DUALPLAN

Version  1.0

A Stand Management Scheduling System\textsuperscript{1}

User's Manual

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ABOUT THE MANUAL

This manual is designed to facilitate the use of DUALPLAN, a forest management scheduling model. This manual is not intended to teach stand management scheduling or forest planning. The authors assume that the users of this program have some expertise in these areas, as well as experience in using personal computers running under the DOS operating system environment.

The manual is broken down into several distinct sections that the user may consult as needed. The first section contains the software disclaimer, and license agreements which explain the obligations and agreement between the users and the authors. It also explains the authorized uses of this software, and the extent to which the users can expect support from the authors.

The second section provides a general description of Forest Management Scheduling "Problems" and the approach DUALPLAN uses to help the planner analyze them. The third section describes model assumptions in more detail including information on the data and input files necessary to implement the model.

The fourth section illustrates the various screen menu options. The manual ends with a list of references.
SOFTWARE DISCLAIMER FOR DUALPLAN

All of the software on the DUALPLAN diskette has been extensively tested and checked for accuracy. To the best of our knowledge, it contains no errors. However, neither the University of Minnesota, the Department of Forest Resources, nor the authors provide any guarantees and are not responsible for errors that may arise during the use of this software. The authors ask that any errors found by users be brought to the authors attention in order to incorporate appropriate changes into future versions.

For permission to use or copy DUALPLAN and for revised versions or updates to existing DUALPLAN installations contact:

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MODEL OVERVIEW

Linear programming (LP) models have been used in forest management planning for almost thirty years. The major difficulty with LP models is that the problem cannot be described completely by a LP formulation of manageable size. This is usually recognized within the planning process and the model is used more like a simulation model to help learn more about the real world problem by changing model assumptions and applying multiple runs. DUALPLAN is a computer model that has desirable characteristics of both an optimization model and a simulation model. DUALPLAN is based on a solution process (Hoganson and Rose, 1984) that utilizes an understanding of the forestry problem; it recognizes some of the key yet simple relationships between an LP formulation of the problem and the economic interpretation of key model variables; it capitalizes on the fact that problems, as specified in a mathematical model, are usually defined more precisely than need be for most situations. In this section we will first discuss the forest-wide scheduling problem and then look at the methods used in DUALPLAN, first, from the viewpoint of a simulation model, and then from the viewpoint of an optimization model. Technical detail in these descriptions will be kept simple. A more thorough mathematical description of the methods can be found in Hoganson and Rose (1984). A general review of the methods can also be found in Davis and Johnson (1987, pp. 669-673).

The Forest-wide Problem

In the simplest case one might think of the forest-wide problem as a problem in which there is only one product (timber) and one consumer (the mill) with the forest composed of many individual stands, each identical, but at a different stage of production (age). Because a mill has a limited processing capacity, it can use only a limited amount of timber at any one time. If one analyzed the individual stands separately to select management options, it is highly unlikely that the flow of timber from the forest would be satisfactory from the standpoint of the mill. As a result, it would be necessary to adjust the timings of the harvests to produce a more desirable flow of timber. Depending on the initial age distribution of the stands and the projected future mill demands, it is likely that the rotation lengths of some stands will change. Depending on the size of the forest in relation to the size of the mill, it might not even be desirable to harvest some stands at any point in time.

The forest-wide problem described above would be rather easy to solve. But the problem is almost never this simple. A number of factors typically complicate the problem:

1. Multiple forest products—the forest produces a wide range of products, both timber and nontimber. Usually it is difficult to analyze opportunities for producing one product without considering the other products.

2. Multiple stand locations—the location of stands in relation to the market is extremely important. The costs of accessing the stand and transporting the products to market are often a large proportion of the total production cost.
3. Multiple products in each stand—harvesting a stand can produce multiple products that are not necessarily shipped to the same market. Harvesting a stand for one product thus might help increase the supply of another product in another market.

4. Multiple markets—seldom is there one buyer to consider for a specific product from a specific stand. Price differences between markets affect product allocations.

5. Substitutable stand outputs—at least some stand outputs can be used for several products. For example, a large log might be shipped to either a sawmill, a pulp mill, or a fuelwood market. The end-use will depend on the differences in transport costs and delivered prices for the possible end-uses.

6. Nontimber product substitutes—for example, fuelwood users can usually utilize some other form of biomass or even coal.

7. Long production periods—it takes time for trees to grow. Long planning horizons are generally needed. Future timber supplies will depend on how much of the forest is harvested in the meantime. It is thus necessary to consider timber demands when evaluating future timber supplies.

8. Uncertain timber demands—the quantity of wood demanded by a mill is likely to depend on the cost of wood and the general state of the economy. Predicting future demand-price relationships for individual markets is extremely difficult.

9. Differences in stand characteristics—stands differ not only in age but also in terms of current species mixes, relative stocking levels and site productivity potential.

10. Future production opportunities—forest management must be concerned with the long-term impact of immediate management actions on future rotations. Each stand has a landholding cost that is due to future opportunities foregone (or postponed) by not harvesting and regenerating the stand today. This cost depends on the production potential and location of the site and the regeneration alternatives that are available. Decisions on regeneration are often extremely important because they involve immediate actions (investments) that can vary significantly in management intensity and cost.

11. Alternative management intensities for existing stands—thinning is one potential management tool. The number of thinning alternatives can be large for some stands, especially if multiple species are involved. Other tools are also generally available such as fertilization, weed control, and general timber stand improvement options.

12. Multiple harvest systems—harvest options can range from traditional roundwood operations to tree-length logging to full-tree chipping to chip-and-sort operations. Within these general harvesting methods there are also a range of plausible harvest equipment combinations.

13. Multiple ownerships—within a region, lands are seldom all under a single ownership or are managed for the same objective. Predicting landowner actions is a difficult task.
14. Changing land base—the amount of forest land changes over time. Marginal agricultural land might be converted to forest land or forest land might be converted to other land uses.

15. Growth and yield uncertainties—forestry deals with a biological process that is in itself difficult to predict. There are also potential catastrophic events of concern such as disease outbreaks, drought or fire. It is extremely simplifying to assume that all acres respond to treatment in an "average" manner.

16. Spatial interactions—the management of one stand is seldom independent of the management of nearby stands. For example, roadbuilding will often access several stands and some general management emphases, like timber production and wilderness, are often not compatible on adjacent acres.

17. Sequential decisions—forest management is a dynamic process. Only those decisions that require immediate action must be made today. Future actions can depend on how the future unfolds. Long-term impacts of immediate actions need to be considered in making decisions not only because forestry involves long production periods but also because actions taken today can influence the range of options that will be available for future decisions.

In developing models it is extremely important to consider how users will consider these aspects of the problem, either through multiple runs of the model or within the model itself. These practical considerations are sometimes forgotten as modelers become involved with the many technical aspects of the model.

Forest Management Scheduling Models

Models used to address forest-wide problems are generally called forest-wide scheduling problems. These models can be thought of as economic analyses of specific forest management units (analysis areas) that are done simultaneously because of some interactions between the units in terms of shared resources or constraints on the system as a whole. Separate economic analyses of the individual analysis areas are not appropriate by themselves because they do not have an acceptable method for incorporating the forest-wide interactions into the analysis. For example, suppose a forest has an abundance of timber in the older age classes and very few acres in the younger age classes. An economic analysis done on each stand separately might indicate that most acres should be cut today, but this type of analysis lacks an acceptable way of coordinating activities across the forest to help achieve a more acceptable flow of timber over time. A closer look at forest scheduling models will show that forest-wide scheduling models use a method of valuing (pricing out) these forest-wide concerns and actually use the same basic concepts that are used in an economic analysis of specific management alternatives for specific forest stands.

Scheduling models use one of two methods for breaking the forest into units for analysis: contiguous analysis areas or noncontiguous analysis areas. Most applications, especially the earlier applications, have used the noncontiguous approach. A noncontiguous approach assumes analysis areas are homogeneous in terms of their biological characteristics. They are not necessarily all located in the same place. An example of a noncontiguous analysis area might be all acres of red pine with a site index of 70 and 40 years old. In contrast, the
contiguous analysis area approach groups stands by location but does not maintain homogeneity in terms of the biological characteristics. The contiguous approach has some advantages for dealing with spatial aspects of the problem, but problems are created because (1) many variables are often needed to describe the many combinations of management options that are possible within an analysis area when an analysis area contains several types of stands, and (2) integer variables (and integer programming methods) are generally needed to describe options for each analysis area because it is usually not realistic to assume that it is desirable to try and implement portions of several management options for the same contiguous land block.

**DUALPLAN Viewed as a Simulation Model**

Simulation models have been used extensively in forest planning to simulate forestry activities over time. Simulation models can handle a significant amount of detail and are generally appealing to users because they are usually easy to understand. A disadvantage of simulation models is that they do not solve problems, they simply mimic a system. Simulation models used for forest management scheduling are often referred to as binary search models because they are used to search for the value of only one decision variable. A good example would be a model used to estimate an allowable cut that can be achieved over a specified planning horizon. Essentially the simulation model is used to mimic different harvest levels and a search technique is used to narrow in on an allowable cut estimate by using the simulation results to adjust upper and lower bounds on the estimate. The simulation model traces the forest through time period by period by harvesting each period until the specified harvest level is reached and then growing the entire forest forward to the next period. Assumptions are necessary in a model of this type regarding the sequencing of stands for harvest and the type of regeneration activities to implement after harvest. Intermediate harvests (thinning), multiple forest products, and mixed species stands are all difficult to handle in this type of framework. For example, when multiple products are present, it is difficult to simulate activities and satisfy harvest levels of several products simultaneously.

Most simulation models for forest management scheduling cannot be classified as economic models because so many assumptions are made concerning harvest priorities and management intensity. **DUALPLAN** is different in that it uses basic rules of economics to select management activities. Like other simulation models it mimics activities in an effort to learn more about the forest; however, a significant difference with DUALPLAN is the general method of simulation. **DUALPLAN** simulates activities analysis area by analysis area rather than period by period. In other words, it simulates the management of each analysis area for the entire planning horizon before moving on to the next analysis area. From a practical standpoint this is extremely important because it helps overcome most of the basic problems of simulation concerning multiple forest products, mixed species stands and intermediate harvests. By considering individual stands for the entire planning horizon, the model can look-ahead to consider the long-term impacts of actions aimed primarily at producing long-term benefits.

A key to understanding DUALPLAN is to understand how management alternatives are selected for individual stands in the simulation process. Alternatives are selected simply by comparing alternatives and picking the one with the greatest estimated value. The valuing system is the same as would be determined using basic concepts of economics for an individual project except that shadow prices rather than market prices are used to value
products (or inputs) that are constrained at the forest level. For the typical case of even-age management, the process of valuing and comparing alternatives is essentially the same as the problem of determining the optimal rotation age. This involves combining an estimate of the value of the existing stand with an estimate of the value of the land for future rotations (or other land uses). For each possible time (t) of final harvest for the first rotation, this could be expressed as

$$MPNV(t) = MCUR(t) + MSEV(t)$$

where:

$$MCUR(t) = \text{the maximum present net value that can be achieved from the current stand if the final harvest of the first rotation occurs at time } t. \text{ This term includes all benefits and costs from the present to the time of final harvest. All costs (and benefits) already incurred are sunk costs and not included in this term.}$$

$$MSEV(t) = \text{the maximum soil expectation value (in present dollars) that can be achieved if "bare land" becomes available for future rotations at time } t.$$ 

$$MPNV(t) = \text{the maximum present net value from an infinite planning horizon if the stand receives its first final harvest at time } t.$$ 

From this relationship it is important to recognize the basic tradeoffs that are likely between alternative rotation lengths (times of final harvest for existing stands). In general, the term MCUR(t) would increase with t until the value growth rate drops below the interest rate. However, for some situations MCUR(t) might not be well behaved over time if significant gains are possible from shifts in product classes as trees grow in size. Finding MCUR(t) can be a problem in itself if intermediate harvests are possible because the number of management alternatives for each t can then be large. The term MSEV(t) incorporates the consideration of a landholding cost in that as t increases, MSEV(t), decreases. In general, one would expect that over time MSEV(t) would decline at the interest rate. Exceptions would be if real price increases are expected, or if returns from future rotations fall within the planning horizon and can thus be influenced by constraints on forest-wide resources or product flows. To find the maximum value of the existing stand one simply needs to determine the maximum value of MPNV(t) over all possible values for t. Mathematically this could be expressed as

$$MPNV^* = \max_t \{MPNV(t)\}$$

DUALPLAN uses this basic approach to determine the value of management alternatives for each analysis area.

To understand DUALPLAN it is also important to understand the prices used to value products (or inputs) that are constrained in the problem. One way to understand the valuing system is to consider the basic concept of economic supply and relate it to what would happen if the stand were lost from the forest.

Timber supply, from a basic economic perspective, is defined as a schedule which shows the
quantity of timber that producers are willing to sell at specific prices during a specified time period. In general, these schedules are very difficult to estimate because of the factors that complicate the problem. Even when recognizing only one timber product, supply schedules for different periods are difficult to estimate because the quantities harvested in earlier periods will influence the supply schedule for later periods. An important objective of the forest planning is usually to learn more about the supply situation from applications of a scheduling model. But to help understand the valuing system used in DUALPLAN, let's assume that the supply schedules (curves) are known for all periods. DUALPLAN does not make this assumption. To keep the discussion simple, we will also assume timber is the only forest product and only two planning periods are involved. It is easy to extend the concept to multiple products and more planning periods.

DUALPLAN is based on the assumption that the goal of management is to minimize the cost of producing a pre-specified flow of products over time. For the basic forest-wide problem as described earlier, the objective would be to minimize the cost of achieving the mill's wood requirements. With only two time periods the problem could be described by the following two graphs where curve S1 and curve S2 (both denoted by *'s) are the supply curves for period 1 and period 2. Q1 and Q2 are the mill requirements for period 1 and period 2, and P1 and P2 are the prices (or costs) necessary for achieving the last unit of output in each period.

For this simple case the supply curves show the volumes of wood available to the mill in each period with the costs increasing (per wood unit) with increasing quantity harvested because of increased transport costs for hauling wood greater distances. Small portions of each curve could be thought of as different timber stands with the corresponding price on the supply curve equal to the cost of harvesting and transporting the stand to the mill. In actuality these curves would be interdependent; one could not construct a curve for period 1 without first making assumptions about the cost of producing timber in period 2 and one could not construct a curve for period 2 without first estimating which stands would be harvested in period 1.

The critical question in valuing a timber stand in a forest-wide context is: If this stand were
deleted from the forest, what would be the impact on achieving the desired forest-wide goals? For our case with assumed forest-wide production goals, this question would be easy to answer if the marginal costs of production were known for each period (P1 and P2). These marginal costs represent the marginal values (shadow prices) of timber in each period; to satisfy the forest-wide product flow constraints one would need to harvest more wood at the margin if a stand currently supplying wood was lost from the forest. The value of the stand is thus measured by the cost-savings that can be achieved by using it rather than a stand at the margin. In the graphs shown above, the prices P1 and P2 are thus the relevant prices to use to value alternatives. Costs would be measured by the actual costs incurred by management. Stands at the margin would thus have zero value--the benefits of management would be offset by their costs. Stands beyond the margin (for example, stands located far from the market) would have negative values. The negative values would show how much management costs for those stands would need to be reduced before the stand would be worth harvesting.

The same concepts would apply to determine the best time of final harvest (or management intensity) for each analysis area; one is simply comparing tradeoffs between producing less at the margin in one period versus producing less at the margin in another period. In other words, each analysis area can contribute to the forest by reducing some of the production that would otherwise be done by using stands at the margin. In terms of general forest-wide concerns related to imbalanced age distributions or periods of supply shortfalls, one would expect the concern would be reflected in different marginal costs of production for different periods with the periods of short supply simply resulting in higher marginal costs (shadow prices). These higher prices would make it profitable from this valuing method to shift some production to that period from stands that would otherwise be harvested in an earlier or later period if timber prices were constant over time.

The marginal cost of production for the harvest level requirements are the focus (key dual variables) in DUALPLAN. The major emphasis of the model is to develop good estimates of them considering all aspects of the problem including the opportunity costs associated with harvesting and regenerating a stand in one period versus another period. Essentially once the shadow prices associated with the forest-wide concerns are adequately estimated, individual projects can be evaluated correctly because these prices incorporate the impacts on forest-wide concerns. They are the key link between forest-wide planning and individual project analysis.

Perhaps even more important is the information that the marginal costs of production give to policy makers and decision-makers concerned about general forest management direction. In general, forest-wide planning is aimed at examining different management options at the forest-wide level to learn more about general management strategies. Multiple model runs to look at alternative production levels can help identify the tradeoffs between different production levels. In comparing tradeoffs, the cost of changing constraint levels (marginal costs of production) are usually a key issue.

Three characteristics of the forestry problem are utilized by DUALPLAN in the solution process. First, is the serial correlation or general relation that is almost certain to be present between the marginal costs of production for each product over time. Forest management involves relatively long production periods with harvests for most stands usually possible in several planning periods. Considering the way marginal costs of production are used to value management alternatives of individual stands, it is highly unlikely that one would find large shifts in the marginal costs between successive periods.

DUALPLAN USERS' MANUAL – MODEL OVERVIEW.
If large shifts occurred, one would probably find it advantageous to shift large volumes of output into periods with high shadow prices and shift output out of periods with low shadow prices. With management options available to shift product flows between periods one can essentially think of the marginal costs for a product over time as essentially a single curve whose values must be serially correlated unless the levels of the product flow constraints shift dramatically between periods.

Another similar characteristic of the forestry problem used by DUALPLAN is the general ability to predict how management options would change as marginal costs of production (product prices) change. For example, for a given set of price estimates one can probably shift some output from one period to the next simply by increasing the relative value of the product in the period for which more output is desired. Similarly, if more output is desired for all periods one would simply need to raise prices to make it profitable to push the margin out to harvest more stands and to make desirable to implement more intensive management on some stands. Although these are very simple concepts, they give general direction as to how results might be improved in a way not considered in most mathematical solution techniques.

A key characteristic of the forestry problem utilized with the solution method used in DUALPLAN is the basic notion that forest-wide constraints do not necessarily need to be achieved precisely. For example, if one wants to produce an even flow of timber of 1000 units per period, an optimal solution for producing say 1000 units plus or minus 50 units is likely to be acceptable. The acceptable deviation is likely to vary by problem, but for the most part, precision of the data used in the analysis is lacking, so users are probably fooling themselves if they think that exact achievement of specified output levels is necessary.

DUALPLAN can be summarized as a simulation model with seven steps:

1. Identify which forest products have constrained product flows over time. For products with constrained output levels, estimate the desired output levels to be considered in this run of the model. For the products that are unconstrained, input assumed product values.

2. Estimate the marginal costs of production for the constrained products at the desired output level for each period.

3. Using the estimated marginal costs of production as prices, determine the optimal management strategy for each analysis area.

4. Tally the product (and input) flows for the forest to determine the total production level for the forest based on the estimate of the marginal cost of production.

5. Compare the forest-wide outputs for the schedule developed to the desirable output levels to determine whether the schedule is acceptable. If acceptable, report the solution found and stop. Otherwise go to step 6.

6. Use the results of the last solution found and an understanding of the problem to re-estimate the marginal costs of production for each constrained product in each period.

7. Return to step 3 and repeat the scheduling process.
For the unconstrained case, DUALPLAN can find, in a single pass through the steps (iteration), the management plan that maximizes present net value of the forest. This should not be surprising as in this case one does not have a forest-wide problem; each analysis area can be analyzed independently without concern for forest-wide interactions. For the case where forest-wide concerns are present, the key to the approach is in the process of reestimating the marginal costs of production. Experience to date has shown that the process is not sensitive to the initial estimates of the marginal costs of production. Of more concern are the parameters used in the methods for reestimating the marginal costs of production. This process is discussed in detail in a later section of this document.

**DUALPLAN Viewed as a Linear Programming Model**

Most Linear programming models applied in forestry use one of two basic forms that are commonly referred to as Model I or Model II (Johnson and Scheurman, 1977). DUALPLAN can be described in terms of either format and can utilize either type of format in terms of management prescriptions used as input. Here, we will describe the similarity with LP from a Model I type of formulation simply because it is easier to describe.

Linear programming models for forest management scheduling can be developed for a range of different management objectives. DUALPLAN assumes the objective is to minimize the cost of producing pre-specified output levels. From an analysis standpoint this shifts the focus on the cost of production with multiple runs necessary to compare alternative production levels. Some might argue that the objective should be to maximize net present value of the forest. Although this objective might be a more appropriate goal of management, a counter-argument can be made that forest outputs are difficult to value and thus one is confounding the analysis by incorporating values into the analysis of the forest production process; it is difficult to compare and interpret solutions when one run uses one set of price assumptions and another run uses another set of prices. Using a minimum cost approach, users can probably make basic value judgments about alternative production levels by comparing the marginal costs of production with their views on the marginal revenues for those levels.

In a Model I formulation of a forest management scheduling problem two basic types of constraints are used: analysis area constraints and forest-level constraints. The analysis area constraints define the number of land units and the specific management alternatives available for each analysis area. Forest-level constraints define requirements and limitations that apply to the entire forest as a whole. With a minimum cost objective, the forest-wide constraints are usually constraints that define the required forest-wide production levels for each planning period. In almost all cases, the number of stand-level constraints is significantly larger than the number of forest-level constraints.

Most computer packages for solving LP problems use some form of the simplex algorithm. This algorithm is a general mathematical technique. Whether the formulation represents acres in a forest or patients in a hospital, the solution process is the same. With every LP formulation (primal problem) there is an associated dual problem. The optimal solution to the primal problem can be determined either by solving the primal problem or by solving the dual problem. Generally, the problem with the fewest number of constraints is the easiest to solve. For the forest management scheduling problem the primal problem will
almost always have the fewest number of constraints.

As the term management scheduling implies, the optimal solution to the model formulation produces an "optimal" management schedule. But with obvious model limitations in describing the real world problem and with different optimal solutions for alternative problem formulations, how does one develop a management schedule? One aspect of the problem that is often overlooked is the information that is given in the values of the dual variables in the optimal solutions.

The value of the dual variables associated with the analysis area constraints are measures of the marginal value of the associated analysis area on a per land unit basis. There is one dual variable for each analysis area. The values for these variables can be extremely valuable for considering options related to land sales, land purchases, or shifts in land uses to other uses not considered in the model. The value of the dual variables associated with the forest-level constraints can be even more valuable. For a formulation with a "minimize cost" objective the interpretations of the dual variables associated with the forest-wide constraints measure the marginal cost of achieving the constraint. From an economic standpoint, these dual variables represent the marginal cost of production for the associated product and period. A close look at the dual formulation of the problem shows that the constraints in the dual simply force the values of each analysis area to be equal to maximum value achievable where analysis area values are defined by the valuation process described earlier using marginal costs of production in each period as product prices!

As discussed earlier, a desirable characteristic of the management scheduling problem is the general understanding of marginal costs of production--the dual variables associated with the forest-level constraints. This understanding of the dual variables is used by DUALPLAN to solve the LP formulation of the forest management scheduling problem by focusing on the dual problem. The algorithm takes advantage of the fact that some of the forest-wide constraints in the LP formulation can be relaxed without significantly influencing the interpretation of the formulation. When the basic simplex algorithm for solving the LP formulation is used, considerable effort is given to maintain feasibility (satisfy the constraints exactly) throughout the solution process. For most forest management scheduling problems this is not necessary because there is at least some uncertainty surrounding almost every parameter of the formulation. For example, the formulation might specify producing 300 units in period 2, but an optimal solution for producing 297 units would seldom be considered infeasible or even significantly different from an optimal solution that meets the constraint exactly.

The solution approach capitalizes on the fact that if the values of the dual variables for the forest-wide constraints are known, then the dual problem can be decomposed and solved in parts with essentially one part for each analysis area. This fact reduces the memory and computation requirements needed to solve the problem, and as a result, the user can consider much larger formulations. Solving each of the small problems is essentially a series of cash-flow analyses of the alternatives available to the corresponding analysis area.
The diagram below shows the general structure of a LP forest management scheduling problem. Columns used in the diagram represent the decision variables (management alternatives) and the rows represent the constraints.

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For each row, asterisks denote the variables that could appear in that constraint. The constraints with relatively few variables define the options for each analysis area. As mentioned earlier, these constraints are usually great in number. The forest-wide constraints, the last three rows in the diagram, tie the problem together. Without the forest-wide constraints, the problem could be solved in parts by considering each analysis area separately because none of the constraints would share common variables.

The dual formulation of the problem has a very similar structure. A diagram for it essentially flips the diagram above on its side.

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This problem is tied together by key dual variables rather than key constraints. These key dual variables are the marginal costs of production for each period and product. If they were known, the dual problem could be broken into parts and the value of each analysis could be found independent of the analyses for the other analysis areas. Each constraint in the dual relates directly to one management option for a specific analysis area. It simply states that the value of its corresponding analysis area must be greater than or equal to the value of the management alternative corresponding with the constraint. Each constraint
actually calculates a value for the associated management option using the product flows as coefficients for the key dual variables.

In terms of the linear programming formulation of the forest-wide problem, the solution approach used in DUALPLAN can be described by the following steps:

1. The values of the dual variables associated with the forest-level constraints (key dual variables) are estimated based on their economic interpretation.

2. The dual problem is decomposed and solved in parts for the remaining dual variables. Each subproblem relates to an individual analysis area or similar analysis areas depending on the type of LP structure used.

3. The solution found is summarized and the forest-level constraints are checked for "feasibility." If the constraints are satisfied, the solution is optimal and the process stops. Otherwise,

4. The solution found is used to re-estimate the key dual variables and the process returns to step 2.

By comparing the solution technique used with linear programming one can prove that the solutions produced by DUALPLAN are optimal solutions. For this proof, one only needs to recognize that solutions to LP problems are optimal solutions if they are feasible solutions to both the primal and dual problems. The solution process used in DUALPLAN always finds feasible solutions to the dual problem. In terms of each DUALPLAN solution and its corresponding solution to the harvest scheduling problem (primal problem), the only constraints that can be violated are the forest-wide flow constraints. This means that the solution found using any set of marginal cost estimates is an optimal solution for the forest-wide output levels that result; one could simply change the levels of the harvest flow constraints in the primal formulation to those levels and both primal and dual feasibility would be achieved. The question is whether those production levels are close enough to the levels specified initially in formulating the problem. If one has flexibility in specifying the "desirable" output levels for a specific model run, then the solution process can take advantage of that flexibility in defining the acceptable tolerance limits for the forest-wide flow constraints.

**Model Applications and Extensions**

The simulation approach has been applied in several studies concerning the timber supply situation in Minnesota. The concept was first applied in a short-term supply analysis that looked at the impact of mill expansions on timber procurement costs for specific mills (Rose et al. 1984). The most recent application focused on the impact of wood energy use on the timber supply costs of more traditional wood users (Hoganson, 1987). Both short-term and long-term impacts were examined with focus on the values of the marginal costs of production (key dual variables). Approximately forty different scenarios (model formulations) were considered with the model recognizing approximately 3000 different analysis areas.

Model size or computation time has not been a concern on any applications to date. Tests of the approach have been limited to several data sets, but success of the approach does not
seem to depend on good initial estimates of the key dual variables (Hoganson, 1987).

Applications to date have used an IBM mainframe computer with only limited concern
given to computational efficiency. DUALPLAN is a recent effort to bring this general
forest management scheduling method to the microcomputer. Considerable attention has
been given to making the model "user friendly", but undoubtedly, additions and
modifications will likely be desirable as more experience is gained. A key to model use is
its linkage with computer software aimed at producing the enormous amount of input
information that is necessary for a forest-wide analysis.

A key aspect of the solution approach is its ability to break the problem into smaller
problems of more manageable and understandable size. This seems to be the general
suggested direction for model improvements from the results of recent LP applications of
forest management scheduling (Alston and Iverson, 1987). It is important to recognize the
distinction between large models and complex models. The advantage of the simulation
approach is that the overall model can still be

relatively large without being very complex. Its primary limitation seems to be the need to
limit the number of forest-level constraints. It is these constraints that make the model
complex.

The modelling process could potentially be improved significantly by better incorporating
an understanding of the forestry problem into not only the solution process but also into re-
formulations of the problem after initial results are obtained. The simulation approach has
a real advantage in that intermediate solution results can be used to adjust the model
formulation before completely solving the problem. As an example, consider the problem
of valuing ending inventory. With a LP approach this is difficult because ending inventory
volumes are sensitive to the prices assumed for ending inventory. With a simulation
approach it is easy to use a simple rule like "value ending inventories using the marginal
prices for the last planning period or a weight average of several of the last few planning
periods."

A general strategy often used with optimization methods is to formulate the model so that
all possible management options are considered in the mathematical formulation. For many
forest management scheduling problems this strategy can lead to prohibitively large
formulations. For example, consider the decision variables that are necessary to describe
one contiguous analysis area with six management options--clearcut in any one of six
periods. Assuming there is only one market, then only six decision variables are needed for
this analysis area. However, if we assume that there are five possible products harvested
in any clearcut and four potential markets for each product, then there are 4 to the 5th
power possible shipping combinations for each of the six clearcut options. This means that
either 6144 variables or 126 variables and 30 additional constraints would be needed in the
model just to describe the 6 clearcut options for the one analysis area. Problems with
model size can increase even more rapidly when several stands are grouped together into
a single contiguous analysis area. For example, if only 5 stands are grouped together with
100 management options available for each stand then there are 10 billion possible
management options for the one analysis area.

The simulation approach has the potential of overcoming model size problems by using
simple rules rather than complete enumeration of all possible combinations. For example,
if multiple markets are considered in the LP formulation, the interpretation of the dual
problem indicates that the products would be shipped to the "most profitable" market where the values of the dual variables would be used to measure profit. Rather than consider all combinations, the simulation model could follow the simple rule "ship products to the most profitable market" where procurement zones could be defined and adjusted as the marginal cost (price) estimates are adjusted during the solution process. This type of approach could likely utilize some of the recent developments with geographic information systems.

The sequential nature of the decision-making process is another aspect of the forest-wide problem that the simulation approach could plausible help address. Models become large and solution processes become more complex when stochastic elements are recognized within the modelling process. Very little attention has been given to the uncertainty problem and the issue of flexibility of immediate actions in terms of the options that will remain available for the uncertain future. Some work has been done on this problem using the simulation approach and it was found that it is very difficult to model the process of how uncertainty about the future actually unfolds (Hoganson and Rose, 1987). Simple heuristics might be the most practical approach for modelling this aspect of the scheduling problem.

A simulation approach which actually interprets its own initial results to adjust the model formulation might be considered an "expert system." The "expert" would be a systems analyst who has a good understanding of forestry and economics and can learn more about the problem from intermediate results.
MODEL DETAILS

Items and Item Groups

DUALPLAN uses the same concepts that would be used in a economic "cash flow" program to evaluate specific forestry projects. To evaluate management alternatives DUALPLAN uses the term item to refer to both resource inputs and forest outputs. Items are identified by an item number and an alphanumeric label. The item number is used in input to describe both input and output flows for management prescriptions. For example, "harvest costs" might be set as item #1. Red pine saw logs might be referred to as item #7. Users have the flexibility to define items in any method they choose. It is important to note that the item numbers are used to define the type of input/output involved in all management alternatives. DUALPLAN does not distinguish inputs from outputs other than through the item number used in describing the flow.

Items are grouped into item groups for the purposes of forest-wide constraints. For example, constraints on softwoods might refer to red pine, jack pine and white spruce. These items would be grouped into item groups for the analysis. Each item is assumed to belong to one and only one item group. These groups have index numbers and labels just like items. Item groups can be defined such that only one item is in an item group. This would be necessary if one wanted to constrain the flow of one specific item.

Forest-wide constraints apply to item groups and not items. Constraints are not limited to item groups that refer to timber flows. For example, constraints could be used to represent budget limitations. In that case, it might be desirable to use different items for the different types of costs and group together only those costs that are incurred by the organization and impacted by the budget limitations.

The marginal costs of production (the key dual variables) apply directly to item groups because the forest-wide constraints apply to item groups. To recognize relative value differences of products within item groups, the user can define a simple value relationship for each item in the group. The value for each item is expressed in the form

\[
\text{Value}(\text{item}) = a + bX
\]

where X is the value of the item group and a and b are model parameters input by the user. This relationship is assumed to apply throughout the planning horizon. For example, red pine sawlogs could be defined as being worth $15 per cord more than the price of the softwood sawlog category (a=15, b=0). This linear form also lets one define the relationship as a fixed percentage relationship such as 10% more than the item group category (a=0, b=1.1). A specific item might be used as the base price for an item group (a=0, b=1). These relationships can apply to cost items as well. The only distinguishing feature between costs and benefits in the model is that costs have negative values.

Planning Periods and Forest-wide Constraints

The planning horizon is divided into equal-length time increments called TICs. All management actions are assumed to occur at the midpoint of a TIC. All net present worth calculations are discounted back to the midpoint of the first TIC. In describing management
actions for the immediate future, it is assumed that these actions occur at the midpoint of the first TIC. For example, if a TIC represents ten years, then the first possible harvest time would be five years from now, the midpoint of the first TIC.

For the simplest case, TICs can be thought of as planning periods. It is possible to group several TICs into one planning period. Furthermore, planning periods need not all have the same number of TICs. It might be desirable to give more attention to the near-future and thus use shorter planning periods near the beginning of the planning horizon. At this point the recommended approach is to use one TIC for each planning period as these additional features have received relatively little testing. Nonetheless, they will be described here as an understanding of them will help in understanding the structure used for model input.

The concept of planning periods enters DUALPLAN in the way constraints are defined. In the model, flows for items are traced for every TIC. Specific flow constraints can apply to specific TICs or the total flow summed over several TICs. Each item group must be identified as having either constrained or unconstrained flows. If flow constraints are to be considered for an item group, constraints need not be assumed for the entire planning horizon. However, a beginning TIC and an ending TIC must be identified to define the range over which flows are constrained. For each flow within the identified range, each TIC is assumed to have a "desirable flow." Constraints on flows must be defined such that every TIC within the range is constrained; however, there is not necessarily a one to one correspondence between the number of TICs in the range and the number of constraints.

Constraints that cover several TICs bring in the concept of planning periods of unequal length. For example, a constraint could be defined to cover flows for TICs 6, 7, and 8 to mean that one is concerned about the total flow for TIC's 6, 7, and 8 and deviations for individual TICs in that range are acceptable as long as the constraints for the three-TIC "period" are acceptable. Relevant ranges for specific constraints can also be overlapping. For example in relation to the three-TIC example described above, one might also include another constraint that applies to TICs 7, 8 and 9. This would imply that the user is not necessarily concerned about the flow in any one TIC, but the total flow over any three consecutive TICs is important.

It is important to consider how detailed one will be in defining prescriptions when selecting the time increment to use as a TIC. One would like to use small intervals as there is always the potential of missing the optimal rotation age if long intervals are used. For example, the value of one species might be significantly underestimated if the optimal rotation is 35 years and only rotation lengths of 30 and 40 years are considered. However, there are also arguments for using a longer interval to define the length between TICs. Specifically, scheduling models assume that enough management options have been included so that any difficulty in achieving harvest levels is not a result of "simplifications" in the formulation of the problem. Model size and computation time is thus likely to be sensitive to the length of a TIC if a separate prescription must be included for every TIC within the range of potential rotation ages. Misleading results might be obtained if only a sample of potential harvest ages are included.

The ability to define constraints for multiple TIC lengths, and recent modifications in the price adjustment techniques, especially the "smooth" technique, help overcome the potential problems of using shorter time intervals with only a sample of possible rotation ages. Little testing has been done for cases using only a sample of rotation ages so this approach is not recommended at this time. It might be worth exploring on a test basis.

DUALPLAN USERS' MANUAL – MODEL DETAILS.
Ending Inventory

Methods for addressing ending inventory concerns has been a problem with most forest management scheduling models. In general, it is difficult to specify those concerns in a model before the supply situation has been examined for the assumptions made and constraint levels used in formulating the model. DUALPLAN's method for considering ending inventory is appealing in that the it is based on model results. It is assumed that prices will be constant for all items beyond the end of the planning horizon. Under constant prices, the optimal soil expectation value can be calculated for "bare land" for the possible "bare land" classes and these values can be linked with prescriptions for the existing conditions and prescriptions for each analysis area.

A desirable feature of DUALPLAN is that constant price level used for periods beyond the end of the planning horizon can be defined in terms of the prices (marginal costs) found for periods within the planning horizon. As these prices change within the solution process, so do the values used for ending inventory. The user simply defines the weights to be used for each price. Plausible assumptions for selecting the weights might be:

1. Prices beyond the end of the planning period will be equal to the prices in the last TIC of the planning horizon.
2. A weighted average of prices in the last several periods is appropriate to account for any short term price fluctuation that might be present in any one TIC.

Fixed Price Relationships

Item groups that have flow constraints need not be constrained over the entire planning horizon. DUALPLAN allows the user to define prices for the unconstrained period similar to the way in which prices to value ending inventory are defined. This option is intended primarily for the case where one might want to constrain flows for only the first portion of the planning horizon. For each fixed price relationship the user defines (1) the item group, (2) the range of consecutive TICs for which the price will apply and (3) the weights to use for each constrained period in estimating the price. For the corresponding TICs defined in (2), all prices will be equal and change with changes in the shadow prices upon which they are based.

Prescriptions for Existing Stands

Alternatives for existing stands (analysis areas) are described by a series of stand entries and associated product flows. Each stand entry refers to a specific point in time (TIC) when the stand is physically entered and some type of benefit or cost is incurred. Each stand entry can have a number of item flows where each flow is defined by a specific item number and a specific quantity. In describing quantities for item flows only integer values can be used with a maximum value of 32,767. This limitation on flow values is used to help reduce the size of the input files used and the speed at which data input operations can be completed. These limitations should be the major consideration used in selecting units to use when writing prescriptions. All values used to describe flows are assumed to be expressed in a per land unit basis.
Prescriptions can be developed in a Model I or Model II format. With the Model I format one simply includes several rotations in the prescriptions for what the "existing stand." The Model II format links prescriptions for existing stands with prescriptions for "bare land" classes to try and save on calculations and the necessary data input as many stands, initially different, become identical once clearcut. The user can use both types of formulations in a single model formulation as the only distinguishing feature is the linkage of the prescription to a "bare land" class at some point in time.

The timing of product flows is not limited to TICs within the planning horizon. Flows can occur at TICs beyond the end of the planning horizon; however, the last TIC considered in any initial prescription must be identified by the user in describing the general problem formulation. This value impacts the amount of memory required by the model. In general, it is probably best to either link the analysis area to some "bare land" class shortly after the end of the planning horizon or include some estimate of the value of ending inventory in the prescription. Linking the value to a "bare land" class has the advantage in that the prices used to value ending inventory can be based on model results.

Prescriptions for "Bare Land" Classes

With a Model II type of formulation, one classifies the "bare land" of each analysis area in terms of its biological characteristics and its locational characteristics. When evaluating alternatives, each prescription for the existing stand is linked to soil expectation values (SEV) that have been determined for the corresponding type of "bare land" as defined by the biological and locational identifiers. The SEV estimates are based on the set of item prices assumed for the current iteration and thus change as the item prices change each iteration.

Alternatives for managing bare land are input for each of the possible biological classes and the model then analyzes each alternative for every possible location class. With this method of analyzing alternatives, transport costs are not included directly in the "bare land" alternatives as input by the user. Instead, transport costs (per unit transported) are input for each of the possible location classes and DUALPLAN adds the transport costs in the calculations.

Locational identifiers for "bare land" differ only by the price stream they use for different items to describe the transport costs for the different items. For example, one could have one class that represented land close to a softwood pulpwood market and far from a softwood sawlog market. The number of classes could be fairly large.

Considerable flexibility is available in defining biological classes for "bare land." For the simplest case one might think of biological classes as identifying both how the land would regenerate naturally and its general growth potential (site index is one possible measure). Each prescription for an existing stand can be linked to one "bare land" class. As part of the linkage in the "existing stand" alternative, a cost can be included so that site conversion options can be considered.

All management alternatives for "bare land" are assumed to represent one full rotation. In other words, all benefits and costs are included for one full rotation. In evaluating "bare land," consideration is given to the fact that the best method for managing the land might depend on the time. Over time it might be desirable to shift rotation lengths or even the
species to regenerate because of changing forest-wide conditions. Bare land values are thus determined for not only every combination of possible biological and locational classes, but also for every TIC in the planning horizon. For periods beyond the end of the planning horizon, prices are assumed to be constant and thus optimum management rotations would not be expected to change. The solution approach for determining bare land values begins with TICs beyond the end of the planning horizon and calculates maximum soil expectation values. These values are then linked in a simple network that solves for bare land values for successively earlier TICs.

**Price Adjustment Process**

DUALPLAN uses three procedures for automatically adjusting item prices based on the results of the previous iteration. These procedures have been labelled the float, shape and smooth procedures. Using the automatic price adjustment option of the model, only one of these three adjustment procedures is used in developing the next set of price estimates each iteration. Shadow prices for each constrained item group are each adjusted separately. Each procedure calculates an "average percent deviation" for each item group in each TIC. This average deviation measures an average deviation in flows for each item group from the desirable flow level as defined in the model formulation. It is calculated differently for each adjustment procedure, and its method of calculation is the only difference between the different adjustment procedures.

For each item group and TIC combination, the associated "average deviation" estimate is the only statistic from the prior iteration used in reestimating the price for that item group and TIC. For each price adjustment procedure, the user has the flexibility to define the relationship between the average percent deviation and the size of the price adjustment for each item group. This type of relationship is defined in a piecewise linear framework. The graph below is an example that illustrates the general approach.

![Graph showing price change vs. average percent deviation](image)

The user simple inputs the percent deviation and the price adjustment associated with all of the break points (end of each line segment). The example shown in the graph is defined by three break points, points A, B and C on graph. For the last break point selected (point C) all average deviations greater than the deviation corresponding with this value will use
the same price adjustment, the adjustment defined by the last break point. All relationships are assumed to pass through the origin (no adjustment if desirable levels satisfied exactly). For each of the three adjustment processes, the model uses the relationship defined by a graph of this type to estimate the size of the price change for the next iteration. Each adjustment procedure and item group uses a different graph. The direction of the deviation does not impact the magnitude of the price change. The direction of price change does not depend on whether an item group is a benefit or a cost. Benefits are distinguished from costs only in that costs generally have negative values. The direction of the price change is such that prices are always lowered (raised) if flows are above (below) the desirable level. Note that raising the value of a cost actually makes its value less negative.

In considering the prices of item groups over time, it is important to think of the how prices change over time and how such changes impact the optimal rotation age of individual stands. The solution approach is designed to take advantage of the relationship (serial correlation) that is likely to be present in the set of prices that produces an optimal solution.

**Float Procedure**

The float procedure is designed to consider the flow of the item group in question over the entire planning horizon. With the float procedure, one is simply checking the total flow from the forest as a whole, and all prices are either raised or lowered the same amount depending on the size of the average deviation. In terms of a graph of the shadow prices over time, one is simply "floating" the entire curve up or down depending on the direction of the price change needed. Coefficients input by the user. In general, this adjustment process is most appropriate in the early stages of the search process in an effort to move prices to the general price level associated with the desirable flow levels specified.

Shadow prices are not floated for an item group if the average deviation is less than a cut-off level identified by the user. This option is included because for cases with small average deviations, it might be difficult to identify the direction that shadow prices should move.

**Smooth Procedure**

The smooth procedure is the adjustment procedure that bases the "average percent deviation" estimate for each TIC on the smallest range of neighboring TICs. In calculating this statistic, it uses an interval that is based on the number of TICs considered in the constraints. For the most straightforward case where one constraint is included for every TIC, then the average deviation is simply the percent deviation for the corresponding TIC. For case where more constraints are present, the average deviation for each TIC is simply the average percent deviation of each constraint that corresponds with that TIC; actual percent deviations for each TIC itself are not used because of the potential of having some TICs for which there are relatively few alternatives for producing flows.

The primary objective with the smooth procedure is to shift flows to neighboring periods. A secondary objective is to move prices in the appropriate direction, but the impact on expanding the margin is not as likely to be as great for most cases. To shift flows from period to period by adjusting prices, the key issue is the percentage change in stumpage price between periods. By basing average percent deviation estimates on only the TIC in question, TICs with deviations opposite in sign will be adjusted in opposite directions, and
thus the percentage change between the TICs will be affected. This should shift some of
the flows between the TICs if the price changes are large enough. In contrast, neighboring
TICs with identical deviations will move the same direction and same amount so the impact
on the percentage change in price over time will likely be minimal. However, some
improvement in flows would still be expected as the direction of price change should be
correct.

Shape Procedure

The primary objective with the shape procedure is designed to adjust the general shape of
the price curve when plotted against time. It estimates an average deviation for each TIC
by using not only the percent deviation of that TIC, but also the deviation for several
neighboring TICs. The shape procedure thus changes prices the most where several
neighboring TICs all have flows that deviate from the desirable levels in the same direction.
The weights and number of TICs to consider in estimating the "average percent deviation"
is input by the user. Several time periods (TICs) are used in estimating the deviation
because it is assumed that shifts in flows from neighboring TICs can probably be
accomplished simply by fine-tuning that region of the curve with the Smooth procedure; in
other words, prices in that portion of the curve might not need to change much if deviations
can be reduced simply by shifting flows from neighboring periods.

The shape procedure might be thought of as simply an adjustment technique that attempts
to do in one iteration what might take several iterations with the smooth adjustment
process. For example, consider the following graph of average percent deviations over time.

For this situation, the shape iteration would adjust prices for the peak areas of the curve
the most, with TICs in the middle of the peaks probably receiving the greatest adjustment.
In a sense, it is looks at neighboring TICs to see how much excess might be available for
shifts with closer TICs receiving greater weights and adjusts the price changes accordingly.
For this situation, the smooth iteration would initially adjust the peak areas of this graph
the same. If we assume that the smooth iteration process has very little impact on the
margin -- making more stands profitable to manage -- then the price changes would
probably shift some between periods, with the greatest shifts occurring where the curve is

DUALPLAN USERS' MANUAL – MODEL DETAILS. 23
the steepest. In the flat portions of the curve, flows might change relatively little until successive smooth iterations cause the steep portions of the curve to move to the areas of largest deviations.

Discounting Flows Option

For both testing whether constraints are satisfied and calculating "average deviations", the user has the 3 options for "discounting" of item flows. The basic reason for discounting flows would be to represent the fact that the volumes will grow over time. When trying to shift flows to neighboring periods it might be help to recognize that some additional growth would or would not take place depending on the direction of the shift. For example, if 20,000 cords were not harvested at TIC = 2, then at TIC = 3 those 20,000 cords might have grown significantly, especially if relatively long time intervals are represented by each TIC. The 3 options associated with this type of discounting of flows are:

1. No discounting
2. Discount all flows using the general interest rate
3. Discount all flows using an estimate of the growth rate for stands likely to shift from one period to the next.

The third option requires an estimate of the average processing cost to produce this item. This process cost (per unit basis) represents all costs that are incurred in harvesting and transporting the item group. It is needed to obtain an estimate of the stumpage price for the average stand at different points in time. The marginal growth rate (discount rate) is estimated as the growth rate necessary to make one indifferent between harvesting at the current stumpage price or waiting until the next TIC. A different rate is estimated for every item group and TIC. Land costs are ignored in the estimates. The marginal growth rate varies over time as it depends on whether prices are increasing or decreasing. It will be smaller for intervals with rising prices. This process of discounting can thus recognize the simple fact that stands likely to shift in the time of harvest are likely to be growing at significantly different rates depending on whether prices are increasing or decreasing.

Each item group can use a different method of discounting. When discounting is done to estimate the percent deviation from the desired level, both the actual flow and the desirable flow are discounted (or compounded) to the base year.

In general, the adjustment process cannot be expected to move rapidly to the optimal solution in just a few iterations; therefore, attempting to fine tune the adjustment process using the most appropriate discounting procedure and interest rate is probably not as important as one might think initially. Additional model testing will help give more insights on the value of discounting. The potential gain from using these discounting procedures are likely the greatest for: (1) the float procedure because longer time periods are considered and (2) in cases where TICs represent longer periods of time and thus growth increments between successive TICs are likely to be larger.

Automatic Sequences of Price Adjustments

The model can use a specified sequence of price adjustments in successive iterations. The user has considerable flexibility in defining this sequence. The first iteration is the set of
initial price estimates that are input by the user. The adjustment process begins by first performing a series of float iterations, the number is specified by the user (NFLOAT). In each float iteration the prices are adjusted for an item group only if the "average deviation" for that group is above a level specified by the user (STOPFLOAT(SET)). This option is included because for small average deviations, the direction of general price change is not always known. If none of the item groups have average deviations above this level, then the adjustment process moves on to the next adjustment method. After the float iterations come NSMTHFLT smooth iterations. This is then followed by a nested loop of iterations where the entire loop is completed NSHAPE times. Within this loop one shape iteration is first performed followed by NSMTHSHP smooth iterations. Smooth iterations are performed after each shape iteration in an attempt to "smooth out" some of the "TIC-to-TIC" deviations that might cause some problems in the next shape iteration if the parameters for the shape procedure are set relatively high.

Guidelines in Setting Price Adjustment Parameters

Probably the most difficult aspect of the modelling procedure is selecting the parameters for the adjustment procedure. A few guidelines might help along those lines:

1. A basic understanding of the actual costs involved and the likely range of those costs over the forest can help considerably both in developing initial price (marginal cost) estimates to start the solution process and in setting price adjustment parameters. Before attempting to satisfy any specific flow goals, it is suggested that some general price levels be explored. This can be accomplished relatively easily by using just the float procedure with adjustments for all deviation levels set to a single price increment that might be relatively large, at least at first. One would probably want to hold the value of all but one item group constant and float the price through a range of price levels.

2. Unless computation time per iteration is a major concern, it is probably easier to keep the price changes small per iteration as with small changes, one can feel more confident that the solution will move toward the optimal solution. Increasing the relative number of smooth iterations might also help if one is concerned that prices might sometime "jump" significantly far in the wrong direction and have difficulty self-correcting. This kind of jump will occur if the parameters for the price adjustments are set extremely high for any of the adjustment procedures.

3. Price changes for all possible average percent deviations for the float and shape procedures should probably be larger than the price changes for the same averages for the smooth procedure. There are several reasons for this. First, both the shape and smooth deviations use more TICs for estimating the average deviation for each TIC. An average deviation for a longer time period is probably more significant and thus probably needs a larger price adjustment. Also, remember the primary objective of each adjustment process. The smooth procedure is trying to "fine tune" the flows by moving flows to neighboring periods. For some stands this is likely to occur with relatively small price adjustments.

4. The price adjustments for the possible average deviations should probably not differ for the different adjustment procedures by more than an order of magnitude.
5. Relative weights used in the shape procedure should probably be greatest for the TIC being adjusted, with lower weights the greater the distance from the TIC of adjustment. If the planning period uses many TICs and some TICs having relatively few alternatives for producing flows, then it is probably best to use more TICs in calculating the deviations and not to put high relative weights on any one TIC.

6. The change in a specific flow level between iterations is likely to exhibit some "lumpiness" because all acres within each analysis area are assigned to one prescription. It is important to get a feel as to how large a change occurs in the solution by shifting a final harvest of one "average" analysis area from one TIC to another TIC. This information should not be hard to determine outside the model. Knowing it should help in selecting the level by which flows can deviate from the desirable flow level and still satisfy the constraints.

7. The piecewise linear relationship (absolute price change plotted against absolute average percent deviation with price change on the y-axis) should probably have a decreasing slope over most of its relevant range for all three adjustment procedures. However, for small average percent deviations, especially the shape and float procedures, the price changes might best be kept small as large changes in prices are probably not necessary. In that case, the piecewise relationship should probably be sigmoid shaped with the slope relatively flat until the average deviation is at a level that can be considered significant for the corresponding adjustment process.

8. When parameters are set too high, the model tends to overcorrect and cause the process to actually move away from a feasible solution. This is identified by successive iterations that have deviations that alternate in sign and tend to get larger in magnitude. For example, in successive iterations a 10 percent deviation might change from -20 percent to 33 percent to -45 percent. It is also important to note that these types of occurrences might occur over only a range of deviations meaning the adjustment parameters maybe only need to be adjusted over that range of deviations.

9. Defining the piecewise linear relationship for each of the adjustment procedures might seem difficult. Lets consider an example and assume that some initial unconstrained runs were made to gain a general feel for the production potential. Lets assume that the analyst feels relatively confident now to say that marginal costs of production of $30 per cord would seem extremely low for any TIC and $50 per cord would seem relatively high. Based on this $20 range in prices, the following values might be adequate parameter values for defining the adjustment process, at least for an initial estimate.

<table>
<thead>
<tr>
<th>Break Point</th>
<th>Average Deviation</th>
<th>Price Change ($ per cord)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Smooth Procedure</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>$.05</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>.10</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>.15</td>
</tr>
</tbody>
</table>

One could use these values as a general guideline for setting parameters for specific problems. They would need to adjusted to fit the range of potential prices. For example, if prices might range by $200 rather than $20 as in this example, then the values would
need to be multiplied by 10. Notice that if one was conservative in trying to define a range (large range assumed possible) then the parameters would used be larger.

These guidelines might make the approach seem difficult to someone unfamiliar with the process. Undoubtedly, one might have some difficulty with some first runs. However, it is encouraging to remember that the number of iterations necessary is not likely to be critical unless the formulation is extremely large. Also, as one gains information about the forest, subsequent runs are likely to be much easier. Changes in parameters will probably not be needed unless flow goals change dramatically. In general, one can probably learn more about the forest through multiple runs than trying to fine tune the solution for one set of flow goals for the item groups. In trying to find "optimal" solutions, remember, nobody will be too concerned about estimating shadow prices to the nearest $.01. Even if deviations seem large, they are unlikely very significant if small price changes can cause them to essentially reverse in sign. Try to put it in context with the entire planning process.

Control of Solution Process

The model has several options to control the solution process including the set sequence of adjustment types, possible manual adjustments each iteration, options to pick method of adjustment, and back-up features to begin iterating again using the results of an earlier iteration. The model has an automatic stopping rule: if all constraints are within acceptable limits, stop the solution process and report prices. Acceptable limits must be input by the user for each constraint. The total number of iterations to apply can also be limited, and a "hot key" is available to stop and interact with the process after the iteration in progress is completed.

General Description of Input Requirements

The model uses three types of input files: a file containing general run parameters for the model (Model Formulation file), files describing the management prescription options and for the analysis areas (AA files), and files describing management alternatives for the bare land classes used to value future rotations (Regen files). The AA files and the Regen files are all written in a special binary format to help minimize data input time. These files can be up to 64K in length and still the entire file can be loaded into memory in one read operation using the QUICKBASIC programming language. The names of all regen files and all AA files are stored on master lists that are read as separate files by DUALPLAN. The names of the files containing these master lists are part of the input information on the Model Formulation File.

Model Formulation File

The model formulation file is the only input file that users are likely to edit manually between runs. The file has been structured such that comment lines are included to identify the variables. Many of the parameters can be edited using the edit options within DUALPLAN. And for those parameters that cannot be edited within DUALPLAN, any simple editor should work fine. For cases where many changes are desired, an outside editor would probably work best as most editing options in DUALPLAN change only one value at a time.
Listed below is a brief description of the parameters that are input on the Model form file. The parameters are listed in the order they appear in the file. The numbers before the parameters are the block number followed by a group number within the block followed by a parameter number for within the group. On the input file each block and each group within the block begins on a new row. Some blocks (and groups) contain variable length arrays that stretch out over several lines of input.

1-1-* File2$ The name of the file that contains the names of all the binary files that describe the prescriptions for the bare land classes

1-2-* File3$ The name of the file that contains the names of all the binary files used to describe the prescriptions for the existing analysis areas.

1-3-1 NPRSET The number of different initial price estimates to be considered in the run. Successive iterations use all these estimates before any adjustments are considered.

1-3-2 RUNBATCH If runbatch is greater than 0 then the program will run in batch mode rather than interactive mode.

1-3-3 WRITECNSTRNT If greater than zero then a summary of the constraint achievement levels will be written on the output file after each iteration. Note that this option can be turned on interactively.

1-3-4 WRITESET If greater than zero then a summary of the flows for the product sets will be written to the output file after each iteration. Note that this option can be turned on interactively.

1-3-5 WRITETYPE If greater than zero then a summary of the specific item flows will be written after each iteration. Note that this option can be turned on interactively.

1-4-1 NTIC The number of TICs in the planning horizon (see discussion in manual concerning the planning horizon and "planning periods")

1-4-2 DCRATE! The discount rate required based on the time interval represented by one TIC. This value is expressed as a decimal, i.e. 10% rate equals .10.

1-4-3 NTYPE The number of specific items recognized, whether constrained or unconstrained. Note that items can be costs or inputs as well as outputs.

1-4-4 NSET The number of item groups (sets).
1-4-5 MXREGROT

The maximum rotation length possible for any regeneration alternative. This value is expressed in TICs and can be overestimated; however, storage requirements and computation time will increase as this value is increased.

1-4-6 NREGLOC

The number of location classes identified for classifying analysis areas as "bare land" for valuing future rotations.

1-4-7 NREGBIO

The number of biological land classes identified for classifying analysis areas as "bare land" for valuing future rotations.

1-4-8 DOLUNIT

Most calculations are done in integer values in the model. Dolunit is the number of integer units used to represent one dollar. Precision is lost by setting this value to small. An appropriate value might be in the neighborhood of 1000-10000 depending on the precision desired. Most test applications have used 10,000, but additional testing would be desirable.

1-5-1 TRANTYPE

For evaluating bare land DUALPLAN automatically adds the transport costs for all item flows. This is the item index number that represents transport costs in the formulation.

1-5-2 MXCNRSTRNT

This value is used in dimensioning arrays. It must be set greater than or equal to the number of constraints considered in the formulation.

1-5-3 NPRFIX

The number of fixed price relationships used in the formulation (see fixed price relationship section in the model details section)

1-5-4 NSAVE

The number of prior iterations to retain in memory. This information can be examined interactively and used again as a basis for price adjustments if it is desirable to "back-up" in the solution process and reset some parameters.

1-6-1 NFLOAT

The number of float iterations to perform in the sequence of automatic price adjustments. (see Price adjustments section)

1-6-2 NSMTHFLT

The number of smooth iterations to perform after the float iterations in the sequence of automatic price adjustments. (see Price adjustments section)
1-6-3 NSHAPE  The number of shape iterations to perform in the sequence of automatic price adjustments before starting the process again with a series of float iterations. (see Price adjustments section)

1-6-4 NSMTHSHP  The number of smooth iterations to perform after each shape iteration in the sequence of automatic price adjustments. (see Price adjustments section)

1-6-5 MXBREAK  The maximum number of break points used in defining the price adjustments with any of the price adjustment methods.

*** Block 2 is repeated once for each item type

2-1-1 ZTYP$()  A one-line label for the item type.

2-2-1 ITPYSET()  The item group number (set) to which this item type is classified.

2-2-2 UNITCONV!()  The conversion factor by which one must multiply flows form this item type to convert the units to those used for the item group.

2-2-3 ITYPFIX!()  The fixed value difference term used in the linear equation that defines the item type value as a function of the item group value. See also the earlier section on Items and Item groups.

2-2-4 ITYPVAR!()  The slope term used in the linear equation that defines the item type value as a function of the item group value. See also 2-2-3 ITYPFIX!

***  Block 3 is repeated once for each item group. The term group is used synonymously with the term set.

3-1-1 ZSET$()  A one-line label for the item group.

3-2-** PRSET!(jTIC,)  The initial price estimates, one for each TIC starting with the first TIC and ending with the last TIC in the planning horizon. This value is entered as a real number.

3-3-** EWGHT(jTIC)  The weights to be used for each TIC in estimating the value of the item group for periods beyond the end of the planning horizon. For most cases these weights should sum to 100 as the model simply sums the products of these weights times the corresponding prices ( 3-2-** PRSET!(jTIC) and divides by 100. These weights must be integers as EWGHT() is an integer array.
3-4-1 NCNSTRNTSET() The number of constraints for this item group.

the remainder of Block 3 is included only if the flows for this item group are constrained NCNSTRNTSET()>0

3-5** GOAL (jTIC) The flow goals for each TIC.

*** BLOCK 3a is repeated within block 3 once for each constraint (NCNSTRNTSET())

3a-6-1 TICBEGCN() The first period for which the constraint applies.

3a-6-2 TICENDCN() The last period for which the constraint applies.

3a-6-3 ACCEPTPC!() The maximum acceptable percentage deviation for the constraint expressed as a percent, i.e., 1.5 equals 1.5%.

3-7-1 CONSTRAINTTDC() The index of the discount method to use for estimating the deviation from the desired level over the range of the period for which each constraint applies. The relevant values are (0) no discounting (1) discount using the general discount rate (2) discount by estimating the growth rate for stands likely to shift harvests between periods.

3-7-2 FLOATDC() The index of the discount method to use for estimating the average deviation from the desired flow deviation from the desired level in the float procedure. The relevant values are (0) no discounting (1) discount using the general discount rate (2) discount by estimating the growth rate for stands likely to shift harvests between periods.

3-7-3 SMOOTHDC() The index of the discount method to use for estimating the average deviation from the desired flow deviation from the desired level in the smooth procedure. The relevant values are (0) no discounting (1) discount using the general discount rate (2) discount by estimating the growth rate for stands likely to shift harvests between periods.

3-7-4 SHAPEDC() The index of the discount method to use for estimating the average deviation from the desired flow deviation from the desired level in the shape procedure. The relevant values are (0) no discounting (1) discount using the general discount rate (2) discount by estimating the growth rate for stands likely to shift harvests between periods.
3-8-1 STOPFLOATPC() The float procedure is not used if the total deviation in item group flows over the constrained period is less than this percentage (expressed as a percent). This option is included because the direction of the price change is not necessarily clear for small average percent deviations.

3-9-1 NFLOATBREAK() The number of break points used in the float procedure for defining the adjustment in price that will be made for possible "average deviation" values.

3-9-2 NSMOOTHBREAK() The number of break points used in the smooth procedure for defining the adjustment in price that will be made for possible "average deviation" values.

3-9-3 NSHAPEBREAK() The number of break points used in the shape procedure for defining the adjustment in price that will be made for possible "average deviation" values.

*** Block 3b is repeated once for each NFLOATBREAK()

3b-10-1 FLOATBREAK() The average percent deviation (integer only) for the price break.

3b-10-2 FLOATVAL!() The dollar amount by which prices should be changed for the average deviation associated with this price break.

*** Block 3c is repeated once for each NSMOOTHBREAK()

3c-11-1 SMOOTHBREAK() The average percent deviation (integer only) for the price break.

3c-11-2 SMOOTHVAL!() The dollar amount by which prices should be changed for the average deviation associated with this price break.

*** Block 3d is repeated once for each NSHAPEBREAK()

3d-12-1 SHAPEBREAK() The average percent deviation (integer only) for the price break.

3d-12-2 SHAPEVAL!() The dollar amount by which prices should be changed for the average deviation associated with this price break.
3-13-** SHAPEWGT(jTIC, jTIC)  An array that defines the weights to be used for each TIC in estimating the average deviation within the shape adjustment procedure. The first NTIC weights input are the weights to be used for each TIC in estimating the deviation for TIC = 1 (row 1 of the array). The last NTIC weights are the same except they apply to the estimation of the average percent deviation for the last TIC in the planning horizon. For the set of weights for any one period, the weights are relative and need not sum to any specific value.

3-14-1  PROCESSCOSTINP()  The estimate of the cost per item unit for harvesting and transporting the average stand that produces this item. Used in estimating the growth rate if the option 2 discount rate is used. See also the section on discounting flows.

***  Block 4 is repeated once for each bare land location class (NREGLOC)

4-1-1  ZREGLOC$  A label for the location class.

4-2-1  TRANC&(jTYPE,)  A value is input (as a real number) for each specific item type (converted to integer internally). The value should represent the cost per unit for transporting item jTYPE to market if located in this location class.

***  Block 5 is repeated once for each bare land biological class (NREGBIO)

5-1-1  ZREGBIO$  A label for the biological class.

5-1-2  IBIOLOC(jLOC)  Used to save on calculations by recognizing any similarities between transportation classes. One value is input for each location class. The value is assumed to be the lowest location class identifier that has equivalent characteristics as this location class for this specific biological land class. If this location class is unique when compared to all transport classes with lower class identification numbers, then this value should be the ID number for the location class and calculations will be repeated for it.

***  Block 6 is repeated once for each fixed price relationship

6-1-1  ISETFIX()  The index of the item group.

6-1-2  FTICFIX()  The index of the first TIC for which the relationship holds.

6-1-3  LTICFIX()  The index of the last TIC for which the relationship holds.
6-2* WGHFTIX(JTIC)  The weights to use for each TIC in defining the relationship. All weights for TIC=1 to TIC = NTIC must be input. For most cases the weights should sum to 100 as the sum of prices times weights are determined and then divided by 100.

*** BLOCK 7 is repeated for every additional set of initial price estimates beyond the first set. The number of sets is defined by 1-3-1 NPRSET

7-1-1 ZSET$()  same as 3-1-1 except for next price estimates.

7-2-** PRSET!(JTIC,)  same as 3-2-** except for the next set of price estimates.

AA Prescription Files

The AA Prescription files are all binary files that are designed for fast input. They must all be input once for each iteration of DUALPLAN. A short conversion program BSAVEAA is used to create the binary files. The user must develop two input files for BSAVEAA. One file is easy to create. It is simply a list of file names to use when creating the binary files. Each binary file is limited to 64K, so quite a few binary files could be created by Program BSAVEAA if the data set is large. One output from BSAVEAA is a file that contains a master list describing the names and lengths of each binary file created. This file serves as input to DUALPLAN, its name must be included as FILE3$ on the Model Formulation file (location 1-2*-). Program BSAVEAA asks the user to input the name to use for this master file before execution begins.

The binary input files need not all be developed in a single run of BSAVEAA. For large problems this might be difficult as many analysis areas would be involved. If multiple runs are to be used, the user will need to combine the master list file (binary file names and lengths) for the two runs to input as FILE3$ to DUALPLAN. In combining the master files the user will need to edit out the dummy file name and its negative length that is a signal to dualplan that the last file has been processed.

The basic raw data file for stand prescriptions is very similar to an input file that might be used for a simple cash-flow program. Essentially it has a separate section for each stand with several nested loops for prescriptions, stand entries, and product flows. All values on this input file must be integers less than 32767. This limitation should be considered in selecting the units to use to represent item flows, especially the potential for round-off errors. Also pay particular attention to the fact that DUALPLAN assumes all quantities are expressed on a per land unit basis.

Listed below are brief descriptions of the parameters that are input to Program BSAVEAA to describe management prescriptions for the existing analysis areas. The parameters are listed in the order they appear in the file. The numbers before the parameters are the block number followed by a group number within the block followed by a parameter number for within the group. On the input file each block and each group within the block begins on a new row.
*** Block 1 is repeated once for each analysis area. The end of the list is signalled by a final Block 1 with a NPRES less than zero.

1-1-* STANDID$  
A one line identifier for the analysis area.

1-2-1 NPRES  
The number of prescriptions for the analysis area.
1-2-2 KREGLOC  
The location class identifier for this analysis area in terms of its "bare land" regeneration options.

1-2-3 ACRES1000  
The number of 1000's of acres in the analysis area. This value along with ACRE1 (1-2-4) are used together to define the size of the analysis area. Two terms are used because the input file uses (16-bit integers and thus values greater than 32,767 cannot be represented.

1-2-4 ACRE1  
See 1-2-3 ACRES1000

1-2-5 VRESERVE  
The value of the stand if none of the prescriptions are implemented. The value of the "do nothing" alternative. It could be used to represent the value of nontimber uses if only timber flows are considered.

*** Block 2 is repeated once for each of the NPRES prescriptions. Note that Block 2 is thus nested within Block 1

2-1-* PRESLAB$  
A one-line alphanumeric label for the prescription

2-2-1 NENT  
The number of times the stand is "entered" for this prescription. Stand "entries" include any time in which input or output flows are involved that would influence a "cash-flow" analysis.

2-2-2 KREGTIC  
The TIC in which the next stand can be regenerated (linked with bare land) with this alternative

2-2-3 KREGBIO  
The biological "bare land" class of the stand at the time it is linked with "bare land" regen alternatives.

*** Block 3 is repeated once for each of the NENT stand entries. Note that Block 3 is thus nested within Blocks 1 and 2

3-1-1 KTCENTRY  
The TIC in which the corresponding stand entry occurs

3-1-2 NITEM  
The total number of items that flow during this stand entry.
Block 4 is repeated once for each of the NITEM item flows. Note that Block 4 is thus nested within Blocks 1, 2 and 3.

4-1-1  KTYPE  The index number of the item for the corresponding flow

4-1-2  QUAN  The quantity of the flow. This value will be multiplied times the price for the item to determine the value of the flow.

Regen Prescription Files

The Regen Prescription Files contain the information that describe the regeneration options for the different bare land classes. Prescriptions at this point do not depend on the locational identifiers for bare land. All flows other than transport costs are assumed to be included in the prescriptions. Transport costs are added in DUALPLAN to eliminate the need to write separate prescriptions for each location class by biological class combination.

Like AA prescription files, Regeneration Prescription files are binary files that are designed for fast input. Each file must be read by DUALPLAN twice during each iteration. Regen Prescription files are developed through a short conversion program, Program BSAVERG. Two input files are used. One file is simply a list of file names to use when creating the binary files and the other file contains all the information about the regeneration prescriptions.

One output from Program BSAVERG is a file that contains a master list describing the names and lengths of each binary file created. This file serves as input to DUALPLAN, its name must be included as FILE2$ on the Model Formulation file (location 1-1-*). Program BSAVERG asks the user to input the name to use for this master file before execution begins.

The basic raw data file for regeneration prescriptions is very similar to an input file that might be used for a simple cash-flow program. Essentially it has a separate section for each biological land class with several nested loops for prescriptions, stand entries, and product flows. All values on this input file must be integers less than 32767. This limitation should be considered in selecting the units to use to represent item flows, especially the potential for round-off errors. Also pay particular attention to the fact that DUALPLAN assumes all quantities are expressed on a per land unit basis.

Listed below are brief descriptions of the parameters that are input to Program BSAVERG to describe regeneration prescriptions. The parameters are listed in the order they appear in the file. The numbers before the parameters are the block number followed by a group number within the block followed by a parameter number for within the group. On the input file each block and each group within the block begins on a new row.
*** Block 1 is repeated once for each biological "bare land" class. The end of the list is signalled by a final Block 1 with a NPRES less than zero.

1-1-* BIOTYPES

An alphanumeric label for the biological "bare land" type.

1-2-1 KBIO

The index number that describes this biological land type. This index number is the KREGBIO number used in the AA prescriptions to link the AA with the different "bare land" types.

1-2-2 NPRES

The number of full-rotation prescriptions for this biological land class.

1-2-3 VRESERVE

The value of the "bare land" if none of the prescriptions are implemented. This value could be used to consider converting the bare land to another land use.

***

Block 2 is repeated once for each of the NPRES prescriptions.

2-1-* PRESLABS

A one-line alphanumeric label for the prescription

2-2-1 NENT

The number of stand entries. Each stand entry represents a point in time (TIC) when one or more item flows would occur.

2-2-2 ROTLEN

The length of the rotation in TICs for this prescription.

***

Block 3 is repeated once for each of the NENT stand entries. Block 3 is thus nested within both Block 1 and Block 2.

3-1-1 ENTRYAGE

The age (in TICs) at which this stand entry would occur.

3-1-2 NITEM

The number of item flows that are associated with this stand entry.

***

Block 4 is repeated once for each of the NITEM item flows associated with the stand entry. Block 4 is thus nested within Blocks 1, 2, and 3.

4-1-1 KTYPE

The index number of the item associated with the flow

4-2-2 QUAN

The quantity of the item that flows. This value is assumed to be expressed in a per land unit basis.
SCREEN MENUS

The execution of DUALPLAN is controlled by a number of menus and submenus. A good understanding of the concepts explained above will help the user in understanding these menus and with some experience and improved understanding of the solution procedure the user will become more and more efficient in arriving at an acceptable solution. The program begins execution after typing "DUAL10" and hitting <ENTER>. The following screen will be displayed:

The current directory is listed below. If you want a file not listed please specify the complete directory path.

D:\DUALPLAN

. <DIR> .. <DIR> OUT
CRAA .1  CRAA .2   CRAA .3
CREATEAA.FNL CREATEAA.FNL CREATERN.BAS
CREATERN.FNL CRRG .1 DUAL1 .BAS
DUAL1 .LST PICTURE .CAP DUAL1B .BAS
BRUN45 .EXE DUAL2B .BAS DUAL3 .BAS
DUAL4 .BAS DUAL4B .BAS HYPO .1
RGRES  QB .INI BSAVEAA .BAS
COMMON5.BI CRUNCH10.BAS D12 .1
DUAL12 .MAK D12 .EXP D12 .BAK
CREATEAN.BAS DUAL12 .EXE DUAL12N .EXE

2154496 Bytes free

Run parameters are on file: 

The user enters here the name of the input file that was created in the format described under the section "Model Details" above. The user can also utilize the default input file "DFCASE1.INP".

Next the program asks for the name of an output file:

Name output file: 

Here the user can enter any legal DOS file name including any path name. After entering the name of this file, the program displays the following main menu screen:

Model Parameters Data can be edited now

Pick an option

0. Finished Editing
1. Edit Parameters that define iteration process
2. Edit Parameters for specific products
3. Edit Options for writing results to output file

In most menus, entering any of the option numbers will immediately cause a system response and the user is not required to hit <ENTER>.

DUALPLAN USERS' MANUAL – SCREEN MENUS.
We will begin with the menu choices 1, 2, and 3 which allow to set parameters that control the iteration process, parameters for specific products, and output options. Most of the menu items are self-explanatory and will not be demonstrated in detail. Only where menus options create sub-menu options or where complex entries are required, will we provide detailed examples.

Main Menu Choice 1: (Edit parameters that define iteration process)

Model Parameters Data can be edited now

Pick an option

0. Finished Editing
1. Edit Parameters that define iteration process
2. Edit Parameters for specific products
3. Edit Options for writing results to output file

Option 1 is used to change parameters that control the iteration process in terms of the type and number of iteration steps, i.e., float, smooth, and shape. Selection of choice 1 from that screen will open the following menu that permits the user to change parameters that control the iteration process as described in the main section of the manual.

Submenu for main menu choice 1:

0. No more changes
1. Number of Float iterations per iteration set = 6
2. Number of Smooth iterations after the Float iterations = 3
3. Number of Shape iterations per set = 5
4. Number of Smooth iterations after each Shape iteration = 2
5. Make the first Float Iteration the next step in Adjustment Process
6. Make the first Smooth-after-Float iteration next
7. Make the first Shape iteration next
8. Make the first Smooth-after-Shape iteration next

For each case, the program will ask the user for the option (e.g., 1) selected:

Option 1 was selected
Are you sure? (Y=Yes, N=No)

The user has, therefore, a chance to return to the same menu without making any change or entry by answering "No".

For a "Yes" answer, the user would be directed to input a new number for the number of iterations desired for options 1-4, and would make the program execute specific types of iterations through options 5-8.
Main Menu Choice 2: (Edit parameters for specific products)

Option 2 is used to change parameters for a selected product that control the iteration process.

Model Parameters Data can be edited now

Pick an option

0. Finished Editing
1. Edit Parameters that define iteration process
2. Edit Parameters for specific products
3. Edit Options for writing results to output file

Submenu for main menu choice 2:

Selection of choice 2 from that screen will open the following menu:

Product sets are:

1 = COST
2 = SOFTWOOD
3 = HARDWOOD

WHICH PRODUCT SET ?

Here the user can select one of the existing products, in this case three. If 3 were selected, the next screen would display 7 options for changing price, flow, and iteration parameters for the selected product category, in this case "SOFTWOODS."

Current Product Set = SOFTWOOD

Which one do you wish to edit?

0 Finished editing parameters for this product set
1 A different product set
2 Price estimates
3 Flow goals
4 Discounting methods for adjustments
5 No Float if within 5 percent of total
6 Float Break Points, # of Breakpoints currently = 3 and Price Adjustments
7 Smooth Break Points, # of Breakpoints currently = 3 and Price Adjustments
8 Shape Break Points, # of Breakpoints currently = 3 and Price Adjustments
9 Acceptable average percent deviation for all constraints currently = 5
Option 0 will leave this editing routine and return to the main menu, while option 1 allows to switch to a different product, displaying again:

Product sets are:

1 = COST  
2 = SOFTWOOD  
3 = HARDWOOD

Option 2:

Product Set = SOFTWOOD

<table>
<thead>
<tr>
<th>TIC</th>
<th>CURRENT PRICE ESTIMATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>34</td>
</tr>
<tr>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
</tr>
</tbody>
</table>

TIC TO CHANGE ( 0 = NO CHANGE)

Entering "0" returns user to the submenu above with its 8 product parameter editing options.
The user can input a TIC number (here from 1 to 5 to enter the new price for that product and the TIC number:

TIC TO CHANGE ( 0 = NO CHANGE)? 1  Price for TIC=1 ? 28

Option 3:

Product Set = SOFTWOOD

<table>
<thead>
<tr>
<th>TIC</th>
<th>GOAL</th>
<th>FLOW FROM LAST RUN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>900000</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>900000</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>900000</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>900000</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>900000</td>
<td>0</td>
</tr>
</tbody>
</table>

TIC TO CHANGE ( 0 = NO CHANGE)

Entering "0" returns user to the submenu above with its 8 product parameter editing options.
The user can input a TIC number (here from 1 to 5 to enter the new goal for that product and the TIC number:

TIC TO CHANGE ( 0 = NO CHANGE)Goal for TIC = 1 ?85000
Option 4:

Option 4 allows the user to change the discounting methods as described on page 21 of the manual.

**Editting Product SOFTWOOD**

Methods for Discounting when adjusting prices
0 = No Discounting
1 = Discounting but no recognition of changing prices
2 = Discounting and recognition of changing prices

0. No Changes

An entry of "0" will return user to submenu, entering a number between 1 and 3 will result in the request concerning the discounting method to use for the adjustment procedure selected:

Input Method Number?

Here the user simply selects one of three methods (0, 1, or 2). The change is instantly reflected on the screen.

Option 5:

With this option the user can control the level in terms of the average percent deviation for the selected product at which float procedures would be disabled until again reactivated by the user.

No Float if Percent Dev <= ?
Options 6, 7, and 8:

With these three option the user can change the number of break points and associated price adjustments that will be used in the float, smooth, and shape procedures. The following output is shown for option 6. Option 7 and 8 would generate the same screen displays for appropriate substitution of the word "FLOAT" with another procedure such as "SMOOTH" or "SHAPE". The following would result if option 7 were selected:

Product Set = SOFTWOOD

Smooth Break Points and Price Adjustment Values

<table>
<thead>
<tr>
<th>PERCENT</th>
<th>PRICE ADJUSTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVIATION</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>.05</td>
</tr>
<tr>
<td>50</td>
<td>.15</td>
</tr>
<tr>
<td>150</td>
<td>.3</td>
</tr>
</tbody>
</table>

Edit Options are:
0. No Change
1. Edit

If edit option 1 is selected the model asks:

# of specified price adjustments for Smooth procedure?

Suppose the user wanted to change from 3 to 4 break points and thus responded "4". The model would then display

Smooth Break Points and Price Adjustment Values

<table>
<thead>
<tr>
<th>PERCENT</th>
<th>PRICE ADJUSTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVIATION</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>.05</td>
</tr>
<tr>
<td>50</td>
<td>.15</td>
</tr>
<tr>
<td>150</td>
<td>.3</td>
</tr>
<tr>
<td>150</td>
<td>.3</td>
</tr>
</tbody>
</table>

and one by one the cursor would move through the table allowing the user to change any or all of the values.
Main Menu Choice 3: (Edit options for writing results to output file)

0. Finished Editing
1. Edit Parameters that define iteration process
2. Edit Parameters for specific products
3. Edit Options for writing results to output file

Which do you wish to change?

Selection of choice 3 from that screen will open the following menu that allows the user to control the type of output that the program will produce on the output file:

Summary of Current Reports written to output file after each iteration

Option--Current Status
0. Status of all options OK
1. Summary for each constraint--YES
2. Summary for each product set--YES
3. Summary for each individual product type--YES

OPTION TO SWITCH?

Entering a number between 1-3 will toggle between "YES" and "NO".

Main Menu Choice 0: (Finished editing)

This option is selected after all parameters are set to their desired values. Selecting this option will begin the iteration process to generate an acceptable solution to the scheduling problem.

Model Parameters Data can be edited now

Pick an option

0. Finished Editing
1. Edit Parameters that define iteration process
2. Edit Parameters for specific products
3. Edit Options for writing results to output file

Which do you wish to change?

Are you sure you are finished? (Y=Yes, N=No)

If the user entered an "n" or "N" at this point, the same menu would be displayed again. After entering "y" or "Y", the computer will begin the iteration process and display the following:
Results can be reviewed again after iteration # 3
Type an 8 to stop after current iteration

<table>
<thead>
<tr>
<th>Iteration Number</th>
<th>Iteration Type</th>
<th>Stands Completed</th>
<th>Average Percent Deviation</th>
<th>Average % Absolute Deviation</th>
<th>Number of Nonacceptable Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INPUT</td>
<td>3840</td>
<td>69.87</td>
<td>127.2</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>FLOAT</td>
<td>3840</td>
<td>62.67</td>
<td>110.2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>FLOAT</td>
<td>3840</td>
<td>55.5</td>
<td>101.4</td>
<td>9</td>
</tr>
</tbody>
</table>

The model will fill in the table above as the solution progresses. After the specified number of iterations, the following will appear near the bottom of the table.

HIT ANY KEY TO CONTINUE

After entering a key, the following display with 10 options will appear:

Product Set = SOFTWOOD
Last iteration was number = 3
Current iteration of interest is number = 3

Iteration 3 was based on iteration number 2
Iteration 3 was the result of FLOAT Iteration
Iteration for basis of comparison is number 2

Options are:

0. Finished reviewing results
1. Choose another product set for review
2. Reset iteration of interest
3. List prices over time
4. Graph prices over time -- Auto Scaling
5. Graph prices over time -- Manual Scaling
6. List Product flows over time
7. Graph Product flows over time -- Auto Scaling
8. Graph Product flows over time -- Manual Scaling
9. Examine deviations from constraints

Option 0 returns user to the main menu.

Option 1 allows the user to select another product set for review. It will have the same general outputs and menus as the ones shown for "SOFTWOODS." Options 4, 5, 7, and 8 generate graphical outputs that will not be displayed in this version of the manual.
Main Menu Option 0, Submenu Option 2:

The 2nd option allows the user to go back to any previous iteration number and make the associated marginal cost estimates the starting point for any further iterations. This feature is useful in that one can return to "better" values if solutions started to become worse than better because of poorly selected iteration or price parameters.

SELECT AN OPTION? 2

EARLIEST AVAILABLE ITERATION IS ITERATION NUMBER 1

INPUT ITERATION NUMBER OF INTEREST )?

Main Menu Option 0, Submenu Option 3:

SELECT AN OPTION? 3

PRODUCT SET = SOFTWOOD

PRICES

<table>
<thead>
<tr>
<th>TIME</th>
<th>ITERATION # 3</th>
<th>BASE ITERATION ( # 2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>3</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>36</td>
<td>37</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
<td>39</td>
</tr>
</tbody>
</table>

Main Menu Option 0, Submenu Option 6:

SELECT AN OPTION? 6

FLOWS FOR PRODUCT 2

<table>
<thead>
<tr>
<th>TIME</th>
<th>FLOW</th>
<th>GOAL</th>
<th>PERCENT DEVIATION</th>
<th>BASE ITERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>184,700.</td>
<td>900,000.</td>
<td>-79.48</td>
<td>-81.55</td>
</tr>
<tr>
<td>2</td>
<td>356,900.</td>
<td>900,000.</td>
<td>-60.34</td>
<td>-61.37</td>
</tr>
<tr>
<td>3</td>
<td>520,100.</td>
<td>900,000.</td>
<td>-42.21</td>
<td>-40.51</td>
</tr>
<tr>
<td>4</td>
<td>588,700.</td>
<td>900,000.</td>
<td>-34.59</td>
<td>-39.56</td>
</tr>
<tr>
<td>5</td>
<td>1,725,200.</td>
<td>900,000.</td>
<td>84.82</td>
<td>91.69</td>
</tr>
</tbody>
</table>

Main Menu Option 0, Submenu Option 9:

This option provides useful information on how achievement of individual goals progresses from iteration to iteration. If no improvements are visible, the user could decide to make appropriate changes in price or iteration parameters via the appropriate menus. This is best done by entering "Q" or "QUIT" after the summary of constraints output has been displayed and selecting the appropriate menu item.
SELECT AN OPTION? 9

SUMMARY OF CONSTRAINTS

<table>
<thead>
<tr>
<th>CONSTRAINT NUMBER</th>
<th>FIRST PERIOD</th>
<th>LAST PERIOD</th>
<th>ITERATION 3 PERCENT DEVIATION</th>
<th>ITERATION 2 PERCENT DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-79.47778</td>
<td>-79.47778</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>-60.34444</td>
<td>-60.34444</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>-42.21111</td>
<td>-42.21111</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>-34.58889</td>
<td>-34.58889</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>91.68888</td>
<td>91.68888</td>
</tr>
</tbody>
</table>

INPUT CONSTRAINT NUMBER TO SUMMARIZE FOR PAST ITERATIONS (0=QUIT)?

Main Menu Option 0, Submenu Option 0:

This menu provides the user several options. If no need for parameters adjustments exists, the iteration process can be continued automatically under option 0. But several options for making price and iteration parameter adjustments are also available before continuing with the iterations. Option 5, 6, and 7 can be used to force the program to carry out a specific type of iteration, namely float, smooth, or shape, at the next iteration step. The experienced user will appreciate these options to accelerate the process of finding an acceptable solution to the scheduling problem.

What do you wish to do next?
0 = Continue the Iteration Process -- Automatic Price Adjustments
1 = Set Price Estimates of a prior Iteration as the basis for Adjustments
2 = Look again at the results of last/prior Iteration
3 = Manually Adjust Price Estimates -- no Automatic Adjustment
4 = Modify Adjustment Process --Parameters or Sequence of Iteration Types
5 = Perform 1 Float Iteration
6 = Perform 1 Smooth Iteration
7 = Perform 1 Shape Iteration
8 = Stop this Run
9 = Write new input file using all current values

Option 8:

Are you sure you want to stop? (Y=Yes, N=No)

"Yes" will return user to DOS, "No" will open the menu above???
REFERENCES


