AD-A162 204 IMPACT OF RELIABILITY/MAINTAINABILITY (R&M) ON LOGISTICS COSTS FOR USAF AIRCRAFT(U) COMPTROLLER OF THE AIR FORCE WASHINGTON DC A J SHERBO ET AL 20 SEP 85 1/1

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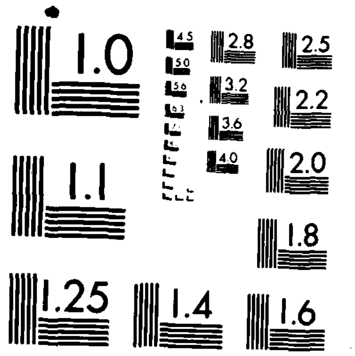

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Impact of Reliability/Maintainability (R&M)
On Logistics Costs for USAF Aircraft

by

Captain Andrew J. Sherbo
and
Captain Gregory J. Lochbaum

Directorate of Cost & Management Analysis
Comptroller of the Air Force
Headquarters United States Air Force
Washington, DC 20330-5018

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DISCLAIMER-ABSTAINER

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STATEMENT OF THE PROBLEM

The Air Force is firmly committed to improving the Reliability and Maintainability (R&M) of new and fielded weapon systems. The formation of R&M 2000, the Air Force R&M Action Plan which defines R&M goals and a strategy for meeting these goals, is evidence of this. One of the objectives of R&M 2000 is a reduction in the costs associated with maintenance and logistics support of weapon systems through R&M type improvements.

The general perception is that more reliable and maintainable weapon systems are cheaper to maintain and support. Here we are making reference to hardware R&M that is based on the design and manufacturing quality of the system. We do not disagree with this perception, however, we are unaware of any statistical study conducted at the weapon system level that supports this perception.

STUDY OBJECTIVE

The purpose of this study is to develop some cost estimating relationships (CERs) that the supports the contention that higher R&M results in lower logistics support costs, and can be used in a variety of ways. Our primary need is a methodology that enables us to quantify the impact of R&M changes or levels on existing and new aircraft in terms of logistics support costs. The CERs we are searching for need to be at the weapon system level as opposed to the subsystem or component level.

ASSUMPTIONS

In our study we made the following five assumptions:

(1) The data bases we used (D056, H036C, MCS, etc.) reflect accurate data as reported through the respective data collection system.

(2) The years FY75-FY83 include a representative time period of reliability and maintainability (R&M) improvements. This enabled us to measure changes in costs associated with the independent variables and apply these to future cost factors.

(3) The six independent variables we used were considered to be measures of an increase (or decrease) in reliability and maintainability.

(4) We used the arithmetic average of the nine years FY75-FY83 for all six independent variables and the six dependent variables. We felt these averages would better represent the variables we employed. The averages would help to "smooth out" the data within each weapon system and enable us to provide a cost equation applicable to all weapon systems.

(5) Our regression coefficients (i.e., the slopes of the lines) would be a specific cost applicable to all weapon systems. Expensive weapon systems would tend to generate more maintenance manhours per flying hour and hence generate a greater total cost. The key factor we considered in the direct application of our cost factors is the percentage reduction in maintenance manhours per flying hour. For example, a 10% R&M related reduction in Organic Depot Manhours per Flying Hour for the B-52 would mean a reduction of about four hours. The same 10% reduction for the F-15 would mean a reduction of 1.2 hours. Since both are multiplied by the same regression coefficient (slope of the line), the B-52 would show a larger overall dollar decrease than the F-15. Thus, we believe that our results can be used for a multitude of weapon systems given an acceptance of this assumption.

METHODOLOGY

Only certain dependent variables were tested against certain independent variables. We made judgements on the "cause-effect" relationships between the dependent and the independent variables. For example, it was appropriate to estimate Depot Maintenance Per Primary Authorized Aircraft (Depot $/PAA) as caused by Organic and Contract Depot Manhours Per Flying Hour. However, it would not be appropriate to estimate the same Depot $/PAA as caused by Base Maintenance Manhours Per Flying Hour (BMH/FH) since the two variables are associated with different levels (base versus depot) in the maintenance organizational structure.

The following lists the specific combinations of variables which were tested:

Dependent Variable	Independent Variables
Base Maintenance Supplies Per Flying Hour (BMS/FH)	Base Maintenance Manhours Per Flying Hour (BMH/FH)
"	1/Mean Time Between Maintenance Events (1/MTBM)
Replenishment Spares Per Flying Hour (REPLEN $/FH)	Base Maintenance Manhours Per Flying Hour (BMH/FH)
"	Organic & Contract Base & Depot Manhours Per Flying Hour (OCBDMH/FH)
"	1/Mean Time Between Maintenance Events (1/MTBM)
"	Organic Base Depot Maintenance Hours Per Flying Hour (OBDMH/FH)
"	Organic & Contract Depot Manhours Per Flying Hour (OCDMH/FH)
"	Organic Depot Manhours Per Flying Hour (ODMH/FH)
Condemnations Per Flying Hour (COND $/FH)	Base Maintenance Manhours Per Flying Hour (BMH/FH)
"	Organic & Contract Base & Depot Manhours Per Flying Hour (OCBDMH/FH)
"	1/Mean Time Between Maintenance Events (1/MTBM)

(Continued)

Dependent Variable	Independent Variables
Condemnations Per Flying Hour (COND $/FH)	Organic Base Depot Maintenance Hours Per Flying Hour (OBDMH/FH)
"	Organic & Contract Depot Manhours Per Flying Hour (OCDMH/FH)
"	Organic Depot Manhours Per Flying Hour (ODMH/FH)
Depot Costs Per Flying Hour (DEPOT $/FH)	Organic & Contract Depot Manhours Per Flying Hour (OCDMH/FH)
"	1/Mean Time Between Maintenance Events (1/MTBM)
"	Organic Depot Manhours Per Flying Hour (ODMH/FH)
Depot Costs Per PAA (DEPOT $/PAA)	1/Mean Time Between Maintenance Events (1/MTBM)
"	Organic Depot Manhours Per Flying Hour (ODMH/FH)
"	Organic & Contract Depot Manhours Per Flying Hour (OCDMH/FH)
Total Depot Costs Per Flying Hour (TOT DEPOT $/FH)	Organic & Contract Depot Manhours Per Flying Hour (OCDMH/FH)
"	Organic Depot Manhours Per Flying Hour (ODMH/FH)
"	1/Mean Time Between Maintenance Events (1/MTBM)

We employed the use of simple linear regression analysis. Although we may be criticized for being a little too simple in our approach, we wanted to use a method that could achieve proper results, be easily understood, and applied in a fashion which would be workable for budget analysts and programmers. Despite its shortcomings, simple linear regression does provide a statistically usable equation that can be easily applied and understood.

Our key statistics for testing the validity of each equation were:

Coefficient of Determinmation (r^2)

Standard Error of the Estimate (SEE)

Significance (or confidence) of slope through use of of t-test to determine if slope significantly different than zero.

DATA/DATA SOURCES

First we will discuss and define the cost variables that were used in the analysis followed by the R&M variables. A matrix of all the variables and the sources for their values is shown in Table A. The actual values for all the variables are contained in Table B.

The cost variables and their definitions are identical to the logistics cost factors contained in AFR 173-13, with the exception of condemnation spares costs and total depot costs. The logic for including these additional two will be explained later. The cost variables are:

a) Replenishment Spares cost per flying hour (Replen $/FH). This is the cost to procure high cost repairable items which are purchased under Budget Program 1500 of Appropriation 3010.

b) Condemnation Spares cost per flying hour (Cond $/FH). This is the cost associated with those replenishment spares which are bought to replace those items which are condemned. They do not include spares bought for a repair pipeline or management reserve. Cond $/FH was added to perform analysis on a subset of Replen $/FH which should be related to R&M.

c) Base Maintenance Supplies cost per flying hour (BMS $/FH). This is the cost of all maintenance supply expenses at the base level. The costs include expendable supplies directly associated with the flying mission (i.e. nuts, bolts, small tools, ground fuel etc.).

d) Depot Maintenance cost per flying hour (Depot $/FH). These are the costs of all organic and contract elements of expenditures incurred to inspect, repair, overhaul, and perform other maintenance on an aircraft. It includes Interim Contractor Support (ICS).

e) Depot Maintenance cost per Primary Authorized Aircraft (Depot $/PAA). The definition is identical to Depot $/FH, but it also includes Class IV Modification Installation costs. Depot $/PAA are those depot maintenance costs that are assumed to be calendar time driven in the data source, while Depot $/FH are those depot maintenance costs assumed to be totally flying hour driven. Depot $/PAA are in thousands of dollars.

f) Total Depot Maintenance cost per flying hour (Tot Depot $/FH). This cost variable is derived by converting Depot $/PAA to a cost per flying hour and adding it to Depot $/FH. The reason for this adjustment is because all of the R&M variables are stated in terms of flying hours only.

Our choice of R&M variables was limited to what was available in existing data systems. There was no real choice in data sources. We are defining reliability as frequency of failure/maintenance; and maintainability as how many manhours to repair/maintenance a system. The R&M variables are:

a) 1/Mean Time Between Maintenance Events (1/MTBM). This is the reciprocal of Mean Time Between Maintenance. MTBM is the number of flying hours divided by the number of maintenance events. Maintenance events include inherent, induced, and "cannot duplicate" defects.

b) Base Manhours per flying hour (BMH/FH). This is the number of manhours expended at the organizational and intermediate levels. They include both on and off-equipment maintenance.

c) Organic depot manhours per flying hour (ODMH/FH). The number of organic only manhours expended for depot level maintenance.

d) Organic and Contract Depot manhours per flying hour (OCDMH/FH). The same as ODMH/FH but it includes an estimate of contract manhours. The data source tracks organic manhours only. Since contract dollars are separately identified, we estimated what the total manhours (organic plus contract) might be by using the ratio of organic costs to contract costs.

e) Organic Base and Depot manhours per flying hour (OBDMH/FH). This is the sum of BMH/FH and ODMH/FH.

f) Organic and Contract Base/Depot manhours per flying hour (OCBDMH/FH). The sum of BMH/FH and OCDMH/FH.

TABLE A

DATA SOURCES MATRIX

A) R&M VARIABLES

Data Source:	BMH/FH	1/MTBM	ODMH/FH	OCDMH/FH	OBDMH/FH	OCBDMH/FH
Maintenance Data Collection System (D056)	X	X			X	X
Weapon System Cost Retrieval Sys (H036)			X	X	X	X
History of USAF Flying Hours (AVSURS)	X	X	X	X	X	X

B) COST VARIABLES

Data Source:	Replen$/fh	Cond$/fh	BMS$/fh	Depot$/fh	Depot$/paa	TotDepot$/fh
AFR 173-13	X		X	X	X	
H036		X		X	X	X
Visibility and Management of Operating and Support Costs			X			
AVSURS	X	X	X	X	X	X
Accounting System for Operations			X			
Maint Cost System			X			
Financial Status of RDT&E And Procurement Report	X					

TABLE B

VARIABLE VALUES

A) R&M VARIABLES

Aircraft	BMH/FH	1/MTBM	ODMH/FH	OCDMH/FH	OBDMH/FH	OCBDMH/FH
A-10	13.83	.78	1.55	3.82	15.38	17.67
B-52	44.28	4.17	40.39	45.10	84.67	89.38
C-5	65.64	6.25	38.53	51.85	104.17	117.49
C-130	20.44	1.72	7.05	8.78	27.49	29.22
C-135	29.46	2.22	7.44	13.47	36.90	42.93
C-141	22.00	1.96	8.92	10.33	30.92	32.33
F-4	39.15	2.78	17.05	21.16	56.20	60.31
F-15	33.29	2.22	12.25	20.78	45.54	54.07
F-16	21.21	1.33	4.25	17.49	25.46	38.70
F/FB-111	49.14	4.00	26.63	33.56	75.77	82.70
T-37	6.01	.49	.37	.88	6.38	6.89
T-38	11.85	.72	.77	1.91	12.62	13.76

B) COST VARIABLES

Aircraft	Replen$/fh	Cond$/fh	BMS$/fh	Depot$/fh	Depot$/paa	Tot Depot$/fh
A-10	287	42	188	149	18	208
B-52	504	635	572	916	365	1829
C-5	1800	938	777	1322	503	2106
C-130	112	90	248	266	93	422
C-135	123	307	309	361	94	640
C-141	78	131	252	217	249	445
F-4	195	194	492	467	132	1013
F-15	870	435	465	795	55	1036
F-16	218	219	337	519	65	828
F/FB-111	1499	849	668	1353	99	1774
T-37	23	21	63	25	5	36
T-38	51	63	153	52	13	79

RESULTS

Exhibts E-1 through E-29 display the results of our regression analysis. Contained in these exhibts are:

1) the key regression statistics
2) a rank order of the regression results for each pair of cost/ R&M variables from best to worst
3) a plot of the computed regression lines versus the actual data points
4) the equation of each regression line

The exhibits themselves tell the story of our findings. Overall, our analysis clearly shows a direct relationship between the various R&M variables and the different cost variables. Our best results were with BMS $/FH and Tot Depot $/FH. Our worst results were with Replen $/FH, but even here there is evidence of a relationship with R&M.

The equations of the regression lines provide us with a set of useable CERs. They can be used to compute cost deltas due to R&M improvements, and would be helpful in estimating the logistics support costs for a new aircraft with a projected R&M level. Having more than one CER for each cost element would also be useful as cross-checks.

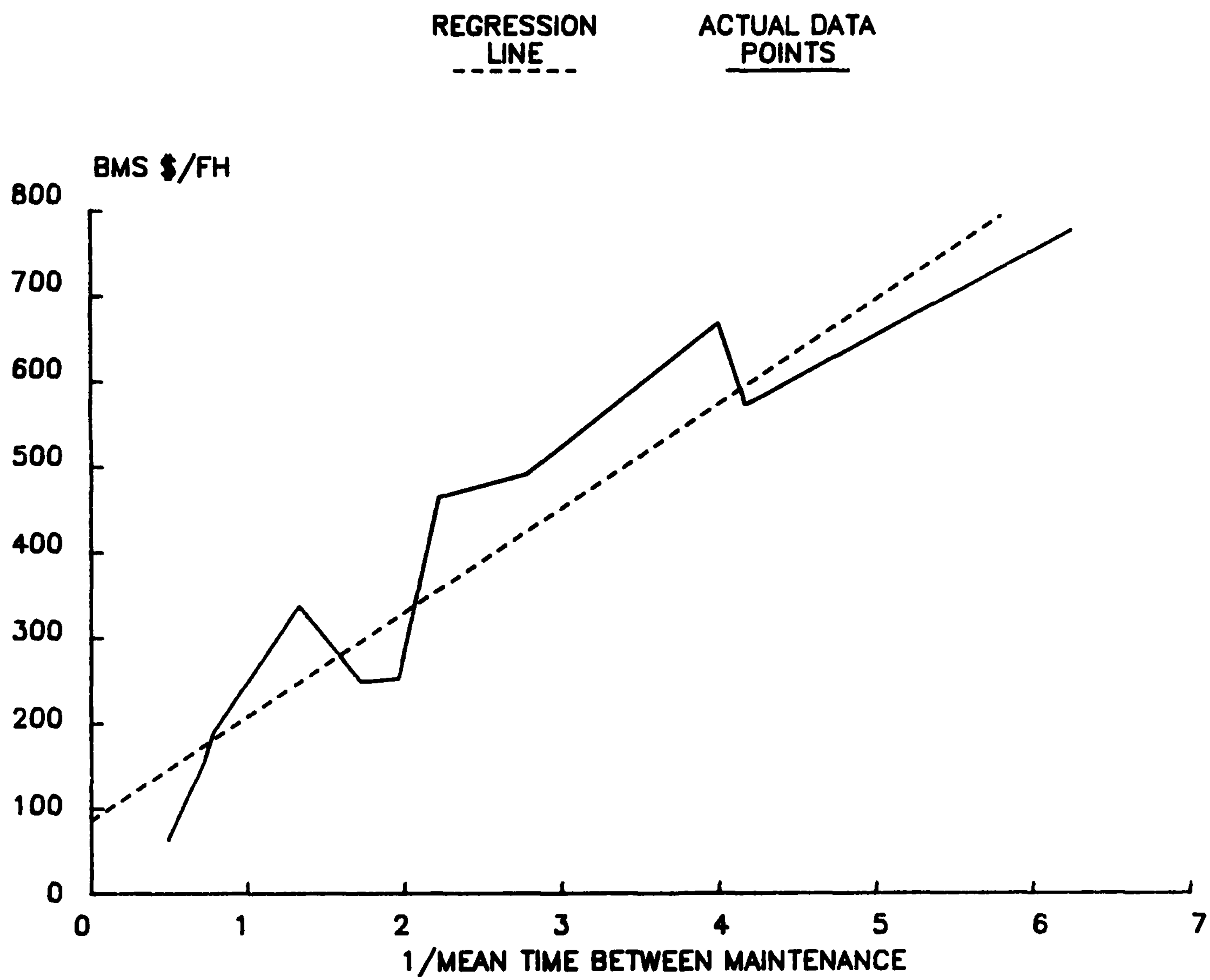
REGRESSION RESULTS

DEPENDENT VARIABLE = BMS $/FH

INDEPENDENT VARIABLE	R SQUARE	STD ERROR OF ESTIMATE	CONFIDENCE ON SLOPE
BMH/FH	.97	41	99.9%
1/MTBM	.89	75	99.9%

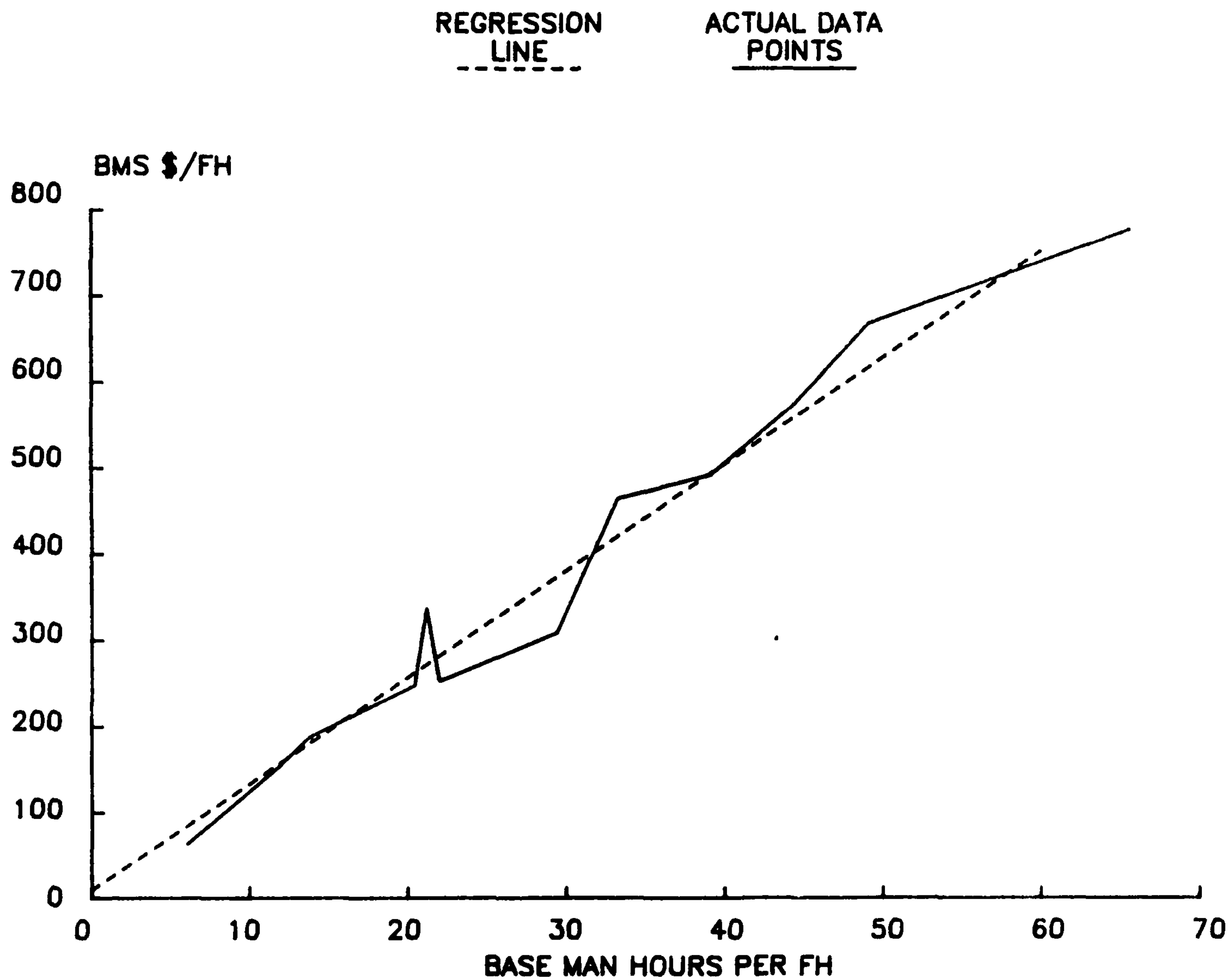
REGRESSION RESULTS

$$BMS\ \$/FH = 85.7375 + (122.0374 \times 1/MTBM)$$



REGRESSION RESULTS

BMS $/FH = 9.7483 + (12.3688 x BMH/FH)



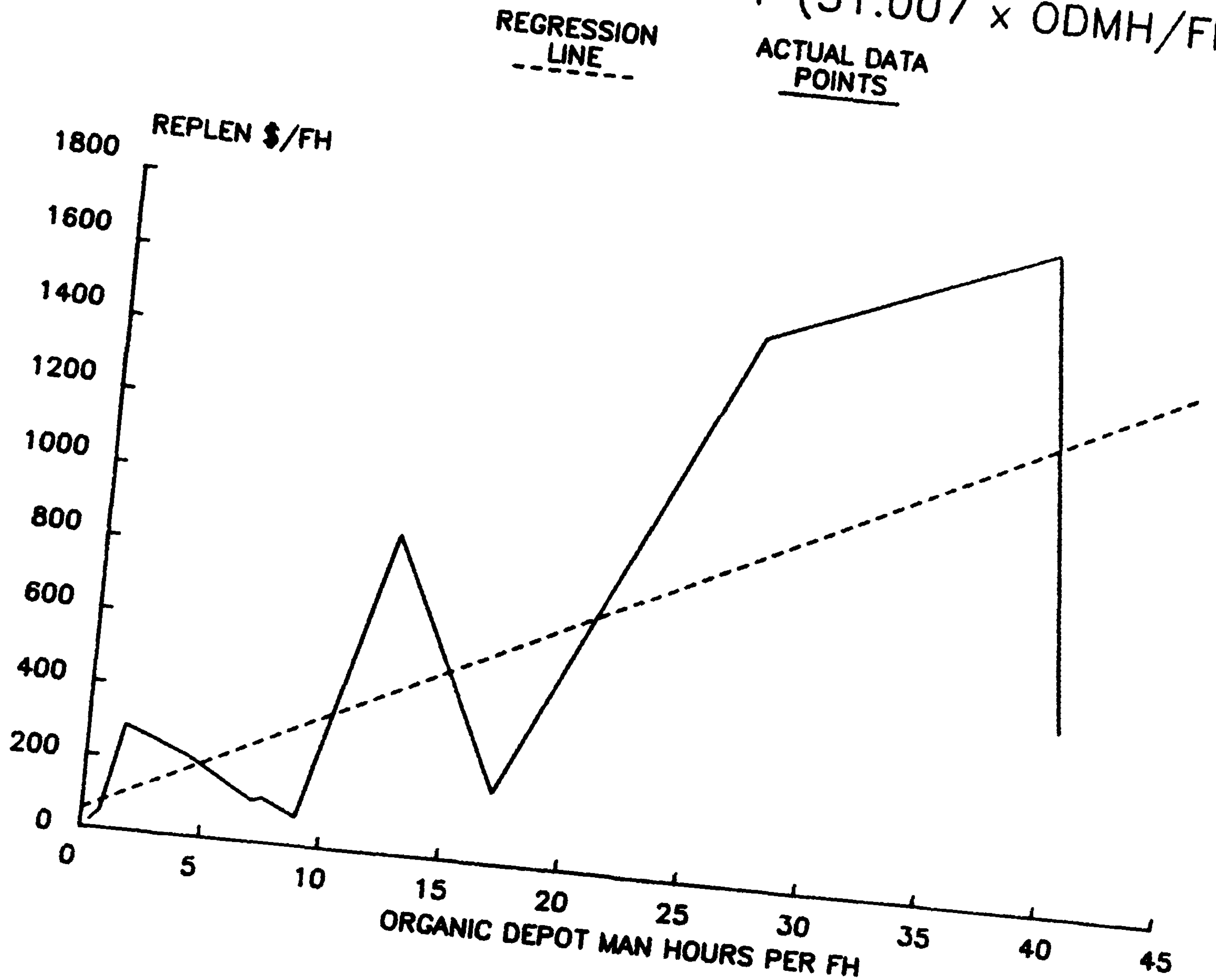
REGRESSION RESULTS

DEPENDENT VARIABLE = REPLEN $/FH

INDEPENDENT VARIABLE	R SQUARE	STD ERROR OF ESTIMATE	CONFIDENCE ON SLOPE
BMH/FH	.71	337	99.4%
OCBDMH/FH	.69	349	99.8%
1/MTBM	.69	351	99.8%
OBDMH/FH	.66	367	99.8%
OCDMH/FH	.63	380	99.8%
ODMH/FH	.54	427	99.3%

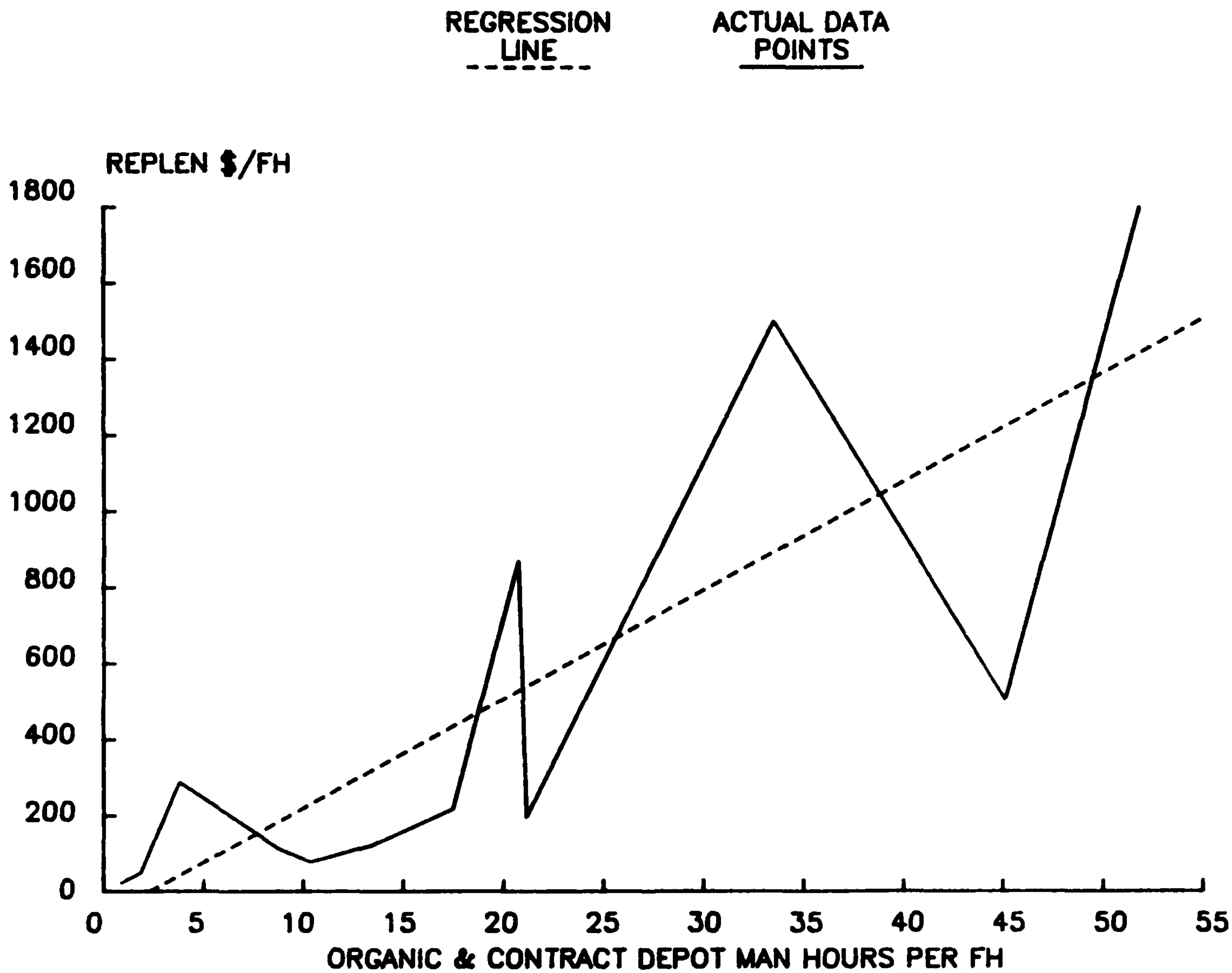
REGRESSION RESULTS

REPLEN $/FH = 53.1367 + (31.007 x ODMH/FH)



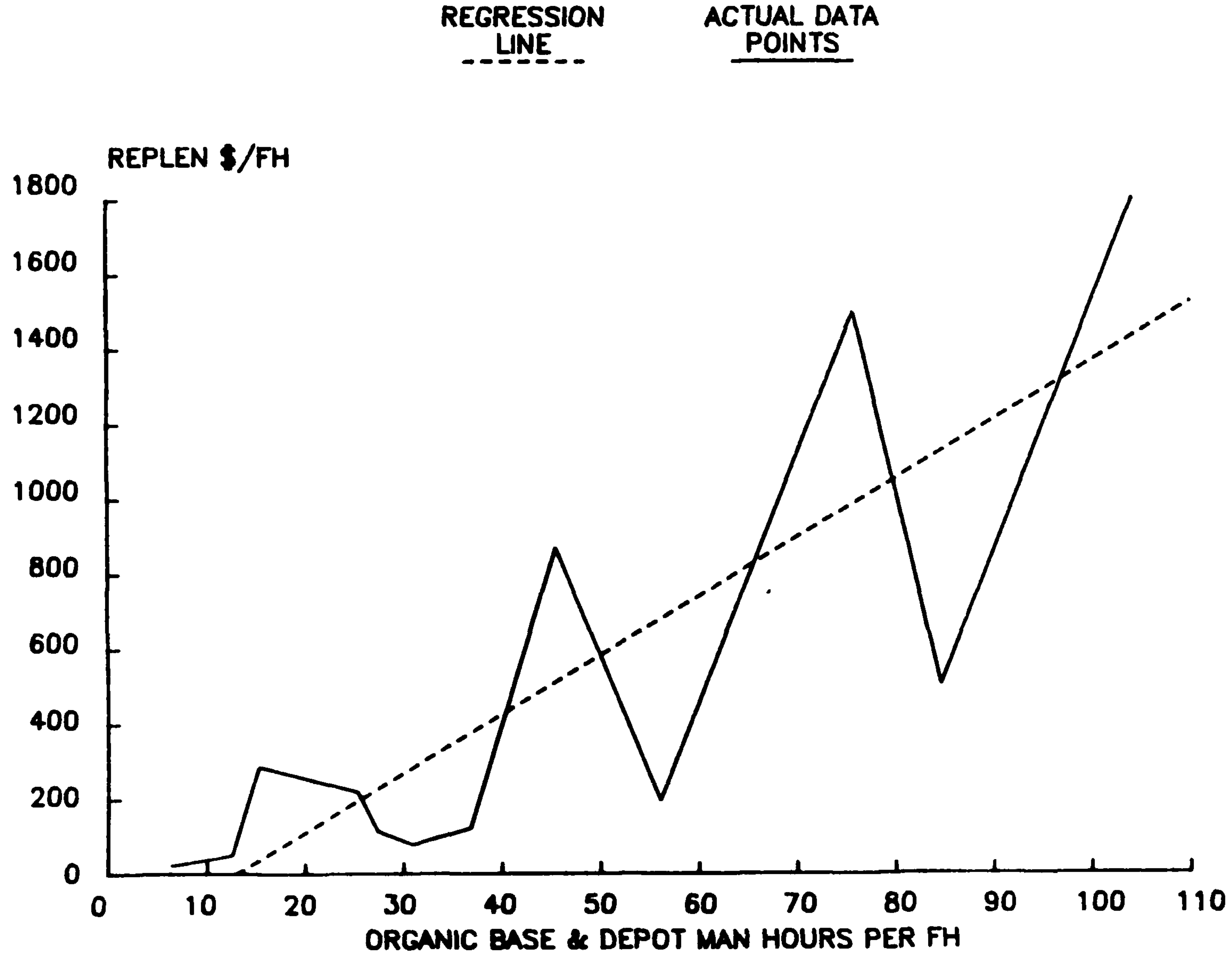
REGRESSION RESULTS

REPLEN \$/FH = −66.2291 + (28.6071 x OCDMH/FH)



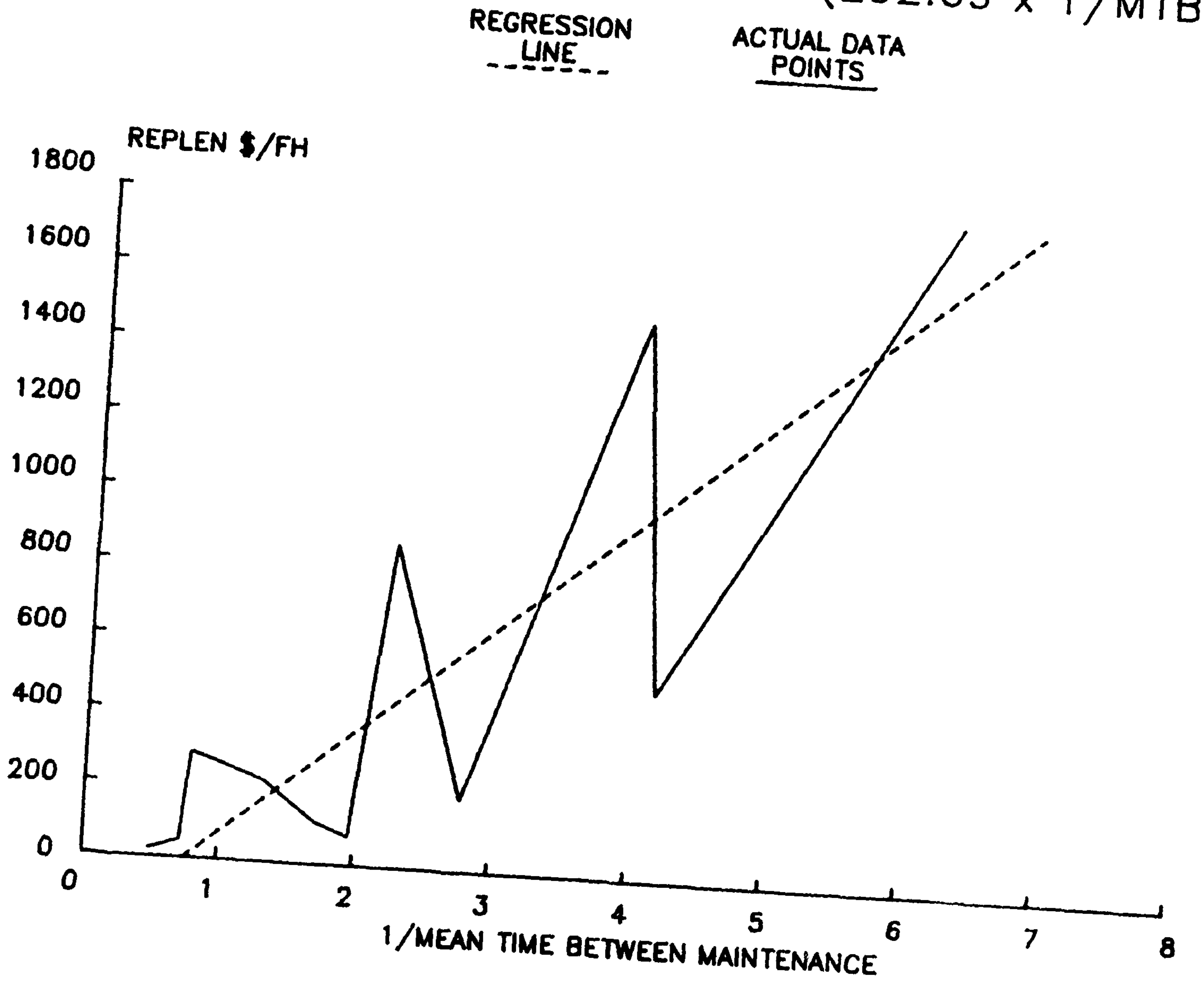
REGRESSION RESULTS

REPLEN $/FH = −202.8516 + (15.713 x OBDMH/FH)



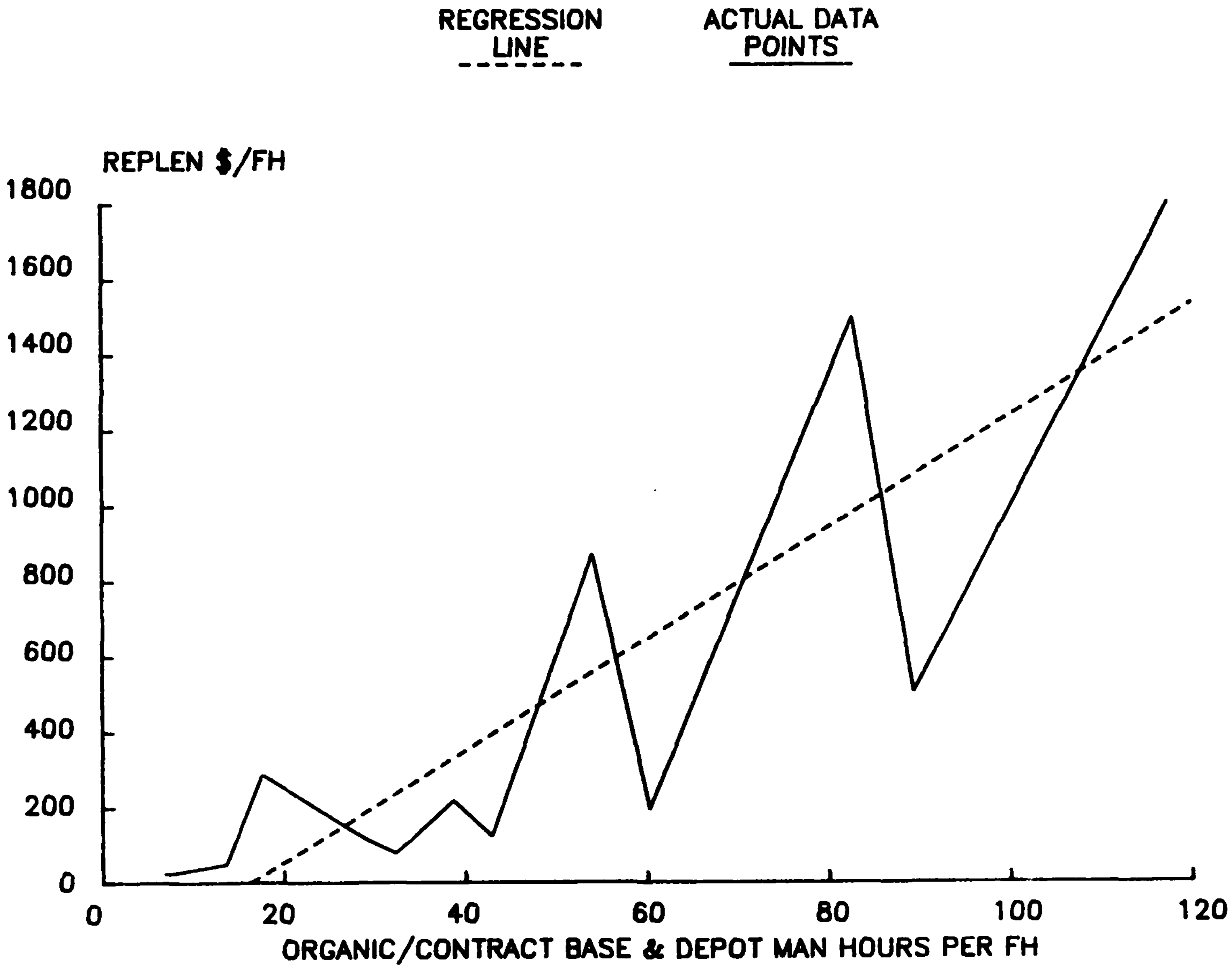
REGRESSION RESULTS

REPLEN \$/FH = −218.5534 + (292.69 x 1/MTBM)



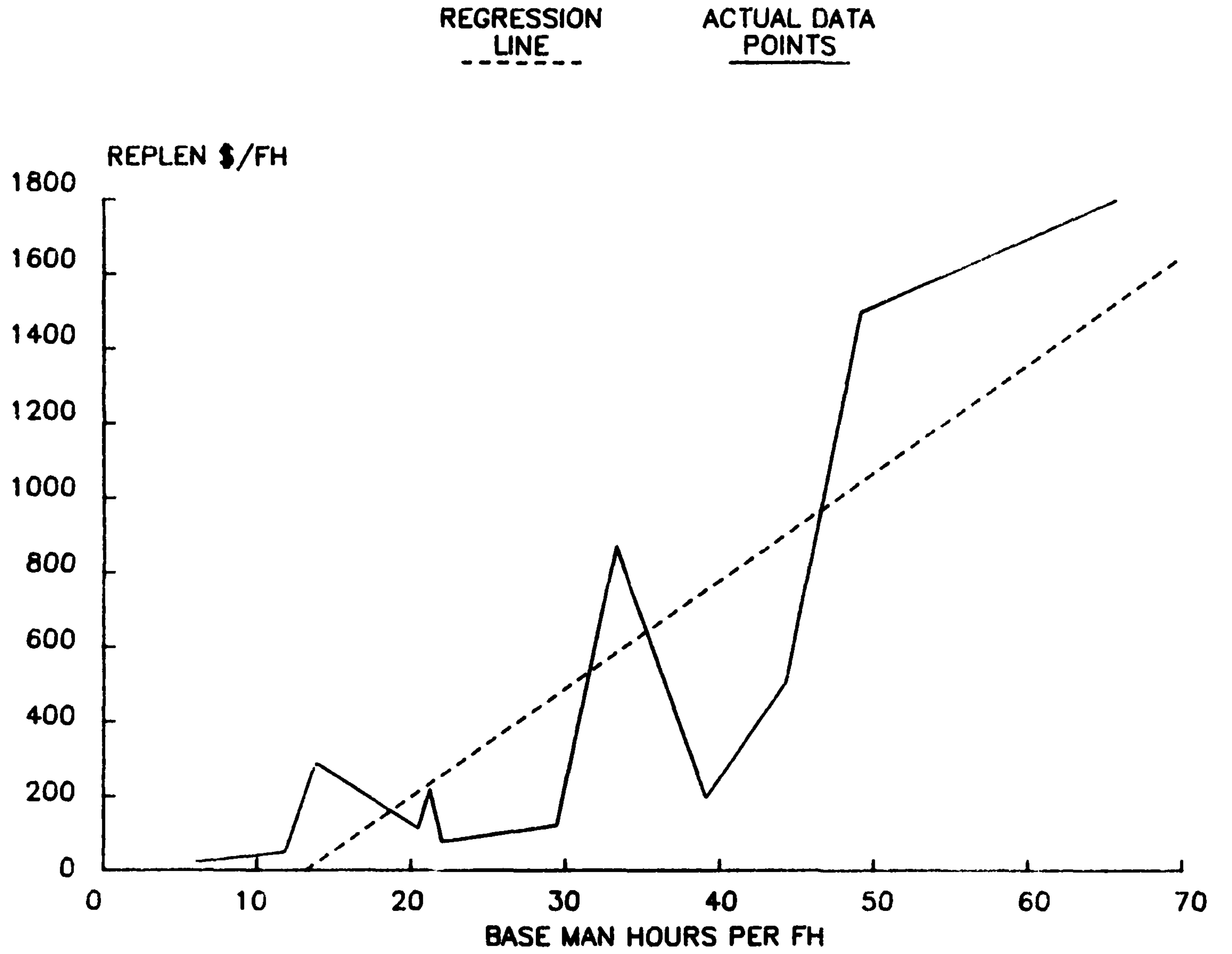
REGRESSION RESULTS

$$\text{REPLEN \$/FH} = -241.759 + (14.794 \times \text{OCBDMH/FH})$$



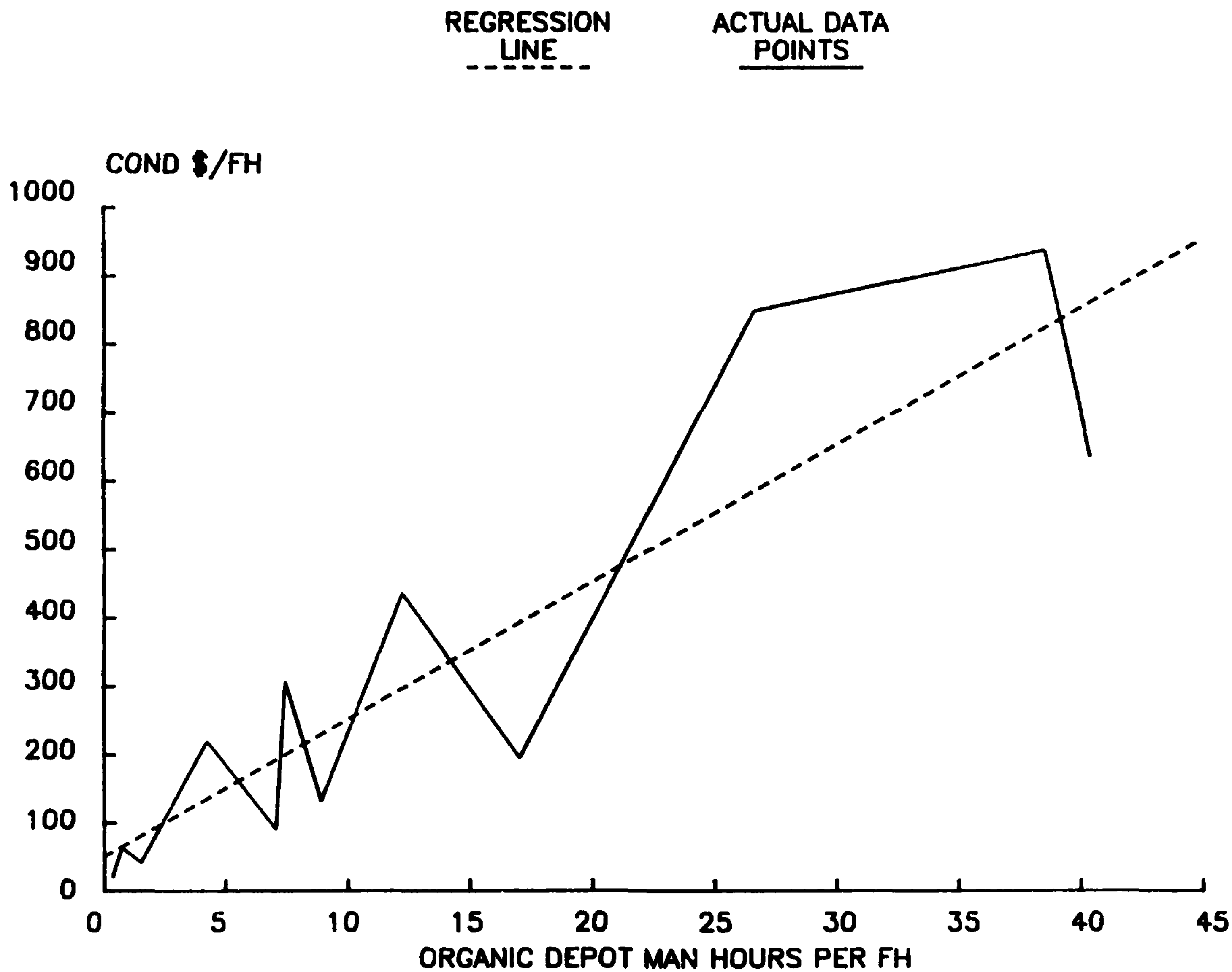
REGRESSION RESULTS

REPLEN \$/FH = −381.0866 + (29.0010 x BMH/FH)



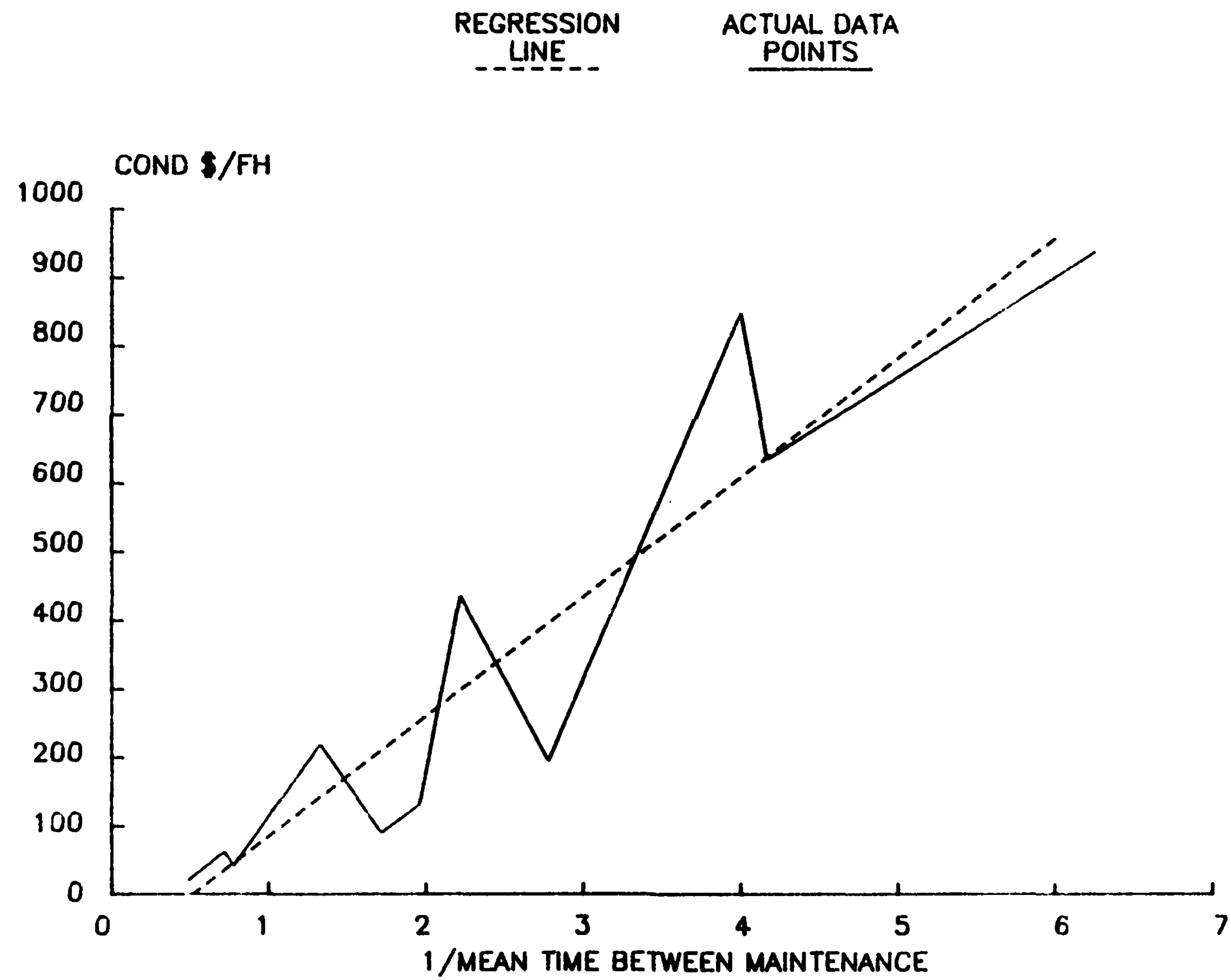
REGRESSION RESULTS

COND \$/FH = 50.3826 + (20.0933 x ODMH/FH)



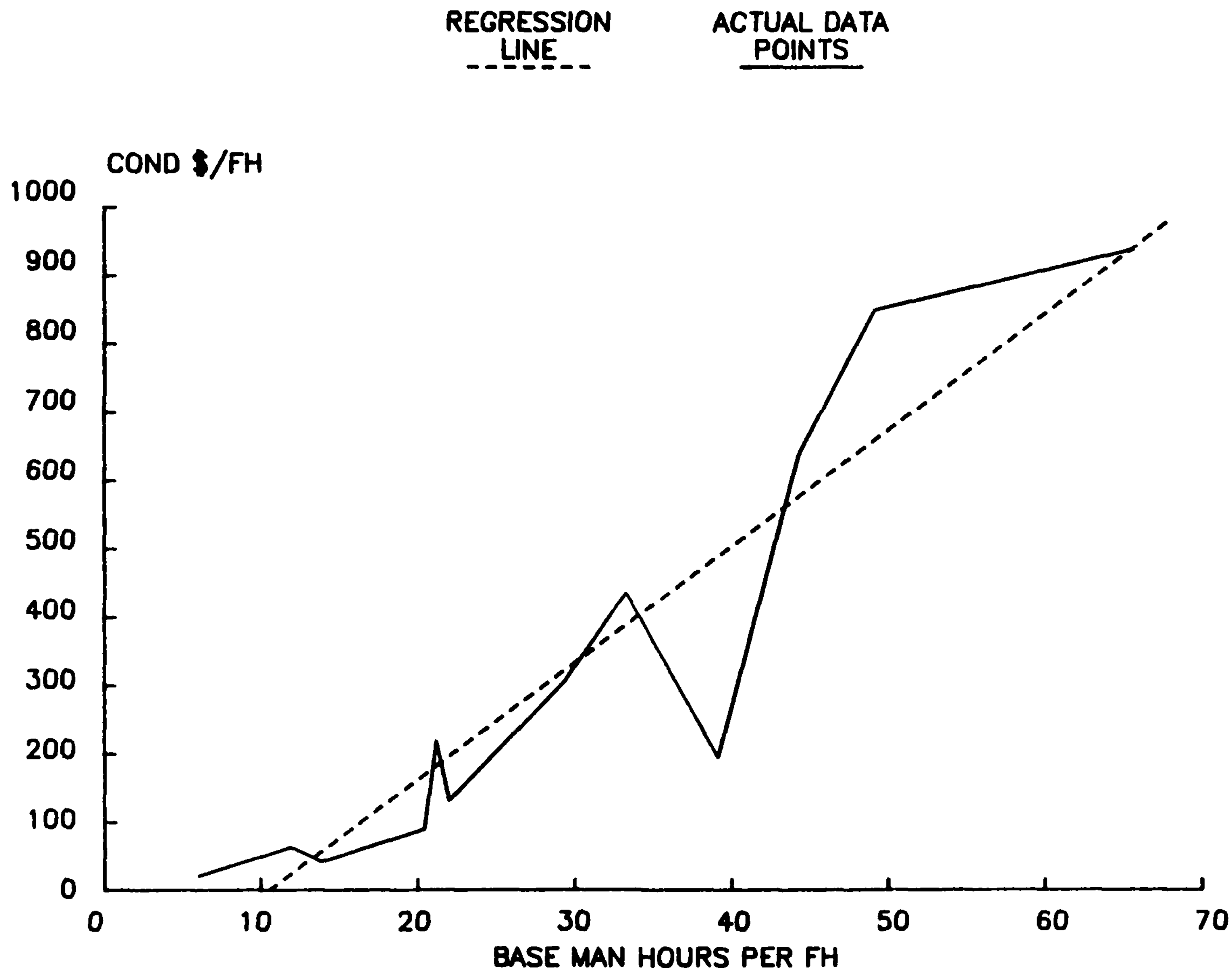
REGRESSION RESULTS

COND \$/FH = −89.5928 + (174.55 x 1/MTBM)



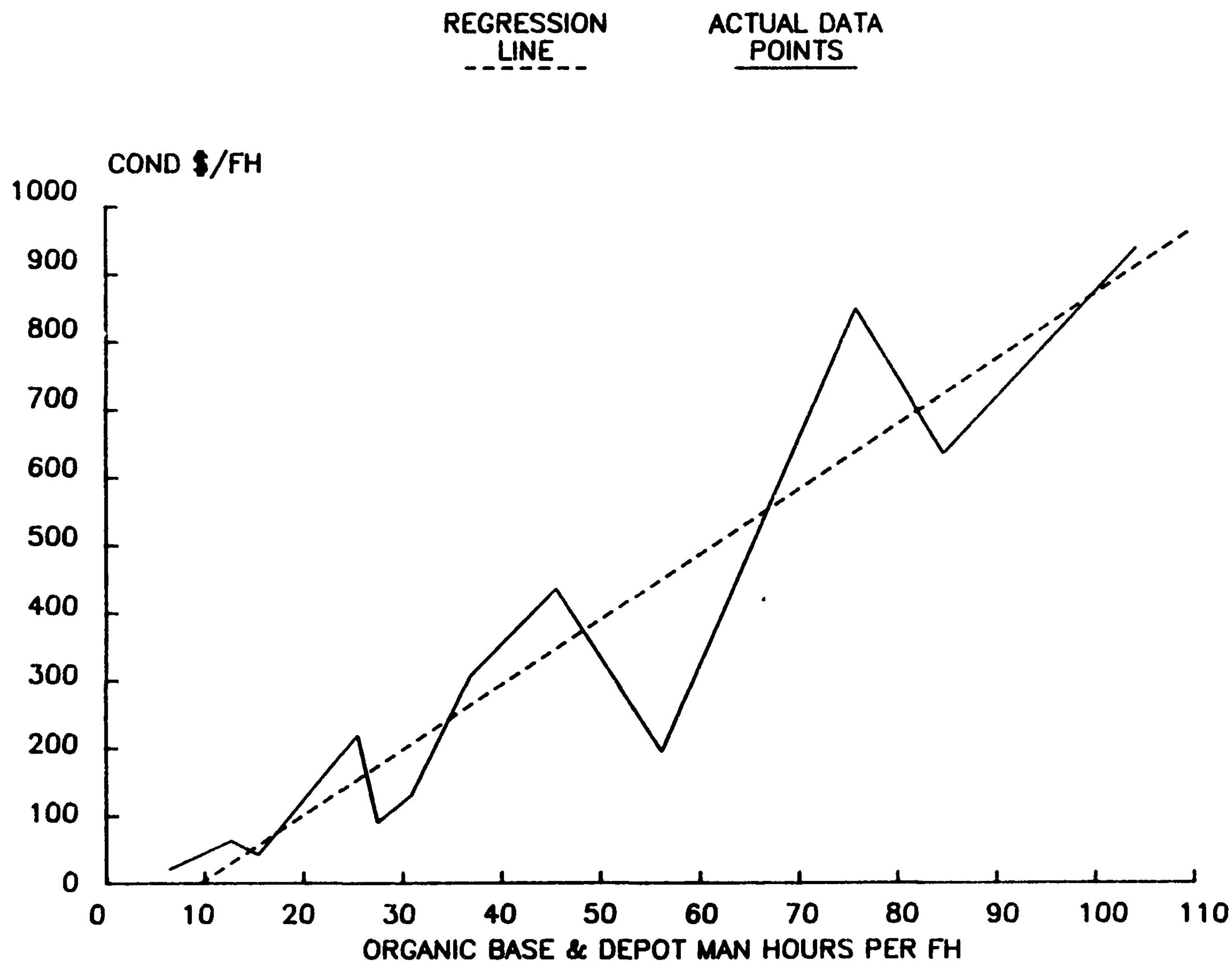
REGRESSION RESULTS

$$\text{COND \$/FH} = -179.3045 + (17.0521 \times \text{BMH/FH})$$



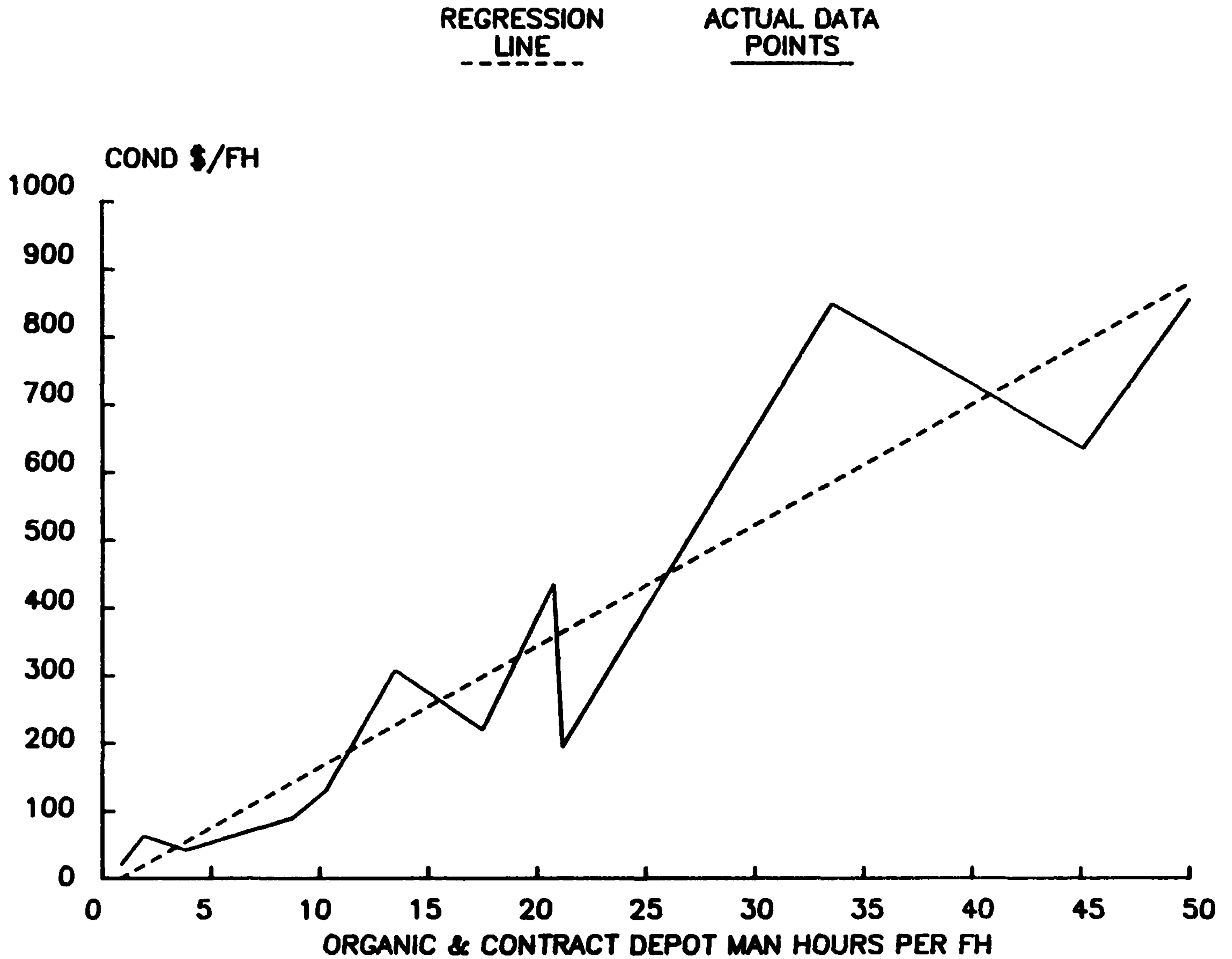
REGRESSION RESULTS

COND \$/FH = −91.455 + (9.6289 x OBDMH/FH)



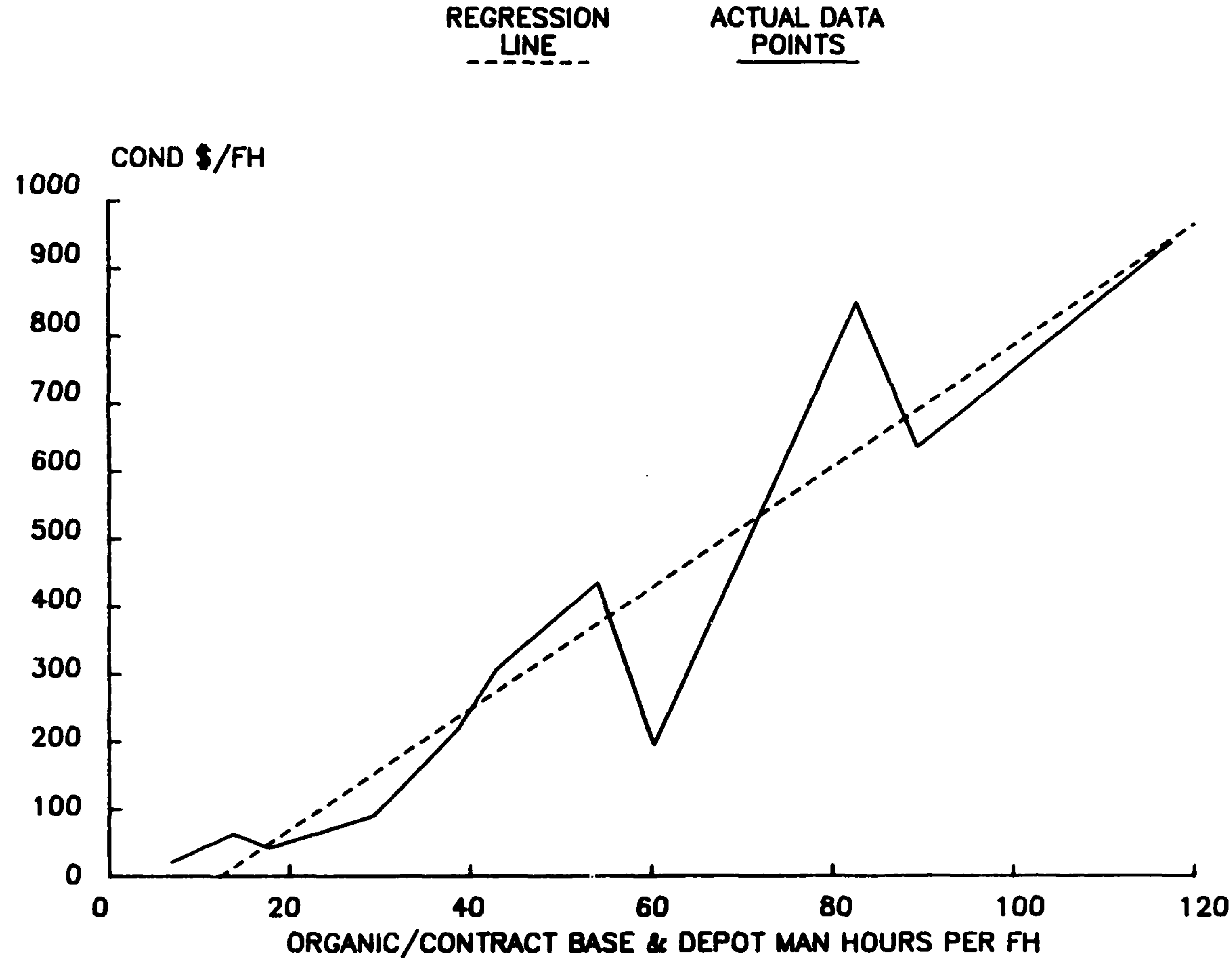
REGRESSION RESULTS

COND \$/FH = −14.2654 + (17.8728 x OCDMH/FH)



REGRESSION RESULTS

$$\text{COND \$/FH} = -109.949 + (8.956 \times \text{OCBDMH/FH})$$



REGRESSION RESULTS

DEPENDENT VARIABLE = COND $/FH

INDEPENDENT VARIABLE	R SQUARE	STD ERROR OF ESTIMATE	CONFIDENCE ON SLOPE
OCBDMH/FH	.89	112	99.9%
OCDMH/FH	.87	122	99.9%
OBDMH/FH	.87	122	99.9%
BMH/FH	.86	123	99.9%
1/MTBM	.86	126	99.9%
ODMH/FH	.79	153	99.9%

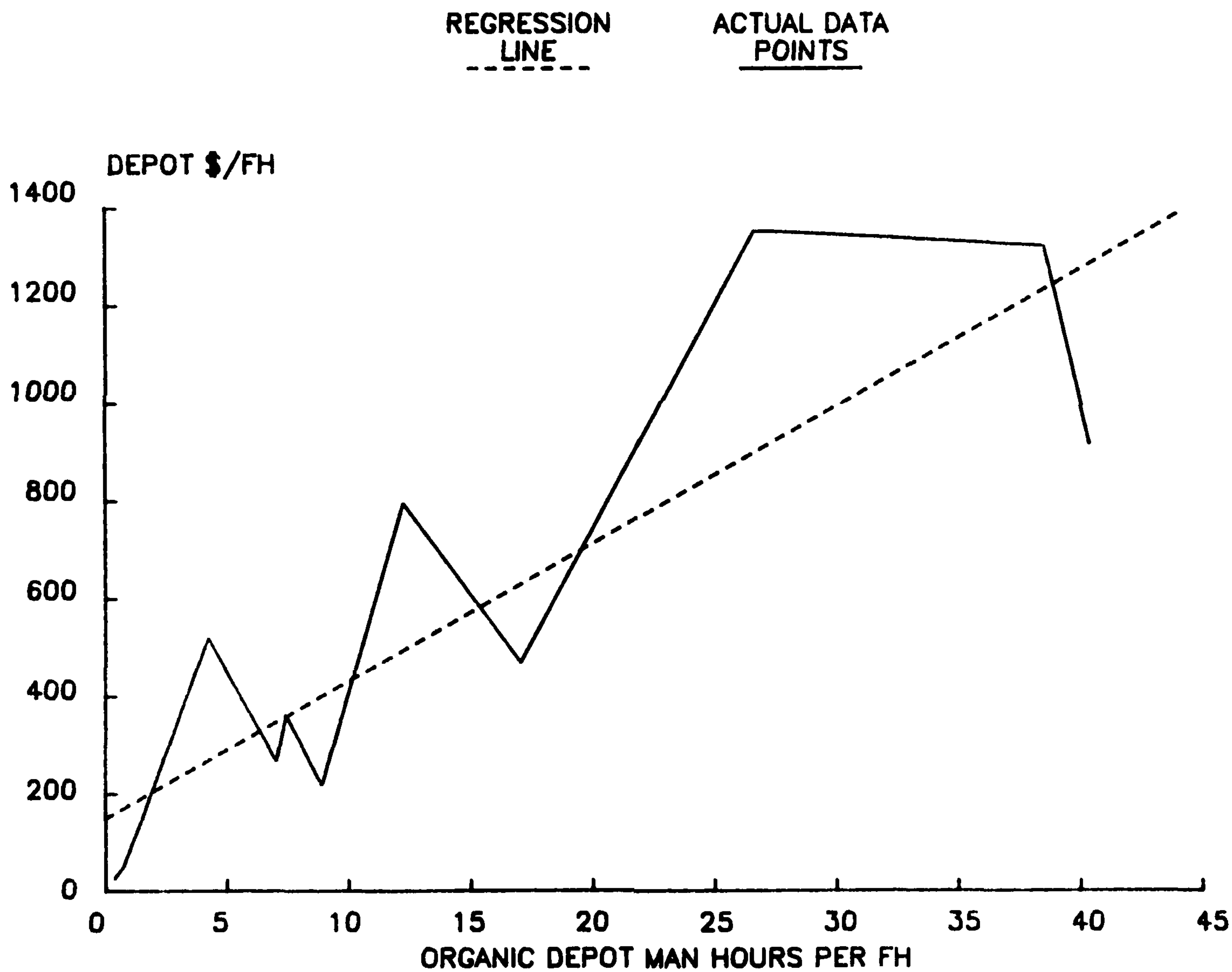
REGRESSION RESULTS

DEPENDENT VARIABLE = DEPOT $/FH

INDEPENDENT VARIABLE	R SQUARE	STD ERROR OF ESTIMATE	CONFIDENCE ON SLOPE
OCDMH/FH	.85	190	99.9%
1/MTBM	.80	216	99.9%
ODMH/FH	.74	246	99.9%

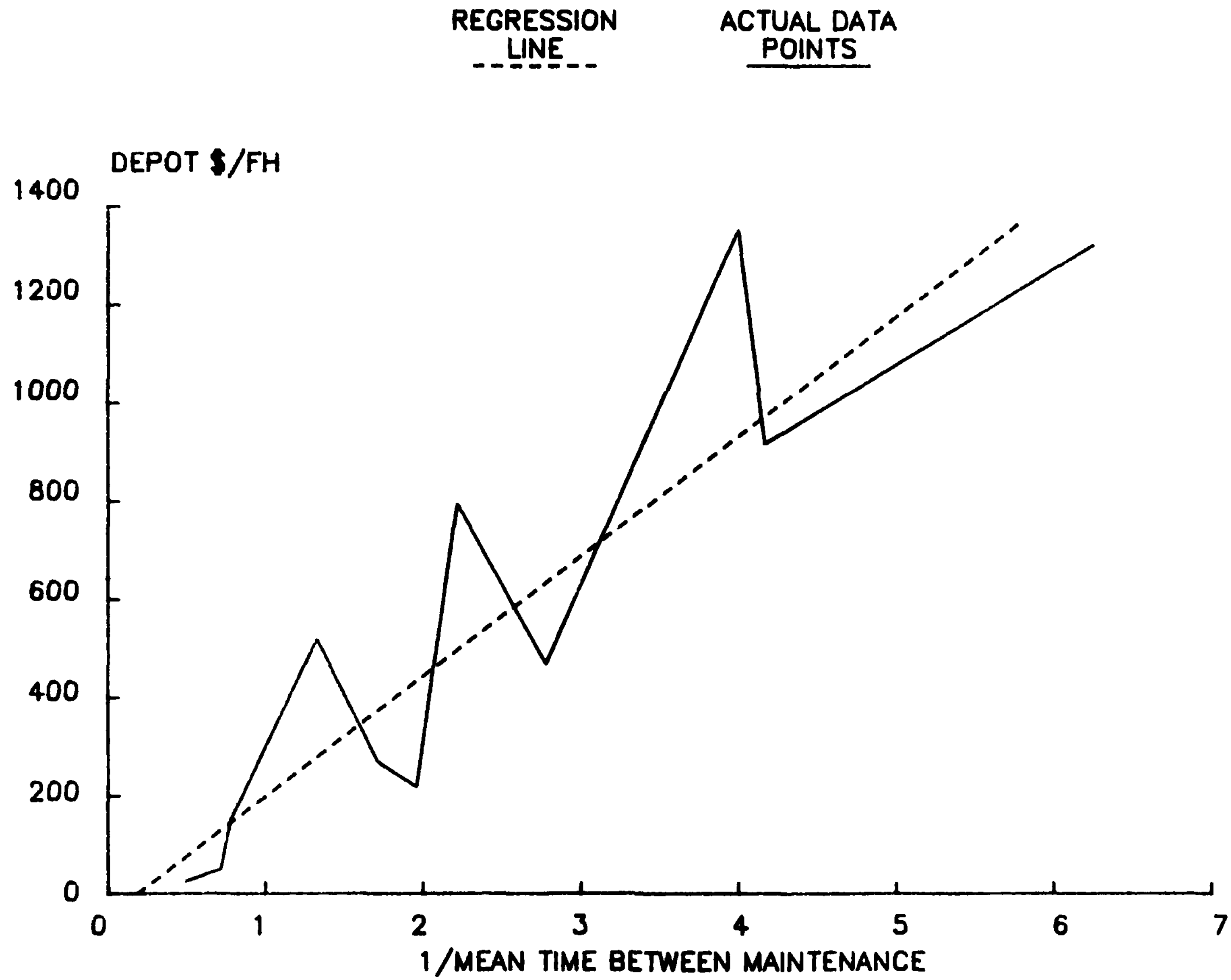
REGRESSION RESULTS

DEPOT $/FH = 148.6344 + (28.1985 + ODMH/FH)



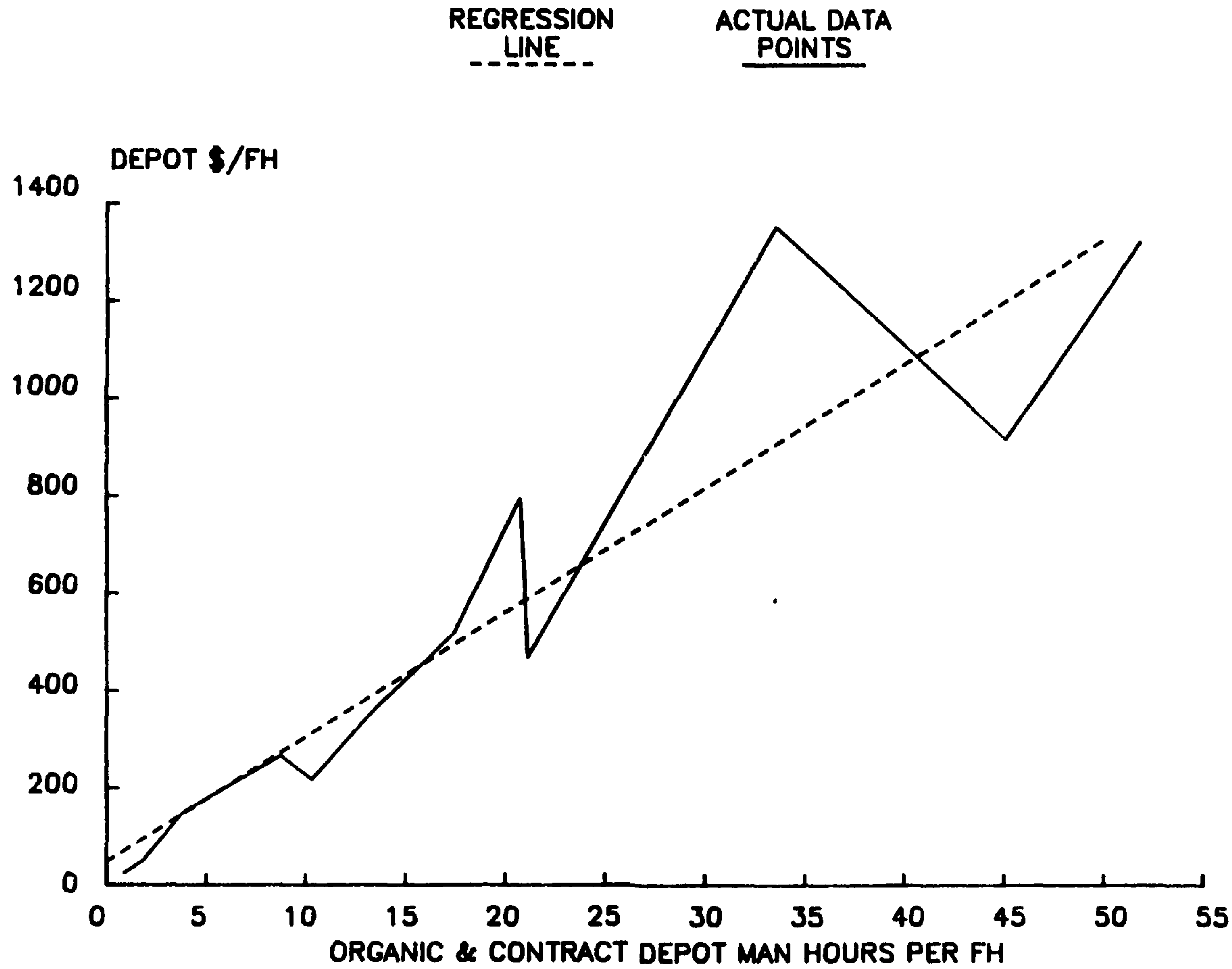
REGRESSION RESULTS

DEPOT $/FH = −46.1215 + (244.2548 x 1/MTBM)



REGRESSION RESULTS

DEPOT $/FH = 48.2827 + (25.5864 x OCDMH/FH)



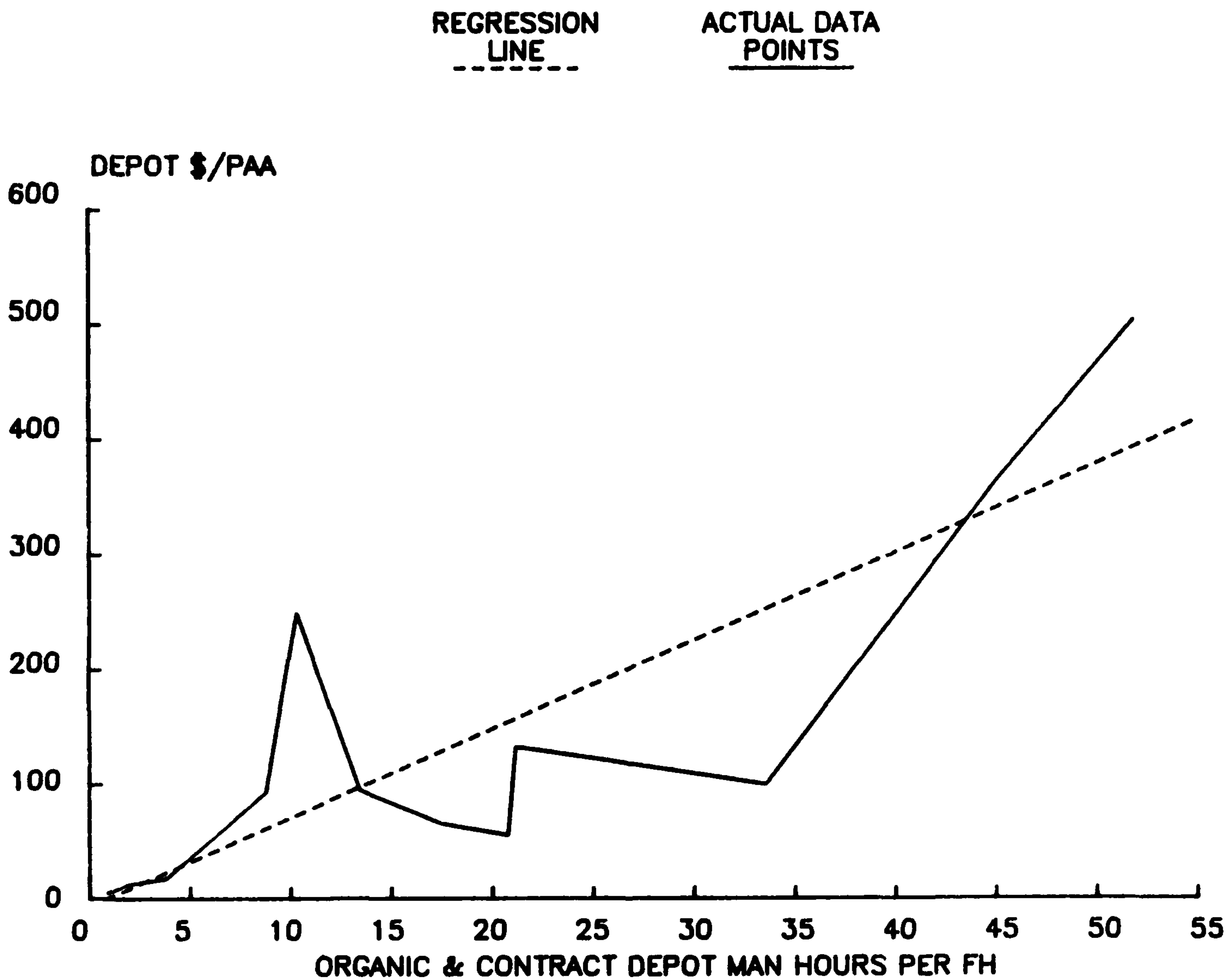
REGRESSION RESULTS

DEPENDENT VARIABLE = DEPOT $/PAA

INDEPENDENT VARIABLE	R SQUARE	STD ERROR OF ESTIMATE	CONFIDENCE ON SLOPE
1/MTBM	.74	82	99.9%
ODMH/FH	.71	87	99.9%
OCDMH/FH	.69	91	99.9%

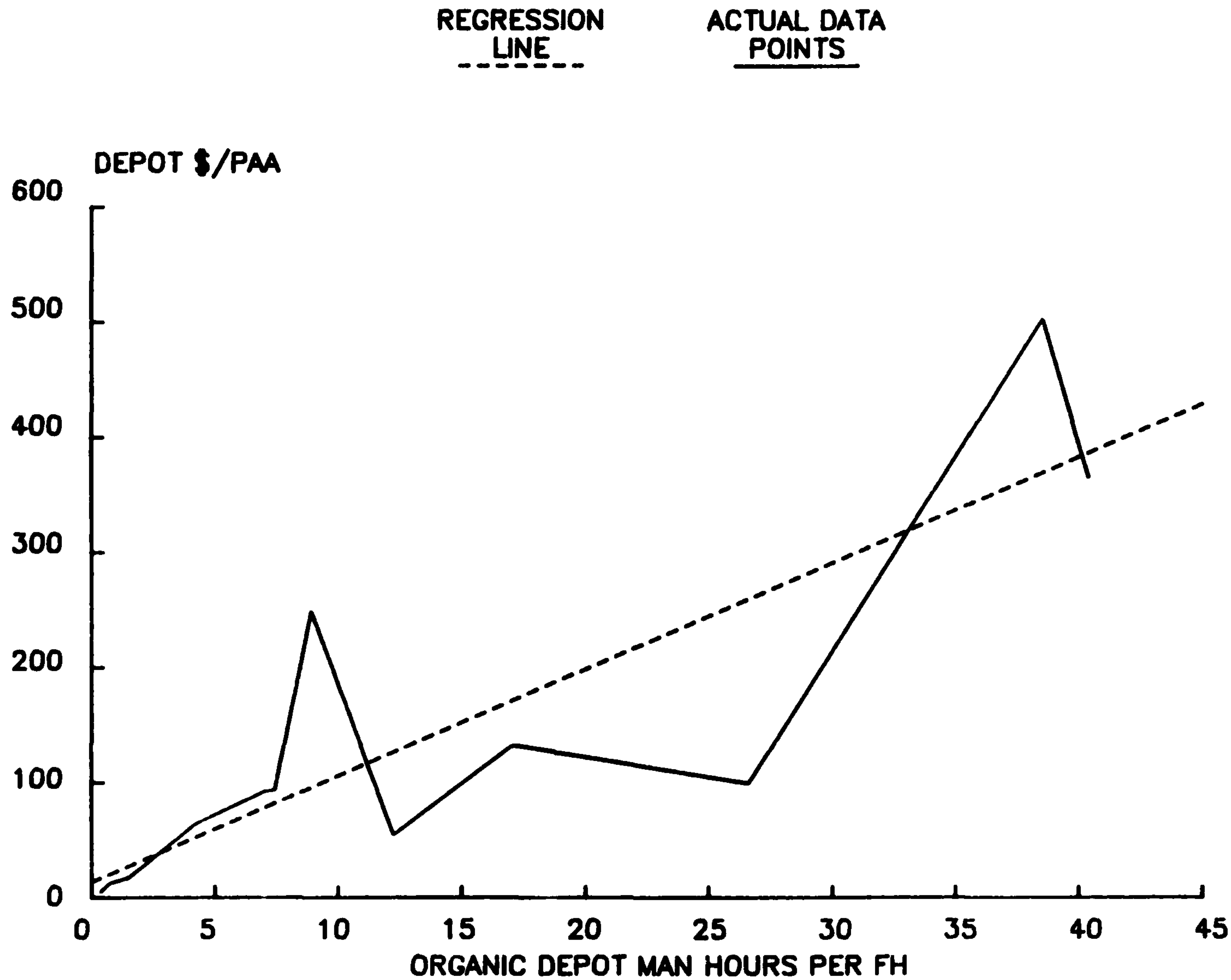
REGRESSION RESULTS

$$\text{DEPOT \$/PAA} = -5.908 + (7.689 \times \text{OCDMH/FH})$$



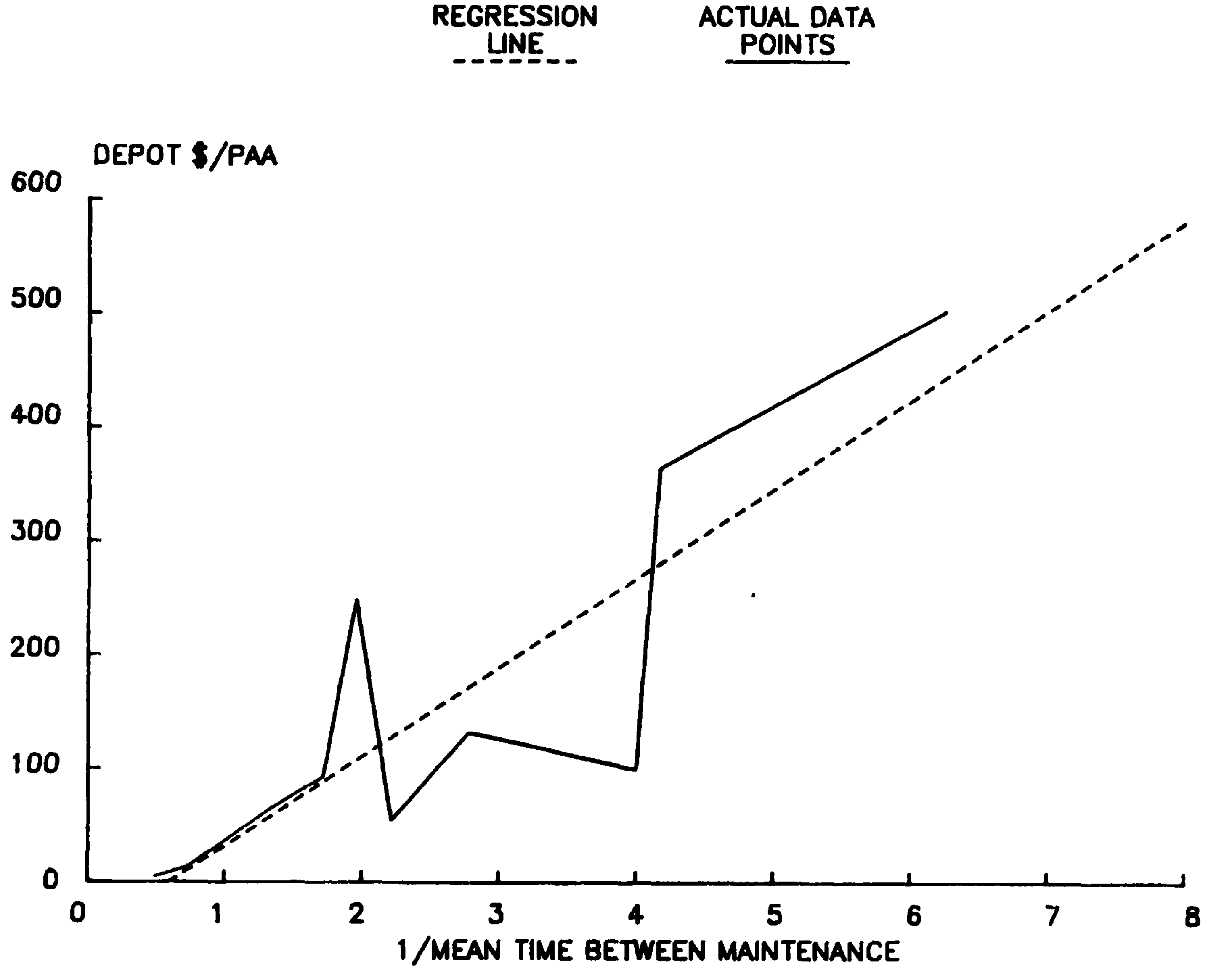
REGRESSION RESULTS

DEPOT $/PAA = 13.7605 + (9.2365 x ODMH/FH)



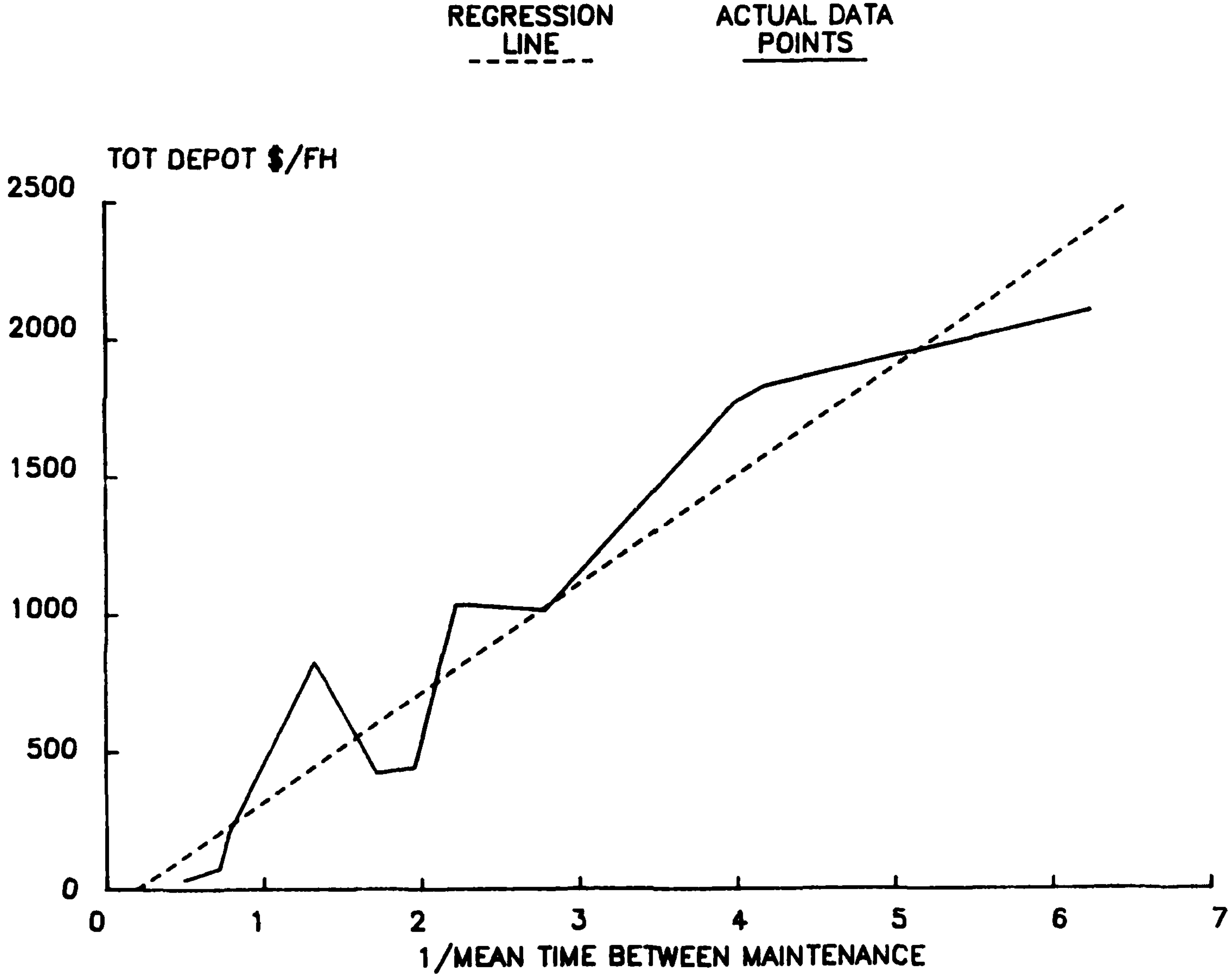
REGRESSION RESULTS

DEPOT \$/PAA = −46.5841 + (78.5618 x 1/MTBM)



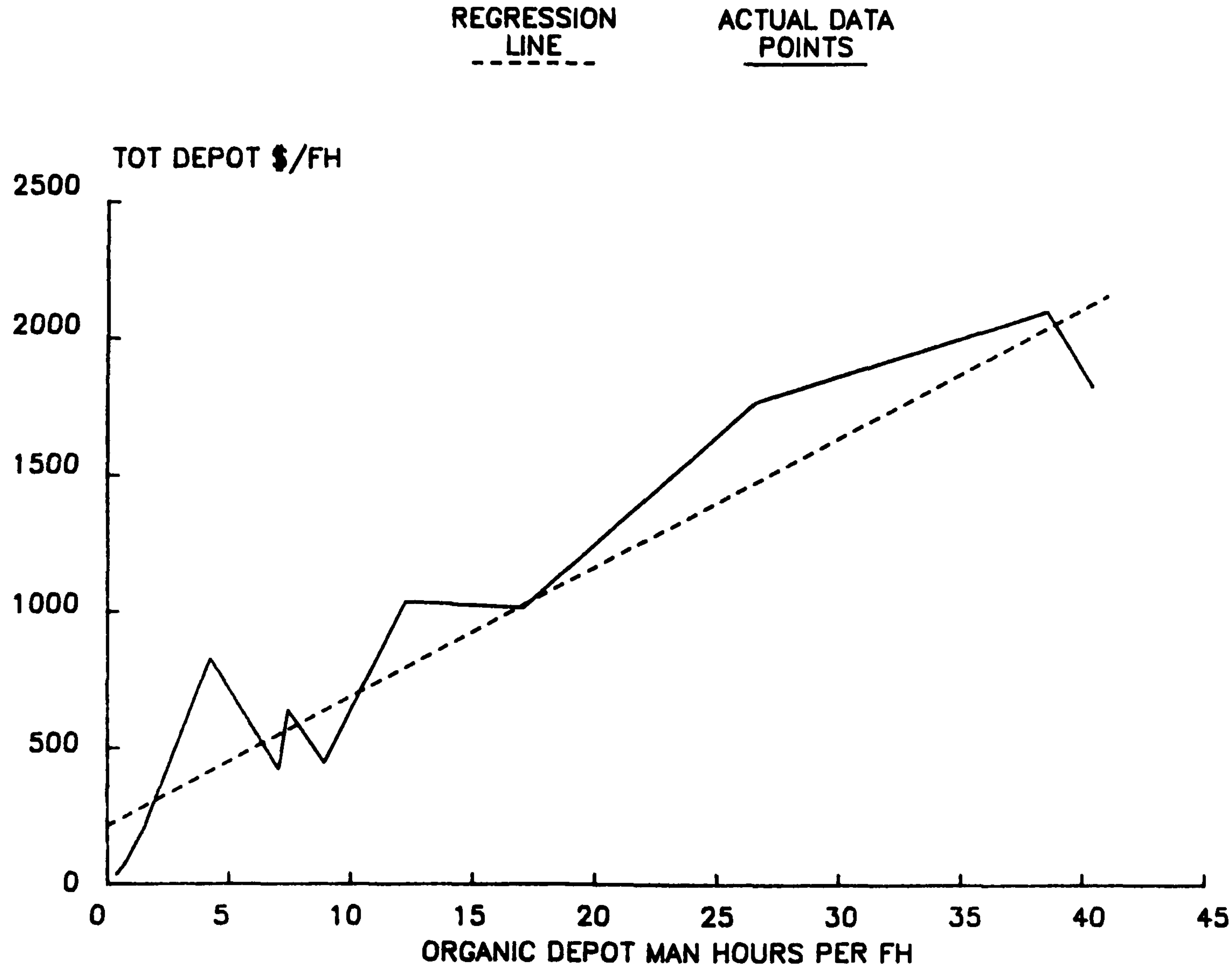
REGRESSION RESULTS

TOT DEPOT \$/FH = −75.457 + (395.303 x 1/MTBM)



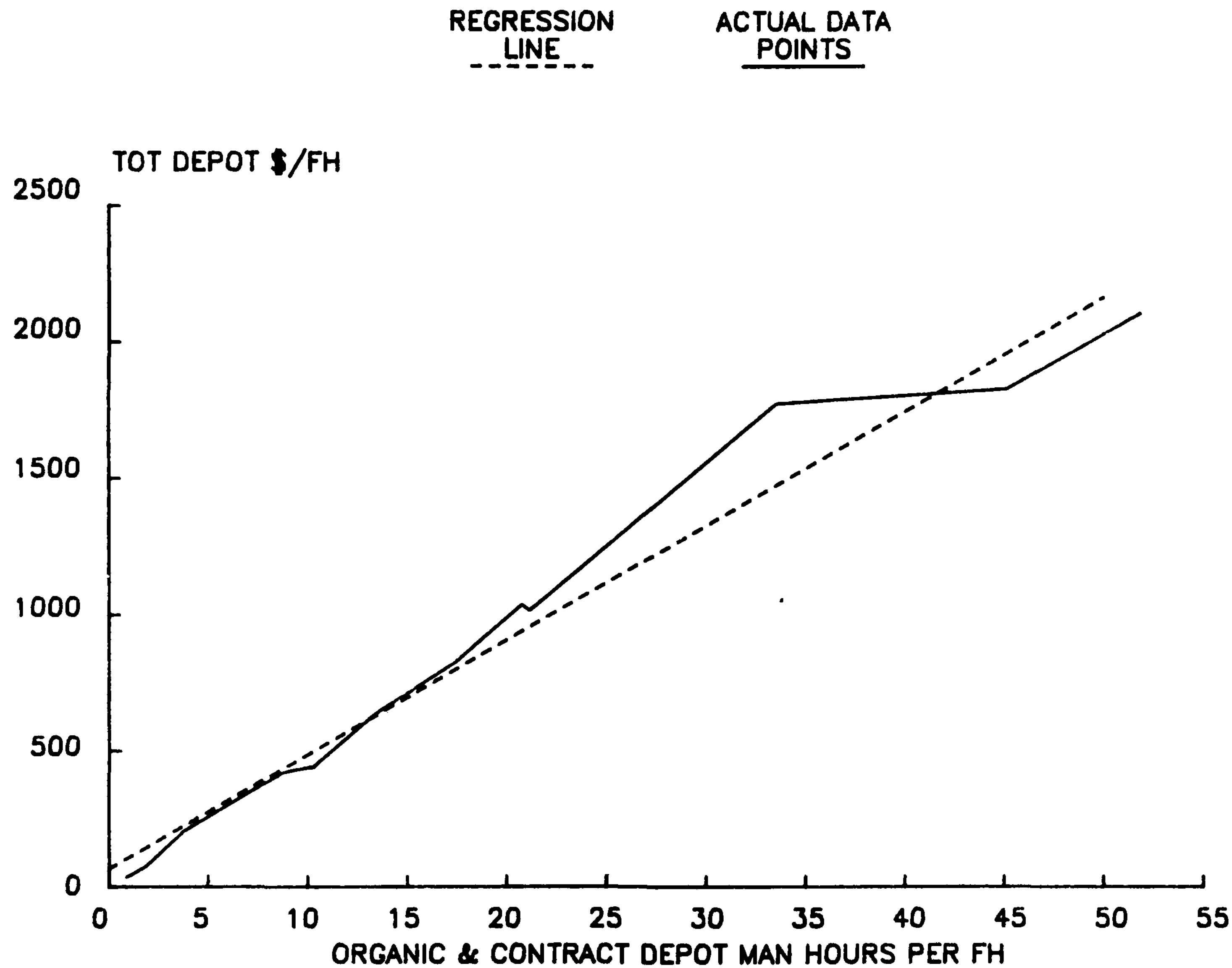
REGRESSION RESULTS

TOT DEPOT $/FH = 213.623 + (47.533 x ODMH/FH)



REGRESSION RESULTS

TOT DEPOT \$/FH = 66.935 + (41.953 x OCDMH/FH)



REGRESSION RESULTS

DEPENDENT VARIABLE = TOTAL DEPOT $/FH

INDEPENDENT VARIABLE	R SQUARE	STD ERROR OF ESTIMATE	CONFIDENCE ON SLOPE
OCDMH/FH	.97	123	99.9%
ODMH/FH	.90	233	99.9%
1/MTBM	.90	238	99.9%

SUMMARY

In conclusion, we have achieved our objectives. We have presented strong evidence that high R&M results in lower logistics support costs, and we have developed CERs which can be used to translate R&M to costs. In addition, it is our hope that other studies pick up where our study has ended. There is certainly much more analysis that can be done. We believe that the key to the practical utility of these or similar CERs is the availability of good, consistent, and reliable R&M data (both actual and forecasted data).

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