 0.37\ r$

Thus, each 10% improvement in cost per ton-mile can result in savings of \$0.03/t-product and \$0.04/t-product for tails and clays, respectively. A 25% improvement can provide combined savings of \$0.17/ton.

For a future mine characterized by longer pumping distances and operating under SOTA practice, the combined savings for a similar degree of improvement could be as much as \$0.39/ton.

6.4.6 Risk Analysis

Risks in the area of waste pumping are associated with production losses or operating cost excess, as well as with the potential for permanent technical failure with attendant loss due to capital expenditure. Installation of an alternative to present practice that fails to perform well over the long-term will account for excess costs; and should periodic failures occur, production will be adversely impacted unless provision is made for short-term alternative approaches to waste clay and tails disposal, e.g., contingency systems capable of separately conveying tails and clay, which ordinarily would be mixed. Systems that incorporate a buffer, such as a surge pond for waste clays and a near-plant dump areas for tails are characterized by only a low risk with respect to production loss

6.5 HIGH SAND-CLAY RATIO WASTE DISPOSAL STUDY

6.5.1 Problem Statement

The fundamental problem of waste phosphatic clay disposal is one of volume. Water retention by waste clays leads to such huge volumes of waste that under conventional disposal conditions a large fraction of the land mined must be dedicated to clay disposal within above-grade impoundments. Experience with sand/clay mix disposal by some operators has provided evidence of more rapid water release and consequent volume reduction than with clays alone. There may be incentive, however, to explore the potential benefits of waste mixing at still higher sand-clay ratios (4:1 or higher). Such benefits might include:

- Similarity to expected waste production ratios for orebodies lying south of existing operation.
- Improved trafficability of reclaimed areas.
- Improved agronomic value in terms of nutrient availability, water percolation, and tillability.
- Ultimately higher clay consolidation levels.

6.5.2 Study Objectives

The goal of this study would be the conceptual design of a high sand-clay ratio disposal system and assessment of its applications and benefits.

6.5.3 Ideas for Solution

This study would provide a preliminary design and capital and operating cost estimate for one or more systems that would dispose of wastes at higher sand-clay ratios than are representative of usual ore characteristics. Overburden would be used for admixture with waste clay or with a clay/tailings mix. Such disposal would be "clay-in-sand" rather than "sand-in-clay" and its benefits and shortcomings would be evaluated.

6.5.4 Potential Study Results

The end product of the study will be conceptual design and preliminary cost estimation report on one or more systems for delivering high-ratio sand-clay mix backfill to mined-land reclamation areas. The report would be supplemented by a review of published ideas concerning the benefits of sand-clay waste disposal and factors influencing the selection of sand-clay ratio.

6.5.5 Cost Analysis

The benefits of high sand-clay ratio waste disposal to the agronomic worth and trafficability of reclaimed land are unlikely to translate to a savings in operating costs, though the value of the reclaimed land may be enhanced. Waste clay consolidation levels will be increased. If, in any given disposal area, overburden already resident is used to increase the sand-clay ratio of a waste clay or mixed stream, a net waste volume reduction will occur and the volume of construction fill associated with required impoundment dikes will consequently be reduced. The cost of dike construction is sufficiently high that even a 5% reduction in waste volume (for example, for the present-day mine, SOTA case) could lead to savings of \$0.06/ton. See Appendix 6-1 for calculations.

5% x 8509 af/yr x \$452/af ÷ 3.29 (10^6) tpy product = \$0.06/t-product

For the future mine operating under SOTA practice, a 5% volume reduction could save \$0.11/ton.

5% x 10,941 ac/ft x \$523/af ÷ 2.71 $(10.^6)$ tpy produce = \$0.11/t-product

6.5.6 Risk Analysis

To the extent that adoption of alternative practice involves employing new equipment in unfamiliar applications, there will be medium to high technological risk. If the conception of a high sand-clay ratio system involves the use of overburden to the extent that system failure causes a breakdown in overburden stripping operations, a significant production risk is also involved. This risk is reduced by providing for alternative overburden spoiling capability, at least for the short term.

APPENDIX 6-1

SAVINGS SUMMARY

For 25% improvement in earthmoving cost, tails pumping cost, and slimes pumping cost, the following savings accrue to the SOTA case

slimes disposal (dike building)	
0.25 x 1.17 =	0.29
land reclamation	
0.25 x 0.32 =	0.08
slimes pumping	
0.25 x 0.31 =	0.08
tails pumping	
0.25 x 0.37 =	0.09
	$0.54/t

WASTE PUMPING COSTS

1. SOTA "Present" ore body case characteristics (per file #6r)

tails, tpy 10^6	5.28
slimes, tpy 10^6	3.43
product, tpy 10^6	3.29
tails pumping distance, miles	3.0
slimes pumping distance, miles	2.5
unit cost, tails $/ton-mile	0.065
unit cost, slimes $/ton-miles	0.143

2. Influence of fractional reduction in pumping cost on waste disposal

let r(t) = fractional reduction in tails pumping cost
R(t) = Reduction in cost of mining ops in $/t product

r(t) x 0.065 x 5.28(10^6) x 3.0 / 3.29(10^6) = R(t) = 0.31 r(t)

thus, each 1% improvement in tails $/t-mi results in savings of 0.3 cents/t product

let r(s) = fractional reduction in slimes pumping cost
R(s) = reduction in ops cost in $/t product

r(s) x 0.143 x 3.43(10^6) x 2.5 / 3.29(10^6) = R(s) = 0.37 r(s)

thus 1% improvement saves 0.4 cents/t product

WASTE DISPOSAL & RECLAMATION CALCULATIONS

ITEM	DESCTIPTION
1	SOTA case characteristics
2	Assumptions for waste disposal & reclamation calcs
3	General magnitude of disposal problem
4	Specific requirements of waste disposal
5	Waste clay disposal area characteristics
6	Waste clay disposal cost
7	Influence of fractional reduction in earthmoving cost on slimes disposal
8	Land reclamation requirements
9	Land reclamation costs
10	Influence of fractional reduction in earthmoving cost on land reclamation

WASTE DISPOSAL & RECLAMATION CALCULATIONS

1. SOTA case characteristics (file #6, 10/87)

matrix thickness (ft)	14.50	
overburden thickness (ft)	33.78	
mining acres/yr	422	
matrix rate (10^6 tpy)	9.30	
overburden rate (10^6 cyd/yr)	19.50	
product (10^6 tpy)	3.29	
slimes (10^6 tpy)	3.43	28.60% of matrix
tails (10^6 tpy)	5.28	44.00% of matrix
slimes volume (af/yr)	8509	

2. Assumptions for waste disposal & reclamation calcs

overburden spoil slope	1.50
overburden spoil swell	1.15
dike upstream slope	2
dike downstream slope	3
dike crest (ft)	10
tails disposal density (pcf)	100

track is 100% minabel, so no unminded parcels remain within settling areas

all dikes except ISA are entirely within pit, none based on natural ground

ISA is same cross-section as in-pit dikes, all rolled fill

all dikes constructed entirely of overburden, no tails

in-pit dikes are partly cast fill, partly rolled fill

doulbe spoiling is pracheed along dike alignment sufficient to place all spoil equivalent to 300' cut width within dike cross-section

3. General magnitude of disposal problem

tails 5.28(10^6) tpy x 2000 lb/t / (100 lb/cft x 43560 sft/ac)
= 2425 af/yr

tails	2425 af/yr	/ 442 ac/yr =	5.49 ft
slimes	8509	/ 442 =	19.25
		subtotal	24.74

matrix thickness		14.50 ft
overburden swell 33.78 ft x 0.15		- 5.07
	net	9.43
net above natural ground 24.74 - 9.43 = average over entire tract		15.31 ft

4. Specific requirements for waste disposal

tails storage volume required	af/yr		2425
below grade storage vol. avail. 9.43 ft x 442 ac/yr		÷	4168
fraction consumed by tails, at-grade			0.58
			1.00
fraction of tract available for slimes			0.42

slimes - normal height over entire tract			19.25 ft
fraction available		÷	0.42
nominal height over fraction available			45.83
below grade height available		-	9.43
	subtotal		36.40
dike freeboard requirement			5.00
dike height above natural ground			41 ft

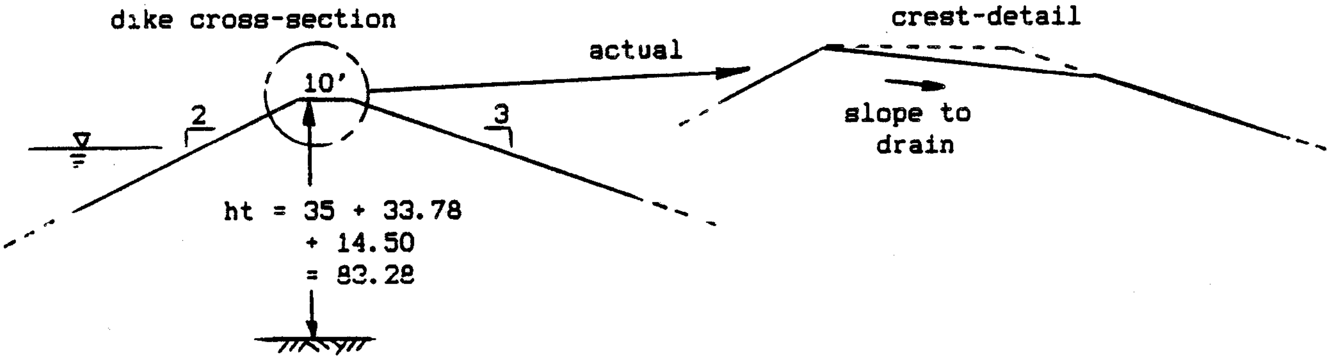
this is possibly too high to be economical and probably too high to be permittable

compromise resolution
adopt 35-foot above-grade dike height and above-grade sand-fill as required; for diversity of reclamation, minimization of tails pumping cost, and practical inability to backfill final areas of mining, reserve 10% of tract for land-and-lakes reclamation

5. Waste clay disposal area characteristics

dike cross-section

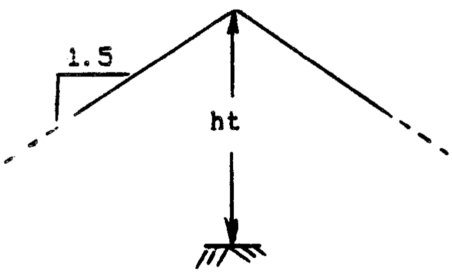
crest-detail



total fill requirement

[1/2(2 x ht^2 + 3 x ht^2) + 10 x ht] / 27 = 83.28/27 (5/2 x 83.28 + 10)
= 673 cyd/lf total

spoil cross-section



volume from 300 ft cut width

33.78 x 300 x 1.15 / 27 = 432 cyd/lf

cross-section

432 x 27 = 1/2 x 2 x 1.5 x ht^2
ht = 88.2 ft

compare to 83.3 ft crest height of dike; assume, then, as a practical matter, that all spoil is w/in dike section

net fill requirement	total	673 cyd/lf
	spoil	- 432
	net	241 cyd/lf

settling area size
consider 400 ac, square layout
storage volume available

net above grade	30 ft
net below grade	9.4
	39.4
	x 400 ac
	15,760 af

if operation is divided into 2 separate mine areas, somewhat more than two full years would be required to open 400 acres in either of them; an additional period would be required to complete construction, though construction may parallel mining in parts of the area

assume up to 1/2 year required to complete construction, then characterize ISA

capacity req'd 8509 af/yr x 2.5 yr =	21,273 af
ISA storage height avail. (35' crest)	÷ 30
	709 acres

other settling areas
settling area life 15,760 af / 8509 af/yr = 1.9 yr if second mine area is dedicated to tails disposal, only about 2 years is available for developing the second in-pit settling area; this is insufficient to allow construction completion, therefore, ISA size must be increased to accommodate this requirement

assume for other settling areas that mine planning will provide greater contiguity of mine areas, allowing more flexibility tan with areas being independent

resolution	ISA	950 ac
	all other settling areas	400 ac

disposal area capacity

ISA 950 ac x 30 ft	28,500 af
other settling areas	15,760 af

requirement for assumed 20-yr mine life

8509 af x 20		170,180 af
	ISA	-28,500
	subtotal	141,680
	per area	÷ 15,760
total number of areas req'd after ISA		9

construction fill requirements

assume maximum use of in-place spoil, square dike configuration, and one common wall, on the average for each settling area except ISA

ISA cross-section 35/27(5/2 x 35 + 10 = 126 cyd/lf

Isa dike length (950 ac x 43,560 sft/ac)^(1/2) x 4 = 25,732 lf

ISA fill 126 x 25,732 = 3.24(10^6) cyd

other settling areas (400 x 43,560)^(1/2) x 3 = 12,523 lf

area fill 241 x 12,523 =	3.02(10^6) cyd
no. of areas	x 9
	27.18
ISA	3.24
total fill requirement	30.42(10^6) cyd, life-of-mine

6. Waste clay disposal cost

assume base case cost of $2.20/cyd covers in-place fill, water return ditching and control structures, engineering and permitting

long-term slope inspection and maintenance not included; waste clay pumping in separate module

life of mine	30.42(10^6) cyd fill
	x $2.20 per cyd
	$66.92(10^6)
15% add-on, long-term maintenance	x 1.15
	$76.96(10^6)
life-of-mine disposal requirement	
8509 af/yr x 20 yr ...	÷ 170,180 af
	$452.24/af

life-of-mine production	$ 76.96(10^6)
3.29(10^6) tpy x 20 yr ...	÷ 65.80(10^6) t
	$1.17/ton product

life-of-mine slime generation	$76.96(10^6)
3.43(10^6)tpy x 20 yr ...	÷ 68.60(10^6) t
	$ 1.12/ton dry slimes

7. Influence of fractional reduction in earthmoving cost on slimes disposal

let r = fractional earthmoviing cost reduction
R = reduction in mine operating cost in $/t product

R = r x 2.20 x 30.42(10^6) x 1.15 / 65.80(10^6)
= r x 1.17

thus, each 1% reduction amounts to 1.2 cents/t product

8. Land reclamation requirements

total area disturbed by mining	
442 ac/yr x 20 yr	8840 ac
land and lakes, 10% of total	884
slime disposal, in-pit 9 x 400	3600
sand-fill, overburden cap (balance of mine)	4356
sand-fill: from init. 3-6 mo. of ops	200
slime disposal, ISA	950
total	9990 ac

9. Land reclamation costs

reclamation cost model provides the following general cost estimates in $/acre

item	sand-fill area	settling area	land & lakes
land survey	100	100	200
supervision	150	150	250
engineering	100	250	250
earthmoving	2760	1330	2500
dewatering	-	500	-
runoff control	250	250	500
revegetation	530	300	2000
maintenance	200	200	1000
	$4090/ac	$3080/ac	$6700/ac

average reclamation cost

4090 x (4556 / 9990 ac) + 3080(4550 / 9990) + 6700(884 / 9990)
45.61% 45.55% 8.85%
~= $3860/acre

earthmoving component

2760 x 0.4561 + 1330 x 0.4555 + 2500 x 0.0885 = $2086/acre

10. Influence of fractional reduction in earthmoving cost on land reclamation

let r = fractional earthmoving cost reduction
R = reduction in mine operating cost in $/t product

R = r x 2086 $/ac x 9990 / 65.80(10^6) t
r x 0.32

thus, each 1% reduction amounts to 0.3 cents/t product

Appendix 6-2

EXCERPT FROM CENTRAL FLORIDA COMPREHENSIVE REGIONAL POLICY PLAN, JULY, 1987 (pp II-197 to 204)*

Involved Agencies: DNR, DER, DACS/DOF, RPCs, SCS, GFWFC, WMDs, DCA, Counties, FIPR, FPC

Regional Goal (a): All disturbed lands, including nonmandatory, shall be reclaimed or put to productive use, within a time frame established by statute, except those lands which have been successfully reclaimed by nature.

Regional Policies:

(1) ~~The post-mining land use shall determine and control the reclamation.~~ The post-mining reclamation shall be determined and controlled by projected land use as determined by the region and local governments in accordance with applicable local, state, or federal regulations.

(2) Mining companies shall commit to post-mining land uses to be accomplished within a binding time frame including, but not limited to, a productive, tax generating land use for decommissioned waste clay ponds.

(3) Approval of a reclamation plan shall be predicated upon the post-mining land uses identified and committed to by a mining company.

(4) Land use decisions pertinent to DRI/ADA matters shall be made only by the RPC, and local governments, and the Governor and Cabinet, acting as the Land and Water Adjudicatory Commission, under Section 380.07, F.S.

(5) Projected land use decisions shall be made with approximately equal consideration given to all needs; however, protection and/or restoration of the environment shall be given primary consideration.

(6) Agencies shall develop ~~better~~ incentives for reclamation of nonmandatory lands.

(7) Innovative and interim land uses shall be considered at any stage of a review.

(8) Wildlife habitat and forestry are viable end land uses, and as such, shall be ~~considered~~ provided for in reclamation plans.

* Annotation compares 7/87 final version with 11/86 draft: ~~deletion;~~ addition; only substantive changes are noted.

Regional Goal (b): Improve the consistency of treatment of the mining industry by regulatory agencies.

Regional Policies:

(1) The legislature shall be encouraged to require the state legally to confer with regional agencies and local governments, accept regional and local comments, act upon those comments and defer to the recommendations ~~wishes~~ of regional agencies and local governments.

(2) The legislature shall be encouraged to formulate and require the state to utilize alternatives to the state's present plan for establishing financial responsibility.

(3) The legislature shall be encouraged to formulate alternatives to the present disbursement method of severance tax funds for promotion of innovative reclamation technology ~~shall be used.~~

Regional Goal (c): ~~The quality of reclamation in this region shall be further improved.~~ Full scale reclamation practices and plans shall reflect only proven best available technology. Experimentation to further reclamation technology shall be encouraged.

Regional Policies:

(1) The weight accorded an agency's comments shall be controlled by that agency's expertise and validity of recommendations in the formulation of reclamation plans.

(2) The timing of reclamation shall be set as reasonably as possible within mining operations constraints, but expeditious restoration of the environment shall always be the primary interest and concern.

(3) Measures shall be employed to ensure and enforce the development of technology that promotes faster, more reliable, and better consolidation and reclamation of waste clays.

(4) All mined/disturbed areas must be returned to a reasonably compatible condition with surrounding areas.

(5) Reclamation ~~plans~~ must be compatible with natural topography ~~include wildlife corridors.~~

(6) Soils must be returned to proper loading-bearing capacities, and stability, as appropriate for the planned end land use.

~~(7) Promote better reclamation technology.~~

Regional Goal (d): The taxable value and revenue-producing capacity of decommissioned waste clay ponds shall increase.

Regional Policies:

(1) Approval of any proposed mining activities shall be predicated upon the exclusive use of the stage-filling method for clay disposal.

(2) Any reclamation practice which has or would have the effect of rendering a decommissioned waste clay pond to be economically nonproductive shall be forbidden. The use and definition of the term "economically nonproductive" shall be the exclusive prerogative of appropriate affected local government.

SECTION 7

PRODUCT MANAGEMENT AND MINERAL RESOURCE CONSERVATION

7.1 INTRODUCTION

Technology workshop meetings in the area of Product Management and Mineral Resource Conservation were held in FIPR's office at Bartow, Florida on July 31, August 27, and October 21, 1987. Meetings commenced at 8:00 a.m. and adjourned at about noon. Each meeting was conducted by the designated ZW Workshop Leader, Maywood W. Chesson and his assistant, James M. Williams. Agendas were circulated to attendees to assist in guiding the conduct of each workshop and to stimulate active participation and discussion of all issues.

Participation of workshop attendees was sponsored by respective employers. The following named persons and companies were represented in the Product Management and Resource Conservation Workshops.

George Love, Mobil
A. L. "Judge" Holmes, CF Industries
Dave Barnett, Estech
Ed Hafferley, U.S. Agri-Chemicals
Mark Brendenmuhl, U.S. Agri-Chemicals
Bruce Goers, W.R. Grace
Pete Kantor, IMC

The total cost of the Product Management Work Area is the same for all the cost cases developed in this study. Each of the three modules making up this work area are in units of finished wet rock product (pebble and concentrate) and for purposes of this study remain constant. Modules are described in Section 3.5. Production costs are presented in cost case files, SOTA "present" orebody (file 6r), SOTA "future" orebody (file 8), Alternative Technology "present" orebody (file 7r) and Alternative Technology "future" orebody (file 9) in Section 3 of this report.

The Product Management Work Area cost contribution to each of the cost case files, by module, in dollars per short ton of product is given below.

Product Management Work Area Modules	Unit Cost $/ton
(o) Conveyor	0.01
(p) Storage	0.23
(q) Loadout	0.22
Total Work Area Cost	$0.46

The Product Management Work Area accounts for about 4½% of "present" SOTA orebody total production cost, and about 3% of "future" orebody total production cost. The "present" orebody cost contribution is graphically illustrated in Figure 3.1.

The contribution of Product Management Work Area to total production cost in the examples showing alternative technology potential increases to about 5% in the case of "present" orebodies (file 7r) and to about 3½% for "future" orebodies (file 9).

The effort in this area, therefore, focuses on mineral resources and on other areas of opportunity. The concepts for cost improvement suggested in this Section of the report have not been incorporated into the Alternative Technology operating cost estimates prepared to demonstrate overall cost reduction potential.

The workshop discussions on Product Management and Mineral Resource Conservation have generated ideas for new technology and increasing resource recovery which, if developed and fully implemented, would improve the Florida Phosphate Industry's economic status. Obtaining funds for developing and implementing new technology under existing economic conditions is a severe problem.

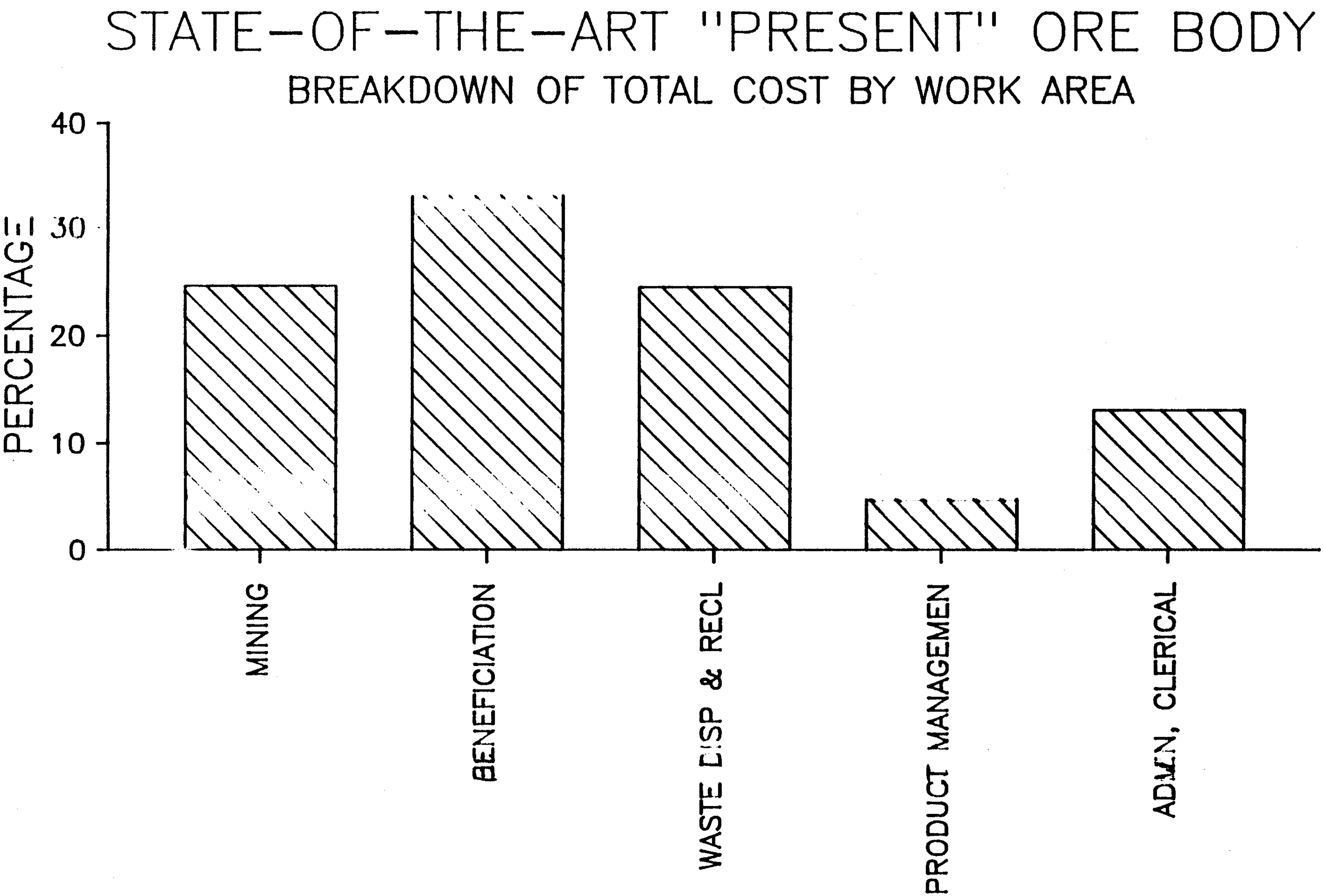

STATE-OF-THE-ART "PRESENT" ORE BODY
BREAKDOWN OF TOTAL COST BY WORK AREA
PERCENTAGE
0
10
20
30
40
MINING
BENEFICIATION
WASTE DISP & RECL
PRODUCT MANAGEMEN
ADMIN, CLERICAL

Figure 3-1

New capital investments to increase P_2O_5 recovery, especially as low grade rock products, from native resources, are not generally economically attractive to operators owning other unmined reserves. An existing operator, when considering a new marginal investment opportunity, has the following alternatives (assuming that his market is saturated and no revenue from new sales is possible):

1. Expend capital, reduce mining rate equivalent to incremental recovery tonnage, substitute more tons of lower grade rock in local fertilizer production for tonnage that would have been mined without the investment, realize the modest net production cost savings, and hope longer mine life will yield in the long term higher profit margin.

2. Do not expend new capital, maintain mining rate, minimize production costs by selective mining, and accept a shortened mine life.

An existing operator most likely will not make the new investment when considering the past trends of phosphate mining economics in Florida, because the current value of cash flows from the existing investment would be higher. Some incentive needs to be developed to induce mine operators to invest capital that will recover more lower grade phosphate rock and extend mine life.

The underlying economic merit for acceptance of lower grade phosphate rock products is based on consumption in nearby facilities for production of phosphoric acid for use in high analysis fertilizers. During the past 2 decades Florida's highest grade deposits have been depleted and exports of the remaining lower grade rock can not be delivered to distant consumers at prices competitive with other sources. Florida producers have made major investments in Florida to upgrade rock to high analysis fertilizers in order to market phosphate (P_2O_5) in the distant consuming areas. This conversion effectively reduces freight cost of the delivered P_2O_5; i.e., 1.0 ton of DAP (containing 46% P_2O_5)

contains P_2O_5 equivalent to 1.6 tons of 68 BPL rock (31% P_2O_5). The freight cost per ton of DAP is approximately equal to rock freight per ton; therefore, freight for P_2O_5 in DAP to the consumer is about 33% less than in rock.

The cost of producing phosphoric acid and fertilizers from lower grade rock is more than that from high grade rock. This increased phosphoric acid production cost is herein referred to as a penalty for low grade rock use and has been included as an added cost for incremental low grade rock production. As such, it is a disincentive to making capital investments to recover incremental tonnage of low grade rock. It combines with the severance tax payment on incremental tonnage of low grade rock to form a significant deterrent to development and implementation of new technology in a mature industry like the Florida phosphate industry.

Serious consideration should be given to finding acceptable programs for alleviating these inhibitions and providing incentives for developing and implementing new technology. Examples of capital investments in new technology resulting in more low grade rock production are given herein, some of which are not economically attractive as evaluated. By abating the obvious disincentives, these investments may become acceptable. Increased resource recovery that may result will improve the producer's economic status, increase life of Florida's reserves, increase value added to Florida' resource (fertilizer production) in Florida, and increase benefits to local, regional, and national economy.

Ideas discussed in these Workshops are listed below and described in the following sections of this chapter.

7.2 Improved Resource Recovery
- o Pebble from Waste Clay
- o Concentrates from Slimes;
- o Fine Rock from Tailings;

7.3 Computerized Blending and Inventory Control

7.4 Phosphate From Wetlands

7.5 Transportation and Port Costs

7.6 Potential By-Products

7.2 IMPROVED RESOURCE RECOVERY

Increased product recovery from the typical deposit in the hypothetical mine and beneficiation plant following current practice may be achieved with new technology and/or new process equipment at 3 points in the process and with revised environmental constraints.

7.2.1 Pebble from Waste Clay

To protect generally accepted pebble specifications from excessive contamination of stiff clay pellets, it is necessary to reject some matrix by draglines and to reject some matrix as oversize particles in the washer. Variations in frequency and extent of these losses may relate to variations of: matrix composition of clay and pebble (often as pebble decreases, clay increases), clay characteristics, pebble quality specifications, and washer process and equipment. In current practice, the amount of loss generally is not recorded or measured and may be accepted as unavoidable in order to meet mine and plant production schedules, as in fact is the case with the equipment and process currently employed in some operations.

Obviously, unlimited clay contamination in pebble is not economic. Some deposits contain thick clay strata which economically should be wasted by draglines, but when the clay waste strata are thin and highly irregular, and at the interfaces of thick matrix strata, clay rejection by draglines can result in significant matrix losses.

Typical washers contain limited capacity for removing clay, and scrubbing is dependent on the attritioning action of phosphate pebbles to separate the clay in log washers. As clay content of the matrix increases, pebble content generally decreases, which reduces scrubbing efficiency. Consequently, normal pebble product becomes contaminated with stiff clay pellets and matrix processing (production) rate diminishes. This intolerable condition generally is corrected by rejecting matrix at the mine, and/or rejecting oversize lumps from the washer.

Some clay-contaminated pebble remains in the product stream and creates serious problems in subsequent process stages. When the pebble is dried for rock shipment to distant consumers, the clay pellets cause excess fuel consumption and create particulates from pollution control scrubbers that normally clean the dryer gas discharge. When pebble with excessive clay pellets is used in local phosphoric acid plants it retains excessive water, thus having different flow characteristics which create problems in controlling feed rates to the rock grinding and phosphoric acid processes.

Rejection of matrix by the dragline and rejection of oversize material from the washer may be avoided, or at least reduced, by accepting a lower grade pebble as phosphoric acid feed rock; provided, the resulting pebble does not contain excessive clay chips or pellets which prevent water drainage from the pebble, thereby destroying normal pebble flow characteristics and creating severe problems in controlling feed rates to phosphoric acid rock grinding processes.

- Problem Definition

  The primary problem is that typical washers can not disaggregate and eliminate clay from pebble when processing stiff clay matrix. This causes resource losses in the pit and in the washer and creates handling, drying, and process problems in downstream use of clay contaminated pebble.

o Study Objective: Develop Process to Control Stiff Clay Pellets in Pebble

New equipment and/or new process technology must be developed to remove or reduce the stiff clay pellets to recover incremental tonnages of low grade pebble currently being lost as waste. A program for achieving this objective is described below.

oo Field Data Collection

Current losses of resources to avoid problems in processing stiff clay are not identified. Some portions of deposit are not mined due to stiff clay and other reasons. Some strata of mined deposits are rejected due to stiff clay, and in many plants, washers reject matrix to eliminate excessive clay. In the absence of actual data it is assumed that 5% of the mineable matrix is lost.

Review practice and experience in existing mining and washer operations. Determine frequency and tonnage of matrix rejection by draglines to relieve overloaded scrubbing capacity in washer.

Also determine frequency and tonnages of oversize material rejected from the washer to avoid excessive pebble contamination. Determine effects of contaminated pebble on downstream operations.

Arrange with mine operators to collect information and samples of the following type when contaminated pebble is being produced:

1. description of matrix, especially clay lenses or strata and pebble content; obtain samples for clay characteristics studies (try to correlate with prospect data);

2. description of matrix slurrying, pumping, washing and desliming operations;
3. samples from the principal streams in the washer during production of pebble containing clay pellets.

Obtain data and samples of clay contaminated pebble from as many operations as possible to determine variability of clay content, relationship of clay to pebble in the matrix, and range of clay characteristics. Pebble samples with different levels of contamination will be required for laboratory analysis and pilot plant tests.

oo <u>Laboratory Studies</u>

Analyze samples of clay pellets and pebble to determine physical and chemical characteristics which may suggest potential techniques for rejecting the clays. Test potential methods or techniques in bench tests to the extent possible to design pilot plant tests.

oo <u>Pilot Plant</u>

Using information collected in the field and laboratory, develop appropriate pilot plant tests for new process and/or equipment.

oo <u>Engineering Studies</u>

Information from pilot plant tests will provide sufficient data to estimate cost of installing and operating additional equipment in existing or new washers. Pebble analysis before and after tests will show grade enhancement. Correlation of field data and prospect data must be sufficient to provide a basis for estimating the tonnage of currently unacceptable clay contaminated pebble.

Utilizing the above data, make economic analysis of the various alternative new processes and/or equipment investments and prepare report.

o Possible Solutions

Possible processes or procedures suggested for studies are based on the assumption that existing washers contain trommel or vibrating screens for separating +2" oversize material either for rejection as waste, or for processing through log washers without any impact mills.

1. Impact Mill - Add disintegrator or hammermill to crush oversize particles and recycle milled material to screens. Compare alternative types of new equipment with existing equipment to select the best.

2. Weathering - Add facilities for transferring clay contaminated pebble (containing crushed oversize) to a special weathering pile for air drying and stirring by bulldozing. Front-end loaders can be used to feed weathered contaminated pebble into the washer when matrix with low clay content is being mined.

3. Impoundment - Store clay contaminated pebble under water to soften clays before returning to the washer.

4. Grinding - Add rod mill to grind weathered clay contaminated pebble to -28 mesh in either open or closed circuit. Test deslimed flotation size material in an independent flotation circuit; also, test it as a mixture with natural flotation size material.

5. Hydraulic Classification - Testing coarse ground clay contaminated pebble in various types of hydraulic sizers followed by high intensity or attrition scrubbers may produce an acceptable product without use of flotation process.

- Potential Results

In the absence of actual field data, test data and engineering studies, a preliminary economic analysis has been prepared on the following conceptual results:

- oo $115,000 Study Cost Estimate
- oo add impact mill and weathering process; do not use grinding and flotation;
- oo $250,000 new capital (mill);
- oo $522,000 per year operating cost;
- oo 110,000 additional tons per year of 60 BPL pebble, assumed yield from 5% increased matrix recovery;
- oo $133,081 per year penalty to phosphoric acid production cost from using 60 BPL instead of 64 BPL in Base Case.

Descriptions of these estimates are in Project 29-A366 files.

- Economic Analysis

The additional recovery of 110,000 tons per year of 60 BPL low grade pebble will produce 27,185 tons of phosphoric acid P_2O_5 that will replace the use of 100,883 tons of 68 BPL pebble which has typical average cost of $9.95 per ton.

Study Cost	$115,000
New Capital Investment	$250,000
ANNUAL POTENTIAL SAVINGS (100,883 X 9.95)	$1,004,000
Capital recovery (250,000 X .1627)	-41,000
Additional operating costs	-522,000
Phosphoric acid penalty	-133,000
Additional severance tax (10,000 X $1.35)	-13,000
ANNUAL NET SAVINGS	$295,000

The potential savings are very attractive and the investment risk low, assuming study results are positive and decisive. Most operators would likely adopt the new technology, if it is applicable to their reserves and markets.

o <u>Risk Analysis</u>

New technology developed in this study will be valuable to some existing operations and of increased value as the mining industry progresses south to new reserves containing lower quantities of pebble and higher quantities of stiff clay. Major risks of this method for overcoming excessive clay problems are described below.

oo The estimated tonnage of additional low grade pebble may not be proven from data collected during the study. Obviously the offset risk is that more than the estimated tonnage is attainable with no more capital outlay or increase in operating costs.

oo Weathering may not produce an acceptable product. In this event, the test work would continue through grinding and flotation. Capital investment would be greater, operating costs higher, product tons lower but product with significantly higher grade, and value would be obtained. This process is currently practiced at one operation in Florida.

oo Improvement of matrix processing rate and on-stream time may be realized by alleviating washer bottlenecks.

oo Slightly more slimes will be generated from attritioning more clay, but disposal of washer oversize rejects is eliminated.

oo Processing washer oversize should release some flotation feed agglomerated in the currently rejected clay balls.

- oo Feeding more clay pellets with pebble into phosphoric acid may become a greater deterrent than is considered in estimate of penalty.

- oo Severance tax as currently applied may be a serious inhibition to incremental low grade production, and may obviate potential savings, if the incremental tonnage proves to be lower than estimated or the new investment and operating costs are higher than estimated..

7.2.2 Concentrates From Slimes

In current practices, losses of +150 mesh flotation feed occur due to fluctuation in cyclone feed conditions and fixed capacity of existing equipment. Reliable measurements of the current variable feed losses are not available, but the losses are estimated at 3% of the recovered feed to illustrate the potential benefits of new technology. Elimination of losses will increase concentrate recovery and reduce cost of storing slimes.

The main components of matrix, after removal of +14 mesh particles as pebble during the washer operation, are clay, sand, and phosphate particles. Most of the clay is rejected in hydrocyclone overflows as well as other sand and phosphate particles finer than 150 mesh. The hydrocyclone underflows contain most of the -14/+150 mesh sized particles which represent feed to the flotation process. Inadvertent losses of flotation feed in the cyclone overflows occur primarily as a result of the following variables which can not be accommodated with the current technology as practiced:

- o matrix composition changes; e.g., radical variations in percentages of pebble, slimes, and -14/+150 mesh phosphate particles;
- o matrix pumping or processing rate changes;
- o less than optimum process design and installation;
- o inadequate dilution water;

- o cyclones and feed pumps maintenance and operation.
- o distribution to individual cones;
- o plugging with debris.

o <u>Problem Definition</u>

The typical desliming installations using single stage cyclones with limited capacities can not achieve maximum recovery due to uncontrolled process conditions.

Improved, more effective, technology can be employed to avoid the flotation feed losses and increase concentrate recovery. A program to achieve this improvement should consist of the following main parts.

o <u>Study Objective: Optimize Desliming Process</u>

oo <u>Field Data Collection</u>

Review desliming operations at 3 to 5 existing operations to obtain design and operating data, and operating results, especially measurement of feed losses. The volunteer plant operators are expected to assist in collection of data which will not be identified to the particular plants. The data collected would be evaluated to ascertain losses resulting from a typical installation employing current technology. If the losses are materially below the estimated 3%, then the study may be terminated. Assuming the study continues, it will be necessary to fully describe the typical installation in terms of process flows, material balance, installed equipment, etc. The engineering studies would provide capital and operating costs of the current typical installation with its measured feed losses for comparison with the new technology described below.

oo <u>Conceptual Design of New Technology</u>

Performance characteristics of new equipment furnished by manufacturers and altered process controls will be used to prepare capital and operating cost estimates for two alternative processes. Both processes would contain additional instrumentation and automated process controls and additional or modified pumps, cyclones and feed distribution systems. One process would be single-stage cycloning; the other process would be double-stage cycloning. The capital and operating costs for both processes would be based on the same type of engineering work used to define the base or typical case.

oo <u>Economic Comparisons</u>

Results from engineering cost estimates of the three processes and measured losses in the current technology would be evaluated to determine: (1) if new technology is economically justified, and (2) if double-stage desliming is superior.

There is a possibility that some equipment in the new technology requires test installation to confirm the manufacturer's claims. In such an event, an addition to the study scope would then be considered.

o <u>Possible Solutions</u>

oo New technology or new process equipment and process control instrumentation may be sufficient to alleviate the current insidious and intermittent feed losses with single-stage cycloning. Current practice of desliming has evolved during 25 years of use; however, the latest more efficient technology including new cyclones, density control systems, feed control and distribution, may not be incorporated in most operations. Detailed engineering analysis may show single stage cycloning with these latest improvements is acceptable.

- oo Although double-stage desliming will be more costly than single-stage, it may also be more efficient, and should be considered after optimization of single-stage desliming.

- oo Additional surge storage capacity of feed to desliming may be essential.

- oo Other alternative technology may be defined and evaluated after careful study of the field data.

o <u>Potential Results</u>

In the absence of actual field data and results of proposed engineering studies, a preliminary economic analysis has been prepared on the following conceptual basis:

- oo \$80,000 Study Cost Estimate
- oo \$750,000 new capital
- oo \$237,000 per year operating cost
- oo 48,000 tons per year additional 66 BPL concentrate
- oo \$22,000 per year penalty to phosphoric acid cost for 66 BPL in place of 68 BPL rock.

The results are based on the concept that additional surge storage of cyclone feed, additional dilution water, appropriate feed density and flow rate controls, proper distribution of feed to cyclones, properly designed cyclones, and good inspection/maintenance programs will save losses equal to 3% of flotation feed.

Double-stage cycloning is an alternative.

Description of the above estimates are given in the Appendix.

o <u>Economic Analysis</u>

Recovery of feed losses in current desliming operation will increase production by 48,000 tons per year of 66 BPL concentrate and replace production of 46,333 tons of 68 BPL rock with a typical average cost of $9.95 per ton.

Study Cost	$ 80,000
New Capital Investment	$750,000
ANNUAL POTENTIAL SAVINGS (46,333 x 9.95)	$461,000
Capital Recovery (750,000 x .1627)	-122,000
Additional Operating Costs	-237,000
Phos.acid Penalty	-22,000
Additional severance tax (1,667 x 1.35)	-2,000
ANNUAL SAVINGS	$ 78,000

o <u>Risk Analysis</u>

The net savings are not especially attractive when evaluated in this manner, which does not take into consideration the full market value of 66 BPL rock that, on an incremental basis, has a cost of only $7.48 per ton. The conceptual capital cost estimate of $750,000 places this investment in the high risk category; however, it is only a "best-guess".

- oo The current feed losses probably vary widely from plant to plant and within most plants from time to time, for reasons previously cited; however, losses do occur as evidenced by feed deposits in slimes storage areas and reported abrasion in slimes pumps and pipes.

- oo Sharper separation of feed and slimes not only can reduce feed losses but reduce slimes inclusion in flotation feed, the benefits of which are not included in the estimates.

- oo Operating cost estimates are only approximations and will be better determined after processes modifications are estimated and field data are available.

- oo Process water requirements likely will be increased, but only as a small percent of current total flow.

- oo This study may be expanded to consider potential benefits from changing classification size from 150 mesh to 200 mesh or fines as suggested in the Beneficiation Workshop. The results from the beneficiation workshop showed that treatment of the primary slimes after desliming by using hydrocyclones was not economically attractive, but if a single processing step were used in lieu of current primary desliming, it could become attractive. Recovery of phosphate in sizes smaller than 150 mesh will introduce new problems in handling rock in downstream processes. The finer sizes will require some equipment and probable process changes. Also, the finer concentrate may contain higher concentrations of I, Al, MgO and other contaminants.

7.2.3 Fine Rock from Tailings

In current practice losses of -14/+28 mesh phosphate occur in tailings from flotation processes. Losses in this size range are especially high when coarse flotation processes are not employed, but also are high from some coarse flotation processes with typical feed preparation processes. Under some conditions a portion of the phosphate in these sizes is being recovered or has been recovered as Fine Rock, meaning smaller particles than pebble which is nominally defined as +14 mesh. Typically, products in this size range are low in BPL, high in insol, and difficult to market or consume.

Employment of new technology may be required in two beneficiation modules (process stages) to reduce these losses. The first module is Feed Preparation. In this process the deslimed mixture, primarily consisting of sand and phosphate particles, is classified by particle size for flotation. Recovery of -28/+150 phosphate particles by flotation is very good, especially when carefully treated in separate coarse and fine size circuits. Recovery of -14/+28 phosphate requires different processes for separating phosphate and sand than those used for the finer sizes. Therefore, sharper classification of particle sizes in Feed Preparation is required to avoid contamination of fines in the coarse product and to avoid losses of coarse phosphate that is not recoverable in the fine flotation circuit. The second module is Flotation. This is where excessive losses of -14/+28 phosphate currently occur.

Actually, losses vary widely from time to time in any specific plant due to variations in size distribution of flotation feed in the matrix and to variations in the nature or composition of the phosphate. Also, losses can vary widely between different operators because of employment of different processes, equipment and operating and maintenance practices. Measurement of losses is difficult and commonly may not be done accurately; at least actual loss measurements are not now available.

In order to illustrate benefits of the envisaged new technology, recoverable losses equal to 5% of the pebble tonnage are estimated. It is assumed that the -14/+28 phosphate will be recovered as a Fine Rock at 50-54% BPL with 25% Insol. The feasibility of recovering and using this material is based on the proximity of a local phosphoric acid plant which has capacity to process this product stream with high contents of silica sand without incurring significant freight cost.

o Problem Definition

Typical beneficiation plants constructed many years ago do not employ the latest technology in flotation feed preparation and coarse particle flotation experience excessive losses of -14/+28 mesh phosphate particles.

o Study Objective: Optimize Feed Preparation/Flotation

To reduce -14/+28 mesh phosphate losses, new equipment and processes must be utilized or developed to improve particle size separation and flotation efficiency. The following study outline is suggested to achieve this objective.

oo Field Data Collection
Review beneficiation processes, particularly feed preparation and flotation, at 5 existing operations and select 3 plants to collect detailed data in order to fully and accurately define current practice. Data should include the following information to be used in describing typical, current practice:

- process flow diagrams;
- material balance solids and water;
- material balance of particle sizes by weight;
- material balance of BPL by particle size.

oo Metallurgical Engineering Analysis
Study field data, prepare data for computer evaluation, use computer to predict process conditions required to recover -14/+28 mesh phosphate from tailings as a special low grade product (50-54 BPL) with high silica sand contamination.

oo Capital and Operating Cost Estimate
Prepare flow diagram of new process, describe new equipment and other modifications required to eliminate losses. Estimate new capital and operating costs.

oo Economic Evaluation and Report

Prepare economic analysis, including sensitivity studies, to reflect benefits from new technology investment. Prepare comprehensive report of study and results.

o Possible Solutions

An optimistic solution is use of hydraulic classification to remove fine flotation feed (35 or 48 mesh) after the deslimed feed is screened through 20 mesh to remove tramp pebble. This scalping screen oversize would constitute part of the Fine Rock. Underflow of hydraulic sizers would be screened on 28 mesh to recover oversize as Fine Rock and coarse flotation feed as the undersize.

This, or similar technology may be used in part by some operators, but is not in general use. The coarse feed flotation processes in some operations do not efficiently recover larger phosphate particles.

A second alternative to be studied is an additional flotation circuit to reject silica sand from Fine Rock. This should be included in the metallurgical studies to test technical and economic feasibility.

A third alternative is to consider grinding Fine Rock before flotation to ascertain if a high grade concentrate of premium value can be recovered. This alternative is not used as the basis for cost estimate.

o Potential Results

In the absence of actual field data and engineering study, a hypothetical solution is proposed containing the following major additions:

1. Scalping screen after desliming;

2. Hydraulic sizers to remove all -48 mesh for fine flotation;

3. Screens to retain all +28 mesh for Fine Rock and material passing screens going to coarse flotation;

4. Should Fine Rock grade be less than 50 BPL, the addition of a flotation circuit may be required to reduce silica content. This circuit is not included in this evaluation.

5. Equipment to remove Fine Rock and convey to storage system.

Assuming these additions, without flotation, would recover the -14/+28 mesh phosphate, the major inputs for the economic analysis are:

- oo $60,000 Study Cost
- oo $600,000 new capital
- oo $326,000 annual operating cost
- oo 79,000 tons per year of additional 50 BPL product, equal to 5% of pebble production.
- oo $104,000 phosphoric acid penalty

o Economic Analysis

Annual recovery of -14/+28 mesh phosphate from tailings as 79,000 tons of 50 BPL Fine Rock will replace 60,000 tons of 68 BPL rock with a typical average cost of $9.95 per ton.

Study Cost	$ 60,000
New Capital Investment	600,000
ANNUAL POTENTIAL SAVINGS (60,000 x 9.95)	$ 597,000
Capital recovery (600,000 x .1627)	-97,000
Additional operating costs	-326,000
Phos. acid penalty	-104,000
Additional severance tax (19,000 x 1.35)	-26,000
ANNUAL NET SAVINGS	$ 44,000

o <u>Risk Analysis</u>

The investment does not appear very attractive when analyzed on this basis, with consideration to operating cost savings only. When consideration is given to the full market value of the incremental 79,000 tons of 50 BPL at a production cost of $5.36, the investment becomes more attractive.

Technical risks are high. Similar technology has been installed previously, but not practiced successfully. Improved equipment, process controls, and design techniques now suggest superior installations can be made. A major revised factor is acceptance of a lower grade product (50 BPL) based on use in a nearby phosphoric acid plant; whereas, previously <u>Fine Rock</u> under 55 BPL was not acceptable and only marginal tonnage at that grade could be utilized.

The "best-guess" estimates used for this conceptual economic evaluation are considered to be conservative. <u>Fine Rock</u> production of 79,000 tons annually at 50 BPL is estimated at 5% of the pebble tonnage. This may easily increase to 10% of the pebble, especially if the product can be used in phosphoric acid without great penalty. An increase in <u>Fine Rock</u> will not increase capital cost and only marginally increase operating costs. Therefore, if <u>Fine Rock</u> increased 50% to 7.5% of the pebble, the results would be:

Study Cost	$ 60,000
New Capital Investment	$600,000
Fine Rock Annual Tons +50%	118,500
ANNUAL POTENTIAL SAVINGS, +50%	$880,000
Capital recovery	-97,000
Additional operating costs, +25%	-407,000
Phos.acid penalty, +50%	-156,000
Additional severance tax, +50%	-39,000
ANNUAL NET SAVINGS	$181,000

The upper limit for Fine Rock production is when any additional Fine Rock tonnage would reduce pebble production or reduce flotation concentrate production.

To fully accomplish the objective of recovering -14/+28 mesh phosphate from tailings, some plants may require additional flotation circuits for coarse size feed. This potential increased recovery is considered in the Beneficiation Workshop. However, it is possible this can be eliminated if Fine Rock can be successfully recovered as described here, and economically consumed in nearby phosphoric acid plants.

7.3 COMPUTERIZED BLENDING AND INVENTORY CONTROL

Problem: Presently, there is a large annual cost of working capital committed to maintaining phosphate rock inventories. Based on industry statistics compiled by the Bureau of Mines, an inventory in the range of 3 to 4 months production has been maintained by the phosphate industry over the past 5 years.

For the hypothetical 3,000,000 TPY mine, this equals at least 750,000 tons of phosphate rock, at a processing cost of $9.77 per ton, plus $1.35 per ton severance tax for a total of $11.12 per ton and represents $8,340,000 of working capital.

There are a number of reasons which may be advanced for the necessity of keeping this quantity of inventory, but the cost of this inventory to the operator during these highly competitive times must be re-examined with an eye toward effectively reducing this cost. A reduction of one-third of this inventory would free $2,777,000 of working capital, which if invested at 8% annual interest rate compounded for 20 years, would have a value of $12,900,000. This is equal to $0.20 per ton for the 60,000,000 tons produced during the 20 years mining life with this unused inventory.

Solution: Establish an interactive inventory control computer system in an artificial intelligence environment, which would supervise the blending of all shipments. The goal of this program would be to reduce inventory levels from 3 months production to 2 months production.

The computer system would consist of a sophisticated blending module which would formulate shipments from inventory by selecting the components based on a prioritized need to dispose of each category of inventory. On a real time basis the supervisory program would review:

- Monthly sales forecasts vs. actual sales
- Monthly mine plans vs. mine production
- Inventory goals vs. inventory level.

The relative need to dispose of individual rock grades would be established in the supervisory module, which would also take into account:

- Management philosophy,
- Accumulated experience,
- History of variance from plans.

An additional key item would be the establishment of an agreement with a local phosphoric acid plant (either captive or client), to provide varying product grades using a mutually acceptable sliding scale of pricing. The supervisory program could then use this contract as a balance point to reduce the inventories having the highest priority for disposal.

The computer program would continually evaluate marketing and mine plans, as well as formulas for individual shipments in comparison to the actual results. The computer system would be designed to "learn" from these comparisons, which would enable the producer to formulate blends closer to specification and to determine the most cost-effective inventory levels and blending strategies.

As a first step, management philosophies on maintaining inventory would be rigorously scrutinized in the light of operating history and cost. This history would be used to establish probabilities for emotionally charged events, such as:

- o Transportation strikes,
- o Extended unforeseen mine shutdowns,
- o Inability to make shipments,
- o Large variance in grade or impurity level for individual shipments,
- o Loss of money or customers due to low grade shipments.

This catastrophe history would be used to establish more rational inventory goals and determine the initial blending tolerances. As the computer system develops its own experience, and sampling procedures and estimating techniques are improved, blending tolerances can be more stringent; low grade production can be utilized more effectively; and the need to maintain high grade inventory can also be reduced. This can ultimately lead to a significant decrease in inventory requirements, and working capital will be liberated for more productive uses.

7.4 PHOSPHATE FROM WETLANDS

Wetlands cover large areas of phosphate deposits in the vicinity of currently operating mines and in prospective mining regions of central Florida. The total wetlands areas that conflict with phosphate mining have not been determined. In the past decade most phosphate mining has occurred on lands permitted for mining prior to current wetlands regulations. As a consequence, the full economic impact of wetlands protection has not been felt by the industry. Government agencies, aware of their legislative responsibility, are proceeding with caution to minimize the economic impacts on industry. Phosphate miners are engaging in various types of wetlands restoration demonstration projects. The interested parties are discussing problems relating to wetlands protection and impacts on phosphate mining.

Industry, government agencies, and concerned citizens recognize that our laws declare wetlands to be a valuable resource and the courts have found that the laws establishing regulatory authority over wetlands are valid. Two of the important questions not yet fully resolved are: 1) what areas are truly wetlands? and 2) what is acceptable mitigation for mining phosphate resources under wetlands? Industry and regulators have been considering these questions since the laws were established and continue to discuss issues involved in defining wetlands, evaluating alternative mitigations, and implementing regulations with equity to mineral owner and to the public.

The potential loss of phosphate resources appears to be very large. Recent resolution of the wetlands preservation issue in the north Florida mining area had the following conclusion:

100,000 acres with mineral rights owned for mining when the laws were enacted,
23,000 acres of wetlands were defined,
19,000 acres of wetlands must be preserved; e.g., no acceptable mitigation,
4,000 acres potentially mineable if restoration programs can protect water quality standards and are shown to be acceptable.

This resolution of the wetlands preservation issue, in commpliance with current regulatory interpretation of laws, will have the following impact on phosphate mineral resources:

- 19% of the phosphate resource <u>cannot</u> be mined to preserve wetlands,
- 4% of the phosphate resource <u>may</u> be mined, if certain conditions can be met to restore wetlands,
- potential loss of resources is between 19% and 23% of the total mineral ownership.

This has the effect of increasing the cost of owning and holding reserves, for that company, between 23 and 30%. Whether or not the 4% of the property is mined will depend on the technological risk and cost associated with acceptable mitigation. The extra costs related to extraordinary operating costs required to protect the wetland areas are not considered. Also, no consideration is given to lost revenue.

The 1977 Environmental Impact Statement (EIS)[1/] evaluating the phosphate industry's impact on central Florida, prepared for EPA, reported that wetlands covered 12.3% of the study area. The correlation of wetlands and economically mineable areas was not established in either the EIS or north Florida regions.

This information indicates that wetlands may cover from 12% to 23% of Florida's phosphate resource. To preserve wetlands, it appears that for each 100 tons of resource produced, between 14 and 30 tons may not be mined.

On this basis, if the industry continues to mine at annual rates of 35,000,000 tons for the next 20 years, it may by-pass or avoid mining wetlands potentially holding 98-210 million tons. Assuming 20% (17% in the north Florida example) may be permitted for mining, the apparent loss would be reduced to 78 and 168 million tons.

This estimate is presented only to illustrate that the potential loss is very large. No estimates are available to quantify the environmental impact if the mineable wetlands are mined and reclaimed with acceptable reclamation programs. Also, cost estimates of acceptable reclamation or restoration are not available.

1/ Central Florida Phosphate Industry Areawide Impact Assessment Program, June 1977, prepared by Texas Instruments, Incorporated.

Preservation of the wetlands requires mining around the subject lands as mining operations progress through the contiguous area. The mine operator suffers losses of two types; 1) mineral acquisition cost, 2) inability to fully utilize the capital investments that are in position for mining and beneficiation.

The substantial latter loss is the most severe. The latest mine and beneficiation operation constructed in Florida had a reported capital investment of approximately $130 per annual ton of capacity. On this basis, a 3 million tons per year operation would represent approximately $390 million investment and have a normal life of 20 years. Therefore, the investment amortization is about $6.50 per ton.

The mineral wealth under wetlands not mined will not yield any benefit to the land-owner (miner), or to the local, regional or national economy.

- <u>Problem Definition</u>

  Acceptable mitigation for mining wetlands is not clearly defined because:

  1. Wetlands are not clearly defined in generally acceptable terms.
  2. Wetlands functions are not defined.
  3. Wetlands economic values are not defined and quantified.
  4. Acceptable restoration/reclamation programs are not defined.
  5. Wetlands functional and economic value assessments of alternative types of land reclamation are not established.

- <u>Potential Solutions</u>

  The following brief comments are presented only to stimulate the reader's mind to envision alternative studies that may be considered in the search for acceptable solutions of different problems affecting a great number of individuals with widely diversified interests.

1. Representatives of industry, regulatory agencies, legislative bodies, and concerned citizens join in a common effort (General Assembly) to develop an acceptable generalized mining and reclamation program for the central Florida mining region at a rate of 35 million tons per year for 20 years. The General Assembly may engage 3 independent agents to perform the following services according to policies approved by majority vote of the General Assembly.

   - Technical Administrator (TA). Responsible for gathering facts to describe the 20-year mining area, year by year, most likely beneficiation sites, tons of waste products and other data necessary to develop a regional mining and reclamation plans and costs. The primary item will be wetlands as defined by proper authority. Other detailed data defining phosphate deposits for the 20-year mining plan will be prepared from the best available sources.

     The TA would be responsible for developing a regional mining and reclamation plan entitled: Scenario 1, Wetlands Preservation, which preserves all wetlands.

   - Reclamation Specialist 1 (RS1). The RSI will be responsible for developing regional mining and reclamation plan entitled: Scenario 2, Wetlands Restoration, using the same basic data defining wetlands and 20-year mining plan, which preserves all wetlands, except those that can be permitted for mining and restored.

   - Reclamation Specialist 2 (RS2). The RS2 will be responsible for developing regional mining and reclamation plan entitled: Scenario 3, Wetlands Replacement, using the same basic data defining wetlands and 20-year mining plan, which assumes all wetlands can be mined and replaced with acceptable land forms.

2. The General Assembly of representatives from all interested parties would select a study team to examine completed reclamation projects, collect data and evaluate results of previous wetlands reclamation, and make a comprehensive economic evaluation of Scenarios 1, 2, and 3 described above. The study team would recommend the most favorable scenario to General Assembly for adoption as best regional mining and reclamation plan.

- <u>Potential Results</u>

Only in an effort to illustrate the range of potential benefits which will accrue from finding acceptable mitigation for mining wetlands is the following estimate presented. In the absence of accurate field data, assume 6 million tons per year (17% x 35,000,000) of Florida's phosphate resources are left under preserved wetlands, if no mitigation is found to be acceptable. This is mid-way in the range (12-% - 23%) defined above.

If acceptable mitigation is defined, assume that only 3 million tons per year are left under preserved wetlands. In other words, restoration or replacement for 50% of the wetlands is shown to be acceptable.

This means that the industry can avoid a $390 million investment and produce the same tonnage through other mines and plants. Also, the miner can recover his mineral acquisition costs, which likely was invested many years previously and taxed at increasing rates over the years.

The local, regional, and national economies would receive the benefits of increased life (8.6%) of mining and processing industry in terms of employment, consumption of services and supplies, and taxes.

o Risk Analysis

The problem is currently being addressed by responsible regulatory agencies and affected parties on a case-by-case basis. Efforts to expedite solutions by involving a group of affected parties may complicate and delay finding solutions to individual cases which must be resolved on specific facts relating to each case.

On the other hand, synergism flowing from combined ideas and thoughts of several people similarly affected could produce better solutions in less time. Also, combined efforts may provide greater financial resources for funding importatn mantine of essential specialits for data collection and evaluation.

Absence of combined efforts will likely result in individual parties accepting some previous case as being applicable to his case because the cost of taking issue in terms of time and money is not acceptable. After this occurs repeatedly, it does become precedent, whether it is good or bad. Complete and careful definition of alternative mitigation plans and objective technical evaluations of each has good possiblities for determining if mitigation is possible in terms acceptable to all parties.

The amount of time to find ways and means for conducting the envisaged comprehensive work may be extended for 1 or 2 years. In fact, different opinions of interested parties will likely extend the time even to establish guidelines for selecting the General Assembly, defining studies to be conducted and determining sources of required funds.

Consequently, it appears timely to begin discussions now to determine if acceptable technical alternatives to wetlands preservation can defined and objectively evaluated to determine if the loss of great amounts of phosphate minerals under wetlands can be mitigated.

7.5 TRANSPORTATION COSTS

In the July 31 workshop, it was suggested that the BASE CASE cost, ending with wet rock in storage at the mine, be extended to dry rock aboard vessel at Tampa. This is to focus more attention on transportation cost as a major component of the phosphate industry's total cost, which is not competitive with some international sources, and which has materially increased in recent years with rail service supplied by a single carrier.

- Problem Definition

Following is a cost summary entitled "Cost of Product: Mine Wet to Port on Vessel Dry per Short Ton". This is intended to represent current practice using public railroads and current rates.

The in-transit rail rate, \$1.86 per ton wet (\$2.11 per ton dry), is the published rate for a single car movement, by CSX Transportation Inc., the one existing public service railroad, between any shipping and receiving points in the Bone Valley area. Rates for large tonnages in regular unit train movements are privately negotiated contracts and not published. Rates for shipments of wet rock from mines to chemical plants, ports, or to central dryers within the Bone Valley are negotiated if via CSX for ore transported over private railroads. In some situations, wet rock shipments are made via privately owned trucks, or contractor-owned truck, at negotiated rates.

Truck transport is usually the method of choice for one-way haul movements short-distance, while rail shipment is normally used for shipments of rock to port. Rail rates for this movement are kept at the present level because these are slightly below the

FILE 6AR

COST SUMMARY

12/17/1987

COST OF PRODUCT: MINE WET TO PORT ON VESSEL DRY PER SHORT TON

29-A366

UNIT CONSUMPTION

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DRYING, STORAGE, & LOADING — DRY TON BASIS

MODULE	UNIT	ELECT. KWH	OP. LABOR MHR	OP SUPPLY $	MAN. LABOR MHR	MAN. SUPPLY $	FUEL OIL GAL	HEAT MBTU
IN TRANSIT FREIGHT (12% H2O)	TONS							
UNLOAD TO STORAGE/DRYER	TONS	.2	.004	.001	.004	.086		
DRYING (FROM 11% TO 2% MOISTURE)	TONS	2.3	.008	.001	.008	.204	2.17	.326
STORAGE AND LOADING (DRY)	TONS	.42	.012	.003	.012	.290		
FREIGHT TO PORT (DRY)	TONS							
LOAD VESSEL	TONS							
WEIGHING	TONS							
PORT IMPROVEMENT CHARGE	TONS							
TOTAL		2.92	.024	.005	.024	.579	2.17	.326

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UNIT COSTS

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COST FACTORS	ITEM	UNIT	$ COST/UNIT
	LABOR	MANHOUR	16
	ELECTRICITY	KWH	.045
	FUEL OIL	GALLON	.54
	FREIGHT	TON WET	1.86

DRYING, HANDLING, OVERLAND FREIGHT, STORAGE, AND VESSEL LOADING (WORK ARE) — DRY TON BASIS

MODULE	UNIT	ELECT.	OP. LABOR	OP SUPPLY	MAN. LABOR	MAN. SUPPLY	FUEL OIL	FREIGHT	TOTAL
IN TRANSIT FREIGHT (12% H2O)	TONS							$2.11	$2.11
UNLOAD TO STORAGE/DRYER	TONS	$.01	$.06	$.00	$.06	$.09			$.21
DRYING (FROM 11% TO 2% MOISTURE)	TONS	$.10	$.13	$.00	$.14	$.20	$1.17		$1.75
STORAGE AND LOADING (DRY)	TONS	$.02	$.19	$.00	$.19	$.29			$.69
FREIGHT TO PORT (DRY)	TONS							$3.39	$3.39
LOAD VESSEL	TONS							$1.67	$1.67
WEIGHING	TONS							$.20	$.20
PORT IMPROVEMENT CHARGE	TONS							$.33	$.33
TOTAL		$.13	$.38	$.01	$.39	$.58	$1.17	$7.70	$10.36

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cost of operating trucks over the present highway system. The trucker is called on by industry to quote on the longer distance haulage to keep railroad rates in line.

Wet rock cost totaled at the end of the conveyor module (o) page 3 of SOTA case cost scenarios places mine product in segregated open storage piles for all producers at the mine. If the wet storage is at some distant location from the mine the conveying and loading cost ($0.24) is deducted and in-transit freight cost is added to define cost at the drying site.

The cost of drying, $1.75 per ton, (moisture reduction of 9%), is incurred only for long distance shipments, or where the receiver is not prepared to consume wet rock. Drying of rock is not economically justified for freight savings when the freight cost is under about $20 per ton. However, when the consumer invests capital to avoid drying costs, it is reasonable that he share part of the costs savings in the form of reduced price. Data defining tonnages of dry vs wet rock consumed or sold have not been compiled.

The next operating cost module is dry rock storage and loading, $0.69 per ton. This may be overstated, but no comments from industry have been heard. Significant components of costs are operating and maintaining dry rock storage capacity and dust abatement in the handling steps, especially for rail car or truck loading.

Freight to port, $3.39 per ton, is given by the public service railroad from any Bone Valley point of origin to Rockport, the railroad's dry rock storage and vessel loading facility in east Tampa. The same rate applies to the other Tampa locations at Port Sutton (IMC), or at Big Bend (Agrico). At Rockport, only dry phosphate rock and granular fertilizers are accepted; no wet rock or truck deliveries are received. Wet rock via rail or truck is accepted and dried by IMC at Port Sutton under privately negotiated contract terms. Piney Point port in

Manatee County regularly handled wet rock from the Wingate mine via truck delivery when the mine was operating. It is capable of receiving wet or dry rock from other sources via truck or rail for transfer to vessels; no covered dry rock storage is available.

Vessel loading, $2.20 per ton, includes car unloading, weighing and sampling, and the Tampa Port Channel Improvement charge for environment safeguards. The published rate by the public service railroad is for dry rock only. Similar charges for wet or dry rock through the other terminals are negotiated by the private owners.

The cost of processing wet rock from the typical Florida mine to aboard vessel can be summarized as follows:

	Cost Range $/Short Ton	
	High Cost	Low Cost
Wet at Mine, 9.95 - 0.24 (SOTA file 6r)	9.71	9.71
Freight to central dryer	2.11	.25
Drying	1.75	1.75
Store and load	0.69	0.69
Freight to Rockport, or others	3.39	3.39
Vessel loading	2.20	1.10
Total FOB Vessel	19.85	16.89

The lowest is purely a "guess" based on private transport from mine to nearby dryer and private ownership or negotiated rate of loading large volumes on vessels at high rates. The purpose of assigning of "Lowest" cost is to emphasize the high cost of processing; i.e., $10.14 ($19.85 minus $9.71) to $7.18 ($16.89 minus $9.71) per ton, from wet at mine to dry on vessel.

o Possible Study

One suggestion was to examine the potential benefits that may result from a dedicated TRANSPORTATION CORRIDOR between phosphate production centers and a Tampa Bay port, or ports. Traffic to port would include rock and chemical products of the industry, and possibly other commodity products. Traffic from port could include sulfur, ammonia, and fuels. Increasing area population and traffic places increasing conflicts on the existing infrastructure, which threatens to further increase costs to industry.

In order to more fully understand the current transportation and port problems, it is necessary to compile data described above. Projection of future industry trends, tonnages, production locations, methods of transportation and infrastructure development to accommodate growing population will provide information for planning future needs of the industry.

Opportunities for reducing this cost are limited, especially since the trend of dry rock shipments is declining. The industry is trending to more shipments of high analysis fertilizers to reduce transportation cost to distant consuming areas.

7.6 POTENTIAL BY-PRODUCTS

1. Slimes to bricks.
2. Slimes to aggregates.
3. Sand to concrete.
4. Slimes ponds to farms.
5. Sand-covered slime ponds to citrus groves.
6. Heavy minerals and rare earth metals.
7. Mix slimes and gypsum.
8. Develop higher uses for reclaimed lands.

The above suggestions are presented to illustrate, but not limit, potential items for new industry products or by-products. Some of these have been evaluated in previous studies; some may be currently under investigation. The scope of this project did not encompass technology development for new products of this type, although some of them offer potential economic benefits to the industry.

SECTION 8

ADVISORY PANEL REPORT

8.1 INTRODUCTION

The Advisory Panel representatives were:

Mr. Joseph Bakker, Dept. of Natural Resources
Mr. David L. Batt, Florida Phosphate Council
Mr. W. T. Glover, CSX Transportation, Inc.
Mr. Sidney W. Carter, Consultant
Mr. Allen N. Geddings, Florida Power Corporation
Mr. Dan Williams, Dept. of Environmental Regulations
Mr. R. G. Lytch, Florida Phosphate Rock Export Association
Mr. Ken Parks, Consultant
Mr. Arthur J. Roth, Consultant
Prof. Brig Moudgil, University of Florida
Mr. Karel Konicek, CTL Distribution, Inc.
Mr. Robert A. Brinkman, CTL Distribution, Inc.
Mr. R. Clay Dickinson, Tampa Electric Company

Advisory Panel meetings were held at FIPR on August 18, September 11, and November 3, 1987. The meetings were chaired by James M. Williams and Robert S. Akins, and each was attended by a majority of those named above.

The purpose of these group discussions was to provide an overview of the phosphate industry in Florida from the point of view of interested parties not directly involved in the production of phosphate products.

Like any major industry, the Florida phosphate business is intricately woven into the economic, social, and political fabric of our state and nation. Phosphate is also an international business dependent on export for 60% of its direct and equivalent rock production, and to a greater degree when its equivalent in exported grain is considered.

The goods and services required by this industry, and the taxes, primary and secondary employment, provide a major economic base affecting many people. The economic well-being of this industry is, therefore, of broad general interest. This panel was selected to provide a wider perspective to the scope of study.

Our objectives in the discussion meetings of the Advisory Panel were to provide input of ideas to improve technology, to reduce costs within the industry, and to suggest methods of improving communication and cooperation to promote the general progress in areas of common interest.

The following sections provide an outline of the major topics discussed and suggestions made concerning methods of advancement of this industry.

8.2 DISCUSSION AND COMMENTS ON TECHNOLOGY

The various technical problems faced by the industry are discussed in other sections of this report. These problems are of many general forms, among which are:

- Problems where insufficient knowledge or understanding of the process limits our ability to make improvements.

- Limitations of progress due to availability of information or restrictions on data availability due to cost.

- Limitations on operating factors due to wear (materials of construction), reliability, maintenance and repair time, complex sequenced systems, and ore variability.

- o Control problems associated with uniformity of feed rate and feed composition. General lack of feed forward data (e.g., related to item 2) and the lack of knowledge on process response to changes in feed.

- o Economic constraints of capital utilization - all the factors considered involve economic constraints; however, in this case our concern about economics was directed at the capital cost problems of building new high technology operations. The return on investment is historically low in the early years of mine life. This is especially risky in a volatile market where prices are unstable. This area of concern deals with the essentially downward spiral of competitive position due to insufficient profit to refit with new lower cost technology.

- o Optimization of phosphate products in production and marketing - As the Florida orebodies become less competitive due to grade, quality, and yield, the search for more economical products and the acceptance of those products in the market place have become more important issues. For example, the replacement of DAP by MAP in the market has been very minimal compared to the economic advantages of MAP. The rock market has continued to decline as more conversion to chemicals takes place in captive chemical plants near the mining sites. This is an important advantage in Florida; however, loss of rock sales is also an important consideration since these rock sales are not generally replaced, in kind, by chemical sales.

- o Solution of technical environmental problems - the base of scientific facts concerning many environmental issues is not complete and, as a result, there is often confusion as to proper mitigation or correction. Corrective action can be expensive without achieving objectives. These problems often involve all the technical disciplines and natural sciences, and are, therefore, very demanding. Basic research is often so far ahead of practice that worst case theoretical impacts are used to establish guidelines, but more serious is the option to stop any activity which disrupts the present environment. A good example is the restoration of mined wetlands. The time required and degree of success of restoring hardwood wetlands is not established, so it becomes a hiatus point.

- Equipment design problems - new types of equipment are needed for many of the present operations as performance and efficiency are low. There seems to be a lack of incentive for development of new equipment and employment of high tech.

The Advisory Panel's interest in these problems was mainly in the most effective methods of conducting research and applying new technology. Our discussions on the subject of technology fell into three general areas: 1) Research and development, 2) incorporation of new technology into daily use, and 3) adaptation of established technology to present problems. These areas are discussed in the following section.

8.3 CURRENT STATUS OF RESEARCH AND DEVELOPMENT

Dr. Moudgil of the University of Florida outlined the problems associated with R&D in the phosphate industry in some detail, as follows:

- Lack of basic interest in old and mature industries - There are so many new and relatively unstudied areas for R&D that it is difficult to develop interest in old technology improvement. The glamor of new areas and the lack of definition and incentive to look at old subjects have resulted in very little research being done on the type of problems previously outlined.

- Definition of problems and familiarity with the phosphate industry - R&D personnel are generally uninformed about industry and the enormous problems faced today, especially in the mature, established industries. As in any instance where options exist, the people making their R&D project decisions will deal with subjects which are familiar and have stimulated their interests. There is a chasm between most researchers and the phosphate industry which includes familiarity and knowledge of the problem.

o Monetary incentives - R&D monies have for some time been primarily directed at "high tech" projects. This is where PhD's will get the best salaries and R&D supported with the best funding.

Discussion of these problems pointed out the difficulties involved in directing R&D. Those phosphate companies still engaged in development activities have generally dropped the long-term research aspects of their program, looking for a quicker return on investment as is necessary in these times. Dependence on others for research to feed in new technology to the development phase is the practice. This feeding of new ideas into development is, however, undirected and depends on chance.

Those institutions which traditionally provided R&D directly related to the fertilizer and mining industries, such as TVA and the U.S. Bureau of Mines, are presently operating with very tight budgets and their efforts are greatly restricted. The universities are not involved to a significant degree, as explained by Dr. Moudgill. The advanced research which may be 5-10 years ahead of present day technology is, therefore, "drying up". Dependence on "chance application" of new research seems to be the present trend.

FIPR's role is much clearer in that the direction and charges of this institute is to deal solely with phosphate industry related problems. The resources for basic research are, however, limited and dependence on others to feed development ideas from research is still required. The importance of FIPR to provide many of the R&D functions in a fully integrated program is well defined.

8.4 EFFECTIVE RESEARCH AND DEVELOPMENT OR IMPROVING RESEARCH AND DEVELOPMENT

The following suggestions were made concerning R&D improvements:

- o Closer involvement of students and professors with industry is needed. Professors and students should be exposed to the industry and its problems through a program where they are allowed to work in industry for a period of 3-6 months.

- o Information on industry problems and opportunities for R&D work should be provided by the companies through seminars, publications and direct contact. In these cases, the long term needs for new technology should be clearly defined.

- o Direct and indirect support of R&D. Provision for some research would provide encouragement and stimulate interest, but development and use of research results would be of most use as it would stimulate interest.

- o A more complete explanation of the basic research approach to problems needs to be presented to industry members. There are often differences of opinion on how to approach a problem and what is important. The goals and objectives of basic research and advanced R&D are often vague and difficult to explain in the purest economic terms. These problems need to be addressed and a common ground found which promotes success. To a great extent this is the problem of the researchers, but it must be a joint effort to overcome the present separation of interests.

- o Student influence as to career direction is a long-term concern. The separation of academia and industry leaves the student solely under the influence of the professor's interests, while leaving the basic needs of industry unfulfilled. Working through professional societies alone is not sufficient to bridge this gap. More direct contact and interchange is needed.

8.5 RESEARCH AND DEVELOPMENT PROJECTS

The types of problems presented in the discussion of technology could lead to R&D which would be directly useful in many industrial applications. Some of these types of projects are outlined below:

- o Process knowledge limitations.
  - oo Flotation feed conditioning
  - oo Reagent functions
  - oo Reagent types
  - oo Flotation technology
  - oo Desliming and clay removal
  - oo Clay technology

- o Data and information limitations
  - oo Geologic mapping technology
  - oo In-pit mining controls
  - oo Process performance prediction
  - oo On-stream mineral analysis (i.e., species, size, composition, etc.)
  - oo Product specification control
  - oo Planning technology

- o Operating factor restrictions
  - oo Technology which facilitates analysis of inter-dependent systems to improve reliability
  - oo Wear, corrosion, and matters related to materials of construction
  - oo Equipment reliability and useful life. Matters related to design and wear.

- o Process control
  - oo Control and optimization of performance on feeds that are constantly changing in size distribution, mineral distribution and chemical composition. Statistical application to control problems may be an area of research.

- oo Development of control and response technology. In many aspects of the separation processes, the proper control variables have not been defined.
- oo Development of feed control equipment.

o Capital utilization

o Product development (optimization)
- oo Development of new products considering all aspects of production cost, marketing, and agronomy.
- oo Improvement of existing products to meet market needs.
- oo Transportation costs as related to product types.

o Various technical environmental problems

o Equipment design
- oo Solids transport equipment technology.
- oo Solids-liquid separation equipment.
- oo Minerals separation equipment.

8.6 APPLICATION OF TECHNOLOGY

Incorporation of new technology into daily use - There was considerable discussion of the problems associated with the development phase of new technology use. There have been many new ideas tried in the phosphate industry over the years and the success rate has been low. The systems presently employed were developed and placed in general operation in the 40's and 50's. Modifications since that time have been relatively minor, but that is not to belittle the importance of these improvements. Since the perfection of the process has continued, it is more difficult to gain interest in new ideas and often those new ideas have already been tried without success.

The problem is, however, that the orebodies and overall economics are also changing so that old ideas and new technology must be tested. The processes involved are very large in size and it is difficult to test new processes without large expenditures. It was clear from our discussions that improved pilot plant and laboratory testing techniques were required. The area of "scale-up" needs to be more completely understood and advancements made to reduce risk of incorporating new technology into existing processing plants.

Since new equipment designs must be manufactured at economic levels before being of industrial use, the expertise of manufacturers is needed in the development phase. The design details and prototypes of new equipment can be very expensive. For example, cost of some of the work done with ore slurry pit pumping devices has been very large. The development phase, therefore, takes considerable time, talent, and money to bring a project to successful use. Methods to accomplish this development phase at lower risks must involve improved R&D programs, more effective pilot plant and scale-up operation, and cooperation of producers and equipment manufacturers. It was agreed that the work by FIPR to define and publicize specific problems, direct research and development efforts, and to bridge these areas with industry should prove to be a major inducement to new technology development.

8.7 ADAPTATION OF ESTABLISHED TECHNOLOGY TO PHOSPHATE PROBLEMS

The Florida Phosphate Council is interested in this concept and is working in this area. There are numerous areas of so-called "high tech" which might be adapted to specific phosphate problems. The difficulty lies mainly in the information gap which lies between the industry and the "high tech" companies, inventors and developers. In essence, they do not know our problems, and conversely we do not understand what they have to offer. Although this dilemma sounds rather simple, it is truly complex, and most of all, an incentive is needed.

It is the opinion of the Florida Phosphate Council that significant business incentive does exist for new technology products. The potential market for many products within this industry is, in fact, very large. It is, therefore, logical that opportunities exist to develop new markets in this area at low cost and with relatively low risk.

Specific problems, however, remain and these must be adequately defined and explained, with some assessment of incentive so that potential problem solvers will be attracted. Cooperation in the study and development of applications will also be necessary.

Phosphate mining and beneficiation involves extremely large quantities of material being moved by large equipment. The transition of ideas applied in "high tech" to this industry will require considerable vision on the part of all parties concerned; therefore, involvement and commitment will be required.

This is considered as an area of good potential for improvement. The work done with problem definition in this FIPR study could be used as a basic shopping list for "high tech" companies looking for applications of their technology.

8.8 TRANSPORTATION

The Advisory Panel was informed about the topics discussed in the industry participant workshops. There was considerable interest in the transportation problem. A review of the tonnages of various materials transported around the phosphate field and within the corridors to the port brought the focus of attention to future problems.

There is a general feeling that the phosphate industry is in a declining mode, which makes investments required for improved transportation infrastructure and equipment undesirable. In fact, the general opinion of railroad management is that as the phosphate tonnage declines over the next 10-15 years, rail services should decline in the area as no replacement tonnage would be available. This long-term plan is also evidenced by the considerable recent abandonment of rail lines in the phosphate district. Investment in new transportation technology, even on the lower levels such as improved rail and rolling stock is not of interest due to the conception that phosphate mining is a declining industry.

It is the general opinion of the panel that the future transportation problems will be more significant because of the large increase in diversified mobile traffic. Projected population growth and attendant increase in required goods and services will be the primary source of increased congestion. The only competitive transportation for rail is trucking, and this competition is limited to special cases. The increased road congestion creates problems for trucking.

The development of major transportation corridors was discussed. Projects of this scope require involvement of numerous agencies and the cost will be large. This type of project would probably have to be undertaken at a high government level after extensive planning. It was the general opinion that phosphate industry requirements would be only a part of the considerations.

Discussions included review of numerous other transportation alternatives which have been studied in the past. No new concepts were advanced. It would appear that the present high cost of transportation will not be affected without a concerted effort to provide a new technology which is economically effective that will stimulate competition.

8.9 POWER

Power, like transportation, seems destined to move along the present path into the future. The only alternative for the industry is to exploit all available co-generation and power savings alternatives available.

8.10 ROCK MARKETING

Florida rock markets are limited by competitive cost, product grade, and shipping cost to the market place. Although the basic wet rock cost FOB mine is competitive, the cost to deliver dry rock to port and load it aboard ships adds so much cost that no competitive edge exists. Product grades have decreased to the basic commodity level of 68 BPL, which does not offer any freight advantages. Back-hauls do not favor the Florida location, so ocean freight costs are high.

These disadvantages make rock products difficult to market in the world, as only certain markets can be economically served, compared to the large and diverse competition. Two key items are needed to strengthen the rock export market capability: 1) lower FOB vessel cost, and 2) a higher grade merchant rock. Both of these items are, of course, basic to any producers competitive position; however, this is still the problem.

Since this entire study was directed at cost reduction, no specific new concepts are suggested here. The concept of a new product to replace or supplement rock was, however, suggested. This subject should be studied further.

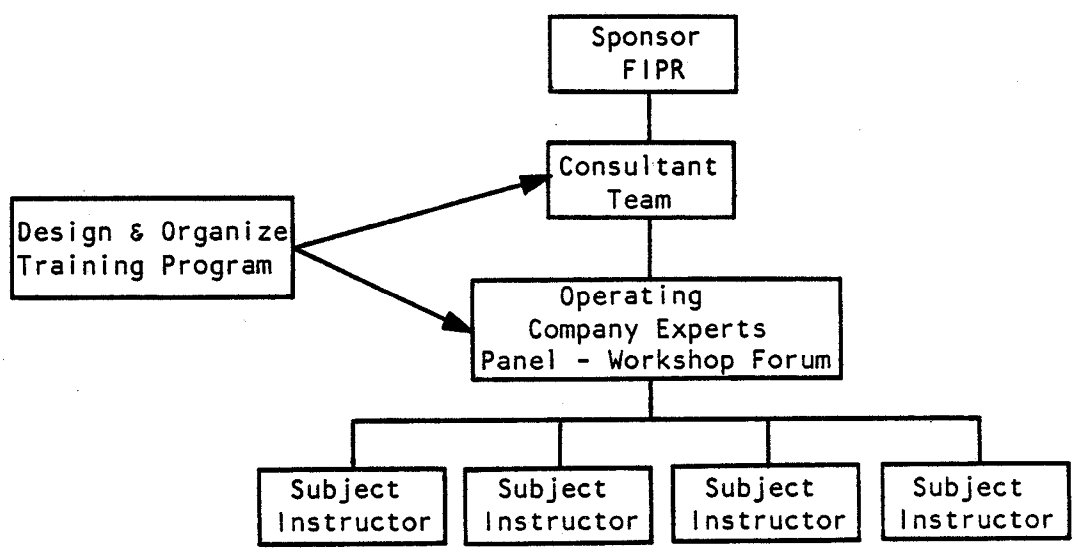
8.11 GENERAL APPLICATION IDEAS

1. Training

Workshop participants repeatedly expressed the importance of Training of Operators as a topic which deserves serious attention. Here we are not talking about training in mechanical equipment maintenance or trouble-shooting, etc. Training is needed in the simple basics of the process. Theory in simple form, and practice or applied theory including cause and effect.

This training might be conducted on an industry-wide basis in a forum which has participation of experts from operating companies, either as instructors or at minimum as advisors.

The following is an idea basis for pursuing this topic, if desired by industry. This training program might be organized as follows:



Set up a school. Located at FIPR, at a laboratory, and at a pilot plant, or at Polk Community College.

Provide apparatus/tools, teaching aids, graphics, text-study outline, simplified self work test.

A nominal fee of $10-$15 would be charged to pay for cost of text materials, etc., and to confirm participation. Principles, Theory and Practice approach would be used on each of the basic process topics, such as:

Matrix disaggregation,
Slurry pumping,
Conditioning,
Recovery,
Flotation,
Instruments (care and use of),
Other general topics.

2. New Phosphate Fertilizer Products

Rock specifications for feed stock to the chemical manufacturing process of phosphatic fertilizers are dictated by the traditional formulation, 18-46-0 for DAP. Why should this specification dictate rock production specifications? Should not DAP, MAP, or other fertilizer product specifications be fashioned to fit rock specifications? Redefine fertilizer specifications with focus on the cheapest method of making P_2O_5 value available for soil application for maximum P nutrient uptake. It is suggested that this is an education process, starting for example, with the customers and sales outlets of cooperatives.

Currently, rock producers respond to whatever specification the sales department says it can sell! Mining, and therefore resource recovery, is governed by these requirements which are dictated by the chemical plant where it is captive, or otherwise directly linked to the mine-beneficiation process.

The problem appears to center on the traditional requirement of "protecting a product grade and specification" (chemical fertilizer).

3. Maintenance Cost

The cost of maintaining mine-beneficiation facility equipment is a major contributor to the cash cost of production. This cost, exclusive of replacement capital, as indicated in the cost summary developed is included in this report, represents 21% to 26% of production cost.

Workshop participants expressed a great deal of concern about maintenance costs. Particular concern was voiced regarding bulldozer and end loader maintenance cost.

The subject of maintenance and maintenance cost and how it is dealt with is a matter which depends on the philosophy adopted by management. Each operating company has its own unique policy and it is beyond the scope of this study to report on the many and varied approaches to maintenance.

The following approach to the problem of maintenance is provided as an example of this philosophy.

One generally accepted philosophy of modern maintenance practice, particularly when applied to heavy equipment, is based on systematic application of procedures to the care of equipment which emphasizes prevention of breakdowns that result in interruption of production.

Mining equipment is subject to rough service which results in wear, and inevitably to breakdown owing to component failure. Some failures of equipment, such as those due to sudden shock loads, cannot be predicted and therefore are not prevented.

This practice is known as "preventive maintenance" (PM). The objective is to replace components before they fail, to minimize down time and maximize availability of equipment. The current and past practice in many operations throughout the world is best described as "catastrophic maintenance" where all efforts focus on repairing unanticipated breakdowns. Little thought is given to why failures occur, and at what frequency, and therefore the work load of maintenance personnel and equipment is erratic and difficult to schedule. This practice results in poor utilization of maintenance facilities, high cost, and often times a level of quality of repairs which is inferior. Inferior repairs are followed by increased occurrence of unanticipated failures. One of the objectives of preventive maintenance is to minimize emergency repairs.

This can be accomplished by implementing a predictive maintenance program known as "planned component replacement" (PCR). The basis of establish a PCR program is to determine at the outset, with the help of manufacturers, the historical component life of mean time between failures for each component on each piece of equipment. This information is plotted against the projected hours designated (scheduled) for operating each unit. At regular intervals, as determined from the historical life and scheduled operating hours, the equipment unit is brought in to the maintenance facility for routine tune-up, minor repairs, and for specific component replacement.

The capability to provide the level of maintenance required to sustain the predicted mechanical availability of equipment is the objective of maintenance and repair facilities.

Replacement schedules for mobile equipment are based on the normal life experience for like equipment in similar operations. This life is predicated on the practice of preventive maintenance and on the premise that a piece of equipment has a practical, useful life. This is dictated by the down time and expense of maintaining the equipment in useful productive condition, i.e., useful life being the period until the failure rate of the equipment increases to such an extent that the unit is no longer economical to run.

Replacement is generally dictated when (1) the annual cost of maintenance exceeds some percent of the replacement cost (this can vary from 25 percent for small machines such as vehicles, trucks, loaders, etc., to 50 percent for large machines, such as draglines), (2) the down time during maintenance accounts for reduction in availability of 15 percent or more, or (3) technological improvements of replacement equipment makes the existing equipment obsolete, in terms of production (unit cost), or in terms of efficiency (recovery).

The frequency of investments required for capital replacement is a function of effective maintenance. The effectiveness of maintenance is judged by the capability of the personnel and equipment to do whatever is required to sustain a high level of mechanical availability of the production units.

SUMMARY

9.1 SCOPE AND METHODOLOGY

In simplest terms, the scope and methodology of this study may be described by asking questions and making statements about how the Florida phosphate industry goes about producing phosphate rock and about how such a study may be conducted.

- o Exactly how do we go about doing it?
- o How can we do it better, at less cost, today, tomorrow (near-term) than we have done it in the past?
- o What are the large contributors to production cost?
- o Which of the cost contributors can we do something about near-term without large expenditures.
- o Does the technological know-how exist to do it at less cost?
- o Ask people in operations ... which costs can be improved upon, and how?
- o Focus on technology, but encourage all ideas that have potential for reducing cost.
- o Refine and expand on all ideas ... new or old.
- o Screen ideas in workshop forum and agree on worthwhile survivors.
- o Estimate cost and benefit of survivors.
- o Evaluate risk factors and develop strategies to reduce risk.
- o Review estimating basis in workshop forum, revise as indicated, and obtain consensus as to success/failure risk.
- o Restate surviving concepts, clarify cost reduction potential and describe suggested study format.
- o Summarize and report.

Zellars-Williams has, in this study, described the present technology of phosphate rock production and identified the chief contributors to operating cost. The workshop format was successfully adopted to accept the ideas of operating personnel and to provide for review of our efforts. ZW has identified many significant ideas, assessed their cost, discussed their benefits, and addressed the issue of risk. The most promising concepts have been taken and a preliminary plan for each to provide a guide for continuing development has been devised.

9.2 BACKDROP

A paper titled "Phosphate Industry Outlook", prepared and presented by J.M. Williams to workshop participants and to advisory panel members, painted the backdrop of an economically depressed Florida phosphate industry. Highly subsidized off-shore producers are effectively competing for the same market share.

FIPR, in response to these concerns, funded a study to assess present practice and to evaluate alternative technology. ZW was to proceed with such a study with the caveat that support of the local producers be obtained.

The support of Florida phosphate rock producers was evidenced by the participation of operating company personnel. The study could not have been conducted without this support.

9.3 STUDY OBJECTIVES

The study undertaken, and reported in this document, was confined to mining and beneficiation, and to some extent the downstream handling of phosphate rock products. Manufacture of phosphatic fertilizers was not within the scope of the study. Effects of grade and quality of phosphate rock as feed to the phosphoric acid plant, however, were addressed.

A brief treatise of the physical and economic aspects of phosphate rock grade and quality was prepared by S.M. Janikowski of ZW[1/] and included in an Interim Report published in October, 1987. This paper is not reproduced in this Final Report.

The focus of the study was to investigate the potential-possibilities for near-term cost improvements and not to look for major long-term technological improvements.

The study has achieved its objectives. Many opportunities for cost reduction have been identified. The most promising of these have been defined and elaborated upon. A proposed route for pursuing these opportunities, and the beneficial effect of their implementation have been defined and presented in this report.

9.4 WORKSHOP FORUM

One of the most important aspects of this study was the conduct of "think-tank" type group meetings. These sessions provided the opportunity to exchange ideas and to identify specific topics within a certain work area or operation which merit detailed analysis.

Each workshop session provided a period for structured discussion following an agenda prepared by the ZW workshop leaders. A deliberate effort was made to limit this period and to provide ample time and opportunity for informal discussion.

The purpose of these thought-discussion sessions was to identify problems. The driving incentive was cost reduction. Any ideas which would result in improvement to present practice (technology) or to operating methodology were encouraged. Participants responded. Concentrated thought was focused on a particular operation or operational problem by a small group of knowledgeable people while

[1/] Florida Phosphate Rock: Conventional Specifications for Feed to Phosphoric Acid Plant and Possible Relaxation of these Specifications.

gathered together for a short period of time. Many ideas, including many to improve on time-worn practices, were generated and discussed.

The workshop forum employed in the conduct of this study was successful. The workshop produced meaningful contributions in the way of alternative technology concepts and ideas. This forum provided the opportunity for technical-operating personnel from a majority of Florida's phosphate rock producers to participate in discussions about their particular area of expertise, and to express their concerns.

Technical staff representatives from eight of Florida's phosphate mining-beneficiation operating companies participated in a series of twelve workshop meetings. These companies are IMC Fertilizers, Inc., Agrico Chemical Company, Gardinier, Inc., Estech, Inc., W.R. Grace & Co., Mobil Mining and Minerals Company, CF Industries, Inc., and U.S. Agri-Chemicals.

9.5 STATE-OF-THE-ART - (SOTA)

The description and assessment of present practice was accomplished by creating a mine-beneficiation plant on paper. The methods and unit process elements of this facility are typical of those employed in Florida, and comprise: mining of overburden and matrix by a single electric-powered walking dragline, matrix disaggregation by high pressure water, matrix slurry pump-pipeline transportation to a central plant washer unit, mechanical separation of matrix into pebble product and sand-size flotation feed by a series of screens, logwashers, and/or trommels, feed preparation by desliming and sizing steps followed by reagentization and double flotation circuits to produce wet concentrate product, and tailing sand and clay reject materials in solids-water mixtures.

The total mine beneficiation process was divided into four work areas and these, in turn, into unit operations modules. The four work areas are: (1) Mining, (2) Beneficiation, (3) Waste Disposal, Land

Reclamation and Water Re-Use, and (4) Product Management. Each module is described mathematically for the purpose of operating cost estimation in Section 3 of the report.

Basic orebody characteristics and a well-matched mining-beneficiation facility, designed to include the most efficient least-cost technology typical of the present practice of all Florida operations, were used to create two state-of-the-art (SOTA) cases.

One case, referred to as the "present" mining scenario, is based on hypothetical characteristics representative of most currently mined orebodies located in the Central Florida District. A second case, the "future" mining scenario, is representative of conditions south of the "Bone Valley". Each of these cases is the basis for measuring the estimated economic benefits of alternative technology.

Principal characteristics of the two orebodies used to develop the SOTA cases are indicated below:

Orebody Characteristics

	"Present"	Future"
Matrix "X"	2.83	4.21
Total "X"	8.76	12.01
% slimes	28.60	30.00
% pebble	13.60	4.60
% sand tails	44.00	51.60
% flotation concentrate	13.80	13.80
Ratio of concentration	4.20	4.70

9.6 PRESENT PRACTICE

The two SOTA cases, developed with the input of workshop participants, represent an assessment of present practice. These are used as a basis to compare the benefit of technology not already employed at any mine. The numerical values for production factors, recoveries, unit consumption and calculated costs are used to evaluate the improvement potential of ideas generated in the workshop sessions. Although these data are not intended to be a basis for comparing one operation to another, nor for the purpose of measuring performance, the rock producer will find the SOTA case printout displays of interest for comparing his operation with these results.

Principal features of the two SOTA orebody mine-beneficiation plant cases are given below.

	"Present" Orebody	"Future" Orebody
Mine Recovery	90%	90%
Flotation Recovery	87%	86%
Flotation Feed, BPL	19%	17%
Pebble Product, BPL	67%	65%
Concentrate Product, BPL	69%	69%

These subjects are covered in report Section 3 "Present Practice and Alternative Technology".

9.7 ALTERNATIVE TECHNOLOGY

The "workshop format" adopted for this study produced a large number of ideas, many of which could be evaluated by application of engineering and estimating procedures and some of which required a more qualitative assessment. All these concepts, with clarification and refinement, are addressed in the report to the extent required to fully define the problem. In many cases, a quantitative evaluation has been possible. In some instances, problem analysis and totally subjective solution possibilities are presented.

The study has identified many opportunities having the support of workshop participant representatives from operating companies. Some of these, although not qualifying as alternative technology, are ideas which express the concerns of technical-operating personnel. The ideas, concepts and alternative technology identified have in common the objective of bringing about improvements which result in better economy of operation. All of these are described under their respective work areas in Sections 4, 5, 6 and 7 of this report.

Twenty-nine alternative technology ideas and suggestions which are opportunities for improving the way the industry operates were generated by the four work area category workshops. The contribution of each workshop is summarized below.

Work Area Category Workshop	Alternative Technology Ideas
1. Mining	3
2. Beneficiation	17
3. Waste Disposal, Land Reclamation and Water Re-Use	4
4. Product Management and Mineral Resource Conservation	5
Total, Identified Opportunities	29

Alternative technology, which in the opinion of ZW and the majority of workshop participants may be economically attractive and suitable for development, has been identified. Those concepts exhibiting greatest promise have been evaluated to the extent required to demonstrate the potential for cost reduction.

Conceptual evaluation of fifteen of the alternative technology concepts has been conducted and the magnitude of the cost reduction opportunity estimated. These are summarized below. The opportunity for realizing potential cost reduction is real and the risk is low for many of the alternative technology concepts reported.

Alternative Technology Concept by Work Area		Approximate Annual Savings Potential
Mining		
o Improved matrix slurry transport	*	$1,013,000
o Reduction of matrix loss and dilution	*	519,000
o Separation of dragline from matrix transport system		1,052,000
Beneficiation		
o Improve anionic conditioning	*	940,000
o Reduce variability of flotation feed	*	230,000
o Recover and re-use reagents	*	260,000
o Optimize mine/chemical plant systems		840,000
o Improve rougher flotation selectivity		300,000
Waste Disposal, Land Reclamation and Water Re-Use		
o Earthwork cost reduction	*	1,274,000
o Waste sand tails and slimes pumping cost reduction	*	585,000
o High sand-clay ratio waste disposal		206,000
Product Management and Mineral Resource Conservation		
o Pebble from waste clay		295,000
o Concentrates from slimes		78,000
o Fine rock from tailings		181,000
o Computerized blending and inventory control		688,000

Details are included in each section of the report by work area. All improvements cannot be applied together (as some are mutually exclusive). Compatible items of alternative technology were combined to produce hypothetical mine-beneficiation plant production cost scenarios. This combination is applied to each of the SOTA cases to demonstrate the magnitude of potential cost reduction, if the potential of the proposed alternative technology is fulfilled. Seven of the most promising concepts (indicated by an asterisk) were "installed" in the unit operation modules of SOTA cost cases "present" and "future" orebodies (files 6r and 8) to determine the overall cost reduction. Comparable production cost for each "present" and "future" orebody was generated by the cost model to produce Alternative Technology Cost Cases (files 7r and 9).

The result of implementing seven of the preceding fifteen ideas (indicated by asterisk) is as follows:

	Cost-dollars per Short Ton			
	SOTA "present" orebodies file 6r	Alt.Tech. "present" orebodies file 7r	SOTA "future" orebodies file 8	Alt.Tech. "future" orebodies file 9
1. Mining	2.45	2.06	4.24	3.48
2. Beneficiation	3.30	3.16	5.27	4.94
3. Waste Disposal, Land Reclamation and Water Re-use	2.44	1.84	4.53	3.35
4. Product Management	.46	.46	.46	.46
5. Administrative, clerical, technical	1.30	1.30	1.30	1.30
Total Cash Cost (Wet rock)	$ 9.95	$ 8.82	$15.80	$13.53

	Cost Reduction	
Alternative Technology Cost Case	$/ton	%
"Present" orebodies (File 7r)	1.13	11%
"Future" orebodies (File 9)	2.27	14%

The annual savings indicated represent the net reduction in annual operating cost and include amortization of capital required for implementation of the concept.

The cost reductions shown are an indication of the potential, and should be viewed as indicative of the opportunity to be realized by detailed development work. The scope of this study did not intend, or include, in-depth examination and evaluation. It is likely that higher levels of cost reduction can be realized by additional effort.

9.8 ADVISORY PANEL

An advisory overview function was performed by an assembly of persons indirectly associated with the Florida phosphate industry. The attendees were:

Bob Akins	FIPR
J. M. Williams	ZW
J. G. Tavrides	ZW
Joseph Bakker	FDNR
Dan Williams	FDER
Prof. Brig Moudgil	University of Florida
David L. Batt	Florida Phosphate Council
Bruce Marsh	Florida Phosphate Council
R. Gil Lytch	Phosrock
W. T. "Bill" Glover	CSX Transportation, Inc.
Karel Konicek	CTL Distribution, Inc.
Robert Brinkman	CTL Distribution, Inc.
R. Clay Dickenson	TECO
Allan Geddings	Florida Power Corp.
Arthur J. Roth	Consultant
Ken Parks	Consultant
Sidney W. Carter	Consultant

This group, consisting of independent consultants and representatives from transportation and utility companies, The Florida Phosphate Council, governmental agencies, and academia, met three times to provide an independent view of the industry. The panel discussed ideas having the potential of benefiting the entire industry. No easy solutions to problems of transportation, energy, and environmental issues were revealed, but some fresh approaches emerged. The view was expressed that much could be done to improve the way research and development is conducted. The panel was critical of the failure of the phosphate industry to properly communicate to academia and the research community the nature of its problems and the kind of technological break-throughs needed to solve them.

The Advisory Panel workshops revealed a startling view. Evidently, the general public and certain elements of the private commercial sector believe that the phosphate industry is in a state of irreversible decline, heading to extinction in the near-term. The railroad industry, for example, holds this view as evidenced by current abandonments, minimal maintenance, and the failure to invest in replacement and/or modernization.

9.9 STUDY RESULTS

The adequacy of present practice to meet future industry needs is uncertain as evidenced by the small margin between product sales price and the cost of production. Each producer has criteria unique to its current operations to judge adequacy of specific present practice. The SOTA cases presented offer an industry-wide basis for examining the adequacy of currently available, but not universally applied, technology in meeting industry needs in the near-term.

The results of applying compatible alternative technology to the two SOTA cases demonstrate the potential for meaningful near-term reduction in production cost, with minimum technical and economic risk. The alternative technology described does not involve lengthy, pioneering research programs; rather, it draws upon well known engineering concepts. Much of this alternative technology has been in existence for a long time, but not seriously developed.

A "blueprint" guide for the undertaking of several specific alternative technology development projects is presented. More general guidance is presented for examining the many other concepts and ideas generated by the workshop sessions.

Alternative technology and ideas generated by the study are presented in four sections of the report under Work Area headings; Section 4, Mining; Section 5, Beneficiation; Section 6, Waste Disposal, Land Reclamation and Water Re-Use; and Section 7, Product Management and Mineral Resource Conservation. An attempt has been made to focus on problem definition and analysis, and to present solution possibilities. It is the intent of this program to demonstrate by example the possibilities which can result from well prepared and carefully conducted studies and subsequent implementation of their positive findings.

Each of the ideas, concepts, and alternative technology items which survived workshop critique and screening is addressed by Work Area according to a common format consisting generally of the following topic agenda.

- Problem statement/definition/analysis.
- Study objective.
- Problem analysis/solution scenarios.
- Potential study results.
- Cost analysis of implementation.
- Risk evaluation.

9.10 CONCLUSIONS

The Florida phosphate industry as it exists today is a mature industry. The future demand and market scenarios which drive the industry are unlikely to require or justify significant increased production. There is, however, sufficient justification to indicate that production at a high level should continue from the Florida phosphate fields well into the 21st century.

Phosphate mineral value contained in property owned or controlled by the industry, which today is classified as resources, will become economic reserves in the future. The industry will make the technological developments and investments required to exploit these natural resources far into the future. The restructuring taking place today will result in a more competitive industry poised to capitalize on the vast resources which remain.

Measured resources estimated to be 470 million tons of P_2O_5 will become the economic reserves of tomorrow. Extraction of these phosphate reserves at the rate of 8-10 million P_2O_5 tons per year indicate a life in central Florida of 47 to 58 years. This does not suggest an industry which is going to disappear in the near future.

Every effort has been made to have the findings in this report represent the expressed concerns of technical-operating participant representatives of the Florida phosphate industry.

The FIPR Technical Manager, ZW Study Manager, Study Advisor, and workshop technical leaders have sought to stimulate participation from the attendees, and it appears from the results reported herein this effort has been successful.

Most costs are amenable to improvement by technical solutions. The study shows that while there are many alternative technology concepts offering opportunity for near-term improvement, large reductions in operating cost are difficult to realize. Nothing boldly new or totally innovative has been revealed. Most, if not all, of the concepts advanced are known and/or have been previously considered.

The study indicates that many previously considered concepts need to be re-examined because properly conducted analysis and study can lead to cost reducing solutions. This may appear to be a case of simply "dusting-off" and reviving old ideas, but in reality it is a case of learning more about little understood basic processes, many of which are taken "for granted". The scope of the study did not permit comprehensive evaluation, but the exercises conducted indicate a real potential for cost reduction. These conceptual evaluations are based on only one possible solution scenario. Many other possibilities exist and investigation of each of the proposed alternative technology concepts will no doubt yield other solutions with more favorable cost reductions. Small capital expenditures, low risk, reasonably short-term payback, and attractive economic benefits appear likely if implementation of the proposed alternative technology is pursued.

Certain costs cannot be improved solely by technical solutions, and may require education and public relations campaigns, and political acumen.

Concepts and ideas have been identified to improve on the way things are done. Conceptual evaluation of alternative technology provides a clear indication of the opportunity for cost reduction. The work product of this study, presented in this report, offers to those who wish to pursue the opportunities a guide and blueprint for doing so.

The study presents rationale to reduce production costs in the near term to bridge the period required for development of production facilities to serve the long term.

Additional study is needed to explore rationale which can result in near term cost reductions to sustain the industry during the period required for development of new technology to serve the long term.

- The technical expertise exists today within the industry to develop and create the improvements required to reduce the cost of producing phosphate.

- The present world excess supply capability has spawned fierce competition for a stagnating market demand; this provides the incentive to commit resources to implementation of alternative technology

- Introduction of cost-reducing alternative technology adapted for and applied to present facilities is necessary to extend the useful life of in-place investments.

9.11 RECOMMENDATIONS

The results of this study make a good case for pursuing alternative technology idea development for near-term cost improvements. Specific problems and alternative technology solutions have been suggested by industry representatives. Commitments need to be made by operating companies or by FIPR to undertake programs for solving problems identified by the study.

Recommendations which flow from the work and conclusions of this study are readily apparent.

- The strength of the industry is founded on sound economics and good citizenship. Any concept which improves on these should be considered and evaluated regardless of perceived notions of exclusivity and political sensitivity.

- The industry should adopt a fresh and aggressive approach to research and development on an industry-wide basis, incorporating a meaningful dialogue between industry and academia.

- The industry should continue and augment its industry-wide cooperative effort to deal with and solve environmental issues.

- The industry should utilize the results of this program as a "blueprint" guide for prioritizing topics meriting further study and for creating the scope and method of execution of each study.

It is suggested that each of the fifteen alternative technology concepts listed on page 9-8 merit further examination and study. Priority however, should be given to initiating the following studies.

In the mining area it is recommended that parallel studies be undertaken. One, to improve on the way matrix is handled between the dragline bucket and the slurry pump-pipeline; a second, to look at the potential of equipment development which would permit separating the dragline from the matrix transportation system.