A PROGRAMMABLE CALCULATOR APPLICATIONS

NOTEBOOK FOR PRACTICING PLANNERS

BY

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MASTER OF COMMUNITY PLANNING

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INTRODUCTION

A practicing planner needs the capability to solve
quantitative problems. No planning curriculum can prepare
its students for every kind of quantitative problem they can
conceivably encounter. In my own field, renewable energy
planning, some of the most important problems have emerged
within the past few years: shadow calculations for solar
access, tax incentive calculations for small hydroelectric
site redevelopment, etc. Planners in this field are turning
to powerful programmable calculator/printer systems as a
means of coping.

Electronics engineers have been using programmable
calculators since these tools appeared in 1977. I first
began using the TI-59/PC-100C system in late 1979, while
working on passive solar design problems with architects at
the Northeast Solar Energy Center. Since then I have done
thousands of runs for a wide variety of problems, mostly
energy-related. It has become increasingly apparent that
most of the advantages of the system can be transferred to
other kinds of public planning.

Given an introductory notebook, most students should be
able to acquire competence in calculator programming and
applications more efficiently than I did. And so I decided
to write such a notebook.

Quantitative problem solving with the TI-59/PC-100C
is a blend of many things, from mathematical theory to
keeping your fingerprints off the magnetic program cards.

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Writing a notebook that respects the utility of brand-name
and housekeeping information is not accepted academic practice
in graduate schools, nor is the required double-spaced format
appropriate for communicating this kind of information in
the most efficient way. I have entered this project with
some trepidation, despite my complete confidence in the
hardware/software system.

Many of you will probably be unfamiliar with the specific
hardware system discussed in this notebook. The Texas
Instruments TI-59 programmable calculator operates much like
the inexpensive TI-57. You may know someone who has a TI-57,
so I will note here that its instruction manual, MAKING TRACKS
INTO PROGRAMMING, is the best possible introduction to the
TI algebraic operating system (AOS) and programming in general.[1]

This notebook is based on several premises that should
be discussed here. First, most planners will not have access
to computers with the software they need. Furthermore, for
problems with fewer than about 100 input data points, the
TI-59 outperforms computers more often than not, simply because
it is so easy to program, access and operate. I own a $4000
microcomputer with a multi-purpose spreadsheet program, and
the TI-59 is the minimal block time choice for most of the
complex calculations in my work. The microcomputer works
well for word processing and data storage, but it cannot compete
as a calculator.

Second, the calculator's small size is a real advantage.
It fits on the corner of a desktop or in an attache case

(with printer). Without the printer it operates on battery power for field applications. There is no substitute for this kind of close and constant utility.

Third, most planners will have at least a refreshable knowledge of algebra. Algebra is an important tool, good for understanding most of the quantitative problems you will face, and good for programming in an assembly language based on algebraic notation.

Fourth, consecutive, quick numerical solutions permit consideration of several values for variables that cannot be accurately determined or estimated. It is reassuring to know when improved accuracy of inputs adds little to the value of a solution, because then we can manage problem-solving resources more efficiently.

Fifth, the above process can be extended to provide broad understanding of the underlying dynamics of a problem, understanding that would otherwise be achieved only by more experienced or more analytical minds. It is difficult to appreciate this phenomenon without experiencing it once or twice. Trust me.

Sixth, the knowledge acquired from the process of quantitative problem solving is a commodity related to power. It can be used constructively to note specific options and consequences, thereby minimizing the latitude for politicizing decisions. Planners who cannot provide specific, accurate solutions to quantitative problems cannot

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expect to be trusted by elected government officials.

Finally, the programmable calculator has been underestimated because of its small size, even though its speed and capacity exceed that of a central processing unit sold by IBM for a quarter million dollars in 1960. In 1980, when the federal government required utilities to provide on-site energy audits for their residential customers, I worked with a small group that designed a complying audit procedure. It required more than a hundred data inputs, more than a thousand calculations, and a complete discussion of results on-site. While other states set up central computer systems to be accessed by portable modem terminals, we developed an incredibly compressed TI-59 program. The Rhode Island utilities' non-profit auditing firm uses twenty calculator/printer systems for more than 10,000 audits per year. These systems save some $300,000 per year in computer programming, leasing and operations costs. The good feeling of having worked on that project has sustained me through more than a few disappointing days since then.

NOTES

[1]Ralph Oliva et al, MAKING TRACKS INTO PROGRAMMING, (Lubbock: Texas Instruments, 1977).

QUANTITATIVE METHODS IN PLANNING PRACTICE

Because quantitative methods have emerged from so many substantive fields and mathematical techniques, planning schools can include only the most practical and understandable in a two-year curriculum. And even this basic approach presents problems.

The economist John Kain has commented that quantitative methods courses in planning schools are too often <u>about</u> methods.[1] Students complete degrees without gaining competence in methods as tools.

In 1974 Daniel Isserman surveyed AIP-recognized schools to find out what methods were being taught. He found almost no consensus: only population projection and economic base were widely taught beyond the introductory level. Isserman also surveyed practicing planners for recommendations on what they thought should be taught. Again he found almost no consensus, and practicing planners collectively had different priorities from those of schools.[2]

Practicing planners listed the methods in which they thought competence should be required, while schools listed methods in which a basic introduction was required. The following list is ranked according to the practicing planners' priorities:

	Planners	Schools
1. Population projection	67%	75%
2. Questionnaire surveys	66	51
3. Housing need	54	17

	Planners	Schools
4. Economic base	50%	75%
5. Market area	49	24
6. Descriptive statistics	43	61
7. Cost-benefit	41	37
8. Cost-revenue	37	24
9. Inferential statistics	27	51
10. Gravity model	26	54
11. Input-output	14	46
12. Multiple regression	14	46

The schools were clearly not providing the training that the profession required, however farsighted they may have been in selected methods such as input-output. The surveys were inconsistent in several ways. Schools were questioned on the gravity model, while planners were questioned on land use and transportation models in general. This makes the planners' minimal interest all the more emphatic. Property development finance was not included, which may account for the practicing planners' response to the housing need methods.

Isserman accepted all responses at face value, despite misgivings. Terms such as "competence" and "introduction" are subjective. It would have been prohibitively expensive to monitor course offerings by questioning or testing students. It might have been even more disconcerting.

The Isserman survey raises some serious questions about the sources of "professional judgment" in planning. For the experienced planner a reputation for wisdom may be sufficient to secure support for a plan or program, but younger planners will be increasingly challenged by management and systems science techniques from tangential fields.

The Isserman survey also raises questions about the

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classification of quantitative methods. The survey did not discriminate between substantive field applications and mathematical techniques. This was most obvious in the case of inferential statistics. How much of inferential statistics are we discussing? Is probability included? What substantive field applications are we concerned with beyond questionnaire surveys?

Many planning schools offer statistics as an introductory techniques course, without attention to the mechanics of substantive field applications. This is particularly true when the course is taught outside the department. Students may concurrently be studying the mechanics of substantive field applications for other mathematical techniques they may not have learned before entering planning school. This double bind situation could be remedied with diagnostic tests and short tutorial courses that incorporate calculator programs. Business schools have done this within and parallel to their curricula.[3]

It would be helpful to classify commonly used planning methods in a two-way table that shows the intersections of mathematical techniques and substantive field applications. Each application method could be linked to at least one published source. For example, the PRACTITIONER'S GUIDE TO FISCAL IMPACT ANALYSIS is probably the most important published information source for that method, although sources for variations of the method could be noted.[4] The manual

calculation method presented in the GUIDE has been enhanced

in programmable calculator and microcomputer software,

but nothing has been published to date.

NOTES

[1]John Kain, "Rampant Schizophrenia: The Case of City and Regional Planning," JOURNAL OF THE AMERICAN INSTITUTE OF PLANNERS, (July 1970), p. 221.

[2]Daniel Isserman, PLANNING PRACTICE AND PLANNING EDUCATION: THE CASE OF QUANTITATIVE METHODS, (Urbana: Illinois, 1975).

[3]LRN, (January 1982), p. 3.

[4]Robert Burchell and David Listokin, PRACTITIONER'S GUIDE TO FISCAL IMPACT ANALYSIS, (New Brunswick: Rutgers, 1980).

ECONOMICS OF PROBLEM SOLVING

Linear programming was developed in the USSR during the 1930's, but it became a practical operations research method in the United States during the 1950's. The number of man-hours required to perform thousands of arithmetic operations increased costs and limited the number of problems worth solving. High-speed computers simply decreased the costs of linear programming (and, of course, increased the speed for real time applications).

Although computation costs have decreased dramatically over the past thirty years, lower costs have not necessarily been directly accessible. Professionals with relatively infrequent quantitative problem solving requirements may find the first cost of a computer and appropriate software to be prohibitive. When consultants are hired to solve the problems, they absorb the difference between the cost of computation and the market value of the solution.

There are some adaptive methods for getting around the cost problem. Large computers may test the limits of error for less complex models that fit into programmable calculators or even nomographs. Screening methods developed from back-of-the-envelope calculations can eliminate alot of problem cases that are not even worth considering for the purpose at hand. This is a bit theoretical, but the bottom line conclusion is that we can often avoid being dependent on equipment we cannot afford.

Think for a moment about how problems are solved.
I might begin with a pencil and some graph paper (non-repro
blue, four squares to the inch). I generally try to assemble
the graphic, numerical and verbal components I need: a stylized
drawing, diagrams, some arrows, a few numbers, book citations,
some equations, more arrows, and erasures of things that
seemed germaine but turned out not to be. I understand some
of the dynamics of the problem from related experiences. In
other ways I feel very inadequate. These are the times that
professionals hide. We all try to cheat our limitations and
avoid defeat (the area under a curve equals the number of
squares you count on the graph paper).

If the problem is quantitative, it eventually boils
down to data, mathematical operations and a useful format.
Then is when it would be nice to have an inexpensive
programmable calculator capable of doing things that would
otherwise require computer access. There is something very
satisfying about accomplishing the apparently impossible with
tools you can easily conceal. To the extent that the Texas
Instruments TI-59/PC-100C system can do this, the practicing
planner has significant new opportunities.

In a world of complex problems, there are a few natural
laws working for those of us using small tools. First, big
models are not necessarily more useful than small models.
William Alonso's old article on sources of error in models
remains a good source of consolation and advice.[1] He notes

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two kinds of error. Measurement errors are those acquired
from inaccurate measurement. Specification errors come from
deliberate (or mistaken) model simplification. Alonso's
central point is that elaborate specification may in fact
generate cumulative measurement errors beyond what a simpler
model would have produced. There is, in almost every case,
a point of diminishing return. His summary advice is to avoid
the operations that generate cumulative error fastest, namely
intercorrelated variables, subtraction and exponentiation.
Add where possible, and multiply or divide if you cannot add.

Second, complex problems can often be broken down into
relatively autonomous sub-problems. If we can represent a
problem graphically, it is often possible to understand how
component parts are connected before that connection is
expressed mathematically. Dennis Meadows' world systems
model appears on the following page; it shows in some detail
which sectors are most directly related to which. If these
linkages were expressed only mathematically, relatively few
people would understand what is going on. And some strange
things would happen as a result of that lack of understanding.

Results generated from mathematical models that have
not been graphically represented may be counterintuitive
(contrary to our intuitive understanding of how things work).
This might be because we have underestimated the extent to
which certain combinations of variables could affect outcomes
(watch out for exponents between 0.9 and 1.1: they strike
surprisingly quickly). Once you know how the game is played,

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Figure 3. The complete World 3 model.

KEY

1. IC. Industrial Capital
2. ICDR. Industrial Capital Depreciation Rate
3. ALIC. Average Lifetime of Industrial Capital
4. ICUF. Utilization Fraction Industrial Capital
5. IO. Industrial Output
6. ICOR. Industrial Capital Output Ratio
7. ICIR. Industrial Capital Investment Rate
8. FIOAC. Fraction of Industrial Output Allocated to Consumption
11. IOPC. Industrial Output Per Capita
12. ISOPC. Indicated Service Output Per Capita
13. FIOAS. Fraction of Industrial Output Allocated to Services
18. SCIR. Service Capital Investment Rate
19. SC. Service Capital
20. SCDR. Service Capital Depreciation Rate
21. ALSC. Average Lifetime of Service Capital
22. SO. Service Output
23. SCOR. Service Capital Output Ratio
24. SOPC. Service Output Per Capita
25. F. Food
25.1. LFH. Land Fraction Harvested
25.2. PL. Processing Loss
26. PAL. Potentially Arable Land
27. AL. Arable Land
28. LFC. Land Fraction Cultivated
28.1. PALT. Potentially Arable Land Total
29. DCPH. Development Cost per Hectare
30. LDR. Land Development Rate
31. IFPC. Indicated Food Per Capita
34. TAI. Total Agricultural Investment
35. FIOAA. Fraction of Industrial Output Allocated to Agriculture
38. FPC. Food Per Capita
39. LY. Land Yield
40. LYF. Land Yield Factor
41. AIPH. Agricultural Inputs Per Hectare
42. LYMC. Land Yield Multiplier from Capital
43. CAI. Current Agricultural Inputs
44. AI. Agricultural Inputs
45. FIALD. Fraction of Investment Allocated to Land Development
47. MPLD. Marginal Productivity of Land Development

48. MPAI. Marginal Productivity of Agricultural Inputs
49. MLYMC. Marginal Land Yield Multiplier from Capital
50. ALL. Average Lifetime of Land
50.1. ALLN. Average Life of Land Normal
51. LLMY. Land Life Multiplier from Yield
52. LER. Land Erosion Rate
53. UILPC. Urban-Industrial Land Per Capita
54. UILR. Urban-Industrial Land Required
55. LRUI. Land Removal for Urban-Industrial use
56. UILDT. Urban-Industrial Land Development Time
57. UIL. Urban-Industrial Land
58. LFERT. Land FERTility
59. LFDR. Land Fertility Degradation Rate
60. LFD. Land Fertility Degradation
60.1. LFR. Land Fertility Regeneration
61. LFRT. Land Fertility Regeneration Time
62. ILF. Inherent Land Fertility
63. FALM. Fraction Allocated to Land Maintenance
63.1. FR. Food Ratio
64. SFPC. Subsistence Food Per Capita
65. PFR. Perceived Food Ratio
65. LYMAP. Land Yield Multiplier from Air Pollution
66.2. IO70. Industrial Output In 1970
67. PCRUM. Per Capita Resource Usage Multiplier
68. NRUR. Nonrenewable Resource Usage Rate
69. NRUF. Nonrenewable Resource Usage Factor
69.2. NR. Nonrenewable Resources
70. NRI. Nonrenewable Resources Initial
70. NRFR. Nonrenewable Resources Fraction Remaining
71. FCAOR. Fraction of Capital Allocated to Obtaining Resources
74. PGIO. Pollution Generation Multiplier from Output
76. PGML. Pollution Generation Multiplier from Land
76.1. POLG. POLlution Generation from Land
76.2. FPL. Fraction of Pollution from Land
76.4. POP70. POPulation in 1970
76.5. ALN. Arable Land in 1970
77. POLGF. POLlution Generation Factor

keeping score is simple enough. Think graphically whenever

you can. Drag the unknowns back to familiar ground. As one

unimpressed reviewer wrote of a noted professor's mathematical

model:

> Is it true, however, that the policy suggestions
> Forrester derives from his model are really surprising?
> The simplest way to answer these questions is to point
> out that one gets out of computer models what one puts
> in. If Forrester has defined a sick city in terms of
> a declining economy, increasing numbers of unemployed and
> high taxes, then it is obvious that a healthy city will
> simply manifest the reverse symptoms.
>
> Keeping the underemployed out of the city . . . would
> certainly lead industry to soak up available labor. Then
> the quality of urban life would improve, the demands on
> taxes diminish because of the decline in large numbers of
> demoralised, discontented workers and the economy would
> begin to recover.
>
> In fact there is nothing at all surprising in Forrester's
> conclusions given his assumptions. The model has only to
> be stood on its head for the solution to appear.[2]

NOTES

[1]William Alonso, "Predicting Best with Imperfect Data," JOURNAL
OF THE AMERICAN INSTITUTE OF PLANNERS (July 1968), pp. 251-55.

[2]H. Cole et al, MODELS OF DOOM, (New York: Universe Books, 1973),
p. 198.

HARDWARE

Texas Instruments and Hewlett-Packard manufacture the only magnetic-card-reading programmable calculators sold in the United States. From 1977-81 the Texas Instruments TI-59 dominated its market, essentially because it offered greater capacity and lower price than the Hewlett-Packard HP-67 and HP-97 calculators. The new HP-41CV is superior to the TI-59, but at more than double the price.

The most obvious difference between the TI and HP equipment is in the assembly language used for programming. TI uses an Algebraic Operating System (AOS) that permits anyone with an understanding of algebraic notation to program almost literally from an equation. The HP assembly language uses Reverse Polish Notation (RPN), a more efficient method for allocating program steps. Competent mathematicians tend to prefer RPN as the more efficient calculation logic. Algebraic notation was developed for concept assembly on paper. My preference for AOS is based on the ease with which it can be translated from program steps back to equations. The review and modification of available programs turns out to be an important activity.

TI and HP programmables also differ in physical design. The TI-59 uses a fast (60 characters per second) printer that runs on 120VAC only. The slower HP printer can run on battery power. The HP-41CV displays letters; the TI-59 does not.

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The HP calculators have superior card-reading tolerances; it is sometimes difficult for one TI-59 to read a card written on another. This has important implications for the way programs are marketed.

The TI-59 was designed as a multi-purpose calculation tool. None of its keys are dedicated to programs for specific substantive field applications. Instead, one program call key and ten user-defined keys access dedicated firmware contained in small modules that slide into the back of the calculator. These interchangeable modules contain up to 5000 program steps (typically a library of 20-25 programs). There are modules for business, investment, farming, etc., but none for community planning. The calculator comes with a master module designed for general use.

The TI-59/PC-100C system is both compact and modular. The diagram on the following page shows the relationship among parts. Note that the printer, calculator and modules each have their own instruction manuals. My entire system fits in a $10 Woolworth attache case lined with thin, rigid foam sheeting from a Xerox packing case. The system costs about $380 at discounted prices. Since repairs to the calculator are made on an exchange basis ($63 per exchange for a replacement after warranties expire), there are no service benefits to buying from a local retail dealer rather than a discount mail order firm. The equipment is remarkably reliable.

For those of you who have seen or used a TI-57, the

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$380 PACKAGE
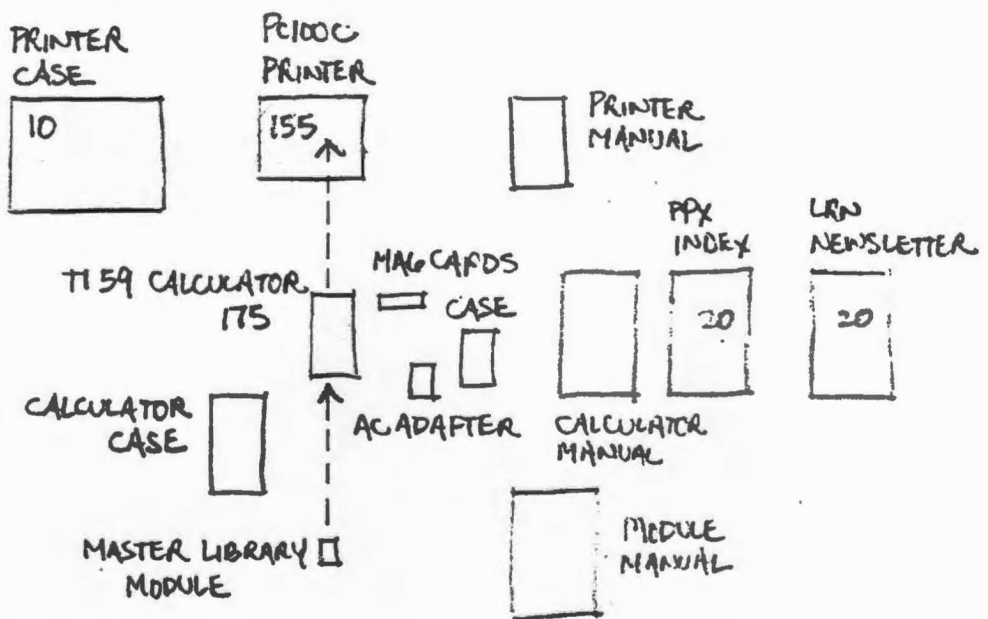
HARDWARE LIST (but not the best available prices)

Texas Instruments

TEXAS INSTRUMENTS CALCULATORS AND ACCESSORIES

CALCULATORS	DESCRIPTION	WEIGHT	PRICE
PROFESSIONAL CALCULATORS			
TI STUDENT BUSINESS ANALYST WITH BOOK		(3 LBS)	29.95
BUSINESS ANALYST II - SLIMLINE LCD BUS/FINAN W/STATISTICS		(3 LBS)	42.95
THE MBA	ADVANCED PROGRAMMABLE W/FINANCE & STATISTICS	(3 LBS)	59.95
SCIENTIFIC CALCULATORS			
TI-30 II	STUDENT SLIMLINE W/CONSTANT MEMORY FEATURE	(3 LBS)	18.95
TI-35 SP	SLIMLINE STUDENT SLIDE RULE W/CONSTANT MEM & BOOK	(3 LBS)	22.95
TI-40	TILT-TOP LCD W/CONSTANT MEMORY & BOOK	(3 LBS)	26.95
TI-55-II	ADVANCED SLIDE RULE PROGRAMMABLE LCD W/BOOK	(3 LBS)	44.95
TI-58C	480 STEPS - PLUG-IN SOLID STATE SOFTWARE	(5 LBS)	99.95
TI-59	960 STEPS - CARD PROGRAMMABLE	(6 LBS)	179.95
PC-100C	PRINTER/PLOTTER FOR TI-58/59	(8 LBS)	179.95
CARRYING CASE FOR PC-100C PRINTER WITH TI-59 MOUNTED		(4 LBS)	39.95
TI LCD PROGRAMMER	ADV TILT-TOP HEX/OCTAL CONVERTER	(4 LBS)	69.95
SOLID STATE SOFTWARE LIBRARIES			
STAT-5859	APPLIED STATISTICS	(2 LBS)	40.00
REI-5859	REAL ESTATE & INVESTMENT	(2 LBS)	40.00
AV-5859	AVIATION	(2 LBS)	40.00
NAV-5859	MARINE NAVIGATION	(2 LBS)	40.00
SURV-5859	SURVEYING	(2 LBS)	40.00
LEIS-5859	LEISURE LIBRARY	(2 LBS)	40.00
SEC-5859	SECURITIES LIBRARY	(2 LBS)	40.00
BUS-5859	BUSINESS DECISIONS	(2 LBS)	40.00
MATH-5859	MATH/UTILITIES	(2 LBS)	40.00
EE-5859	ELECTRICAL ENGINEERING	(2 LBS)	40.00
FARM-5859	FARMING	(2 LBS)	55.00
RPM-5859	RPN SIMULATOR	(2 LBS)	40.00
POOL-5859	POOL WATER ANALYSIS	(2 LBS)	45.00
SPECIALTY PAKETTES			
SP-SECUR	SECURITIES (TI-59 REQUIRED)	(2 LBS)	10.00
SP-STAT/TEST	STATISTICAL TESTING	(2 LBS)	10.00
SP-CIVIL/ENG	CIVIL ENGINEERING	(2 LBS)	10.00
SP-ELEC/ENG	ELECTRONIC ENGINEERING	(2 LBS)	10.00
SP-BLACKBODY	BLACKBODY	(2 LBS)	10.00
SP-OIL/GAS/ENG	OIL GAS ENERGY	(2 LBS)	10.00
SP-PROG/AIDS	PROGRAMMING AIDS (TI-59 W/PC-100C REQUIRED)	(2 LBS)	10.00
SP-PRINTR/UTIL	PRINTER UTILITY (TI-59 W/PC-100C REQUIRED)	(2 LBS)	10.00
SP-ASTROLOGY	ASTROLOGY	(2 LBS)	10.00
SP-59/FUN	59 FUN (TI-59 REQUIRED)	(2 LBS)	10.00
SP-3D/GRAPH	3D GRAPHICS	(2 LBS)	10.00
SP-MATH	MATH	(2 LBS)	10.00
SP-FLUID/DYN	FLUID DYNAMICS	(2 LBS)	10.00
SP-LAB/CHEM	LAB CHEMISTRY (TI-59 REQUIRED)	(2 LBS)	10.00
SP-PROD/PLAN	PRODUCTION PLANNING	(2 LBS)	10.00
SP-MKT/SALES	MARKETING/SALES	(2 LBS)	10.00
SP-QA1	QUALITY ASSURANCE I	(2 LBS)	10.00
SP-QA11	QUALITY ASSURANCE II	(2 LBS)	10.00
ACCESSORIES			
ADAPTERS/CHARGERS			
AC-9130A	SR-50/51/52/56/10/11/2350 111 (FOR BP-1A)	(2 LBS)	9.95
AC-9130SW	DUAL VOLTAGE 120/240V FOR BP-1 OR BP-1A	(2 LBS)	14.75
AC-9131	TI-59/58/51-11/1680/1650/58C	(2 LBS)	6.95
AC-9132	MBA/MBA/57/55/PROGRAMMER/40 FOR BP-7 & BP-8	(2 LBS)	8.95
RK-2	TI-30/BA-1, INCLUDES AC-9132 & BP-8	(2 LBS)	12.00
BATTERY PACKS			
BP-1A	TI-59/58C/SR50/50A/52SA/51/51A	(1 LB)	10.00
BP-6	TI-51-11	(1 LB)	10.00
BP-7	MBA/TI-55/57	(1 LB)	8.95
BP-8	PROGRAMMER/TR-40/BA	(1 LB)	8.95
PAPER PRODUCTS			
TP-20225	TI-5135/5015/5040 (3 ROLLS PER PKG)	(3 LBS)	2.15
TP-27225	TI-5015/5040 (3 ROLLS PER PKG)	(3 LBS)	3.69
TP-30250	PC-100C (3 ROLLS PER PKG)	(3 LBS)	10.00
SP-3	2 1/4" STANDARD PAPER (3 ROLLS) TI-5142	(3 LBS)	1.90
MISCELLANEOUS			
PAD-58/59	PROGRAM RECORD FORMS PAD 58/59	(2 LBS)	2.75
BC-59	40 BLANK CARDS & CARD CASE FOR TI-59	(2 LBS)	20.00
BC-59A	120 BLANK CARDS & CARD CASE FOR TI-59	(3 LBS)	45.00

Programmable TI-59

TI-59
$179.95

Programmable 58C

TI-58C
$99.95

PC100C PRINTER $179.95
CARRYING CASE $39.95

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differences in the TI-59 can be described as capacity-related
rather than format related:

	TI-57	TI-59
Program steps	50	460
Memory registers	8	60
Subroutines	6	72
Subroutine levels	6	6
Conditional branching	yes	yes
User-defined keys	0	10

The TI-59 has modifiable capacity: it can trade 60 program
steps for 10 memory registers. Instead of a fixed 460/60
split, the range can be shifted from 160/100 to 960/0 in
increments of 60/10.

The TI-57 has only 50 program steps, but these are
functionally equivalent to about 80 steps on the TI-59,
simply because more keystrokes are merged. For example,
recalling a number from memory register 02 requires one step
on a TI-57 and two on a TI-59. Of the minor differences in
notation, only subroutine calls are worth mentioning here.
The TI-57 calls numbered labels (eg, LBL 01), while the TI-59
calls key labels (eg, LBL x^2). You can set key/number
equivalencies to keep track, so that programs for the TI-57 can
be run or listed on the more expensive system.

The two instruction manuals are conceptually related,
and the TI-57 uses the apt analogy of a model train layout
to introduce programming concepts. The TI-59 manual, PERSONAL
PROGRAMMING, uses flowcharting without analogies.[1]

The most sensitive component in the TI-59 system is
the magnetic card, but that card sets it apart as a
professional tool. Each card has four banks (magnetic tracks),
and each bank holds up to 240 program steps or 30 memory
registers. Card numbers and bank numbers are not the same;
they are simply equated by convention. The calculator can
hold up to four banks of input at once. By convention the
left side of the first card is called side one and uses bank

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one. The right side of that card is side two and uses bank
two. The left side of the second card is called side three
and uses bank three, etc. Respect the convention and save
your mind for more important complications.

Although the instruction manual fails to mention erasure
and rerecording, the magnetic cards can be used over again.
Since each card side physically includes all four banks (or
tracks), simply remember to overwrite the same bank you used
before. This option is useful when data has to be stored on
cards temporarily. Magnetic cards cost about $.40 each.
When marking magnetic cards, use a black Flair pen that
likes the surface (the ones that like the surface are great,
but not all do). Let the ink dry thoroughly; it stays on
until you wipe it off with soap and water.

Key definition cards that come with program library
modules are black with gold lettering. Those that come with
blank magnetic cards are gold and can be confused with
magnetic cards. Throw them all away. The card case
instruction manual is all you need for a program library   .
module, and that is a good format to adopt for magnetic card
programs as well.

BANK DIAGRAM

This diagram has been redrawn from PERSONAL PROGRAMMING, and it is a necessary reference for intial program/memory allocation. The following pages show the key codes as keys and as printed steps. The latter is a necessary reference
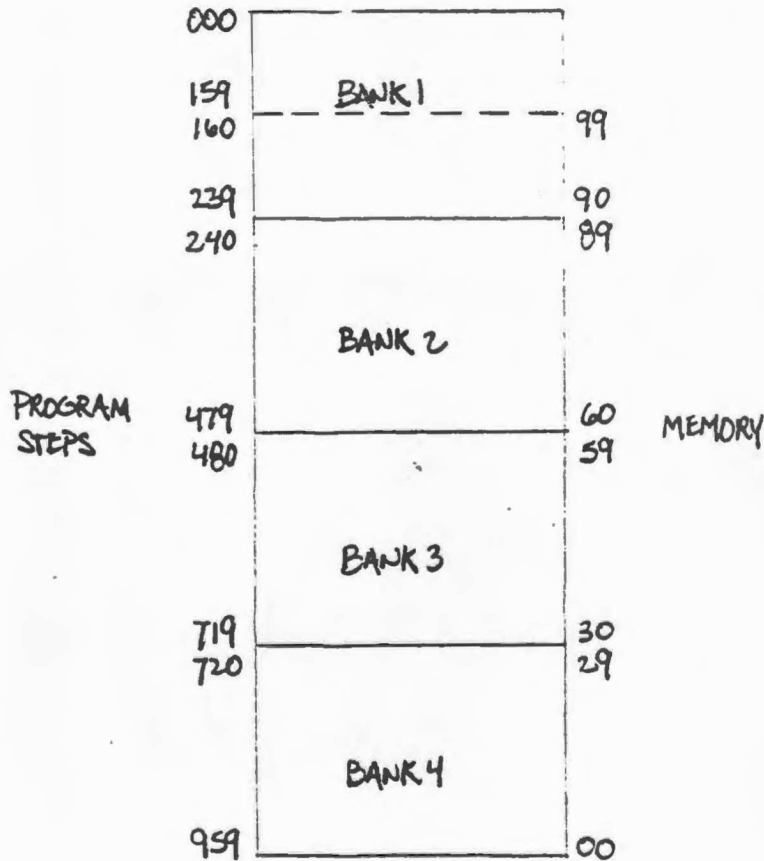
for interpreting other people's programs. Note that the keys and printed steps are not always easy to match. Not all codes are directly entered.

Key Codes in Numerical Order

Key Code	Key	Key Code	Key	Key Code	Key
00	0	39	2nd cos	72	STO 2nd Ind
↓	↓	40	2nd Ind	73	RCL 2nd Ind
09	9	42	STO	74	SUM 2nd Ind
10	2nd E'	43	RCL	75	−
11	A	44	SUM	76	2nd Lbl
12	B	45	y^x	77	2nd x≷t
13	C	47	2nd CMs	*78	2nd Σ+
14	D	48	2nd Exc	79	2nd x̄
15	E	49	2nd Prd	80	2nd Grad
16	2nd A'	50	2nd |x|	81	RST
17	2nd B'	52	EE	*82	HIR
18	2nd C'	53	(	83	GTO 2nd Ind
19	2nd D'	54	)	84	2nd Op 2nd Ind
20	2nd CLR	55	÷	85	+
22	INV	57	2nd Eng	86	2nd St flg
23	lnx	58	2nd Fix	87	2nd If flg
24	CE	59	2nd Int	88	2nd D.MS
25	CLR	60	2nd Deg	89	2nd π
27	2nd INV	61	GTO	90	2nd List
28	2nd log	62	2nd Pgm 2nd Ind	91	R/S
29	2nd CP	63	2nd Exc 2nd Ind	92	INV SBR
30	2nd tan	64	2nd Prd 2nd Ind	93	•
32	x≷t	65	X	94	+/−
33	x²	66	2nd Pause	95	=
34	√x	67	2nd x=t	96	2nd Write
35	1/x	68	2nd Nop	**97	2nd Dsz
36	2nd Pgm	69	2nd Op	98	2nd Adv
37	2nd P→R	70	2nd Rad	99	2nd Prt
38	2nd sin	71	SBR		

NOTES

* This command cannot be directly keyed in, but may be written into a program by going into learn mode and pressing STO 82 and deleting the STO. There is a two-digit number XY which follows the 82 command. X stands for the hierarchy register operation, where 0 is STO, 1 is RCL, 3 is SUM, 4 is *Prd, 5 is INV SUM, and 6-9 are INC *Prd. Y stands for the hierarchy register to be accessed (1-8). XY may be entered in the same manner as code 82 if XY by itself is an invalid keyboard entry.

**The Dsz instruction on the TI-59 can be used with any register (except 40, which implies indirect). Registers 10-99 cannot be keyed in directly but may be generated as follows: LRN *Dsz STO nn BST BST *Del SST − LRN.

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000	00	0
001	09	9
002	10	E'
003	11	A
004	12	B
005	13	C
006	14	D
007	15	E
008	16	A'
009	17	B'
010	18	C'
011	19	D'
012	20	CLR
013	22	INV
014	23	LNX
015	24	CE
016	25	CLR
017	27	INV
018	28	LOG
019	29	CP
020	30	TAN
021	32	X!T
022	33	X²
023	34	√X
024	35	1/X
025	36	PGM
026	00	00
027	37	P/R
028	38	SIN
029	39	COS
030	40	IND
031	42	STO
032	00	00
033	43	RCL
034	00	00
035	44	SUM
036	00	00
037	45	YX
038	47	CMS
039	48	EXC
040	00	00
041	49	PRD
042	00	0
043	50	I×I
044	52	EE
045	53	(
046	54	)
047	55	÷
048	57	ENG
049	58	FIX
050	00	00
051	59	INT
052	60	DEG
053	61	GTO
054	62	PG*
055	63	EX*
056	00	00
057	64	PD*
058	00	00
059	65	×
060	66	PAU
061	67	EQ
062	68	NOP
063	69	OP
064	00	00
065	70	RAD
066	71	SBR
067	00	00
068	00	00
069	72	ST*
070	00	00
071	73	RC*
072	00	00
073	74	SM*
074	00	00
075	75	-
076	76	LBL
077	77	GE
078	78	Σ+
079	79	X̄
080	80	GRD
081	81	RST
082	82	HIR
083	00	00
084	83	GO*
085	00	00
086	00	0
087	84	OP*
088	00	00
089	85	+
090	86	STF
091	00	00
092	87	IFF
093	00	00
094	00	00
095	00	00
096	88	DMS
097	89	π
098	90	LST
099	91	R/S
100	92	RTN
101	93	.
102	94	+/-
103	95	=
104	96	WRT
105	97	DSZ
106	00	00
107	98	ADV
108	99	PRT
109	00	0
133	21	2ND
134	26	2ND
135	31	LRN
136	41	SST
137	46	INS
138	51	BST
139	56	DEL
140	00	0

SOFTWARE

Many people simply purchase the software they need and avoid programming altogether. Program instructions can be treated like cookbook recipes, but there are risks involved. Even good programmers make mistakes that can embarrass you. Most programs can be modified to meet your needs more efficiently. The trick is to integrate review and modification.

TI-59 programs are available from several sources, but the largest and most important source is TI's own Personal Programming Exchange. PPX provides a quarterly newsletter and program catalog for $20 per year. Cataloged programs cost $4 each and are listed by six digit codes. The first two digits denote the subject area. A subject area classification table and sample abstract listings appear on the following pages.

PPX programs are also sold in related groups of 5-10 in books called Specialty Pakettes. The notation numbers are those used in the PPX catalog.

Texas Instruments does not pay for programs submitted to PPX, and there are people who write sophisticated programs worth more than $100 per copy. These are sold independently, often through appropriate professional journals. When they are sold as "protected" magnetic cards, the contents cannot be reproduced or analyzed. Be wary of these: if they have programming mistakes within them, you may never know. Your

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TI-59 may have trouble reading cards written on another machine.

Texas Instruments offers program library modules that can be downlisted. Independent sources typically offer far more expensive modules that cannot be downlisted. If you trust the programmer, note that the modules present none of the reading problems posed by cards, nor do they wear out with extended use. If you do not trust the programmer, cards can at least be "unprotected" with a little effort.[1]

Most planners will probably want to purchase relevant PPX programs, review the listings, and modify them as necessary. The best source for information on modifications and utility routines is LRN, the newsletter of the Washington, D.C. area TI-59 users group. The $20 membership includes twelve issues (some of which are double issues) and at least a hundred directly useful programs, routines and insights.

Addresses for further information are:

PPX-59   LRN
P.O. Box 53   9213 Lanham Severn Road
Lubbock, TX   79408   Lanham, MD   20801

NOTES

LRN, (march 1980), p. 2.

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Professional Categories

BUSINESS
01 Management Accounting
02 Manufacturing Engineering
03 Inventory Control
04 Marketing/Sales
05 Personnel.
06 Transportation
07 Insurance
08 Real Estate
09 Business (General)

FINANCE
10 Accounting
11 Auditing
12 Banking
13 Consumer Finance
14 Personal Finance
15 Economics
16 Leasing
17 Tax Planning/Preparation
18 Securities
19 Finance (General)

STATISTICS & PROBABILITY
20 Regression/Curve Fit
21 Analysis of Variance
22 Statistical Testing
23 Statistical Inference
24 Stochastic Processes
25 Probability Theory
26 Probability Distributions
27 Quality Assurance
28 Reliability/Maintainability
29 Statistics & Probability (General)

MATHEMATICS
30 Linear Algebra/Matrices
31 Complex Variables
32 Harmonic Analysis
33 Nonlinear Systems
34 Numerical Integration
35 Differential Equations
36 Number Systems
37 System Modeling
38 Operations Research
39 Mathematics (General)

NATURAL SCIENCES
40 Physics
41 Chemistry
42 Biology
43 Agriculture
44 Forestry
45 Ecology
46 Geology/Resources
47 Oceanography
48 Anthropology
49 Natural Sciences (Other)

LIFE SCIENCES
50 Clinical / Diagnostic
51 Virology/Immunology
52 Pathology
53 Biochemistry
54 Genetics
55 Physiology
56 Pharmacology
57 Ophthalmology/Optics
58 Nutrition/Food Science
59 Life Sciences (General)

ENGINEERING
60 Aeronautical Engineering
61 Chemical Engineering
62 Civil Engineering
63 Computer Science
64 Electrical Engineering
65 Electronic Engineering
66 Mechanical Engineering
67 Nuclear Engineering
68 System Engineering
69 Engineering (General)

TECHNICAL
70 Acoustics
71 Architecture
72 Ceramics
73 Heating, Air Conditioning, Cooling
74 Optics
75 Programming
76 Seismology
77 Surveying
78 Astronomy
79 Technical (Other)

SOCIAL & BEHAVIORAL SCIENCES
80 Political Science
81 Sociology
82 Psychology/Psychiatry
83 Law Enforcement
84 Social & Behavioral Sciences (Other)

NATURAL RESOURCES
85 Lumber/Forest Products
86 Oil/Gas/Energy
87 Food Resources
88 Water Resources
89 Natural Resources (Other)

GENERAL
90 Utility Programs
91 Demonstration/Games
92 Education
93 Air Navigation
94 Marine Navigation
95 Photography
96 Music
97 Astrology
98 Sports
99 Other

198060G INTERNAL RATE OF RETURN COMPUTATION

THIS PROGRAM CALCULATES THE IRR (INTERNAL RATE OF RETURN)
FOR A WIDE CLASS OF PROBLEMS AND IS SIMILAR TO THE
SECURITIES ANALYSIS PROGRAM 05 (SA-05). HOWEVER, THE
RESTRICTION THAT EACH CASH FLOW BE IN A SUCCESSIVE
SEQUENCE IS REMOVED. THIS ALLOWS ADDITIONAL FLEXIBILITY
BUT DOES REQUIRE THE PERIOD OF EACH CASH FLOW TO BE
ENTERED. THE PERIOD VALUE MAY ALSO BE A NONINTEGER.
THE IRR OF 46 CASH FLOWS CAN BE COMPUTED.

USER BENEFITS: ALLOWS THE USER TO MAKE BETTER DECISIONS
BY ANALYZING FINANCIAL TRANSACTIONS.

RANDALL E. STAPONSKI, TULSA, OK.
104 STEPS

198061G FINANCIAL STATEMENT ANALYSIS

USES 20 LINE ITEMS FROM COMPARATIVE B/S AND P/L TO
PROVIDE 11 MAIN AND 5 SECONDARY ANALYTICAL DATA ITEMS
AS FOLLOWS: WORKING CAPITAL, CURRENTS RATIO, QUICK
RATIO, AVERAGE COLLECTION PERIOD, INVENTORY TURNS, DEBT/
EQUITY %, GROSS MARGIN %, NET PROFIT TO SALES %, RETURN
ON ASSETS %, RETURN ON EQUITY %, ALTMAN'S Z-SCORE, Z-
SCORE "X" TERMS. PROVIDES FOR INDEPENDENT PRINTOUT OF:
INPUT DATA, COMPUTED DATA, Z-SCORE "X" TERMS, AND RECOM-
PUTATION OF Z-SCORE. THIS PROGRAM IS AN EXPANSION AND
REORGANIZATION OF PPX8198004 AND PROVIDES FOR THE USE
OF THE PC-100C PRINTER.

USER BENEFITS: EASY TO USE.

JIM GAINSLEY, MINNEAPOLIS, MN.
718 STEPS, PC-100A

198062G PROFITABILITY MEASURES

GIVEN NET RECEIPTS OF A PROJECT, CALCULATES SOLOMON'S
AVERAGE RATE OF RETURN, NET PRESENT VALUE, PROFITABILITY
INDEX, AND NET FUTURE VALUE; ALL ON A DISCRETE OR
CONTINUOUS BASIS.

USER BENEFITS: READY CALCULATION OF WEALTH GROWTH RATE
AND OTHER PROFITABILITY MEASURES.

JORGE VALENCIA, LIMA, PERU
429 STEPS

198063G IRR WITH INCREASING CASH FLOWS

FINDS RATE OF RETURN OF AN INVESTMENT WHOSE NET RE-
CEIPTS GROW AT A FIXED RATE PER PERIOD.

USER BENEFITS: SIMPIFIES CALCULATION.

JORGE VALENCIA, LIMA, PERU
169 STEPS

198064G PROJECT APPRAISAL UNDER RISK

FOR A PROJECT WITH SEVERAL PROBABLE CASH FLOWS PER
PERIOD, CALCULATES STANDARD DEVIATION OF CASH FLOWS
PER PERIOD, STANDARD DEVIATION AND EXPECTED VALUE
(INCLUDING INVESTMENT) OF PROBABLE NET PRESENT VALUE
OF PROJECT, AND PROBABILITY OF GIVEN NET PRESENT
VALUE OR LESSER AMOUNT.

USER BENEFITS: CONSIDERABLE TIME SAVING AND ERROR
PREVENTION.

JORGE VALENCIA, LIMA, PERU
239 STEPS, MOD 2

198065G VARIABLE CASH FLOWS - CONTINUOUS

GIVES PRESENT VALUE AND FUTURE VALUE OF A SERIES OF
CASH FLOWS BEING DISBURSED CONTINUOUSLY, WITH INTEREST
CONVERTED CONTINUOUSLY ALSO. UNLIKE PPX8198006 THIS
PROGRAM HANDLES A SERIES OF CASH FLOWS.

USER BENEFITS: BETTER FOR INVESTMENT MODELS BECAUSE
OF ITS MATHEMATICAL ANALYSIS APPROACH.

JORGE VALENCIA, LIMA, PERU
152 STEPS

208038G SIMPLE REGRESSION MODELING

COMPARES AND SELECTS THE BEST AMONG 4 COMMON SIMPLE
REGRESSION MODELS. ALSO TIES IN WITH REGRESSION
ANALYSIS AND MULTIVARIATE STATISTICAL METHODS PROGRAM-
MING SYSTEM FOR THE COMPARISON OF OTHER USER-DEFINED
MODELS, ANALYSIS OF RESIDUALS, AND AUTOCORRELATION
ANALYSIS.

USER BENEFITS: ELIMINATES DATA RE-ENTRY.

CHORMAN W. CHING, HAMILTON, CANADA
320 STEPS, PC-100A, MOD 3, REV B

STRUCTURAL PROGRAMS (Side A)

All programs (except Ft. - In. - Sixteenths) include a reproducible calculation sheet, program description, a design example and a preprogrammed magnetic card. Allow approximately 2-3 weeks for delivery. Ten (10) individual program combinations at 20% off; twenty (20) individual program combinations at 30% off; thirty (30) or more individual program combinations at 40% off of list price.

	License Fee		
	HP67/HP97	TI-59	HP-41C
VOLUME I - Programs 1 through 15			
1. Retaining Walls	@ $90.00____	@ $115.00____	@ $130.00____
2. Footing-Axial Load	@ $40.00____	@ $ 50.00____	@ $ 60.00____
3. Eccentrically Loaded Footing/Combined Loads	@ $90.00____	@ $115.00____	@ $130.00____
4. Eccentrically Loaded Footing/Individual Loads	@ $90.00____	@ $115.00____	@ $130.00____
5. Pole Foundation	@ $45.00____	@ $ 50.00____	@ $ 60.00____
6. Bearing Plate/Base Plates	@ $20.00____	@ $ 20.00____	@ $ 25.00____
7. Simple Span Beam/Uniform Load - Simple Span Beam/ Uniformly Varying Load	@ $30.00____	@ $ 35.00____	@ $ 40.00____
8. Overhanging Beam	@ $30.00____	@ $ 35.00____	@ $ 40.00____
9. Beam - Uniformly Distributed Load and Variable End Moment	@ $30.00____	@ $ 35.00____	@ $ 40.00____
10. Plastic Design Continuous Beams	@ $30.00____	@ $ 35.00____	@ $ 40.00____
11. Simple Span Concrete Tee Beam	@ $65.00____	@ $ 70.00____	@ $ 80.00____
12. Section Properties	@ $30.00____	@ $ 35.00____	@ $ 40.00____
13. Fink Truss	@ $30.00____	@ $ 35.00____	@ $ 40.00____
14. Wood Column Design	@ $65.00____	@ $ 70.00____	@ $ 80.00____
15. Feet - Inches - Sixteenths	@ $15.00____	@ $ 15.00____	@ $ 15.00____
VOLUME II - Programs 16 through 30			
16. End Plate Moment Splices for Steel beams	@ $75.00____	@ $ 75.00____	@ $ 60.00____
17. Wood studs, Rafters, or Truss Members	@ $75.00____	@ $ 75.00____	@ $ 80.00____
18. Steel Beam - Biaxial Bending	@ $60.00____	@ $ 60.00____	@ $ 65.00____
19. Simple Span beam with Moving Wheel Loads	@ $60.00____	@ $ 60.00____	@ $ 65.00____
20. Rigid Frames	@ $100.0____	@ $110.00____	@ $125.00____
21. Simple Span Beam Equal and Symmetrical Concentrated Loads	@ $40.00____	@ $ 40.00____	@ $ 40.00____
22. Simple Span Beam: Concentrated Loads at any Point	@ $45.00____	@ $ 50.00____	@ $ 50.00____
23. Simple Span Beam: Uniform and Triangular Loads	@ $45.00____	@ $ 45.00____	@ $ 45.00____
24. Simple Span Beam: Partial Uniform Loads	@ $40.00____	@ $ 40.00____	@ $ 45.00____
25. Beam - Fixed on Right End Concentrated Loads at any Point	@ $40.00____	@ $ 40.00____	@ $ 45.00____
26. Beam - Fixed on Right End Partial Uniform Loads at any Location	@ $40.00____	@ $ 40.00____	@ $ 45.00____
27. Beam - Fixed Both Ends with Concentrated Loads at any Point	@ $40.00____	@ $ 40.00____	@ $ 45.00____
28. Beam - Fixed Both Ends with Partial Uniform Loads at any Location	@ $40.00____	@ $ 40.00____	@ $ 45.00____
29. Cantilever Beam	@ $40.00____	@ $ 40.00____	@ $ 45.00____
30. Payroll tabulation	@ $40.00____	@ $ 40.00____	@ $ 45.00____
VOLUME III - Programs 31 through 45			
31. Steel Column - Combined Axial Load and Biaxial Bending	@ $70.00____	@ $ 75.00____	@ $ 80.00____
32. Column Stiffeners	@ $65.00____	@ $ 65.00____	@ $ 70.00____
33. Flange Plate Moment Splices for Steel beams	@ $65.00____	@ $ 65.00____	@ $ 70.00____
34. Composite Interior Beams	@ $95.00____	@ $ 95.00____	@ $100.00____
35. Composite Spandrel Beams	@ $95.00____	@ $ 95.00____	@ $100.00____
36. Cover Plates	@ $60.00____	@ $ 60.00____	@ $ 65.00____
37. Composite Interior Beams with Metal Deck	@ $90.00____	@ $ 90.00____	@ $100.00____
38. Composite Spandrel Beams with Metal Deck	@ $90.00____	@ $ 90.00____	@ $100.00____
39. Composite Beams General Design	@ $90.00____	@ $ 90.00____	@ $100.00____
40. Beams Fixed at Both Ends - Uniformly Varying Loads	@ $40.00____	@ $ 40.00____	@ $ 40.00____
41. Drilled Piers or Caissons	@ $55.00____	@ $ 55.00____	@ $ 60.00____
42. Double Overhanging Beam	@ $40.00____	@ $ 40.00____	@ $ 45.00____
43. Two Span Continuous Beam with Uniform and Concentrated Loads	@ $55.00____	@ $ 60.00____	@ $ 65.00____
44. Three Span Continuous Beam with Uniform Loads	@ $40.00____	@ $ 40.00____	@ $ 45.00____
45. Four Span Continuous Beam with Uniform Loads	@ $45.00____	@ $ 45.00____	@ $ 45.00____
46/47. Continuous Beam (Rotations and Matrix) with Variable Spans, Moment of Inertia, Concentrated, Uniform and Partial Uniform Loads		@ $160.00____	@ $175.00____
48. Continuous Beam (Positive Moments, Shears, Deflections)		@ $ 80.00____	@ $100.00____
61. Suspended Cables	@ $40.00____	@ $40.00____	@ $45.00____
62. Bolt and Pile Loads Circular and Rectangular Patterns with Biaxial Bending	@ $40.00____	@ $40.00____	@ $45.00____
63. Base Plates with Moment and Axial Loads	@ $40.00____	@ $40.00____	@ $45.00____
VOLUME VII (Programs 71-76) (For Fabricators and Detailers)			
71. Right and Oblique Triangles	@ $100.00____	@ $100.00____	@ $110.00____
72. Stair Solutions for A&E's	@ $ 70.00____	@ $ 70.00____	@ $ 80.00____
73. Stair Solutions	@ $ 60.00____	@ $ 60.00____	@ $ 65.00____
74. Unsymmetrical Knee Bracing	@ $ 80.00____	@ $ 80.00____	@ $ 85.00____
75. Curved Sectors	@ $ 80.00____	@ $ 60.00____	@ $ 85.00____
76. Unsymmetrical Cross Bracing for Beams and Trusses	@ $100.00____	@ $100.00____	@ $110.00____
77. Decimal Number Sorting Program			@ $100.00____
78. Feet - Inches - Sixteenths Number Sorting Program			@ $100.00____
79. Unsymmetrical Cross Bracing for Towers		@ $100.00____	@ $110.00____

Independently-produced, "protected" mag card programs.

HAND CALCULATOR PROGRAMS FOR PASSIVE SOLAR DESIGN

You are probably aware of the special architectural quality, and large energy savings, possible using Passive Solar techniques in buildings. In this context PEGFIX/PEGFLOAT, the first hand calculator solar design aids published by Princeton Energy Group, should be of special interest to you, and to all solar designers, builders, and educators. PEGFIX and PEGFLOAT model both the hourly and daylong performance of direct gain or 'sunspace' solar configurations, using any of the four major card-programmable hand-held calculators.

PEGFIX predicts auxiliary heat demand and excess heat available in a space with user-defined maximum and minimum temperature limits. The program is directly useful in sizing and specifying the system components, including the backup heating and ventilating equipment if needed. The results stored by PEGFIX are: total auxiliary heating load, excess heat available, maximum fan rate needed to vent excess heat, and maximum hourly auxiliary load.

PEGFLOAT predicts hourly temperatures of air and storage mass in a space without auxiliary heat input or removal of excess heat. Its purpose is to evaluate temperature excursions in a 100% solar operating mode. This program can examine non-south glazing orientations with user-specified hourly input values for insolation. PEGFLOAT automatically stores maximum and minimum storage and air temperatures of the system being modelled.

PEGFIX/PEGFLOAT are the first hand calculator programs which allow truly fast, low cost and accurate hour-by-hour analysis of direct gain systems, by designers with little or no experience in building thermal analysis. Both programs require only a few user-defined inputs regarding the building design and local weather: heat loss coefficients; effective thermal capacity and storage surface area; solar energy available, fraction to storage and fraction to air; average outdoor temperature and daily range. The programs automatically differentiate day and night heat loss values if desired, enabling you to evaluate night-deployed moveable insulation. If only a daylong insolation value is available, PEGFIX and PEGFLOAT will automatically proportion this input among the daylit hours. All inputs are expressed in familiar terms, and are clearly explained in the accompanying PEGFIX PEGFLOAT HANDBOOK. The programs can be run through a 24-hour day, without user interaction, in only five to nine minutes. You may also choose hourly display of air and storage temperatures, and of auxiliary or excess heat, without interrupting program execution. Optional hourly display does not affect the stored data.

Our attitude in design is reflected in the clarity and utility of these programs, which support rapid development of design judgement on a sound technical base. It is our experience that using programmable hand calculators in passive design analysis is inherently self-instructive. PEGFIX/PEGFLOAT employ the best available procedures suited to programmable hand calculators, refined in several years' use by PEG staff in all stages of our own design work. PEGFIX/PEGFLOAT combine fast and simple execution with sophisticated numerical methods including a new 'walking' solution of simultaneous equations. We introduced PEGFIX/PEGFLOAT at the Third National Passive Solar Conference in San Jose, where they were warmly received by leading specialist in performance simulation and testing from throughout North America. The programs are now used with confidence by other experienced designers, reducing the time and expense devoted to similar analyses on larger equipment. Less experienced designers gain a fine learning tool, as well as access to hourly simulation capability without costly computer time and programmer expertise which their present work can ill afford. Students and educators especially appreciate the speed with which results are obtained using PEGFIX/PEGFLOAT, allowing quick assessment of design options with very little preparation. (We've been told that from a teacher's standpoint, program results which aren't available until next week's class, might as well be unavailable until next term; not quite true, but we got the point!) The same advantage is important to any designer whose time is valuable.

PEGFIX/PEGFLOAT are available in Hewlett-Packard RPN and Texas Instruments AOS versions. An HP-67, HP-97, HP-41C, or TI-59 card-programmable calculator is required. A printer is convenient but, because of the hourly display option, not needed. Either English or Metric programs are available; they must be ordered separately. Each program package includes prerecorded card(s), printed Worksheets, and 70+ page instruction HANDBOOK. A Library Package, with cards for both English and Metric calculations on all four machines, is offered at a special price. The PEGFIX PEGFLOAT HANDBOOK and worksheets are thorough, clear, and well illustrated. Program use is presented in a way which allows any designer, whether or not previously skilled in passive solar techniques, to effectively apply—and to learn in the process of using—PEGFIX/PEGFLOAT. Extensive references provide ample documentation, and excellent resources for further study.

Although Passive Solar building principles are rapidly gaining acceptance due to proven performance at low cost, strong expertise is still limited to relatively few practicing architects and engineers. Among these, inexpensive and fast hourly simulation techniques have been in great demand. We at Princeton Energy Group believe our programs are the most significant step to date toward solving these problems.

Please take a close look at PEGFIX/PEGFLOAT, and see how valuable these programs can be in your work.

TI-59 SURV-CROM II

DIAGNOSTIC - Checks operation of the calculator and the SURV-CROM II module, partitions the calculator for maximum storage, insures that the calculator is in the degree mode, and prints tape heading.

COORDINATE GEOMETRY - The prime purpose of this program is the storing of coordinates for use in other programs. The bearing-distance, bearing-distance method of entry is used; and angles may be used instead of bearings. Other features include: up to 40 (20) points may be stored; previously stored bearings may be recalled as stored or 90, 180, or 270 degrees right of the stored bearing, unneeded points may be "unstored" to conserve storage space; coordinate may be stored or recalled by point number; horizontal or slope distances may be used, and temperature and grid factor corrections may be applied; you may traverse around a simple curve by arc distance; coordinates may be listed by point number; simple sideshots as well as branching are available.

TRAVERSE 1 - (Parts A, B, and C) (Part A is for traverses with 39 or fewer courses. Part B for those with more than 39 courses and Part C is for use in the field.)
The purpose of this program is closure with area (if a closed loop) to be followed by balancing in Program 06, if desired. It has most of the features of SC-02, and in addition, you may compute error of closure, precision, and area. You may force a closure back to the point of beginning at any time. Entry errors are corrected readily - you may "back out" several courses as easily as they were entered. And it may be used in the field without the printer... You may not recall bearings by number, traverse around a curve, or do sideshots or branching. When sideshots are necessary, after the main traverse has been entered and closure checked, you would go to Program 06 to balance the traverse, and then to Program 02, Step 11 to enter the sideshot(s), and finally to Program 07 to compute the final traverse.

TRAVERSE II - ANGLES - (Programs 04 and 05 are complementary.) When all the angles of a traverse have been entered, this program computes the angular error of closure; balances the angles with the error of closure being distributed equally to all angles, and computes balanced azimuths for use in SC-01. Or, you may use the program to balance angles and compute and print balanced bearings for use in SC-02 or SC-03.

TRAVERSE II-DISTANCES - This program must immediately follow SC-04. Either horizontal or slope distances may be entered and temperature and grid factor corrections may be applied. After all distances have been entered, the error of closure is computed, followed by computation of unbalanced coordinates and area.

BALANCING THE TRAVERSE - This program balances the traverse by either the Transit Rule method or the Compass Rule method from coordinates stored in the calculator using SC-03 or SC-04/05 programs.

AREA FROM COORDINATES/INVERSE - This program computes area from selected coordinates by entering their point numbers and produces a printout of the finished traverse. Curved boundaries may be used. It also may be used for simple inverses from point selected coordinates by entering their point numbers and point number to point number, or coordinates may be entered from the keyboard.

ROTATION AND TRANSLATION - This program will translate stored coordinates from one grid system to another when a common point and the angle between systems are known.

STAKEOUT - This program computes the angles and distances from stored coordinates for field stakeout purposes.

LINE AVERAGING (LINEAR REGRESSION) - This program computes the line that bestfits any number of coordinates which may be entered by point number or from the keyboard.

INTERSECTIONS: BB1 - DD1 - When the coordinates of two points and any two elements of two lines connecting them are entered, this program computes and prints all the other unknowns. Coordinates may be entered by point number or from the keyboard.

PERPENDICULAR OFFSET TO A LINE - This program computes distances along a base line and offset distances to points on either side of the base line. All entries are by point number.

PREDETERMINED AREA - After the required area is entered, bearings and distances are entered until the calculator completes the figure that will produce the desired area.

SIMPLE CURVE DATA - When given the PC or PI station and the delta, and then either the degree, radius, tangent, length, or external, and the offset distances, this program computes all for the centerline curve and offset lines left and right of the the other curve data and deflections as well as the chord data centerline. Also, the length and radius may be entered instead of the delta and another element.

Program includes instruction manual and preprogrammed ROM Module

TI-59 SURV-CROM II......$299

Prices are subject to change without notice.
Merchandise is subject to availability from suppliers.
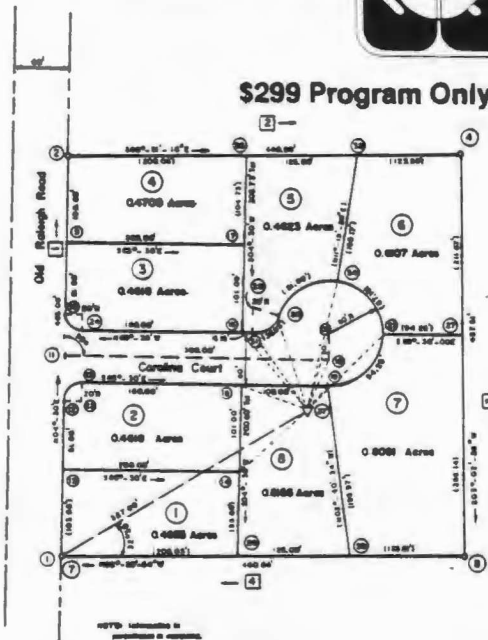
Independently-produced program library module.
CROM = calculator read-only module

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MANUAL PLOTTER-SCALER.   There are lots of automatic plotting programs which will plot
──────────────────   f(x), provided you define f(x) somehow in program memory. But
what if you have a list of data you would like to plot? You could use OP 07 manually,
but you would still be faced with the task of manually scaling your data within the zero
to twenty range of OP 07. After having experienced this problem a couple of times at the
office, I finally settled on this short routine. It is short enough to be used even by
TI-58 fans. The instructions are simple:
Scan your data and spot the lowest point, enter it and press A.MIN printed.
Do the same for your maximum point, enter it and press B. MAX printed.
Now enter in succession all your data points either through key E or R/S.
If you enter a data point out of bounds, either upper or lower, a small e is printed.

LBL E − RCL 00 = DIV RCL 02 =.CP INV GE 083 X:T 20 X:T GE 094 OP 07 R/S

GTO E LBL A STO 00 282429 OP 04 RCL 00 OP 06 RTN   LBL B STO 01 281344 OP 04

RCL 01 OP 06 − RCL 00 = DIV 20 + 1 EE 9 +/− INV EE = STO 02 OP 00 ADV R/S

GTO E 54 EE 8 INV EE OP 01 GTO 098 54 OP 04 OP 05 OP 00 R/S GTO E

───

TWO-VARIABLE GRID-PLOT.   As the name implies, this short routine by Bill Skillman, will
──────────────────   plot simultaneously two variables in the range 0 to 19. If out
of bounds, a "?" is printed at the appropriate edge.The grid spacing is 5 printing spaces.
The symbol for x is the asterisk (*) and for the y he used an "8". A cross-over is indi-
cated with an "x". The instructions are: Write the definition of f(x) in user memory.
Place x in the t-register, place y in the display, a call to E' will plot both.

000: LBL E' INV STF 4 INV STF 5 STO 04 2 OP 01 OP 02 OP 03 OP 04 X:T NOP

SBR 137 EXC 04 SBR 137 OP 22 OP 23 X 49 + RCL 02 X:T RCL 03 EQ 049 2 =

OP IND 02 RCL 04 X 58 X:T 9 = EQ 064 NOP + 2 = OP IND 03 INV IFF 4 093 1

+ 71 X HIR 15 X:T 1 EE 4 +/− GE 090 1 EE 6 +/− = HIR 35 INV IFF 5 134

1 EE 10 +/− X:T HIR 18 GE 123 X 50 = EQ 123 71 X X:T GTO 129 69 EE 12

+/− + 1 = HIR 38 OP 05 RTN INV EE CP INV GE 174 X:T 20 X:T GE 180 INT

+/− + (CE +/− DIV 5) INT X EXC 02 STO 03 5 + 4 = INV LOG x^2 RTN

STF 4 CLR GTO 183 STF 5 3 EXC 02 STO 03 CLR RTN

To demonstrate its abilities, I wrote this short sin-cos routine. Start with A.

LBL A RCL 11 SIN + 1 = X 9.9 = INT X:T RCL 11 COS + 1 = X 9.9 = E'   18

SUM 11 GTO A

Bill's routine uses registers 2, 3 and 4 and flags 4 and 5.

Part on a single page in LRN. Note the density of
information.

PROGRAMMING

PERSONAL PROGRAMMING provides a good introduction to
everything Texas Instruments has chosen to document. The
collected issues of LRN cover additional capabilities that
are far too complex for general use. In this section we
will concentrate on programming formats that planners will
find useful.

Most people develop preferences for particular
programming techniques. Some become adept at conditional
looping; others prefer to set flags to achieve similar ends.
My general suggestion is to work as simply and directly as
possible using the techniques you prefer. There are
benefits to be gained from optimization, but the TI-59 usually
has more than enough capacity to get the job done with some
inefficiencies. Direct logic runs fast enough. Once the
program goes on the magnetic card, no one can tell how
sophisticated you are.

Learn the techniques as you need them. Learn to trans-
late from program steps back to algorithms and equations.
Whatever the problem, it is usually possible to find a program
nearly matched to your needs. Load it, record it, and then
work on modifications to it. Always keep duplicates of cards,
because oily fingerprints, accidental bending, etc. can
destroy cards unexpectedly.

The easiest way to understand someone else's program
is to isolate the alphanumeric labels first, equations second,

and data shifting routines last. When in doubt about
a step sequence, run the program from the nearest preceeding
label with the printer on TRACE. This causes the calculator
to explain what it is doing, step by step. Program labels
can be listed by step location by entering RST OP 08 from
the keyboard when the program is not running. Given these
capabilities, most programs can be listed without
annotation or flowcharting of the kind that would be required
for a microcomputer written in BASIC.

The important issues for planners are input and output
formatting. All of a programmer's work should follow the
same format whenever possible. The user-defined keys A,B,C,D,
E and their primes are like paragraph headings. The first
number in the first data category should be entered through
the A key, with each subsequent number in the same category
entered through the R/S key (one key controls "run" and
"stop"). The next category begins with B, and so on. The E
key should always be reserved for starting the program run.
The prime letters should be used reluctantly (for ergonomic
reasons). The data sequences should feel right to users
familiar with the problem being processed.

Alphanumeric labelling consumes significant amounts of
program step capacity and should be minimized. Alphanumerics
also slow program execution and consume printer paper. Three-
letter margin labels and asterisks will generally suffice.
Planners often need output that can be copied and distributed.

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With this in mind, consider the following method of separating labelling from program processing.

The PC-100C prints 5.68 lines per inch, and the conventional advance moves more than a line (but less than two). We must therefore use a set of background numbers in place of a graph paper grid. The following page shows lines populated by digits 1-9 in reverse order, with blank space at two of the twenty locations. The program used to generate the digits and spaces is listed on the second following page. By laying the digit grid page underneath a clean sheet of white paper, we can fill in block letters for a label sheet. After copying the label sheet, we have paste-up sheets for the numerical outputs.

After establishing a final format, we can write labels from the printer using the print processor program. It appeared in LRN almost as it appears here, except for minor changes in instructions and program steps. Note that some copiers copy at more than 100% of original size, so you may want to generate the label directly from the printer for each paste-up. Any margin labels on the numerical output tapes can be cut off without affecting the numerical output itself. The hydroelectric site screening program uses this paste-up method. All the labels were right-justified (which is why the digits for the background numbers were in reverse order).

The most serious limitation I have encountered is the

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lack of a printed dollar sign. I have used D for dollar and DK for $ 000, but it should be interpreted in a key when you choose to use the label.

There is one other device planners should know about: direct address subroutines run faster than common label subroutines. PERSONAL PROGRAMMING explains the difference, but you should know it is easy to convert. If we use SBR STO, for example, the entry point is LBL STO. If we write the original program steps as SBR STO NOP, we can shift to SBR 01 75 (or whatever) for direct addressing without moving steps out of sequence. The entry point can then be NOP NOP instead of LBL STO. Most good programmers consider NOPs inelegant, but they work nicely.

Finally, documentation needs some attention. Always list the program steps and paste them up on a reference sheet. Pressing OP 08 gives you a list of common labels, so others can find the subroutines. Even after you convert to direct addressing, keep the common label version for documentation. It also helps to downlist the storage registers for future reference. Document the contents.

This is a trace of operations for program steps 282-349 in the hydroelectric site screening program.

0.	RCL 24	10.000	
		1.	-
0.150		1.000	<
0.150	PRT	1.	+
0.15	+	1.	RCL 25
1.	=		
1.150		0.150	
1.15	STD 36	0.15	)
		1.150	
1.150		1.15	YX
1.15	RCL 25	1.15	RCL 26
0.150		20.000	
0.150	PRT	-20.	=
0.15	RCL 26	0.939	
		.9388997211	÷
20.000		.9388997211	RCL 25
20.000	PRT		
20.	RCL 27	0.150	
		0.15	=
0.080		6.259	
0.080	PRT	6.259331474	1/X
0.08	+	0.160	
1.	=	.1597614704	×
1.080		.1597614704	RCL 13
1.08	STD 34		
		2121.239	
1.080		2121.239035	=
1.08	RCL 28	338.892	
		338.892	PRT
0.060		338.8922673	STD 17
0.060	PRT		
0.06	+	338.892	
1.	=	338.8922673	RCL 29
1.060			
1.06	STD 35	10.000	
		10.	STD 2
1.060			
1.06	RCL 29	10.000	
		10.	RCL 26
10.000			
10.000	PRT	20.000	
10.	OP 5	20.	STD 3
		20.000	

RUNNING THE PROGRAM

Clear and load mag card bank 1.

Press A to initialize the alphanumeric code and print one
row of digits. (This is required for the first row only.)

Press B to list one row of digits (except for the initial
row, which requires A).

Press C to advance one.

Press D to list five rows of digits.

Press E to run OP 06. Note that although it prints some
digits, OP 06 in any program lacking labels will cause the
printer to "advance" a distance equivalent to one printed
line. This option is sometimes useful.


```
987654321 987654321
987654321 987654321


987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321


987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321


987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
987654321 987654321
         0.      4321
987654321 987654321
987654321 987654321
```

```
000  76 LBL        050  69 OP
001  11  A         051  05   05
002  08  8         052  91 R/S
003  00  0         053  76 LBL
004  01  1         054  12  B
005  02  2         055  69 OP
006  01  1         056  05   05
007  01  1         057  91 R/S
008  01  1         058  76 LBL
009  00  0         059  13  C
010  08  8         060  98 ADV
011  07  7         061  91 R/S
012  69 OP         062  76 LBL
013  01   01       063  14  D
014  08  8         064  69 OP
015  06  6         065  05   05
016  00  0         066  69 OP
017  05  5         067  05   05
018  00  0         068  69 OP
019  04  4         069  05   05
020  00  0         070  69 OP
021  03  3         071  05   05
022  00  0         072  69 OP
023  02  2         073  05   05
024  69 OP         074  91 R/S
025  02   02       075  76 LBL
026  08  8         076  15  E
027  00  0         077  00  0
028  01  1         078  69 OP
029  02  2         079  06   06
030  01  1         080  91 R/S
031  01  1         081  00  0
032  01  1         082  00  0
033  00  0         083  00  0
034  08  8         084  00  0
035  07  7
036  69 OP
037  03   03
038  08  8         001  11  A
039  06  6         054  12  B
040  00  0         059  13  C
041  05  5         063  14  D
042  00  0         076  15  E
043  04  4
044  00  0
045  03  3
046  00  0
047  02  2
048  69 OP
049  04   04
```

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RUNNING THE PROGRAM

Clear and enter mag card banks 1 and 2.
Note that the program runs in FIX 2, so you must key INV FIX
before reading or writing data cards.

Press E' to clear all previously stored data. The 1.01 in
display indicates that the "pointer" is located at the
first character of the first line (L.nn).

To store print codes, enter up to five 2-digit codes and
press A. The program will store the codes appropriately.
The pointer is then automatically set to indicate the next
available location. When a line is completed it is
automatically printed (unless you turn off the printer).

To end and print a line before 20 characters have been
entered, press A'. To relocate the pointer, specify the
line and character position desired (L.nn), and press E.

To print only the line you want, relocate to the last
character in that line (eg, 4.20), and press E followed by
A'.

To print all the lines you want, from any given point on,
specify the beginning line and character position (eg, 1.01),
and press E followed by B.

To correct line errors, relocate to the line and character
to be changed, press E, and proceed to enter as if for the
first time.

Note that a blank space can be designated as 00 or 80, and
the latter is always preferred if there is any question
about whether the space will be "filled" in a given line.

Unlike the original program, pressing B does not advance the
paper.

```
000   76  LBL      050   85   +        100   22  INV
001   17  B'       051   01   1        101   64  PD*
002   22  INV      052   00   0        102   00   00
003   28  LOG      053   95   =        103   63  EX*
004   52  EE       054   17   B'       104   00   00
005   54  )        055   42   STO      105   75   -
006   92  RTN      056   01   01       106   59  INT
007   76  LBL      057   76   LBL      107   64  PD*
008   18  C'       058   91   R/S      108   00   00
009   69  OP       059   22   INV      109   54   )
010   22   22      060   86   STF      110   65   x
011   69  OP       061   01   01       111   92  RTN
012   23   23      062   43   RCL      112   76  LBL
013   73  RC*      063   00   00       113   11   A
014   02   02      064   55   ÷        114   22  INV
015   84  OP*      065   04   4        115   58  FIX
016   03   03      066   75   -        116   55   ÷
017   92  RTN      067   59   INT      117   52  EE
018   76  LBL      068   42   STO      118   53   (
019   10  E'       069   02   02       119   53   (
020   47  CMS      070   54   )        120   52  EE
021   01   1       071   55   ÷        121   55   ÷
022   76  LBL      072   05   5        122   52  EE
023   15  E        073   85   +        123   00   0
024   88  DMS      074   53   (        124   01   1
025   59  INT      075   05   5        125   94  +/-
026   65  x        076   75   -        126   54   )
027   04   4       077   43   RCL      127   65   x
028   54  )        078   01   01       128   34  ΓX
029   42  STO      079   34   ΓX       129   22  INV
030   00   00      080   28   LOG      130   59  INT
031   82  HIR      081   85   +        131   69  OP
032   18   18      082   01   1        132   10   10
033   85  +        083   54   )        133   17  B'
034   39  COS      084   55   ÷        134   82  HIR
035   59  INT      085   02   2        135   06   06
036   75  -        086   17   B'       136   54   )
037   01   1       087   44   SUM      137   82  HIR
038   54  )        088   02   02       138   07   07
039   55  ÷        089   25   CLR      139   71  SBR
040   05   5       090   43   RCL      140   00   00
041   75  -        091   02   02       141   95   95
042   59  INT      092   58   FIX      142   82  HIR
043   44  SUM      093   02   02       143   16   16
044   00   00      094   92   RTN      144   75   -
045   54  )        095   53   (        145   59  INT
046   65  x        096   43   RCL      146   42  STO
047   01   1       097   01   01       147   03   03
048   00   0       098   82   HIR      148   54   )
049   94  +/-      099   47   47       149   65   x
```

150	43	RCL	200	65	×	250	85	+
151	01	01	201	82	HIR	251	42	STO
152	55	÷	202	18	18	252	02	02
153	82	HIR	203	85	+	253	04	4
154	16	16	204	32	X:T	254	95	=
155	95	=	205	54	)	255	61	GTO
156	74	SM*	206	72	ST*	256	02	02
157	00	00	207	00	00	257	67	67
158	82	HIR	208	69	OP	258	76	LBL
159	17	17	209	30	30	259	12	B
160	75	-	210	43	RCL	260	68	NOP
161	59	INT	211	01	01	261	03	3
162	74	SM*	212	55	÷	262	42	STO
163	00	00	213	02	2	263	02	02
164	54	)	214	32	X:T	264	43	RCL
165	29	CP	215	82	HIR	265	00	00
166	67	EQ	216	16	16	266	32	X:T
167	02	02	217	95	=	267	22	INV
168	10	10	218	77	GE	268	58	FIX
169	69	OP	219	02	02	269	25	CLR
170	20	20	220	27	27	270	42	STO
171	65	×	221	65	×	271	03	03
172	01	1	222	69	OP	272	18	C'
173	52	EE	223	20	20	273	18	C'
174	01	1	224	01	1	274	18	C'
175	00	0	225	00	0	275	18	C'
176	82	HIR	226	17	B'	276	69	OP
177	08	08	227	42	STO	277	05	05
178	22	INV	228	01	01	278	43	RCL
179	64	PD*	229	25	CLR	279	02	02
180	00	00	230	43	RCL	280	22	INV
181	54	)	231	02	02	281	77	GE
182	32	X:T	232	59	INT	282	02	02
183	82	HIR	233	32	X:T	283	69	69
184	16	16	234	43	RCL	284	61	GTO
185	55	÷	235	00	00	285	91	R/S
186	43	RCL	236	55	÷	286	76	LBL
187	01	01	237	04	4	287	16	A'
188	54	)	238	95	=	288	43	RCL
189	82	HIR	239	59	INT	289	02	02
190	68	68	240	87	IFF	290	59	INT
191	64	PD*	241	01	01	291	82	HIR
192	00	00	242	00	00	292	04	04
193	73	RC*	243	06	06	293	65	×
194	00	00	244	67	EQ	294	04	4
195	75	-	245	91	R/S	295	75	-
196	59	INT	246	43	RCL	296	01	1
197	44	SUM	247	00	00	297	82	HIR
198	03	03	248	75	-	298	34	34
199	95	=	249	05	5	299	95	=

300	42	STO	350	00	0	400	02	02
301	02	02	351	01	1	401	71	SBR
302	43	RCL	352	52	EE	402	00	00
303	00	00	353	82	HIR	403	95	95
304	32	X:T	354	41	41	404	02	2
305	71	SBR	355	95	=	405	17	B'
306	02	02	356	65	×	406	22	INV
307	67	67	357	43	RCL	407	59	INT
308	82	HIR	358	01	01	408	65	×
309	14	14	359	95	=	409	43	RCL
310	61	GTO	360	74	SM*	410	01	01
311	15	E	361	00	00	411	95	=
312	76	LBL	362	73	RC*	412	74	SM*
313	13	C	363	00	00	413	00	00
314	86	STF	364	22	INV	414	69	OP
315	01	01	365	59	INT	415	20	20
316	85	+	366	22	INV	416	73	RC*
317	28	LOG	367	74	SM*	417	00	00
318	32	X:T	368	00	00	418	29	CP
319	43	RCL	369	29	CP	419	67	EQ
320	02	02	370	67	EQ	420	04	04
321	82	HIR	371	03	03	421	46	46
322	04	04	372	08	08	422	55	÷
323	03	3	373	65	×	423	01	1
324	77	GE	374	01	1	424	52	EE
325	03	03	375	02	2	425	01	1
326	46	46	376	17	B'	426	00	0
327	00	0	377	85	+	427	72	ST*
328	95	=	378	69	OP	428	00	00
329	11	A	379	20	20	429	52	EE
330	29	CP	380	73	RC*	430	08	8
331	43	RCL	381	00	00	431	75	-
332	03	03	382	95	=	432	22	INV
333	67	EQ	383	55	÷	433	59	INT
334	03	03	384	02	2	434	64	PD*
335	08	08	385	17	B'	435	00	00
336	55	÷	386	72	ST*	436	69	OP
337	82	HIR	387	00	00	437	30	30
338	16	16	388	61	GTO	438	95	=
339	95	=	389	03	03	439	74	SM*
340	71	SBR	390	64	64	440	00	00
341	01	01	391	76	LBL	441	69	OP
342	37	37	392	14	D	442	20	20
343	61	GTO	393	86	STF	443	61	GTO
344	03	03	394	01	01	444	04	04
345	30	30	395	42	STO	445	14	14
346	71	SBR	396	03	03	446	43	RCL
347	00	00	397	43	RCL	447	02	02
348	95	95	398	00	00	448	42	STO
349	93	.	399	42	STO	449	00	00

```
450   97 DSZ
451   03   03
452   04   04
453   01   01
454   61 GTO
455   91 R/S
456   76 LBL
457   19 D'
458   05   5
459   06   6
460   52 EE
461   01   1
462   02   2
463   55   ÷
464   09   9
465   09   9
466   95   =
467   59 INT
468   82 HIR
469   05   05
470   82 HIR
471   06   06
472   82 HIR
473   07   07
474   82 HIR
475   08   08
476   69 OP
477   05   05
478   61 GTO
479   91 R/S
```

The following page is a
copy of the print code chart
published by LRN.

```
001   17 B'
008   18 C'
019   10 E'
023   15   E
058   91 R/S
113   11   A
259   12   B
287   16 A'
313   13   C
392   14   D
457   19 D'
```

	0	1	2	3	4	5	6
00	01	02	03	04	05	06	07
7	8	9	A	B	C	D	E
10	11	12	13	14	15	16	17
—	F	G	H	I	J	K	L
20	21	22	23	24	25	26	27
M	N	O	P	Q	R	S	T
30	31	32	33	34	35	36	37
•	U	V	W	X	Y	Z	+
40	41	42	43	44	45	46	47
×	*	√	∏	$\underline{e}$	(	)	,
50	51	52	53	54	55	56	57
↑	%	:	/	=	$\underline{,}$	x	$\bar{x}$
60	61	62	63	64	65	66	67
$\underline{2}$	?	÷	!	Ⅱ	△	∏	Σ
70	71	72	73	74	75	76	77

DATA MANAGEMENT

The cost of data acquisition can sometimes limit
a planner's ability to solve a given quantitative problem.
Budget restrictions may make it impossible to spend money
on data acquisition, even though such expenditures would be
cost effective.

The practicing planner may have to find alternative
solutions that use less expensive or more readily available
data. In some cases the process may reveal an approach that
is more cost effective than the one originally considered.
In other cases the process may be simply lead to a dead end.

The first question to ask about data is whether someone
else has already collected it in a way that can be directly
or indirectly useful. Talk to someone with experience in
the field and search the literature in that field. Most
professionals are willing to share information with people
who ask thoughtful questions. It usually helps to explain
what you want to do with the information.

Data sources, whether published or otherwise, may not
agree. Estimates of population and resources are notably
various. Sometimes differing sources are each correct in
their own terms: read the fine print. Sometimes sources
are in agreement because both have been copied from a common
incorrect source. Planners have to search critically and
learn to read between the lines.

Every profession has its peculiar sources that are

difficult to find between the time of publication and ultimate entry into a formal indexing system. In New England energy planning the mother lode is the FINAL REPORT of the New England Energy Congress. This large, 454-page paperback costs $24 from the National Technical Information Service, but most of the planners who own a copy got it free when it was free, simply by requesting it. The book's many tables have some frustrating typographical errors, but an owner-annotated copy is a priceless reference.[1]

An almanac is often the least expensive single source for information. The PROVIDENCE JOURNAL publishes one for Rhode Island. Someone ought to edit a paperback almanac for planners, with the basics that one now searches for in various planning standards references, human factors design books, census publications, etc. For unit conversions the best tables I have seen are in THE NEW MATHEMATICS DICTIONARY, a paperback now out of print.[2] The tables are reproduced on the second following page.

When relevant data can be retrieved, we are faced with the storage limitations of the programmable calculator. The data storage capacity can be effectively doubled by "splitting" the storage register at the decimal point.

Suppose we want to store 53467 and 519 in the same register. Load it as 5367.519 into, say, register 01. The 519 can be recalled as the decimal value (INV INT) of register 01 and immediately multiplied by 1000 in the body of the

program. Suppose the numbers to be stored are 53.46 and 51.97. They can be stored as 5346.5197 and retrieved as an integer value (INT) divided by 100 and a decimal value (INV INT) multiplied by 100. Data packing methods were not included in PERSONAL PROGRAMMING, although simple splitting is widely used, often just for the sake of making data entry more efficient. Programs exist for more complex forms of splitting and packing.

Another widely-used approach to data management is curve fitting. In many instances several hundred data points conform to a pattern that we can describe with a curve equation (eg, a fifth degree polynomial). If we find several equation variables with one program, we can then supply the main applications program with several variables instead of several hundred data points. There are programs for fitting data to 5-8 kinds of curves. The user simply instructs the calculator to list the solution that fits best.

NOTES

[1] New England Energy Congress, FINAL REPORT (Boston: NEEC, 1979).

[2] Robert Marks, THE NEW MATHEMATICS DICTIONARY (New York: Bantam Books, 1964).

Units of Volume

Units	Cubic inches	Cubic feet	Cubic yards	Cubic centimeters	Cubic decimeters	Cubic meters
1 cubic inch =	1	0.000 578 704	0.000 021 433	16.387 064	0 016 387	0.000 016 387
1 cubic foot =	1728	1	0.037 037 04	28 316.846 592	28 316.847	0.028 316 847
1 cubic yard =	46 656	27	1	764 554.857 984	764.554 858	0.764 554 858
1 cubic cm. =	0.061 023 74	0.000 035 315	0.000 001 308	1	0.001	0.000 001
1 cubic dm. =	61.023 74	0.035 314 67	0.001 307 951	1000	1	0.001
1 cubic meter =	61 023.74	35.314 67	1.307 951	1 000 000	1000	1

Units of Capacity (Liquid Measure)

Units	Minims	Fluid drams	Fluid ounces	Gills	Liquid pints
1 minim =	1	0.016 666 7	0.002 083 33	0.000 520 833	0.000 130 208
1 fluid dram =	60	1	0.125	0.031 25	0.007 812 5
1 fluid ounce =	480	8	1	0.25	0.062 5
1 gill =	1920	32	4	1	0.25
1 liquid pint =	7680	128	16	4	1
1 liquid quart =	15 360	256	32	8	2
1 gallon =	61 440	1024	128	32	8
1 milliliter =	16.231	0.270 519 8	0.033 814 97	0.008 453 742	0.002 113 436
1 liter =	16 231.19	270.519 8	33.814 97	8.453 742	2.113 436
1 cubic inch =	265.974	4.432 900	0.554 112 6	0.138 528 1	0.034 632 03
1 cubic foot =	459 603.1	7660.052	957.506 5	239.376 6	59.844 16

Units of Capacity (Liquid Measure) Continued. Bold face type indicates exact values

Units	Liquid quarts	Gallons	Milliliters	Liters	Cubic inches	Cubic feet
1 minim =	0.000 065 104	0.000 016 276	0.061 610	0.000 061 610	0.003 760	0.000 002 176
1 fluid dram =	0.003 906 25	0.000 976 562	3.696 588	0.003 696 588	0.225 586	0.000 130 547
1 fluid ounce =	0.031 25	0.007 812 5	29.572 70	0.029 572 7	1.804 687	0.001 044 379
1 gill =	0.125	0.031 25	118.290 8	0.118 290 8	7.218 75	0.004 177 517
1 liquid pint =	0.5	0.125	473.163 2	0.473 163 2	28.875	0.016 710 07
1 liquid quart =	1	0.25	946.326 4	0.946 326 4	57.75	0.033 420 14
1 gallon =	4	1	3785.306	3.785 306	231	0.133 680 6
1 milliliter =	0.001 056 718	0.000 264 179	1	0.001	0.061 025	0.000 035 316
1 liter =	1.056 718	0.264 179 4	1000	1	61.025 45	0.035 315 66
1 cubic inch =	0.017 316 02	0.004 329 004	16.386 61	0.016 386 61	1	0.000 578 704
1 cubic foot =	29.922 08	7.480 519	28 316.05	28 316 05	1728	1

Units of Capacity (Dry Measure)

Units	Dry pints	Dry quarts	Pecks	Bushels	Liters	Dekaliters	Cubic inches
1 dry pint =	1	0.5	0.062 5	0.015 625	0.550 595	0.055 060	33.600 312 5
1 dry quart =	2	1	0.125	0.031 25	1.101 190	0.110 119	67.200 625
1 peck =	16	8	1	0.25	8.809 521	0.880 952	537.605
1 bushel =	64	32	4	1	35.238 08	3.523 808	2150.42
1 liter =	1.816 217	0.908 108	0.113 514	0.028 378	1	0.1	61 025 45
1 dekaliter =	18.162 17	9.081 084	1.135 136	0.283 784	10	1	610.254 5
1 cubic inch =	0.029 762	0.014 881	0.001 860	0.000 465	0.016 386	0.001 639	1

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Units of Mass not Greater than Pounds and Kilograms

Units		Grains	Apothecaries' scruples	Pennyweights	Avoirdupois drams	Apothecaries' drams	Avoirdupois ounces
1 grain	=	1	0.05	0.041 666 67	0.036 571 43	0.016 666 67	0.002 285 71
1 scruple	=	20	1	0.833 333 3	0.731 428 6	0.333 333 3	0.045 714 29
1 pennyweight	=	24	1.2	1	0.877 714 3	0.4	0.054 857 14
1 dram avdp.	=	27.343 75	1.367 187 5	1.139 323	1	0.455 729 2	0.062 5
1 dram ap.	=	60	3	2.5	2.194 286	1	0.137 142 9
1 oz. avdp.	=	437.5	21.875	18.229 17	16	7.291 667	1
1 oz. ap. or t.	=	480	24	20	17.554 29	8	1.097 143
1 lb. ap. or t.	=	5760	288	240	210.651 4	96	13.165 71
1 lb. avdp.	=	7000	350	291.666 7	256	116.666 7	16
1 milligram	=	0.015 432	0.000 771 618	0.000 643 015	0.000 564 383	0.000 257 206	0.000 035 274
1 gram	=	15.432 36	0.771 617 9	0.643 014 9	0.564 383 4	0.257 206 0	0.035 273 96
1 kilogram	=	15 432.36	771.617 9	643.014 9	564.383 4	257.206 0	35.273 96

Units		Apothecaries' or troy ounces	Apothecaries' or troy pounds	Avoirdupois pounds	Milligrams	Grams	Kilograms
1 grain	=	0.002 083 33	0.000 173 611	0.000 142 857	64.798 91	0.064 798 91	0.000 064 799
1 scruple	=	0.041 666 67	0.003 472 222	0.002 857 143	1295.978 2	1.295 978 2	0.001 295 978
1 pennyweight	=	0.05	0.004 166 667	0.003 428 571	1555.173 84	1.555 173 84	0.001 555 174
1 dram avdp.	=	0.056 966 15	0.004 747 179	0.003 906 25	1771.845 195	1.771 845 195	0.001 771 845
1 dram ap.	=	0.125	0.010 416 67	0.008 571 429	3887.934 6	3.887 934 6	0.003 887 935
1 oz. avdp.	=	0.911 458 3	0.075 954 86	0.062 5	28 349.523 125	28.349 523 125	0.028 349 52
1 oz. ap. or t.	=	1	0.083 333 333	0.068 571 43	31 103.476 8	31.103 476 8	0.031 103 47
1 lb. ap. or t.	=	12	1	0.822 857 1	373 241.721 6	373.241 721 6	0.373 241 722
1 lb. avdp.	=	14.583 33	1.215 278	1	453 592.37	453.592 37	0.453 592 37
1 milligram	=	0.000 032 151	0.000 002 679	0.000 002 205	1	0.001	0.000 001
1 gram	=	0.032 150 75	0.002 679 229	0.002 204 623	1000	1	0.001
1 kilogram	=	32.150 75	2.679 229	2.204 623	1 000 000	1000	1

Units of Mass not Less than Avoirdupois Ounces

Units		Avoirdupois ounces	Avoirdupois pounds	Short hundredweights	Short tons	Long tons	Kilograms	Metric tons
1 oz. avdp.	=	1	0.0625	0.000 625	0.000 031 25	0.000 027 902	0.028 349 523	0.000 028 350
1 lb. avdp.	=	16	1	0.01	0.0005	0.000 446 429	0.453 592 37	0.000 453 592
1 short cwt.	=	1600	100	1	0.05	0.044 642 86	45.359 237	0.045 359 237
1 short ton	=	32 000	2000	20	1	0.892 857 1	907.184 74	0.907 184 74
1 long ton	=	35 840	2240	22.4	1.12	1	1016.046 908 8	1.016 046 909
1 kilogram	=	35.273 96	2.204 623	0.022 046 23	0.001 102 311	0.000 984 207	1	0.001
1 metric ton	=	35 273.96	2204.623	22.046 23	1.102 311	0.984 206 5	1000	1

CONVERSIONS

The program documented on the following pages provides
an example of a modification strategy. The unit conversion
program in the Master Library module converts units of
length from English to SI measure and vice-versa. The
program uses conversion factors for multiplications and
divisions as required.

The conversion factors in the existing program use from
four to nine program steps. In the modification the factors
were replaced by recall instructions and inert "no operation"
fillers for the leftover step spaces. The data storage
registers recalled are 91 for A, 92 for B, 93 for C, 94 for
D, and 95 for E.

Data stores 90-99 are in bank 1. By changing the
partition to 159/99, the program steps and stored factors
can reside in the same bank. If you want to change factors,
simply store the new factors in the 91-95 registers and
rewrite the magnetic card (or use a new card). Sometimes
factors have to be changed periodically, as with fuel costs,
for example.

Conversions seem trivial enough, but remember that
planners do alot of converting. We convert assessed values
to tax revenue, map measurements to actual distances,
population numbers to standard service requirements, and so on.
Even fiscal impact analysis consists mainly of conversions.

In my work I read energy and environmental research

that use SI units of measurement. Practicing architects
and land use planners in this country generally use English
units of measurement, even in such recent technologies-of-
interest as solar design and siting. The program documented
on the following pages helped me translate between research
and practice.

There are times when the user needs more conversion
capacity. What if we borrowed the algorithm used in the
Master Library program and kept rolling new numbers into
storage registers 91-95? We would, of course, need to keep
track of what sets of numbers we rolled in, but the technique
would permit us to keep 85 conversions in one program.

Each row stores five conversions. When we want to
change a row number, we reset the program (RST), choose the
new row number (eg, 9), hit R/S, and we are ready to use
a "new" unit conversion program. Any number from 0-17
constitutes a legitimate row call number, but keep a chart
of what you have in each row (and cell).

We can modify the program by inserting SUM 00 R/S
before what is now step 049, and SUM 01 R/S before what is
now step 125. If we hit R/S after a conversion has been
completed, the converted output sums into a register that
we can then retrieve or zero out at will. Note that this
adds more to the fiscal impact analysis capability, among
other things.

The worked example demonstrates a recorded conversion

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from a 14.2 centimeter measurement on a 1:24000 map to an
actual distance in feet. Two more centimeter measurements
are then converted. The third conversion is further
converted from feet to miles, and then from miles to
kilometers. If this had to be done very often, you would
provide a direct conversion or group sequential conversions
on the same row. Grouping by utility is important, even
though the same conversion may be available on more than one
row.

```
000  76  LBL        000  76  LBL
001  11  A          001  11  A
002  53  (          002  53  (
003  24  CE         003  24  CE
004  65  ×          004  55  ÷
005  02  2          005  43  RCL
006  93  .          006  91  91
007  05  5          007  68  NOP
008  04  4          008  68  NOP
009  54  )          009  54  )
010  92  RTN        010  92  RTN
011  76  LBL        011  76  LBL
012  12  B          012  12  B
013  53  (          013  53  (
014  24  CE         014  24  CE
015  65  ×          015  55  ÷
016  93  .          016  43  RCL
017  03  3          017  92  92
018  00  0          018  68  NOP
019  04  4          019  68  NOP
020  08  8          020  68  NOP
021  54  )          021  54  )
022  92  RTN        022  92  RTN
023  76  LBL        023  76  LBL
024  13  C          024  13  C
025  53  (          025  53  (
026  24  CE         026  24  CE
027  65  ×          027  55  ÷
028  93  .          028  43  RCL
029  09  9          029  93  93
030  01  1          030  68  NOP
031  04  4          031  68  NOP
032  04  4          032  68  NOP
033  54  )          033  54  )
034  92  RTN        034  92  RTN
035  76  LBL        035  76  LBL
036  14  D          036  14  D
037  53  (          037  53  (
038  24  CE         038  24  CE
039  65  ×          039  55  ÷
040  01  1          040  43  RCL
041  93  .          041  94  94
042  06  6          042  68  NOP
043  00  0          043  68  NOP
044  09  9          044  68  NOP
045  03  3          045  68  NOP
046  04  4          046  68  NOP
047  04  4          047  68  NOP
048  54  )          048  54  )
049  92  RTN        049  92  RTN
```

Parallel listings of Master Library conversion program (#24) and an all-purpose variation.

050	76	LBL	050	76	LBL	
051	15	E	051	15	E	
052	53	(	052	53	(	
053	24	CE	053	24	CE	
054	65	×	054	55	÷	
055	93	.	055	43	RCL	
056	03	3	056	95	95	
057	06	6	057	68	NOP	
058	08	8	058	68	NOP	
059	09	9	059	68	NOP	
060	07	7	060	68	NOP	
061	06	6	061	68	NOP	
062	02	2	062	68	NOP	
063	04	4	063	68	NOP	
064	54	)	064	54	)	
065	92	RTN	065	92	RTN	
066	76	LBL	066	76	LBL	
067	16	A'	067	16	A'	
068	35	1/X	068	35	1/X	
069	11	A	069	11	A	
070	35	1/X	070	35	1/X	
071	92	RTN	071	92	RTN	
072	76	LBL	072	76	LBL	
073	17	B'	073	17	B'	
074	35	1/X	074	35	1/X	
075	12	B	075	12	B	
076	35	1/X	076	35	1/X	
077	92	RTN	077	92	RTN	
078	76	LBL	078	76	LBL	
079	18	C'	079	18	C'	
080	35	1/X	080	35	1/X	
081	13	C	081	13	C	
082	35	1/X	082	35	1/X	
083	92	RTN	083	92	RTN	
084	76	LBL	084	76	LBL	
085	19	D'	085	19	D'	
086	35	1/X	086	35	1/X	
087	14	D	087	14	D	
088	35	1/X	088	35	1/X	
089	92	RTN	089	92	RTN	
090	76	LBL	090	76	LBL	
091	10	E'	091	10	E'	
092	35	1/X	092	35	1/X	
093	15	E	093	15	E	
094	35	1/X	094	35	1/X	
095	92	RTN	095	92	RTN	
096	00	0	096	00	0	
097	00	0	097	00	0	
098	00	0	098	00	0	
099	00	0	099	00	0	

001	11	A
012	12	B
024	13	C
036	14	D
051	15	E
067	16	A'
073	17	B'
079	18	C'
085	19	D'
091	10	E'

```
          2.      ****              14.2    X:T
         14.2                      1765.
11181.10237      B                    1.    SBR
         12.1                               13
9527.559058      B                    1.    STD
         56.8                               91
44724.40946      B                    1.
44724.40946                          95.     +
8.470532095      A                    95.    RCL
                                            91
         12.      ****                1.
        8.471                         1.     =
13.63277918      E'                  96.
         55.                         96.    STD
88.51408983      E'                         93
                                     96.
                                     96.    RC_
                                            91
```

Printout record of conversions,
with a TRACE for the first
conversion to show how the program
runs.

```
                                      1.
                                      1.     +
                                      1.    RCL
                                            90
                                      2.
                                      2.     x
                                      5.     =
                                     11.
                                     11.    STD
                                            92
                                     11.
                                     11.    RC+
                                            *93
                                            96

                  RST    1400.1465
          2.      STD    1400.1465    OP
                   90                  4
          2.             1400.
                         1400.        X:T
          2.      RCL      14.2       PRT
                   94      14.2        x
5151515151.               14.2       RC+
5151515151.      OP       14.2       *92
                   4                  11
5151515151.
5151515151.      RCL    787.401575    =
          2.      90    787.401575
          2.      OP  11181.10237     OP
                   5  11181.10237      5
          2.      ****  11181.10237    B
                  R/S                 R/S
```

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The rows would normally be filled and listed sequentially. It can be handwritten on graph paper.

ROW 2

A (10)	B (11)	C (12)	D (13)	E (14)
Feet-Miles	Centimeters-Feet at 1:24000	Centimeters-Feet at 1:25000	Centimeters-Feet 1"=100' to 1:25000	1:25000 to 1:24000
.0001893939	787.401575	820.2099725	20.83333333	.96

ROW 12

A (60)	B (61)	C (62)	D (63)	E (64)
Centimeters-Inches	Meters-Feet	Meters-Yards	Nautical miles-Miles	Kilometers-Miles
.3937	3.28084	1.093613	1.151158237	.62137

ROW 15

A (75)	B (76)	C (77)	D (78)	E (79)
Acres-Square feet	Hectares-Acres	Square miles-Acres	$Kilometers^2$-$Miles^2$	Not used
43560	2.4710538	640	.386019	1.

000	42	STO	050	12	B	100	05	5
001	90	90	051	32	X?T	101	95	=
002	98	ADV	052	01	1	102	42	STO
003	43	RCL	053	71	SBR	103	92	92
004	94	94	054	00	00	104	73	RC*
005	69	OP	055	16	16	105	93	93
006	04	04	056	76	LBL	106	22	INV
007	43	RCL	057	13	C	107	59	INT
008	90	90	058	32	X?T	108	65	×
009	69	OP	059	02	2	109	01	1
010	06	06	060	71	SBR	110	00	0
011	91	R/S	061	00	00	111	00	0
012	76	LBL	062	16	16	112	33	X²
013	11	A	063	76	LBL	113	95	=
014	32	X?T	064	14	D	114	69	OP
015	00	0	065	32	X?T	115	04	04
016	42	STO	066	03	3	116	32	X?T
017	91	91	067	71	SBR	117	99	PRT
018	09	9	068	00	00	118	55	÷
019	05	5	069	16	16	119	73	RC*
020	85	+	070	76	LBL	120	92	92
021	43	RCL	071	15	E	121	95	=
022	91	91	072	32	X?T	122	69	OP
023	95	=	073	04	4	123	06	06
024	42	STO	074	71	SBR	124	91	R/S
025	93	93	075	00	00	125	76	LBL
026	43	RCL	076	16	16	126	17	B'
027	91	91	077	68	NOP	127	32	X?T
028	85	+	078	68	NOP	128	01	1
029	43	RCL	079	68	NOP	129	71	SBR
030	90	90	080	76	LBL	130	00	00
031	65	×	081	16	A'	131	84	84
032	05	5	082	32	X?T	132	76	LBL
033	95	=	083	00	0	133	18	C'
034	42	STO	084	42	STO	134	32	X?T
035	92	92	085	91	91	135	02	2
036	73	RC*	086	09	9	136	71	SBR
037	93	93	087	05	5	137	00	00
038	69	OP	088	85	+	138	84	84
039	04	04	089	43	RCL	139	76	LBL
040	32	X?T	090	91	91	140	19	D'
041	99	PRT	091	95	=	141	32	X?T
042	65	×	092	42	STO	142	03	3
043	73	RC*	093	93	93	143	71	SBR
044	92	92	094	43	RCL	144	00	00
045	95	=	095	91	91	145	84	84
046	69	OP	096	85	+	146	76	LBL
047	06	06	097	43	RCL	147	10	E'
048	91	R/S	098	90	90	148	32	X?T
049	76	LBL	099	65	×	149	04	4

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```
130    71   SBR
151    00    00
152    84    84
153    00    0
154    00    0
155    00    0
156    00    0
157    00    0
158    00    0
159    00    0


013    11    A
050    12    B
057    13    C
064    14    D
071    15    E
081    16    A'
126    17    B'
133    18    C'
140    19    D'
147    10    E'


              0.           90
              0.           91
              0.           92
              0.           93
  5151515151.           94
     1300.1365         95
     1400.1465         96
     1500.1565         97
     1600.1665         98
     1700.1765         99
```

0.	00	0.	50
0.	01	0.	51
0.	02	0.	52
0.	03	0.	53
0.	04	0.	54
3.1496063	05	0.	55
7.8740158	06	0.	56
15.748032	07	0.	57
2.5	08	0.	58
5.	09	0.	59
.0001893939	10	0.3937	60
787.401575	11	3.28084	61
820.2099725	12	1.093613	62
20.83333333	13	1.151158237	63
0.96	14	0.62137	64
1.201	15	0.1550003	65
0.2641794	16	10.76391	66
2.352583	17	1.19599	67
1.609	18	.0002471054	68
3.28084	19	1.	69
8.345172596	20	0.06102374	70
2150.42	21	35.31467	71
7.480519	22	1.307951	72
448.83114	23	7.480519	73
325851.4076	24	8.345172596	74
.9259259259	25	43560.	75
.9090909091	26	2.4710538	76
.8928571429	27	640.	77
.8695652174	28	0.386019	78
.8333333333	29	1.	79
0.	30	0.03527396	80
0.	31	0.0625	81
0.	32	2.204623	82
0.	33	0.001102311	83
0.	34	62.426	84
0.	35	3.96831	85
0.	36	3412.	86
0.	37	0.947813	87
0.	38	0.08805471	88
0.	39	316.98518	89
0.	40	12.	90
0.	41	4.	91
0.	42	64.	92
0.	43	99.	93
0.	44	5151515151.	94
0.	45	1300.1365	95
0.	46	1400.1465	96
0.	47	1500.1565	97
0.	48	1600.1665	98
0.	49	1700.1765	99

Data bank for the conversion program. The registers would normally be full.

ROWS AND COLUMNS

The administration of related grants requires creative
budgeting. Suppose the agency budget is adequate, but
program X has more than enough money and program Y has too
little. The accounting for overhead and shared costs can
be modified according to the relationships between the two
programs. This means that we may have to run several trial
budgets to allocate money effectively.

The following ten-row-by-nine-column program has many
practical applications, but I have appreciated it most in the
program budgeting process. It assigns entries to storage
registers (equivalent to grid cells) for later column and
row summations. The ability to keep printing out complete
revisions makes it useful.

Surprisingly, no one had written such a program, probably
because there are more efficient ways to sum rows and
columns without assigning cells for inputs. I bought the
PPX program nearest to what I needed. It could not relist
modified columns, because operations were performed upon
entry and only the results were assigned to (summation) cells.
PPX 908109 handles any combination of rows and columns that
total 79 (eg, 40x39, 50x29, etc.), far more rows and columns
than I needed.

The 10x9 program can function in tandem for 20x9 or 10x18
problems. With two layer processing it might be used to
assemble the totals of 12-90 of the 10x9 macro cells. In the

worked example the seven columns are, from 1-7: personnel, fringe, travel, supplies, printing, contracts and other. Rows 1-6 are programs (make up your own names). The programs could have been labelled using the print processor method, so that columns can be pasted up, as on a typical budget sheet.

TRIAL BUDGET SHEET

1.		5.
30140.		980.
16412.		690.
9080.		1450.
10410.		2100.
14520.		2540.
38200.		3000.
118762.		10760.

2.		6.
7836.		1410.
4267.		1520.
2360.		2560.
2704.		2300.
3775.		1450.
9932.		3600.
30874.		12840.

3.		7.
9410.		24112.
5820.		10870.
4562.		18470.
8320.		12040.
2540.		16500.
5240.		20450.
35892.		102442.

4.		
		75998.
2110.		41449.
1870.		41062.
2580.		41524.
3650.		44305.
2980.		81872.
1450.		326210.
14640.		

RUNNING THE PROGRAM

Partition the memory to 159.99 (10 OP 17). Fix the number
of decimal places to be printed (usually FIX 0 or FIX 2).
Clear and load mag card bank 1.

ENTER	KEY	DISPLAYS	PRINTS	COMMENTS
Number of columns: 7	A	7.		
Number of rows: 6	A'	6.		
Column number: 1	B	10.		
Value for cell 10: 30140	R/S	11.		
Value for cell 11: 16412	R/S	12.		

Enter remaining column values (up to 10 per column). In this
case we would initialize column 2 after entering the seventh
value in column 1. Continue until the chosen number of
columns are completed.

Column number: 1	D	118762		Prints all entered values in that column, along with sum.
Row number: 0	D'	75998		Prints sum of entered values in that row.
No entry	E	402208		Total of completed row sums (only those sums processed by the D' routine)
No entry	E'	0		Prints and totals all columns; sums all rows and prints sums; prints total of row sums.

The user would normally enter values by column, go directly
to E', enter modified values directly into cells (eg, 28450
STO 10), and use E' for another printout.

DATA REGISTERS

00 Sum of a row or column being processed
01 Stores column number being processed
02 Stores seed number for decrementing
03
04 Number of columns in use
05 Number of rows in use
06 Stores contents of register 04 for decrementing
07
08 Stores seed number for incrementing
09 Total of completed row sums
10 First of the series of usable storage cells for entries
99 Last of the series of usable storage cells for entries

Note that we can develop a 7x12 cell grid (for monthly accounts) by shifting the work of register 08 to 03, that of 09 to 99, and using registers 07-91 as the series of usable storage cells. Three control numbers in the program would have to be changed from 10 to 7.

```
000  76 LBL        050  92 RTN        100  91 R/S
001  12  B         051  76 LBL        101  76 LBL
002  65  ×         052  19  D'        102  16  A'
003  01  1         053  68 NOP        103  42 STO
004  00  0         054  85  +         104  05  05
005  95  =         055  01  1         105  91 R/S
006  42 STO        056  00  0         106  43 RCL
007  01  01        057  95  =         107  00  00
008  91 R/S        058  42 STO        108  99 PRT
009  72 ST*        059  01  01        109  00  0
010  01  01        060  43 RCL        110  42 STO
011  69 OP         061  04  04        111  00  00
012  21  21        062  42 STO        112  98 ADV
013  43 RCL        063  02  02        113  92 RTN
014  01  01        064  73 RC*        114  76 LBL
015  91 R/S        065  01  01        115  10  E'
016  71 SBR        066  68 NOP        116  43 RCL
017  00  00        067  44 SUM        117  04  04
018  09  09        068  00  00        118  42 STO
019  76 LBL        069  01  1         119  06  06
020  14  D         070  00  0         120  01  1
021  99 PRT        071  44 SUM        121  42 STO
022  65  ×         072  01  01        122  08  08
023  01  1         073  97 DSZ        123  43 RCL
024  00  0         074  02  02        124  08  08
025  95  =         075  00  00        125  14  D
026  42 STO        076  64  64        126  69 OP
027  01  01        077  43 RCL        127  28  28
028  43 RCL        078  00  00        128  97 DSZ
029  05  05        079  99 PRT        129  06  06
030  42 STO        080  44 SUM        130  01  01
031  02  02        081  09  09        131  23  23
032  73 RC*        082  00  0         132  43 RCL
033  01  01        083  42 STO        133  05  05
034  99 PRT        084  00  00        134  42 STO
035  44 SUM        085  92 RTN        135  06  06
036  00  00        086  76 LBL        136  00  0
037  69 OP         087  11  A         137  42 STO
038  21  21        088  42 STO        138  08  08
039  97 DSZ        089  04  04        139  43 RCL
040  02  02        090  91 R/S        140  08  08
041  00  00        091  76 LBL        141  19  D'
042  32  32        092  15  E         142  69 OP
043  43 RCL        093  43 RCL        143  28  28
044  00  00        094  09  09        144  97 DSZ
045  99 PRT        095  99 PRT        145  06  06
046  00  0         096  00  0         146  01  01
047  42 STO        097  42 STO        147  39  39
048  00  00        098  09  09        148  15  E
049  98 ADV        099  98 ADV        149  00  0
```

001	12	B	0.	00	980.	50
020	14	D	85.	01	690.	51
052	19	D'	0.	02	1450.	52
087	11	A	0.	03	2100.	53
092	15	E	7.	04	2540.	54
102	16	A'	6.	05	3000.	55
115	10	E'	0.	06	0.	56
			6.	08	0.	58
			0.	09	0.	59
			30140.	10	1410.	60
			16412.	11	1520.	61
			9080.	12	2560.	62
			10410.	13	2300.	63
			14520.	14	1450.	64
			38200.	15	3600.	65
			0.	16	0.	66
			0.	17	0.	67
			0.	18	0.	68
			0.	19	0.	69
			7836.	20	24112.	70
			4267.	21	10870.	71
			2360.	22	18470.	72
			2704.	23	12040.	73
			3775.	24	16500.	74
			9932.	25	20450.	75
			0.	26	0.	76
			0.	27	0.	77
			0.	28	0.	78
			0.	29	0.	79
			9410.	30	0.	80
			5820.	31	0.	81
			4562.	32	0.	82
			8320.	33	0.	83
			2540.	34	0.	84
			5240.	35	0.	85
			0.	36	0.	86
			0.	37	0.	87
			0.	38	0.	88
			0.	39	0.	89
			2110.	40	0.	90
			1870.	41	0.	91
			2580.	42	0.	92
			3650.	43	0.	93
			2980.	44	0.	94
			1450.	45	0.	95
			0.	46	0.	96
			0.	47	0.	97
			0.	48	0.	98
			0.	49	0.	99

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POPULATION PROJECTIONS

Population projection methods ranked first with both practicing planners and planning schools in the Isserman survey. The location, number and age distribution of a community's population are data of critical importance to land use planning. Census publications make decennial population data inexpensive to the planner, but useful development of that data can be time-consuming and expensive.

In Rhode Island the Statewide Planning program provides projections of state population by sex, age and race, along with aggregated totals for cities and towns. Local government planners generally do not have access to cohort survival projections for their own census tracts.

Cohort survival population projection is relatively simple to understand when the operations are diagrammed. The calculations are tediously repetitive: multiplication after multiplication followed by additions. The calculations might even be worth suffering through if all the answers to our questions could be answered with one round of processing.

What do we really need to know? The planner might be interested in determining the different migration patterns of each cohort in a census tract. This can be an important indicator of relative stability in neighborhoods.

Assume that the town of Jefferson had a 1970 population of 18475, and a 1980 population of 19921. Given cohort survival rates and fertility rates, what kind of average net

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migration brings 18475 to 19921 in a decade? Once we know

that, specific cohorts can be identified as having greater

or lesser net migration rates. Within overall population

growth there may be signs of serious problems.

This kind of analysis requires iterative runs with

increasing or decreasing migration rates that eventually come

close to generating the 19921 figure. For the town of

Jefferson this may require thousands of arithmetic operations.

With a TI-59 program the runs require 2-3 minutes of unattended

operation once the data has been loaded and stored on a magnetic

card. The printouts can be formatted and labelled for

publication.

Our example begins with 1970 population data. Using

statewide fertility and survival rates, we can project two

sequential five-year periods, to 1980, using a migration factor

of 1.0 (not enough to bring us to 19921). Maybe the women of

Jefferson had higher fertility rates than we expected. That

would show up in descrepancies in the 00-04 cohort in 1975

and 1980, as well as the 05-09 cohort in 1980. Maybe most

cohorts had better survival rates than we expected. That can

be isolated through death records. The point remains that we

have control over the sometimes opaque set of relationships

over time. This is not straight matrix multiplication. If it

had been, the program would have been about 300 steps shorter.

This problem is a good example of the possibilities for

merging graphic and numerical approaches to problems. I found

cohort survival projection difficult because the text I read explained it poorly. Krueckeberg and Silvers' URBAN PLANNING ANALYSIS explains it backwards, with 15 year projections.[1] How much more distant can a theoretical explanation stray from real world applications? David Winsor, a graduate student with remarkable graphic understanding, passed out copies of his diagram to anyone who needed one. That diagram has been redrawn, with several modifications, as the entry point to the calculator program.

NOTES

[1] Donald Kruekeberg and Arthur Silvers, URBAN PLANNING ANALYSIS: METHODS AND MODELS, (New York: John Wiley and Sons, 1974), pp. 276-81, and particularly p. 278.

DIAGRAM FOR COHORT SURVIVAL POPULATION PROJECTION

Note that the numbers used are the same as those on the formatted printout on the following page (1975, 1980).
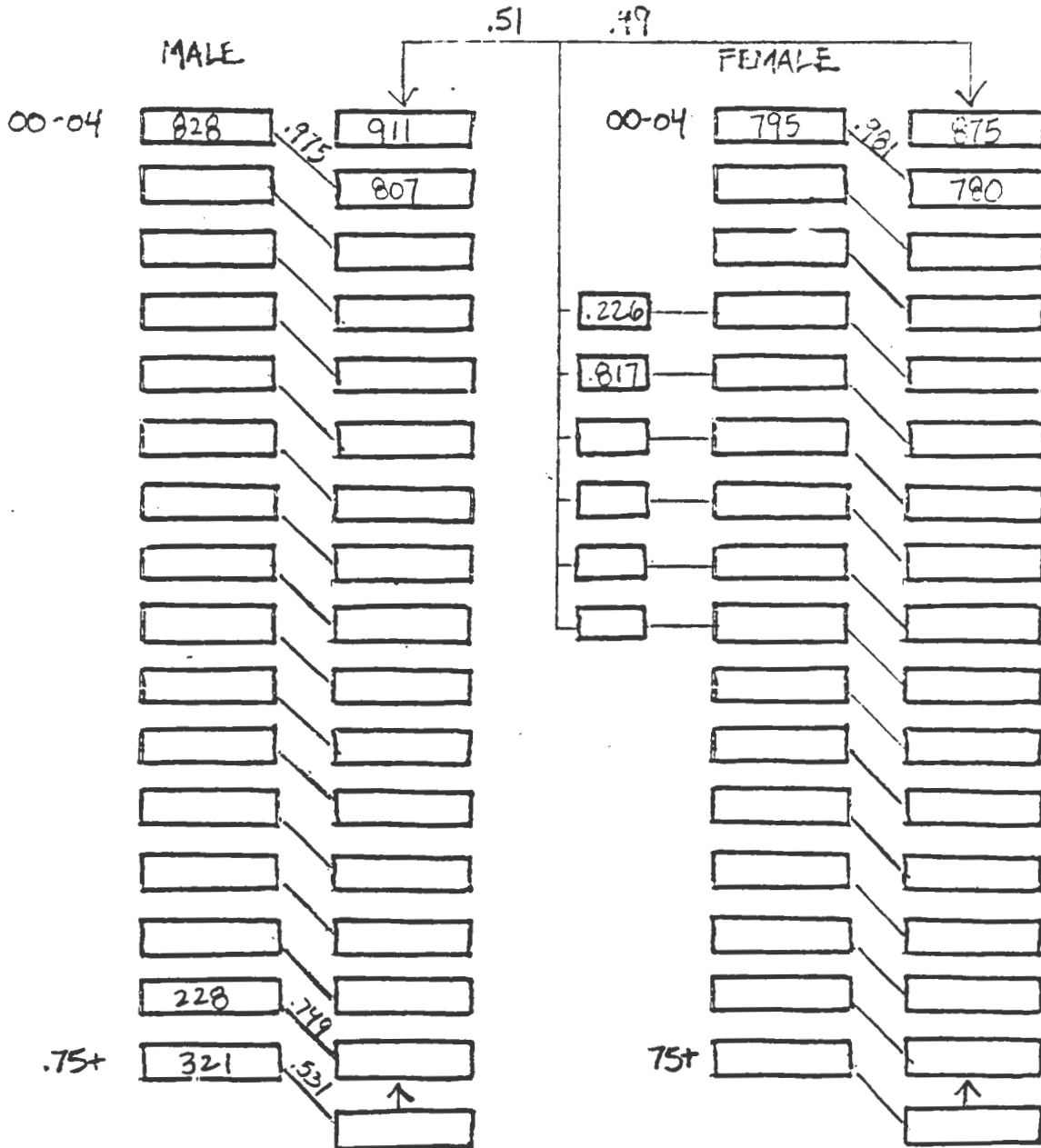
	1975.	YR			1980.	YR
	117.	CT			117.	CT
00-04	795.			00-04	875.	
05-09	692.			05-09	780.	
10-14	780.			10-14	691.	
15-19	885.			15-19	779.	
20-24	771.			20-24	683.	
25-29	723.			25-29	769.	
30-34	682.			30-34	721.	
35-39	558.			35-39	679.	
40-44	448.			40-44	552.	
45-49	403.			45-49	443.	
50-54	505.			50-54	394.	
55-59	513.			55-59	493.	
60-64	533.			60-64	494.	
65-69	483.			65-69	496.	
70-74	333.			70-74	437.	
75-	489.			75-	535.	
	9593.				10021.	

	828.				911.	
00-04	828.			00-04	911.	
05-09	716.			05-09	807.	
10-14	792.			10-14	715.	
15-19	875.			15-19	791.	
20-24	813.			20-24	871.	
25-29	673.			25-29	809.	
30-34	555.			30-34	664.	
35-39	560.			35-39	548.	
40-44	397.			40-44	549.	
45-49	373.			45-49	389.	
50-54	451.			50-54	357.	
55-59	487.			55-59	431.	
60-64	439.			60-64	443.	
65-69	374.			65-69	381.	
70-74	228.			70-74	297.	
75-	321.			75-	341.	
	8882.				9304.	

| | 18475. | | | | 19325. | |

FORMATTED LABELS GENERATED WITH THE PRINT PROCESSOR

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

00-04
05-09
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-

RUNNING THE PROGRAM

Clear and load mag card banks 1,2 and 4.

ENTER	KEY	DISPLAYS	PRINTS		COMMENTS
Year of input data: 1970	A	1970.	1970.	YR	
Census tract number: 117	R/S	117.	117.	CT	
Female 00-04 population and survival rate in the form P.S: 795.981	R/S	5.	795.981		Cue for next cohort
Female 05-09: 692.999	R/S	10.	692.999		

Continue entering all female cohorts. After last entry (75+) the total female population will be printed.

| Male 00-04 population and survival rate in the form P.S: 828.975 | B | 5. | 828.975 | | |

Continue entering all male cohorts. After last entry (75+) the total male population will be printed.

| Female 15-19 fertility rate: .226 | C | .226 | .226 | FR | |

Continue entering required female fertility rates.

| Net migration rate: 1.0 | D | 1.0 | 1.0 | MR | |

| Number of 5 year periods for projection: 2 | E | | Prints year, census tract, cohort projections and totals for females, then males. Prints total population. | | |

Note that before running the program at E, the user will generally want to save the data by writing banks 3 and 4 to a new card. This permits use of various migration rates without the need to repeatedly key in data.

DATA REGISTERS

00 Temporary storage of intermediate results
01 Pointer numbers for indirect recalls
02 Pointer numbers for indirect recalls
03 Counter for number of cohorts (decremented)
04 Total 00-04 generated
05 Female 00-04
06 Male 00-04
07 Alphanumeric code for YR
08 Alphanumeric code for CT
09 Counter for number of five year projections
10 Initial year (incremented by 5 after each run)
11 Census tract number
12 Migration rate
13 Merged population and survival rate for female 00-04 cohort. Subsequent cohorts follow in sequence through storage register 28
29 Total females
43 Merged population and survival rate for male 00-04 cohort. Subsequent cohorts follow in sequence through storage register 58
59 Total males

```
000   76  LBL        050   09   9        100   03   03
001   11   A         051   42  STO       101   01   01
002   32  X:T        052   02   02       102   12   12
003   43  RCL        053   43  RCL       103   73  RC*
004   07   07        054   40   40       104   02   02
005   69  OP         055   69  OP        105   22  INV
006   04   04        056   04   04       106   58  FIX
007   32  X:T        057   71  SBR       107   99  PRT
008   42  STO        058   42  STO       108   98  ADV
009   10   10        059   68  NOP       109   92  RTN
010   69  OP         060   43  RCL       110   68  NOP
011   06   06        061   42   42       111   68  NOP
012   91  R/S        062   69  OP        112   43  RCL
013   32  X:T        063   04   04       113   04   04
014   43  RCL        064   43  RCL       114   85   +
015   08   08        065   29   29       115   05   5
016   69  OP         066   85   +        116   95   =
017   04   04        067   43  RCL       117   22  INV
018   32  X:T        068   59   59       118   58  FIX
019   42  STO        069   95   =        119   42  STO
020   11   11        070   69  OP        120   04   04
021   69  OP         071   06   06       121   91  R/S
022   06   06        072   98  ADV       122   61  GTO
023   91  R/S        073   91  R/S       123   00   00
024   32  X:T        074   76  LBL       124   86   86
025   01   1         075   42  STO       125   76  LBL
026   03   3         076   01   1        126   13   C
027   42  STO        077   06   6        127   32  X:T
028   01   01        078   42  STO       128   02   2
029   02   2         079   03   03       129   01   1
030   09   9         080   00   0        130   03   3
031   42  STO        081   42  STO       131   05   5
032   02   02        082   04   04       132   00   0
033   43  RCL        083   72  ST*       133   00   0
034   38   38        084   02   02       134   69  OP
035   69  OP         085   32  X:T       135   04   04
036   04   04        086   58  FIX       136   32  X:T
037   71  SBR        087   03   03       137   42  STO
038   42  STO        088   69  OP        138   30   30
039   68  NOP        089   06   06       139   69  OP
040   91  R/S        090   69  OP        140   06   06
041   91  R/S        091   00   00       141   91  R/S
042   76  LBL        092   72  ST*       142   42  STO
043   12   B         093   01   01       143   31   31
044   32  X:T        094   59  INT       144   99  PRT
045   04   4         095   74  SM*       145   91  R/S
046   03   3         096   02   02       146   42  STO
047   42  STO        097   69  OP        147   32   32
048   01   01        098   21   21       148   99  PRT
049   02   2         099   97  DSZ       149   91  R/S
```

150	42	STO		200	10	E'		250	11	11
151	33	33		201	68	NOP		251	69	OP
152	99	PRT		202	91	R/S		252	06	06
153	91	R/S		203	91	R/S		253	01	1
154	42	STO		204	76	LBL		254	06	6
155	34	34		205	10	E'		255	42	STO
156	99	PRT		206	43	RCL		256	01	01
157	91	R/S		207	10	10		257	03	3
158	42	STO		208	85	+		258	00	0
159	35	35		209	05	5		259	42	STO
160	99	PRT		210	95	=		260	02	02
161	98	ADV		211	42	STO		261	06	6
162	91	R/S		212	10	10		262	42	STO
163	91	R/S		213	71	SBR		263	03	03
164	68	NOP		214	49	PRD		264	00	0
165	68	NOP		215	98	ADV		265	42	STO
166	68	NOP		216	71	SBR		266	04	04
167	68	NOP		217	16	A'		267	73	RC*
168	68	NOP		218	71	SBR		268	01	01
169	68	NOP		219	17	B'		269	65	×
170	68	NOP		220	68	NOP		270	73	RC*
171	68	NOP		221	43	RCL		271	02	02
172	76	LBL		222	42	42		272	95	=
173	14	D		223	69	OP		273	44	SUM
174	32	X:T		224	04	04		274	04	04
175	03	3		225	43	RCL		275	69	OP
176	00	0		226	29	29		276	21	21
177	03	3		227	85	+		277	69	OP
178	05	5		228	43	RCL		278	22	22
179	00	0		229	59	59		279	97	DSZ
180	00	0		230	95	=		280	03	03
181	69	OP		231	69	OP		281	02	02
182	04	04		232	06	06		282	67	67
183	32	X:T		233	98	ADV		283	43	RCL
184	42	STO		234	92	RTN		284	04	04
185	12	12		235	76	LBL		285	65	×
186	69	OP		236	49	PRD		286	93	.
187	06	06		237	43	RCL		287	04	4
188	90	ADV		238	07	07		288	09	9
189	91	R/S		239	69	OP		289	95	=
190	91	R/S		240	04	04		290	58	FIX
191	76	LBL		241	43	RCL		291	00	00
192	15	E		242	10	10		292	52	EE
193	42	STO		243	69	OP		293	58	FIX
194	09	09		244	06	06		294	00	00
195	71	SBR		245	43	RCL		295	22	INV
196	10	E'		246	08	08		296	52	EE
197	68	NOP		247	69	OP		297	22	INV
198	97	DSZ		248	04	04		298	58	FIX
199	09	09		249	43	RCL		299	42	STO

300	05	05	350	42	STO	400	00	00
301	75	-	351	01	01	401	52	EE
302	43	RCL	352	05	5	402	58	FIX
303	04	04	353	09	9	403	00	00
304	95	=	354	42	STO	404	22	INV
305	94	+/-	355	02	02	405	52	EE
306	58	FIX	356	43	RCL	406	22	INV
307	00	00	357	40	40	407	58	FIX
308	52	EE	358	69	OP	408	32	X¦T
309	58	FIX	359	04	04	409	43	RCL
310	00	00	360	43	RCL	410	00	00
311	22	INV	361	06	06	411	97	DSZ
312	52	EE	362	71	SBR	412	03	03
313	22	INV	363	48	EXC	413	04	04
314	58	FIX	364	32	X¦T	414	35	35
315	42	STO	365	43	RCL	415	85	+
316	06	06	366	41	41	416	73	RC*
317	92	RTN	367	69	OP	417	01	01
318	76	LBL	368	04	04	418	22	INV
319	16	A'	369	32	X¦T	419	59	INT
320	01	1	370	69	OP	420	95	=
321	02	2	371	06	06	421	72	ST*
322	42	STO	372	98	ADV	422	01	01
323	01	01	373	92	RTN	423	32	X¦T
324	02	2	374	76	LBL	424	74	SM*
325	09	9	375	48	EXC	425	01	01
326	42	STO	376	42	STO	426	73	RC*
327	02	02	377	00	00	427	01	01
328	43	RCL	378	00	0	428	59	INT
329	38	38	379	72	ST*	429	99	PRT
330	69	OP	380	02	02	430	74	SM*
331	04	04	381	01	1	431	02	02
332	43	RCL	382	06	6	432	73	RC*
333	05	05	383	42	STO	433	02	02
334	71	SBR	384	03	03	434	92	RTN
335	48	EXC	385	69	OP	435	74	SM*
336	32	X¦T	386	21	21	436	02	02
337	43	RCL	387	73	RC*	437	69	OP
338	39	39	388	01	01	438	06	06
339	69	OP	389	59	INT	439	69	OP
340	04	04	390	65	×	440	00	00
341	32	X¦T	391	73	RC*	441	85	+
342	69	OP	392	01	01	442	73	RC*
343	06	06	393	22	INV	443	01	01
344	98	ADV	394	59	INT	444	22	INV
345	92	RTN	395	65	×	445	59	INT
346	76	LBL	396	43	RCL	446	95	=
347	17	B'	397	12	12	447	72	ST*
348	04	4	398	95	=	448	01	01
349	02	2	399	58	FIX	449	32	X¦T

450	42	STO	140.	00	560.981	50
451	00	00	58.	01	397.981	51
452	61	GTO	59.	02	373.956	52
453	03	03	0.	03	451.956	53
454	85	85	!622.798647	04	487.909	54
455	00	0	795.	05	439.868	55
456	00	0	828.	06	374.793	56
457	00	0	45350000.	07	228.749	57
458	00	0	15370000.	08	321.531	58
459	00	0	0.	09	8882.	59
460	00	0	1975.	10		
461	00	0	117.	11		
462	00	0	1.	12		
463	00	0	795.981	13		
464	00	0	692.999	14		
			780.999	15		
			885.998	16		
			771.998	17		
			723.997	18		
001	11	A	682.996	19		
043	12	B	558.99	20		
075	42	STO	448.988	21		
126	13	C	403.978	22		
173	14	D	585.977	23		
192	15	E	513.962	24		
205	10	E'	533.93	25		
236	49	PRD	483.905	26		
319	16	A'	333.818	27		
347	17	B'	489.538	28		
375	48	EXC	9593.	29		
			0.226	30		
			0.817	31		
			0.777	32		
			0.398	33		
			0.178	34		
			0.047	35		
			0.	36		
			0.	37		
			0.	38		
			0.	39		
			0.	40		
			0.	41		
			0.	42		
			828.975	43		
			716.998	44		
			792.999	45		
			875.995	46		
			813.995	47		
			673.987	48		
			555.987	49		

LIFE CYCLE COSTING

The federal Office of Management and Budget defines life-cycle costing (LCC) as the "sum total of all the direct, indirect, recurring, non-recurring, and other related costs . . . in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life."[1] Everything counts. Most of the costs in the lifetime of a system occur after the initial investment, so that choosing the system with the lowest first cost can be expensive. In LCC costs occurring after the initial investment are appropriately discounted to present value. Some discount rates are more appropriate than others.

Because planners typically assume some responsibility for capital budgeting, LCC falls within our domain. The federal government has developed standard methods for LCC, largely in response to the increased factor costs for energy. In most cases, lifetime savings on energy or maintenance will generally provide the justification for choosing a system with a higher first cost.

Suppose that the town of Jefferson needs a new public works verhicle, and we want to compare the lifetime costs of vehicle A (conventionally called the Defender) and vehicle B (the Challenger). The Defender costs less initially, but the Challenger uses less fuel. If we compare life cycle costs at a discount rate of 14%, the Challenger is the

preferred investment.

Several questions emerge from the discussion. Should we assume everything has an inflation rate, or should we normalize costs and consider only relative inflation rates (higher or lower than the base rate)? If we normalize prices, the actual discount rate equals the stated discount rate plus the general inflation rate, even though that is not explicitly noted. The federal government specifies normalized prices. The FEDERAL REGISTER for November 18, 1981 contains the DOE method. Local government planners would do well to ignore it and use inflated costs explicitly, if only to make the argument understandable.

If inflation is handled explicitly, how do we know what the salvage value will be in 20 years? You have to inflate presently known values and then discount them. The salvage rates entered in the example were previously inflated. For overhauls and other kinds of non-recurring costs, use the same inflate-then-discount approach.

The results of successive program runs are net present costs. This is a quick and relatively clean system. It assumes that the Defender and Challenger both do the same required job, and that doing more of the job provides no additional benefit streams.

NOTES

[1] R. Winslow et al, LIFE-CYCLE COSTING FOR PROCUREMENT OF SMALL BUSES, (Washington, D.C.: DOT, 1980), p. 1. The method uses explicit inflation rates.

RUNNING THE PROGRAM

Clear and load mag card bank 1.

ENTER	KEY	DISPLAYS	PRINTS	COMMENTS
Initial cost: 20800	A	20800.	20800.	
Expected salvage value: 2400	R/S	2400.	2400.	
Economic life in years: 20	R/S	1.	20.	
Fuel cost per year: 2600	B	2600.	2600.	
Expected rate of escalation for fuel costs: 1.08	R/S	1.08	1.08	
Other costs per year: 1900	C	1900.	1900.	
Expected rate of escalation for other costs: 1.06	R/S	1.06	1.06	
Discount rate: 1.14	D	1.14	1.14	
No entry	E	Prints 20 years of cash flow, followed by salvage value.		
Year of non- recurring cost: 10	A'	10.	10.	
Amount of non- recurring cost: 4600	R/S	1240.82	1240.82	Discounted.
No entry	E'	0.	56372.20	Total present value of costs.

The user would normally run the program first for the
Defender and then for the Challenger.

DATA REGISTERS

```
05 Years of economic life
06 Contents of register 05 stored here and decremented
17 Year of non-recurring cost
18 Amount of non-recurring cost
31 Total present value of costs
32 Fuel cost per year (base year)
33 Other costs per year (base year)
40 Expected salvage value
42 Expected rate of escalation for fuel costs
43 Expected rate of escalation for other costs
44 Discount rate
49 Initial cost
```

Note that the storage registers should be allocated in a sequential, logical fashion. What would happen if we wanted to list storage registers for this program? This program could have been designed with some attention to possible future expansion. For example, we might want to run three or more classes of costs with differing escalation rates.

```
000  76  LBL        050  91  R/S        100  43  RCL
001  11   A         051  76  LBL        101  09   09
002  42  STO        052  14   D         102  65   ×
003  49   49        053  42  STO        103  43  RCL
004  99  PRT        054  44   44        104  33   33
005  91  R/S        055  99  PRT        105  54   )
006  99  PRT        056  91  R/S        106  85   +
007  42  STO        057  76  LBL        107  43  RCL
008  40   40        058  15   E         108  48   48
009  22  INV        059  98  ADV        109  95   =
010  44  SUM        060  58  FIX        110  68  NOP
011  49   49        061  02   02        111  65   ×
012  91  R/S        062  68  NOP        112  43  RCL
013  99  PRT        063  69  OP         113  44   44
014  42  STO        064  29   29        114  35  1/X
015  06   06        065  97  DSZ        115  45  Y×
016  42  STO        066  06   06        116  43  RCL
017  05   05        067  00   00        117  09   09
018  55   ÷         068  85   85        118  95   =
019  43  RCL        069  43  RCL        119  99  PRT
020  49   49        070  40   40        120  44  SUM
021  95   =         071  65   ×         121  31   31
022  35  1/X        072  43  RCL        122  61  GTO
023  42  STO        073  44   44        123  00   00
024  48   48        074  35  1/X        124  63   63
025  68  NOP        075  45  Y×         125  76  LBL
026  01   1         076  43  RCL        126  16   A'
027  44  SUM        077  05   05        127  42  STO
028  06   06        078  95   =         128  17   17
029  91  R/S        079  94  +/-        129  91  R/S
030  76  LBL        080  99  PRT        130  42  STO
031  12   B         081  44  SUM        131  18   18
032  42  STO        082  31   31        132  43  RCL
033  32   32        083  95   =         133  44   44
034  99  PRT        084  91  R/S        134  35  1/X
035  91  R/S        085  43  RCL        135  45  Y×
036  42  STO        086  42   42        136  43  RCL
037  42   42        087  45  Y×         137  17   17
038  99  PRT        088  43  RCL        138  95   =
039  91  R/S        089  09   09        139  65   ×
040  76  LBL        090  65   ×         140  43  RCL
041  13   C         091  43  RCL        141  18   18
042  42  STO        092  32   32        142  95   =
043  33   33        093  95   =         143  99  PRT
044  99  PRT        094  68  NOP        144  44  SUM
045  91  R/S        095  85   +         145  31   31
046  42  STO        096  53   (         146  91  R/S
047  43   43        097  43  RCL        147  76  LBL
048  99  PRT        098  43   43        148  10   E'
049  68  NOP        099  45  Y×         149  43  RCL
```

```
150  31  31      20800.00       24300.00
151  99  PRT      2400.00        2400.00
152  47  CMS        20.00          20.00
153  98  ADV      2600.00        1780.00
154  91  R/S         1.08           1.08
155  00   0       1800.00        1900.00
156  00   0          1.06           1.06
157  00   0          1.14           1.14
158  00   0
159  00   0       4943.86        4413.51
001  11   A       4597.66        4082.82
031  12   B       4278.70        3779.99
041  13   C       3984.54        3502.38
052  14   D       3713.00        3247.63
058  15   E       3462.10        3013.62
126  16   A'      3230.06        2798.46
148  10   E'      3015.29        2600.44
                  2816.30        2418.01
                  2631.82        2249.80
                  2460.63        2094.56
                  2301.66        1951.16
                  2153.93        1818.60
                  2016.55        1695.95
                  1888.70        1582.38
                  1769.65        1477.14
                  1658.72        1379.55
                  1555.29        1288.98
                  1458.80        1204.87
                  1368.74        1126.72
                  -174.63        -174.63
                  1240.82        1456.62
                 56372.20       49008.54
```

        Defender   Challenger

Note that this program runs the way we would solve the problem on paper (non-recurring cost entered last). We could modify this program to print alot more and give us a presentation format similar to that designed for hydroelectric site analysis.

Many New England cities and towns have hydroelectric
sites within their jurisdictions. The generating equipment
at such sites has typically been shut down within the past
fifty years. In some cases the existing turbine/generator
sets can be rehabilitated; in most cases at least some major
components need to be replaced.

Even when private parties own the physical site and/or
water rights, the municipality retains development priority
under existing federal law, and hence the ultimate
responsibility for making certain the energy resource is
prudently developed. If the cost of electricity produced
at the site is equal to, or less than, the cost of electricity
otherwise acquired, the site can almost certainly be leveraged
for economic development.

Before thousands of dollars are committed to engineering
design, environmental assessment and financial studies, we
need to know whether the project is worth further study.
Even if the municipality chooses to postpone development, it
is important to know how changing energy and other factor
costs would affect the economics of development. If the
municipality permits investment by private parties, the
economic information developed in a hydroelectric site
review can be useful in any negotiation related to the project.

In 1980 the U.S. Department of Energy released a site

screening software package for the Apple II microcomputer.[1]
The documentation for this package provides the standard
calculation reference in this field.

The screening package provides a conservative
interpretation of the cash flow for a site (as opposed to
investor cash flow or combined investor/site flow). DOE
needed a standard method for comparing projects and deter-
mining that its loan funds for feasibility studies would not
be misallocated. At the time DOE was forgiving 90% of the
loan amount for hydro projects with negative feasibility
study results.

We can look at the hydro screening problem as a set of
problems. Each can be solved, but at different confidence
levels. For example, the available energy at a site over the
course of an average flow year can be calculated with
reasonable precision, but the flow curves for the years of a
project life can only be discussed in terms of probabilities
based on the historical record. Recently negotiated power
purchase contract rates are known, but we are less certain
about the earnings impacts of contract escalator clauses.

Engineering firms face considerable difficulties in
estimating the physical rehabilitation costs for a site,
particularly when dam repairs may be required. At the
screening level cost estimates are based on Army Corps of
Engineers cost tables for 1978 and extrapolations of those
tables. A general cost escalator can be derived for any later
date. The programmable can recalculate bottom line results
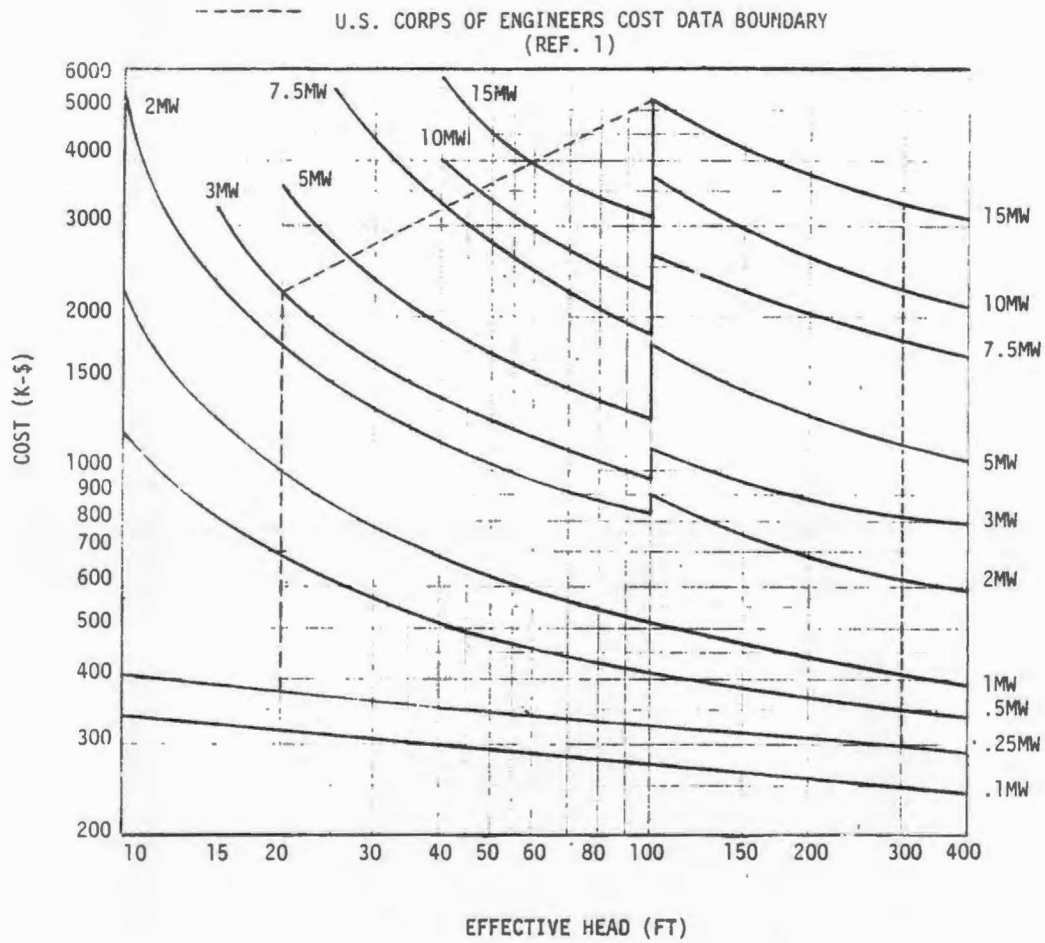
FIGURE 3-2.   EXTRAPOLATED POWER GENERATION EQUIPMENT (SEE FIGURE 3-1)

TABLE 3-1

MISCELLANEOUS RECONNAISSANCE ESTIMATE COSTS*
(Cost Base July 1978)

PENSTOCK COST

Effective Head (Ft)	10	20	50	100	200	300
Cost Index (CI)	960	480	200	110	55	35

Installed cost = CI x Penstock Length (ft) x Installed Capacity (MW)
Minimum Penstock Cost is $50 per linear foot.

TAILRACE COST
Construction Cost = $15,000 fixed plus $200 per linear foot

SWITCHYARD EQUIPMENT COST
(Thousand Dollars)

Plant Capacity	Transmission Voltage			
	13.8	34.5	69	115
1 MW	50	60	110	160
3 MW	85	100	120	175
5 MW	110	125	150	210
10 MW	150	170	210	280
15 MW	185	220	250	320

TRANSMISSION LINE COST
(Thousand Dollars)

Plant Capacity	Miles of transmission line				
	1	2	5	10	15
0.5 MW	30	60	150	—	—
5 MW	45	80	160	320	500
10 MW	60	100	180	380	600
15 MW	80	140	230	460	700

*TABLE 4-2 OF REF. 1
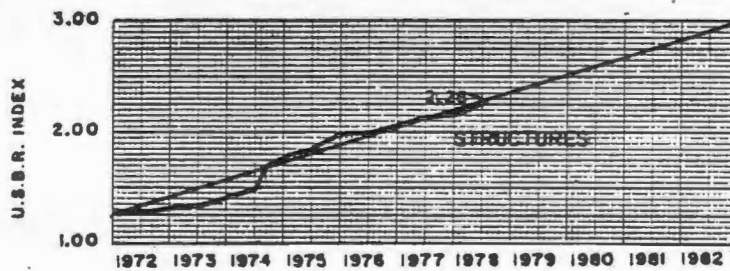
(Note: 2.28 represents July 1978)

FIGURE 3-3. ESCALATION OF SMALL HYDROELECTRIC PROJECT STRUCTURES (FIGURE 6-1 OF REF. 1, VOL. VI)

quickly enough to permit efficient searching for the economic
limits of capital investment. Successive numerical solutions
begin to compensate for our analytical limitations.

A worked example will demonstrate the calculator version
of the DOE screening program. Suppose that the town of
Jefferson owns an existing hydro site. The dam provides 20
feet of usable head, and the nearest U.S. Geological Survey
office informs us that the average flow rate near that site is
800 cubic feet per second. Given some knowledge of the flow
duration curve for the river, we can assume a plant factor of
about .7 (more on the derivation of this later). The program
can then tell us the kilowatt capacity of the site at average
flow, as well as the output in kilowatt hours per year. If
we enter the value of a kilowatt hour the program tells us
the yearly energy revenue, although not right away.

For costs the COE has provided graphs and tables,
reproduced on the following two pages. With a ruler and some
linear interpolation we can derive the appropriate numbers for
entry. (The listed program actually includes interpolation
and formula routines at A',B' and C', but we will not discuss
them here.) After the costs have been entered we press control
keys and let the economic calculations run.

The program includes built-in assumptions about project
life, discount rate, etc. To change those assumptions, enter
the new assumptions directly into the appropriate storage
registers. For example, to change the interest rate from 15% to

89

to 18%, simply key ".18 STO 25" (because the interest rate
is stored in register 25). The instructions for running the
program and the list of data register contents provide all
the information required for running a series of calculations
with changing variables. The instructions and list appear on
the following two pages.

One of the more obvious questions one would ask is, "What
happens if the value of electricity decreases?" If the
purchasing utility offers $.042 per KWH rather than $.050,
note the change in the number of years of negative cash flow.
Some investors might be able to absorb that kind of negative
flow, or compensate for it with the use of available tax
incentives. For other investors that kind of change in the
buyback rate would make the project infeasible.

The date of construction makes a difference in project
feasibility. What would happen if the project is delayed
until October 1983? We can determine that impact by changing
the date (and hence the excalation factor for all costs). We
might need to run the program 20-30 times with different
values for selected variables before feeling confident about
the dynamics of the project. But we could never feel
confident about any one bottom line result, given the nature
of the inputs.

No program is a final product, and this one has serious
weaknesses that undermine its utility. We use it because it
has assumed a life of its own as a DOE standard.   It is not
unusual for government-endorsed formulas to distort reality,

		YEAR	0.
		ENERGY REVENUE	358.073
		O+M	62.453
		EXPENSES	379.508
		EARNINGS	-21.435
			1.
			386.719
			66.200
			383.255
			3.464
DATE	10.81		2.
FT AVERAGE HEAD	20.000		417.656
CFS AVERAGE FLOW	800.000		70.172
KW CAPACITY	1167.883		387.227
PLANT FACTOR	0.700		30.429
KWH/YR OUTPUT	7161459.854		3.
D/KWH ENERGY VALUE	0.050		451.069
			74.383
GENERATING EQP DK	1100.000		391.437
SWITCHYARD EQP DK	50.000		59.631
TRANS LINES DK	34.000		4.
OTHER DK	14.000		487.154
TAILRACE DK	18.000		78.846
PENSTOCK DK	11.000		395.900
			91.254
COST ESC FACTOR	1.234		5.
CONTINGENCY FACTOR	0.100		526.127
INDIRECTS FACTOR	0.250		83.577
O+M FACTOR	0.030		400.631
			125.496
ESC GEN EQP DK	1357.310		6.
ESC SWITCH EQP DK	61.696		568.217
ESC TRANS LINES DK	41.953		88.591
ESC OTHER DK	17.275		405.646
ESC TAILRACE DK	22.211		162.571
ESC PENSTOCK DK	13.573		7.
			613.674
ESC SUBTOTAL DK	1514.018		93.907
CONTINGENCY DK	151.402		410.961
CONST SUBTOTAL DK	1665.419		202.713
INDIRECTS DK	416.355		8.
			662.768
INVESTMENT DK	2081.774		99.541
BASE YR O+M DK	62.453		416.596
BASE YR REVENUE DK	358.073		246.173
			9.
DISCOUNT RATE	0.150		715.790
INTEREST RATE	0.150		105.513
YRS ECONOMIC LIFE	30.000		422.568
REVENUE ESC RATE	0.080		293.222
O+M ESC RATE	0.060		10.
YRS ESCALATION	10.000		773.053
			111.844
ANNUAL PAYMENT DK	317.055		428.899
PRESENT VALUE DK	3189.438		344.154
BENEFIT/COST	1.532		

YEAR	0.
ENERGY REVENUE	300.781
O-M	62.453
EXPENSES	379.508
EARNINGS	-78.727
	1.
	324.844
	66.200
	383.255
	-58.411

DATE	10.81	2.
FT AVERAGE HEAD	20.000	350.831
CFS AVERAGE FLOW	800.000	70.172
KW CAPACITY	1167.883	387.227
PLANT FACTOR	0.700	-36.396
KWH/YR OUTPUT	7161459.854	3.
D/KWH ENERGY VALUE	0.042	378.898
		74.383
GENERATING EQP DK	1100.000	391.437
SWITCHYARD EQP DK	50.000	-12.540
TRANS LINES DK	34.000	4.
OTHER DK	14.000	409.210
TAILRACE DK	18.000	78.846
PENSTOCK DK	11.000	395.900
		13.309
COST ESC FACTOR	1.234	5.
CONTINGENCY FACTOR	0.100	441.946
INDIRECTS FACTOR	0.250	93.577
O-M FACTOR	0.030	400.631
		41.315
ESC GEN EQP DK	1357.310	6.
ESC SWITCH EQP DK	61.696	477.302
ESC TRANS LINES DK	41.953	88.591
ESC OTHER DK	17.275	405.646
ESC TAILRACE DK	22.211	71.656
ESC PENSTOCK DK	13.573	7.
		515.486
ESC SUBTOTAL DK	1514.018	93.907
CONTINGENCY DK	151.402	410.961
CONST SUBTOTAL DK	1665.419	104.525
INDIRECTS DK	416.355	8.
		556.725
INVESTMENT DK	2081.774	99.541
BASE YR O-M DK	62.453	416.596
BASE YR REVENUE DK	300.781	140.130
		9.
DISCOUNT RATE	0.150	601.263
INTEREST RATE	0.150	105.513
YRS ECONOMIC LIFE	30.000	422.568
REVENUE ESC RATE	0.080	178.695
O-M ESC RATE	0.060	10.
YRS ESCALATION	10.000	644.344
		111.844
ANNUAL PAYMENT DK	317.055	428.899
PRESENT VALUE DK	2585.848	220.465
BENEFIT/COST	1.242	

so we will spend some time reviewing how it happened in this particular case.

The DOE method calculates full revenue, operating and maintenance costs, and loan payment for year zero, the capital investment year. The applicable convention of engineering economics is to show only interest on the unspent construction loan balance as year zero revenue. The flow in year zero in the DOE method would normally be assigned to year one. It appears that this quirk was a programming error. The TI-59 program was written for simple conversion to convention by changing seed numbers in one subroutine.

As previously stated, the DOE method focuses on the real cash flow from the project, without regard to the use of available investment tax credits, accelerated cost recovery methods or tax bracket effects. It is too rigid in the sense that it fixes the interest rate at the selected discount rate, even though there are many cases in which separate rates are required. The TI-59 program permits identical or different rates, so that one run can mimic the DOE method and another can reflect reality.

It should also be noted that the benefit/cost ratio is calculated against the required investment independent of mortgage consequences. When the interest rate changes, the payment changes, as does the cash flow, but not the BCR.

The DOE method calculates a site's kilowatt capacity by using average flow. The capacity is then multiplied by a plant factor to determine kilowatt hour output per year. It

is possible to find the appropriate plant factor, but by means external to the DOE method. Rivers flow at varying rates from season to season and day to day. This variation is described by a flow exceddance curve. Turbines are typically matched to a flow rate exceeded only 15% of the time, and turbine efficiencies generally decline on either side of their rated flow. Determining yearly output from turbine efficiency curves and flow exceedance curves is an extremely complex problem. Suffice it to say that we can determine yearly output by the complex method and then divide by average flow KW rating to determine an accurate plant factor for the DOE method. This permits the merger of accurate design with COE costing.

In summary, we have a case in which no standard screening method existed before 1979. The DOE method became a standard by default. Because the microcomputer software was developed by a large engineering firm, few people questioned the method. David Thomas of Hoyle, Tanner and Associates developed reservations similar to mine while working with an HP-97. Similar conclusions from separate sources in different professions tend to reassure both sources.

NOTES

[1] Charles Broadus, HYDROPOWER COMPUTERIZED RECONNAISSANCE PACKAGE, Idaho Falls: DOE, 1980.

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RUNNING THE PROGRAM

Partition the memory to 639.39 (4 OP 17) and clear.
Load mag card banks 1-4.

ENTER	KEY	DISPLAYS	PRINTS	COMMENTS
Date: 10.81	A	0.000	10.81	
Head in feet: 20	R/S	20.000	20.000	
Average flow in CFS: 800	R/S	7161459.854	800.000	
			1167.883	KW capacity
			0.700	Plant factor
			7161459.854	KWH per year
Revenue per KWH in dollars	R/S	0.000	0.050	
Generating equipment costs in $ 000: 1100	B	1100.000	1100.000	
Switchyard equipment in $ 000: 50	R/S	50.000	50.000	
Transmission lines in $ 000: 34	R/S	34.000	34.000	
Other in $ 000: 14	R/S	14.000	14.000	
Tailrace costs in $ 000: 18	R/S	18.000	18.000	
Penstock costs in $ 000: 11	R/S	11.000	11.000	
No entry	C		Prints everything from "cost escalation factor" through "base year revenue"	
No entry	D		Prints everything from "discount rate" through "benefit/cost"	
No entry	E		Prints cash flow for years of revenue and O&M escalation	
No entry	E'		Prints everything in C,D,E without stopping	

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DATA REGISTERS

00 Incremented exponent (revenue, O&M escalation factors)
01 Incremented exponent (discount factor)
02 Register 29 copied (decremented for present value calculation)
03 Register 26 copied (decremented for present value calculation)
04 Revenue in dollars per KWH
05 Tailrace costs in $ 000
06 Penstock costs in $ 000
07 Generating equipment costs in $ 000
08 Switchyard costs in $ 000
09 Transmission line costs in $ 000
10 Other costs in $ 000
11 Construction cost escalation rate
12 Plant factor
13 Investment total in $ 000
14
15 Operating and maintenance costs in $ 000
16 Energy revenue per year in $ 000
17 Annual payment, principal and interest, in $ 000
18 Present value of net revenue (ie, revenue - O&M)
19 Divisor in power formula
20 Hours in year
21 Contingency factor
22 Indirect costs factor
23 Operating and maintenance costs factor
24 Discount rate
25 Interest rate
26 Period of economic evaluation in years
27 Revenue escalation rate
28 O&M escalation rate
29 Years of escalation for revenue and O&M
30 Month and year (entered as MM.YY)
31 Net head in feet
32 Derived capacity in KW
33 KWH per year
34 Contents of register 27 +1
35 Contents of register 28 +1
36 Contents of register 24 +1
37
38 .00868567 (used in penstock cost formula)
39 -.959576 (used in penstock cost formula)

Input data is listed after the program step list.

000	76	LBL	050	32	32	100	07	07
001	11	A	051	65	×	101	91	R/S
002	58	FIX	052	43	RCL	102	99	PRT
003	02	02	053	12	12	103	42	STO
004	99	PRT	054	99	PRT	104	08	08
005	42	STO	055	65	×	105	91	R/S
006	30	30	056	43	RCL	106	99	PRT
007	59	INT	057	20	20	107	42	STO
008	55	÷	058	95	=	108	09	09
009	01	1	059	99	PRT	109	91	R/S
010	02	2	060	42	STO	110	99	PRT
011	85	+	061	33	33	111	42	STO
012	53	(	062	91	R/S	112	10	10
013	43	RCL	063	99	PRT	113	91	R/S
014	30	30	064	42	STO	114	99	PRT
015	22	INV	065	04	04	115	42	STO
016	59	INT	066	69	OP	116	05	05
017	65	×	067	05	05	117	91	R/S
018	01	1	068	91	R/S	118	99	PRT
019	00	0	069	76	LBL	119	42	STO
020	00	0	070	17	B'	120	06	06
021	54	)	071	65	×	121	69	OP
022	85	+	072	93	.	122	05	05
023	01	1	073	02	2	123	91	R/S
024	09	9	074	85	+	124	76	LBL
025	00	0	075	01	1	125	13	C
026	00	0	076	05	5	126	43	RCL
027	95	=	077	95	=	127	30	30
028	42	STO	078	68	NOP	128	65	×
029	30	30	079	91	R/S	129	93	.
030	00	0	080	76	LBL	130	01	1
031	58	FIX	081	18	C'	131	06	6
032	03	03	082	65	×	132	75	-
033	91	R/S	083	43	RCL	133	03	3
034	99	PRT	084	31	31	134	01	1
035	42	STO	085	45	Yˣ	135	04	4
036	31	31	086	43	RCL	136	93	.
037	91	R/S	087	39	39	137	02	2
038	99	PRT	088	65	×	138	08	8
039	65	×	089	43	RCL	139	95	=
040	43	RCL	090	38	38	140	55	÷
041	31	31	091	65	×	141	02	2
042	55	÷	092	43	RCL	142	93	.
043	43	RCL	093	32	32	143	02	2
044	19	19	094	95	=	144	08	8
045	68	NOP	095	91	R/S	145	95	=
046	68	NOP	096	76	LBL	146	99	PRT
047	95	=	097	12	B	147	42	STO
048	99	PRT	098	99	PRT	148	11	11
049	42	STO	099	42	STO	149	43	RCL

150	21	21	200	43	RCL	250	69	OP
151	99	PRT	201	13	13	251	05	05
152	43	RCL	202	99	PRT	252	92	RTN
153	22	23	203	65	×	253	68	NOP
154	99	PRT	204	43	RCL	254	68	NOP
155	43	RCL	205	21	21	255	68	NOP
156	23	23	206	95	=	256	68	NOP
157	99	PRT	207	99	PRT	257	68	NOP
158	69	OP	208	44	SUM	258	68	NOP
159	05	05	209	13	13	259	68	NOP
160	68	NOP	210	43	RCL	260	68	NOP
161	68	NOP	211	13	13	261	68	NOP
162	00	0	212	95	=	262	68	NOP
163	42	STO	213	99	PRT	263	68	NOP
164	13	13	214	65	×	264	65	×
165	43	RCL	215	43	RCL	265	43	RCL
166	07	07	216	22	22	266	11	11
167	71	SBR	217	95	=	267	95	=
168	02	02	218	99	PRT	268	99	PRT
169	62	62	219	44	SUM	269	44	SUM
170	43	RCL	220	13	13	270	13	13
171	08	08	221	69	OP	271	92	RTN
172	71	SBR	222	05	05	272	76	LBL
173	02	02	223	43	RCL	273	10	E'
174	62	62	224	13	13	274	13	C
175	43	RCL	225	95	=	275	14	D
176	09	09	226	99	PRT	276	15	E
177	71	SBR	227	68	NOP	277	91	R/S
178	02	02	228	68	NOP	278	68	NOP
179	62	62	229	65	×	279	68	NOP
180	43	RCL	230	43	RCL	280	76	LBL
181	10	10	231	23	23	281	14	D
182	71	SBR	232	95	=	282	43	RCL
183	02	02	233	99	PRT	283	34	34
184	62	62	234	42	STO	284	99	PRT
185	43	RCL	235	15	15	285	85	+
186	05	05	236	43	RCL	286	01	1
187	71	SBR	237	33	33	287	95	=
188	02	02	238	65	×	288	42	STO
189	62	62	239	43	RCL	289	36	36
190	43	RCL	240	04	04	290	43	RCL
191	06	06	241	55	÷	291	25	25
192	71	SBR	242	01	1	292	99	PRT
193	02	02	243	00	0	293	43	RCL
194	62	62	244	00	0	294	26	26
195	69	OP	245	00	0	295	99	PRT
196	05	05	246	95	=	296	43	RCL
197	68	NOP	247	99	PRT	297	27	27
198	68	NOP	248	42	STO	298	99	PRT
199	68	NOP	249	16	16	299	85	+

300	01	1		350	01	1		400	43	RCL
301	95	=		351	42	STO		401	13	13
302	42	STO		352	00	00		402	95	=
303	34	34		353	42	STO		403	99	PRT
304	43	RCL		354	01	01		404	69	OP
305	28	28		355	00	0		405	05	05
306	99	PRT		356	42	STO		406	92	RTN
307	85	+		357	18	18		407	69	OP
308	01	1		358	43	RCL		408	20	20
309	95	=		359	16	16		409	61	GTO
310	42	STO		360	65	×		410	03	03
311	35	35		361	43	RCL		411	92	92
312	43	RCL		362	34	34		412	68	NOP
313	29	29		363	45	YX		413	69	OP
314	99	PRT		364	43	RCL		414	21	21
315	69	OP		365	00	00		415	61	GTO
316	05	05		366	75	-		416	03	03
317	01	1		367	53	(		417	58	58
318	75	-		368	43	RCL		418	76	LBL
319	53	(		369	15	15		419	16	A'
320	01	1		370	65	×		420	42	STO
321	85	+		371	43	RCL		421	00	00
322	43	RCL		372	35	35		422	91	R/S
323	25	25		373	45	YX		423	42	STO
324	54	)		374	43	RCL		424	01	01
325	45	YX		375	00	00		425	91	R/S
326	43	RCL		376	54	)		426	42	STO
327	26	26		377	95	=		427	02	02
328	94	+/-		378	55	÷		428	91	R/S
329	95	=		379	43	RCL		429	42	STO
330	55	÷		380	36	36		430	03	03
331	43	RCL		381	45	YX		431	91	R/S
332	25	25		382	43	RCL		432	42	STO
333	95	=		383	01	01		433	18	18
334	35	1/X		384	95	=		434	53	(
335	65	×		385	68	NOP		435	43	RCL
336	43	RCL		386	44	SUM		436	03	03
337	13	13		387	18	18		437	75	-
338	95	=		388	97	DSZ		438	43	RCL
339	99	PRT		389	02	02		439	01	01
340	42	STO		390	04	04		440	54	)
341	17	17		391	07	07		441	55	÷
342	43	RCL		392	97	DSZ		442	53	(
343	29	29		393	03	03		443	43	RCL
344	42	STO		394	04	04		444	02	02
345	02	02		395	13	13		445	75	-
346	43	RCL		396	43	RCL		446	43	RCL
347	26	26		397	18	18		447	00	00
348	42	STO		398	99	PRT		448	54	)
349	03	03		399	55	-		449	95	=

450	42	STO
451	14	14
452	53	(
453	43	RCL
454	18	18
455	75	-
456	43	RCL
457	00	00
458	54	)
459	65	×
460	43	RCL
461	14	14
462	95	=
463	85	+
464	43	RCL
465	01	01
466	95	=
467	91	R/S
468	68	NOP
469	68	NOP
470	76	LBL
471	15	E
472	00	0
473	42	STO
474	00	00
475	43	RCL
476	29	29
477	85	+
478	01	1
479	95	=
480	42	STO
481	02	02
482	58	FIX
483	00	00
484	43	RCL
485	00	00
486	99	PRT
487	58	FIX
488	03	03
489	43	RCL
490	16	16
491	65	×
492	43	RCL
493	34	34
494	45	Y×
495	43	RCL
496	00	00
497	95	=
498	99	PRT
499	42	STO

500	01	01
501	43	RCL
502	15	15
503	65	×
504	43	RCL
505	35	35
506	45	Y×
507	43	RCL
508	00	00
509	95	=
510	99	PRT
511	85	+
512	43	RCL
513	17	17
514	95	=
515	99	PRT
516	75	-
517	43	RCL
518	01	01
519	95	=
520	94	+/-
521	99	PRT
522	97	DSZ
523	02	02
524	05	05
525	30	30
526	69	OP
527	05	05
528	91	R/S
529	68	NOP
530	69	OP
531	20	20
532	61	GTO
533	04	04
534	82	82

Value	Reg
0.	00
0.	01
0.	02
0.	03
0.05	04
0.	05
0.	06
0.	07
0.	08
0.	09
0.	10
0.	11
0.7	12
0.	13
0.	14
0.	15
0.	16
0.	17
0.	18
13.7	19
8760.	20
0.1	21
0.25	22
0.03	23
0.15	24
0.15	25
30.	26
0.08	27
0.06	28
10.	29
0.	30
0.	31
0.	32
0.	33
1.08	34
1.06	35
1.15	36
0.	37
0.00868567	38
-0.959576	39

001	11	A
070	17	B'
081	18	C'
097	12	B
125	13	C
273	10	E'
281	14	D
419	16	A'
471	15	E

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