INTERIM REPORT

A PAVEMENT MANAGEMENT RESEARCH PROGRAM FOR OREGON HIGHWAYS

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March, 1985

Prepared for:

STATE OF OREGON
DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

in cooperation with

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

Report No. FHWA/OR 85-03

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/OR 85-03	--	--
4. Title and Subtitle A PAVEMENT MANAGEMENT RESEARCH PROGRAM FOR OREGON HIGHWAYS--INTERIM REPORT		5. Report Date March 1985
		6. Performing Organization Code
7. Author(s) Anthony J. George, P.E., Leon G. Brock, P.E. and Gordon W. Beecroft, P.E.		8. Performing Organization Report No. FHWA/OR 85-03
9. Performing Organization Name and Address Research Section Oregon Department of Transportation, Highway Division 1174 Chemeketa Street NE Salem, OR 97310		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. HP&R 085-5153
12. Sponsoring Agency Name and Address Oregon Department of Transportation State Transportation Building Salem, OR 97310		13. Type of Report and Period Covered INTERIM REPORT July, 1979- December, 1984
		14. Sponsoring Agency Code

15. Supplementary Notes

Conducted in cooperation with U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This is the first in a series of reports documenting progress on a statewide pavement management research project. The overall project is conducting research into pavement life cycles of different rehabilitation treatments; the cost-effectiveness of each treatment; and, the use of objective pavement condition data such as roughness, skid resistance, deflection, percent cracks, percent patches, and rut depth in a statewide pavement management system.

This report describes the project history and previous work conducted to date, as well as the scope of work of the present project. A brief discussion of literature review results is provided.

The major emphasis of this report is a description of the pavement deflection data collection program--a statewide effort which monitors more than 1000 test sites once every two years. Data collected for the correlation of Benkelman beam deflection to Dynaflect deflection is analyzed and an equation relating the two is proposed for use in Oregon. Data collected for developing a Dynaflect deflection temperature correction factor (normalized to 70 degrees Fahrenheit) is described.

17. Key Words	18. Distribution Statement
pavement management, deflection monitoring, life-cycle costs, cost-effectiveness analysis, objective pavement rating, Dynaflect, pavement deterioration	No restriction.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		---

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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TABLE OF CONTENTS

ABSTRACT

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1. INTRODUCTION

In the late 1970's, inflating construction costs and declining highway gas tax revenues combined to greatly reduce the amount of money available for highway maintenance and construction. It was in the face of this severe funding shortage that the idea for a pavement management system was first conceived. Although recent increases in the Oregon gas tax and a decline in the inflation rate have moderated this problem somewhat, continued demand for quality transportation facilities requires that transportation agencies make optimum use of every available dollar. Since many alternate strategies can be employed to provide a serviceable roadway, it is important that a highway agency has the ability to differentiate between these strategies and to select the most cost-effective method of providing a high quality roadway over the entire life cyle.

Historically, the treatments used to maintain highways have been based on the judgment of the responsible engineer. While the quality of the Oregon highway system indicates that these judgments have been sound, there has been no method to determine if the given treatment provided optimum benefit, or if treatment of another section would be relatively more beneficial. The collection of necessary research data on pavement condition, treatment cost-effectiveness, and life cycle costs, and the integration of this data into a pavement management system would provide the method for making these determinations in the future.

The present research project was initiated in response to the need for a statewide pavement management system. This report is the first of several interim reports which will be published to document the progress of this research.

2. PROJECT HISTORY AND PREVIOUS WORK

The elements of a pavement condition rating system were first started in 1969, when pavements were evaluated by recording the amount of cracking, patching, rutting, raveling, and abrasion present in each highway section. These surveys were conducted once every two years. Starting in 1976, the collection of cracking, patching and rutting data was discontinued in favor of a system which ranked pavement sections into one of five possible categories ranging from "very good" to "very poor." These biennial surveys have continued until the present, and the results have been included in the State Highway System Preservation Report.

A proposal for the research and development of a statewide pavement management system was first presented in 1976. The proposal was approved and included in the annual highway research work program in 1977, and the first full year of funding occurred in 1978. In August, 1979, an automated Dynaflect deflection testing system was purchased and placed in operation. A system of pavement deflection monitoring sites was ~~selected~~ chosen from sample sites selected for the Highway Performance Monitoring System (HPMS). During 1980, over 400 sites were tested, and an additional 500 sites were tested in 1981. Since that time, these original sites have been tested once every two years and additional sites have been added. At the end of CY 1984, there were over 56,000 individual deflection tests available for analysis.

In August, 1981, the State Highway Engineer appointed a Pavement Management Task Force to evaluate all activities within the Highway Division that might contribute in some way to pavement management. One Task Force assignment was to determine if data that was being gathered for other purposes could be used in pavement management. Other charges to the group were to: (1) determine the type and detail of data that should be collected; (2) recommend an organizational structure for a pavement management system for Oregon; (3) determine the appropriate funding level; and (4) advise how the system should be utilized.

It was at this time that the responsibilities of the Pavement Management Research Study were divided between the Highway Division Research Section and the Planning Section. The Planning Section was charged with the development, testing, and implementation of a prototype pavement management system. It would utilize computerized pavement condition data as well as other highway statistical data to produce a computer generated prioritization of prospective surface preservation projects. The Research Section was charged with conducting further research into the use of non-destructive testing data and other pavement condition data to predict remaining useful pavement life, and to determine the most cost-effective methods of surface preservation throughout the pavement life-cycle.

In 1982, the Planning Section developed and implemented a computerized pavement condition prioritization index based on the District Maintenance Supervisor's ratings, surface roughness, skid resistance, traffic volume, and safety rating. This system may be the prototype for the final pavement management system.

At the same time the Planning Section was working on the pavement management system, the Research Section was collecting and processing non-destructive test data, including deflections, surface roughness, and skid resistance.

A program was implemented in July, 1983 to track maintenance costs on three highway segments in each of the 82 maintenance sections in the state so that maintenance costs could be correlated with pavement condition. The segments were selected by the Research Section from recommendations provided by the District Maintenance Supervisors. The cost tracking is incorporated into the Maintenance Management System to make the record keeping and information retrieval relatively easy. New deflection test sites were established on a number of these segments and pavement condition data is currently being collected on these sites.

In June, 1984, the research project was expanded to include a study of the effectiveness of various surface preservation treatments that would be constructed under the State Special Surface Preservation funding program. New pavement test sites were established and monitored before and after construction was performed, and monitoring will continue until the end of the treatment life is reached.

3. RESEARCH PROJECT SCOPE OF WORK

The initial scope of work had two major objectives. These were:

1. To develop a pavement management system which will monitor pavement condition and aid in programming the most cost-effective pavement rehabilitation treatments.

2. To determine the typical useful life cycle of various pavement designs, the rate of deterioration of pavement rideability and strength, and the critical point in pavement life when rehabilitation or reconstruction is needed to preserve the initial pavement investment.

Because the responsibility for the development of the pavement management system was transferred to the Pavement Management Task Force, utilizing the staff resources of the Highway Division Planning Section, the research project scope of work was revised to reflect this change.

The overall study design was developed to utilize existing and ongoing pavement condition surveys as a basis for a preliminary pavement management system. This system would then be used for prioritizing pavement treatment while the study was collecting new objective pavement rating and cost effectiveness data for use in an expanded and significantly more detailed long-term pavement management system. The major components of the present work plan are:

1. Review of published literature for reports useful to the refinement of the pavement management system by utilizing objective measurement data such as deflection, roughness, cracking, patching, and rut depth.

2. To continue the measurement of pavement deflections on the statewide system of pavement monitoring sites until adequate life-cycle data is available to develop pavement treatment deterioration rates and life-cycle models.

3. To organize the existing and ongoing collection of pavement condition data (deflections, roughness, skid resistance, cracking, patching, rutting, etc.) into an integrated computerized file system so that it can be analyzed statistically.

4. To correlate pavement condition parameters such as surface roughness, skid resistance, and deflection with other pavement distress parameters such as percent cracking, rut depth, pavement age, or equivalent axle loads; and, to determine which relationships, if any, can be used to predict future pavement performance, and the need for future maintenance.

5. To predict the rate of deterioration of Oregon pavements so that pavement sections can be programmed for rehabilitation before more extensive deterioration occurs.

6. To determine the comparative cost-effectiveness of various pavement treatment strategies so that an optimal program of pavement maintenance and rehabilitation can be developed for each pavement section.

7. To disseminate pavement life-cycle and cost-effectiveness information to the highway administration and to the responsible highway engineers, so that optimal methods of treatment can be selected.

8. To determine the feasibility of using a statewide system of pavement condition monitoring sites to characterize the condition of pavements throughout the state.

9. To improve the existing pavement management system so that it combines the research findings, the knowledge and experience of the responsible engineers, and the objectives of the Highway Division Administration into a tool that can be used for programming and allocation of available funds for rehabilitation and maintenance.

At the present time, it is expected that this research project will continue until at least 1990, at which time between 5 and 10 years of pavement condition data will have been collected on most pavement test sites. It is anticipated that this will be an adequate amount of time to characterize the life-cycle performance of most of the surface treatment types under study. For a complete description of the current project work plan, see Reference 1.

4. PROGRESS TO DATE

4.1 Literature Review

The initial review of available literature revealed a wealth of information regarding the development of a pavement management system, and the use of objective pavement monitoring data in such a system (see References 2 – 11.)

Of the states that have implemented a pavement management system, most have systems that are based on the use of visual condition survey data and subjective opinions about rehabilitation needs. In some states, road roughness is used to supplement the ranking developed by visual condition surveys. A few states have also attempted to use statewide deflection monitoring data in their pavement management system, but have abandoned such attempts due to the level of effort required and the accompanying high cost involved.

Rideability is considered to be the most cost effective and useful type of objective measurement data. Deflection measurements are considered to be useful, but as yet, are not incorporated into an overall system—wide inventory of pavement rehabilitation needs. It is the consensus of opinion that deflection measurements provide the most cost—effective means of determining pavement strength, and many states use deflection data for pavement and overlay design.

The most popular method of deflection measurement has been the Dynaflect trailer. This device simultaneously measures pavement deflection at several locations within the deflection basin, through the application of a sinusoidally varying load to the pavement surface, and detecting pavement deflection at the point of loading and at one—foot intervals away from the load. Some states own several units and use them for pavement design and performance testing. For many, the Dynaflect has replaced the use of the Benkelman beam for deflection measurements, since it produces more consistent and precise results. Some states indicate that the Dynaflect is cheaper and faster to operate than the Benkelman beam; however, this opinion is not shared universally. The Dynaflect is the method most frequently mentioned in studies performed in other countries.

The falling weight deflectometer, a relatively new device in the deflection measurement field, is rapidly gaining in popularity. This device measures deflections at several locations within the deflection basin, but it has the added advantage of being able to measure the deflections for several different load levels, including levels that approach those of a standard 18 kip equivalent axle load. Several surveys of deflection measuring devices identify the falling weight deflectometer as producing pavement deflections most nearly equal to those produced by moving loads. Because it does not preload the pavement structure before testing, as does the Dynaflect, it produces more accurate estimates of base and subgrade elastic moduli. Because the unit can test pavements at several different load levels, it can be used to estimate base and subgrade moduli directly, greatly facilitating the use of mechanistic pavement models for pavement design.

The above literature review summary is only preliminary and brief in nature. Additional literature review will be conducted during the remainder of this study and the results will be reported in subsequent reports.

4.2 Development of the Interim Pavement Management System.

A visual surface condition rating was initiated for Oregon pavements in 1969 that rated the surface condition by recording cracks, patches, rutting, raveling and abrasion. Another more general rating has been made by the district maintenance supervisors for highway sections under their jurisdiction in 1976, 1978, 1980, 1982 and 1984. This State Highway Preservation Study rating evaluates pavement with a five point rating from "very good " to "very poor". The rating is based primarily on appearance, but may be influenced by the supervisor's knowledge of the maintenance history of the section. Photography and monitoring by headquarter's personnel are utilized to maintain a level of uniformity between districts.

In August, 1981, the State Highway Engineer appointed a Pavement Management Task Force to evaluate all activities within the Highway Division that might contribute in some way to pavement management. Data being considered for inclusion in the study were ride quality, traffic volumes, equivalent axle load history, Benkelman Beam and Dynaflect deflections, accident statistics and roadway skid number. Maintenance activities and costs were also considered on a section wide basis.

The Task Force is studying short-term management systems that can be implemented with existing data. It is also considering the long-term need to develop a system that can optimize the type and timing of maintenance and rehabilitation strategies. This study is expected to contribute most significantly to the long-term system but it will also provide valuable information to the short-term system by furnishing information on deflections, spreadability, base curvature index, surface curvature index, ride scores, skid numbers and an estimate of overlay thickness needs on projects being considered for rehabilitation. All of the information developed as part of this study is available to help decision makers prioritize project sections already identified as being in need of rehabilitation.

Under the direction of the Task Force, the Planning Section has implemented a pavement management system. The objectives of the system are to incorporate preservation needs, highway user safety, and driver convenience into an objective rating. The rating thus far developed is called the Pavement Management System Index (PMS Index). For the index to adequately represent administrative priorities, preservation need (as indicated by the surface condition rating) is weighted 60 percent, highway user safety (as indicated by skid number) is weighted 20 percent, and driver convenience (as indicated by road roughness) is weighted 20 percent. Once the basic index is developed, it is adjusted based on a relative traffic coefficient (equivalent axle load level) and a traffic safety index (developed from accident records). The PMS index is developed using the computer program PVMGIX. A more complete description of the PMS Index and PVMGIX is contained in Reference 12.

The present pavement management system can be used to aid in decision making on surface preservation projects. The system will be refined and improved based on the results of this research study. The Task Force will continue to review progress, provide recommendations, and assist with implementation.

4.3 Data Collection

4.3.1 Description of the Statewide Pavement Deflection Monitoring Network

The use of pavement deflection data as input to a statewide pavement management system requires that the deflection measurement sites be representative of the deflections over the total system. Because it would be too expensive and too time consuming to conduct deflection testing over the entire highway system, this study was designed to use a subset of highway test sections to represent the system. The data from this smaller monitoring network will be extrapolated to the entire highway system through similarity of pavement structure, number of equivalent wheel loads, and geographic location.

A random sampling of the highway system was selected as the best way to assure that deflection sites were representative of the system. Since a network of random sample highway monitoring sites had already been established in Oregon for the FHWA Highway Performance Monitoring System (HPMS), these sites were evaluated for use as pavement deflection test sites.

The Field Implementation Manual for the HPMS required that the highway system be divided into homogeneous segments, and that the sample be taken from these segments. The segments were to be established considering traffic volumes, functional classifications, governmental boundaries (stratified by rural, urban, and small urban areas), and geometrics (cross-section, widths and alignment). It also required that all (100%) of the Interstate freeway segments be included in the sample. In Oregon, these criteria resulted in 214 interstate highway segments and over 1,737 non-interstate segments.

The initial deflection monitoring network was established by assigning a number to each HPMS highway segment and then using a random number program to select more than 900 segments. The actual deflection monitoring sites were located at the same point as the HPMS monitoring site for each segment. Since the HPMS site selection criteria specify that only the first mile on rural and small urban segments, and the first one-tenth mile on urban segments be considered, the deflection sample sites were sometimes constrained by these criteria.

The sample sites established by this site selection process were analyzed to determine if they would reasonably represent the typical pavement deflection characteristics of Oregon's highway system. The following items were checked to see if an adequate number of sites were selected in each category:

(1) surface type (AC, PCC and oil mats)

(2) age of the latest surface treatment

(3) area (rural, urban or small urban)

(4) region

The length of the HPMS segments selected for deflection monitoring represents about 23% of the total non-interstate HPMS highway segment length. Based on the characteristics of the segments selected, it appears the sample will adequately represent the overall deflection pattern of Oregon's interstate and non-interstate highway system (see Table 1.)

In August, 1979 an automated Dynaflect deflection testing system was purchased and placed in operation. In 1980, over 400 sites were tested, and an additional 500 sites were tested in 1981. These sites represent about 10% of the highway system. Most of these 900 sites have been retested at two-year intervals as part of a program to monitor the rate of deterioration of the highway segments by measuring the change in deflection over time. At the end of CY 1984, there were over 56,000 individual deflection tests available for analysis. Figure 1 shows the distribution of these sites throughout Oregon.

4.3.2 Description of the Seasonal Deflection Monitoring Sites

Because the strength of a pavement varies by season, it is necessary to monitor pavement deflections at different times of the year in order to accurately determine pavement condition. With an overall sample network of over 900 sites, it was not possible to monitor all sites during each season. Therefore, 17 sites out of the statewide deflection monitoring network were selected for the purpose of monitoring seasonal variations in deflection. The data from these sites will be used to correct (normalize) the deflection test data from the remainder of the sampling network. Once corrected, the data can be used in studies of pavement deterioration rates and in correlation of deflection data with visual surface condition survey ratings.

Each of the seasonal sites lie within one of nine distinct climatological subareas within the state (coast, Willamette Valley, southwestern valleys, high plateau, north central, south central, northeast, and southeast). Seasonal correction factors derived from the seasonal sites will be used to adjust deflection data only from sites within the same climatological subarea. A summary of the seasonal sample site locations is shown in Figure 2. These sites have been tested once each month since May, 1980.

In preparation for development of seasonal adjustment factors, the U. S. Weather Bureau reporting station nearest to each site is selected and the ten-day average of precipitation and temperature data collected prior to the test is entered in the data base for each test.

4.3.3 Description of Maintenance Cost Tracking Sites

One goal of this study is to determine the cost-effectiveness of routine maintenance in pavement preservation and overall life cycle costs of different pavement rehabilitation strategies. In an effort to obtain further information on this subject, a maintenance cost tracking system has been established within the Maintenance Section of the Highway Division. Three segments in each of the 82 maintenance sections were selected to track maintenance costs. These segments cover the major geographic zones, traffic volumes, pavement types, functional classifications and levels of importance represented by Oregon highways.

This system will be used to record maintenance activity on the selected segments. In order to determine the cost effectiveness of maintenance activities on pavement strength, deflection monitoring sites will be located in at least one of the three cost tracking segments located in each maintenance section. Ride data will also be gathered for these test sections to determine the effect of maintenance on rideability.

The maintenance cost tracking study began in July, 1983, and currently, 34 test sites are being monitored. Because only one year of data is available, data analysis has not yet begun. The Dynaflect test sites associated with maintenance cost tracking segments are shown in Figure 3.

4.3.4 Description of Special Surface Preservation Cost-Tracking Sites

In order to determine the effectiveness of special surface preservation treatments, relative to other methods of surface preservation such as new construction or routine maintenance, pavement treatment life cycle and cost information must be collected. This task will be completed through the analysis of the statewide deflection monitoring network data, and through the long term tracking of special surface preservation projects of various types located throughout the State. These surface preservation projects include a broad range of pavement treatments, including oiling, chipseals (including Styrelf (TM) — a polymer modified asphalt), oilmats, thin overlays, and structural overlays (including "B", modified "B", "C", and "E" type mixes). In addition, several experimental features projects involving the use of Armorshield (TM), PlusRide (TM), and Fiber Pave (TM) in the asphalt concrete are being monitored.

Additional deflection monitoring sites were selected in an attempt to measure pavement deflections before and after the various treatments had been completed. Because this study was initiated in June, 1984, many treatments had been completed before deflection measurements were made. Figure 4 shows the sites which were measured in 1984. Additional sites will be added in the spring of 1985 as new projects are programmed. Dynaflect and ridescore data will be collected on a representative sample of these various pavement treatments, and the results correlated with visual surface condition ratings over the pavement life. This study will continue over the useful life of the various pavement test sections.

4.3.5 Deflection Testing Procedure and Test Spacing

A review of the literature pertaining to the use of deflection tests in pavement evaluation did not reveal a consensus as to the proper testing pattern. Oregon's Surfacing Design Group uses a Benkelman beam to test pavement deflections. Tests are conducted at 50-foot intervals within a 1,000-foot test section, once every half mile in the project section. This testing pattern is used for all projects for which overlay designs are to be done. This was the same pattern used by Caltrans at the start of this project.

Traffic safety and traffic control is an important factor in selecting an optimum test pattern. The placing of necessary traffic control devices consumes more time than the testing. On two-lane roads it takes approximately 30 minutes to deploy and pick up signs. The testing takes 15 to 30 minutes, depending on the number of tests taken. Sign spacing and safety requirements on two-lane highways limit the length of a test section to 1,500 feet, with a shorter length being even more desirable. The longer the test section, the greater the distance from the signing to the operation and flagger.

To determine the optimum test pattern two sections were extensively tested. The first test section is a 12.5 mile section of Interstate 5 freeway traversing a very uniform, level section of the Willamette Valley. Most of the section is constructed on a low fill (0 – 5 ft), with one major fill for a railroad overcrossing. The section was constructed in 1960 and 1961, and had a 7 inch overlay in 1972. At the time of testing, the pavement was in good condition with no visible cracking. The second test section is a 1,000 ft section of Oregon Highway No. 30 (OR Route 22) in west Salem (this section had higher deflections and more variability than the freeway section).

A total of 716 individual tests were taken on the I–5 test section. A three–mile section was analyzed, with tests taken every 50 feet to determine an optimum pattern. This pattern was then tested on the entire 12.5 miles, using the data available.

The mean deflection for the 328 tests taken on the three mile section is 0.65 mils with a standard deviation of 0.09 mils. The mean of the 66 tests from 500 foot sections every half mile is 0.62 mils with a standard deviation of 0.06 mils. The mean of the 33 tests from 500 foot sections every mile is 0.65 mils, with a standard deviation of 0.05 mils.

To check the reliability of using one 500–foot section per mile, one 500 foot section was isolated in each mile for the 12.5 mile length of the project. This was done for both southbound and northbound lanes. In the southbound lanes the mean value of 492 deflection tests, is 0.64 mils. The mean value of the tests from twelve 500 foot sections in the southbound lanes is 0.65 mils. In the northbound lanes the mean value of 244 deflection tests is 0.71 mils, with the mean value of the deflections in twelve 500 foot sections being 0.71 mils.

This data demonstrates that one set of deflection tests per mile can reliably represent the mean pavement deflection in uniform terrain. This is based on each set of tests covering 500 feet, with tests at a 50 foot spacing. This pattern results in tests covering approximately 10 percent of the section.

A total of 21 tests were taken on Oregon Highway No. 30 in a 1,000-foot test section (50 foot spacing). This section had higher deflections and more variability than the other sections. As might be expected, the average of the deflection values changed more as the number of tests considered decreased.

Based on the above results, the testing pattern chosen was 11 tests at 50 foot intervals (a total of 500 feet) for each test site. It was also decided to perform the tests on the outside lane in each direction for each test segment, since the outside land usually shows signs of distress before the inside lane.

Initially, it was concluded that the test pattern and spacing would be adequate to characterize a one-mile long section of pavement. This conclusion was the basis for the assumption that the present deflection monitoring network could ultimately be used to characterize the entire state highway system. Because an interstate freeway section was the principle test section, and because only a limited amount of analysis was performed on non-interstate highways, this assumption may not be valid for the entire state system. Further analysis will be performed on the original test data to determine the degree to which the pavement test sections actually characterize non-freeway pavement sections.

4.3.6 Collection of Surface Condition Information

During Dynaflect testing, surface condition information on the test section is observed and recorded by Research Section personnel. Cracking and patching are recorded as a percentage of the test section and the rut depth is recorded in hundredths of a foot.

Methods for determining the values for cracking, patching and rut depths follow:

Cracking

Cracking is defined as single longitudinal or transverse cracks or as interconnected or interlaced cracks forming a series of polygons (sometimes called "map cracking"). Extensive cracking is generally a sign of severe distress. It usually indicates unstable base, weakened pavement, or dry and brittle pavement.

To keep the sampling technique as simple as practical, transverse cracking, longitudinal cracking, and edge cracking are combined, by assuming the distressed area on each side of each crack is six inches wide. The amount of cracked area is determined by multiplying the crack length by a width of one foot. The percent of cracking is determined by dividing the cracked area by the total area in the test section.

Patching

An estimate is made of the area patched. This is divided by the total surface area in the 500 foot sample to determine the percent area patched. The combination of percent cracking and percent patching cannot exceed 100 percent. If a patched area is cracked, the percentage of the area cracked is deducted from the area patched.

The fact that a portion of road is patched indicates that some form of surface distress or distortion has occurred. Only areas recognizable as patched are considered in the percent area patched. If the patch is old enough to have lost its identity it is considered the same as original surface and surveyed for cracking and wheel rutting.

Rut Depth

The rating for rut depth is the average depth of the wheel ruts in the lane being tested. The depth is measured to the hundredth of a foot with a five-foot straight edge.

4.3.7 Determination of Surface and Base Depth and Type

Base and surfacing depth-and-type information was collected from existing department records for use in the correlation of pavement conditions with deflection data. In a few instances, core samples were taken in the field to supplement or verify pavement design data for use in the development of temperature corrections. All test sites have the best known pavement depth-and-type data available stored in the data base. Approximately 40 percent of the deflection data collected to date has the pavement depth and type information included in the data base record.

4.4 Data Analysis

4.4.1 Correlation of Benkelman Beam and Dynaflect Test Results

The Oregon Department of Transportation currently uses Benkelman Beam deflection measurements in its pavement design procedures. In order to make the Dynaflect readings more meaningful to pavement design personnel and to provide a relationship between the two measuring techniques, a correlation of the two instruments was accomplished in 1979. The work was reviewed in 1984 and extended to cover the full range of Dynaflect readings (0.0 to 5.00 mils.) experienced in the field.

In 1979, 15 test sections were selected and concurrent Dynaflect and Benkelman Beam tests were taken. Standard equipment setups and testing procedures were used. From this data, a total of 245 tests were selected for regression analysis. Before the data was analyzed, it was normalized to a standard temperature of 70 degrees Fahrenheit. A linear regression of this data gave the first equation shown in Table 2.

This linear relationship was considered adequate over the range of the data collected (0 – 2.25 mils.), since the slope of the line compares favorably with other similar work (see References 13, 14, and 15) being in the range 18 to 28.

A review of earlier deflection measurements showed some of the data collected was outside the effective range of the 1979 equation. Six new sites were selected and duplicate Dynaflect and Benkelman Beam tests were taken at 128 locations. A linear regression of this new data gave the second equation shown in Table 2.

The range of this data is higher (1.15 – 4.62 mils.) and the slope is substantially different than that obtained in the original work.

A nonlinear analysis of the combined data was performed (including 20 tests from the 1979 data which were not included in the original analysis), giving the third equation shown in Table 2.

After the original regression analyses were performed, and because the

Benkelman beam and Dynaflect deflections were measured on the same day and under similar temperature conditions, a regression analysis of the raw data, uncorrected for temperature, was performed. The results of this analysis are also shown in Table 2. As can be seen, for each of the linear and non-linear equations, the correlation coefficient and accompanying R2 values is better (larger) for the raw data than for the corrected data. Since the non-linear equation for the raw data has the best overall fit to the data, it is recommended as the equation which should be used to convert Oregon Dynaflect deflections to equivalent Benkelman beam deflections.

The data and the line of best fit to the above equations are plotted in Figures 5, 6, 7, and 8.

4.4.2 Development of Interim Temperature Correction Formula

Because the modulus of elasticity of asphaltic concrete is temperature dependent, deflection measurements need to be corrected for the in-situ pavement temperature if they are to be compared to design criteria or other measurements made at different temperatures. Oregon chose to correct to a mean temperature of 70 degrees Fahrenheit to conform with several other states. However, because pavement materials and construction techniques vary from state-to-state, it was decided that temperature correction factors from other states would be verified using data collected for Oregon pavements. As a result, a pavement deflection vs. temperature study was conducted.

In developing a relationship between the observed temperature variation and the observed variation in deflection, several variables were considered including surfacing depth, base type, and the seasonal variations in subgrade moisture.

The mean temperature of the pavement is determined by punching or drilling a 1/2 inch diameter hole 1 1/2 - 2 inches into the pavement, then putting 1 inch of water in the hole and measuring the water temperature. This temperature is used to approximate the mean pavement temperature.

Surfacing depth, base and subgrade variables were controlled by conducting multiple tests over the same pavement test section. Seasonal variations were controlled by conducting the tests during the summer when the pavement, base and subgrade were dry.

Data for a 4 inch thick pavement surface was collected on State Highway No. 191 (Kings Valley Highway) at mile point 30.080 to 30.171 using 11 locations spaced at 50-foot intervals. Fourteen sets of deflection tests were run over a temperature range of 61F to 90F. The data was analyzed statistically, and the method giving the most consistent results and highest correlation involved taking the mean of the 11 tests at each site as being representative of the section. The 14 mean deflection values were regressed against the mean temperature producing a linear equation with an acceptable R2 value of 0.97.

A similar technique was used to collect and analyze data at other data collection sites representing 2, 6, and 10 inch pavement thicknesses. The results of the temperature correction factor analyses at these sites is preliminary, and further analyses of the temperature correction factor data will be conducted. Depending on the results of these analyses, additional data may be collected and analyzed before temperature correction factors are published for Oregon pavements. A supplementary report describing the status of the temperature correction factor analysis and/or proposed additional data collection is scheduled for completion in April, 1985.

4.4.3 Correlation of Deflection, Ride, and Skid Data with Pavement Performance and Age

No progress to date. Progress on this analysis will be documented in subsequent annual interim reports.

4.5 Development of Life Cycle Costs

Data collection is currently in progress, however the information is still too limited to allow meaningful analysis.

4.6 Development of a Long-Term Pavement Management System

The pavement management system discussed in Section 4.1 above will be used as a basis for the development of the long-term pavement management system. The refinement of this system will proceed as soon as the analysis of the objective pavement condition data (deflection, roughness, and skid data) has been completed.

5. SUMMARY AND CONCLUSIONS

The pavement management research program for Oregon highways has been ongoing for five years and is the largest single research project in Oregon at the present time. Up to now, the collection of pavement deflection and other objective surface condition data has been the primary emphasis of the project. Over 5000 deflection tests have been recorded at over 1000 individual test sites representing a broad cross section of Oregon pavement types, ages, and states of deterioration.

In addition to data collection, the correlation of Benkelman beam to Dynaflect deflections was completed to aid the Department of Transportation in assessing the strength of pavements tested with the Dynaflect trailer, as well as allowing historical Benkelman beam deflection data to be incorporated into the research data base. The correlation of pavement deflections with temperature is currently underway and will be reported in a subsequent interim report.

As the study progresses, information on pavement life-cycles, rates of deterioration, and treatment cost-effectiveness will be developed. It is anticipated that these results will contribute to the improvement of the accuracy and effectiveness of Oregon's pavement management system, with the long-term prospect of substantial savings in the cost of maintenance and rehabilitation.

TABLE 1

SUMMARY OF NON-INTERSTATE DYNAFLECT SITE CHARACTERISTICS
BY PAVEMENT TYPE, PAVEMENT AGE, POPULATION AREA, AND HIGHWAY REGION*

Characteristic	Percent of Sites
Pavement Type	
Asphalt	72
Concrete	2
Oil Mat	26
Pavement Age (Years)*	
1 - 5	10
6 - 10	12
11 - 15	15
16 - 20	17
21 - 25	15
26 - 30	10
31 - 35	3
36 - 40	2
41 >	11
Unknown	5
Residential Area	
Rural	51
Small Urban	11
Urban	38
Highway Region	
1	16
2	27
3	23
4	18
5	16

* (Data Compiled in 1979 When Dynaflect System was Developed)

TABLE 2

DYNAFLECT VS. BENKELMAN BEAM STATISTICAL ANALYSIS SUMMARY

Test Data*	R	R2	Std Error	Regression Equation Coefficients A	B	C
Old (1979) Corr Data	0.91	0.82	4.04	–	22.73	1.34
New (1983) Corr Data	0.81	0.66	21.27	–	36.71	−15.99
Combined Corr Data	0.93	0.87	14.28	4.83	13.99	1.95
Combined Raw Data	0.94	0.89	11.59	3.83	18.78	−.87

* Corr Data had deflections adjusted for temperature before analysis.
R = Correlation Coefficient

Regression Equation: Benkelman = A(Dynaflect2) + B(Dynaflect) + C

FIGURE 1

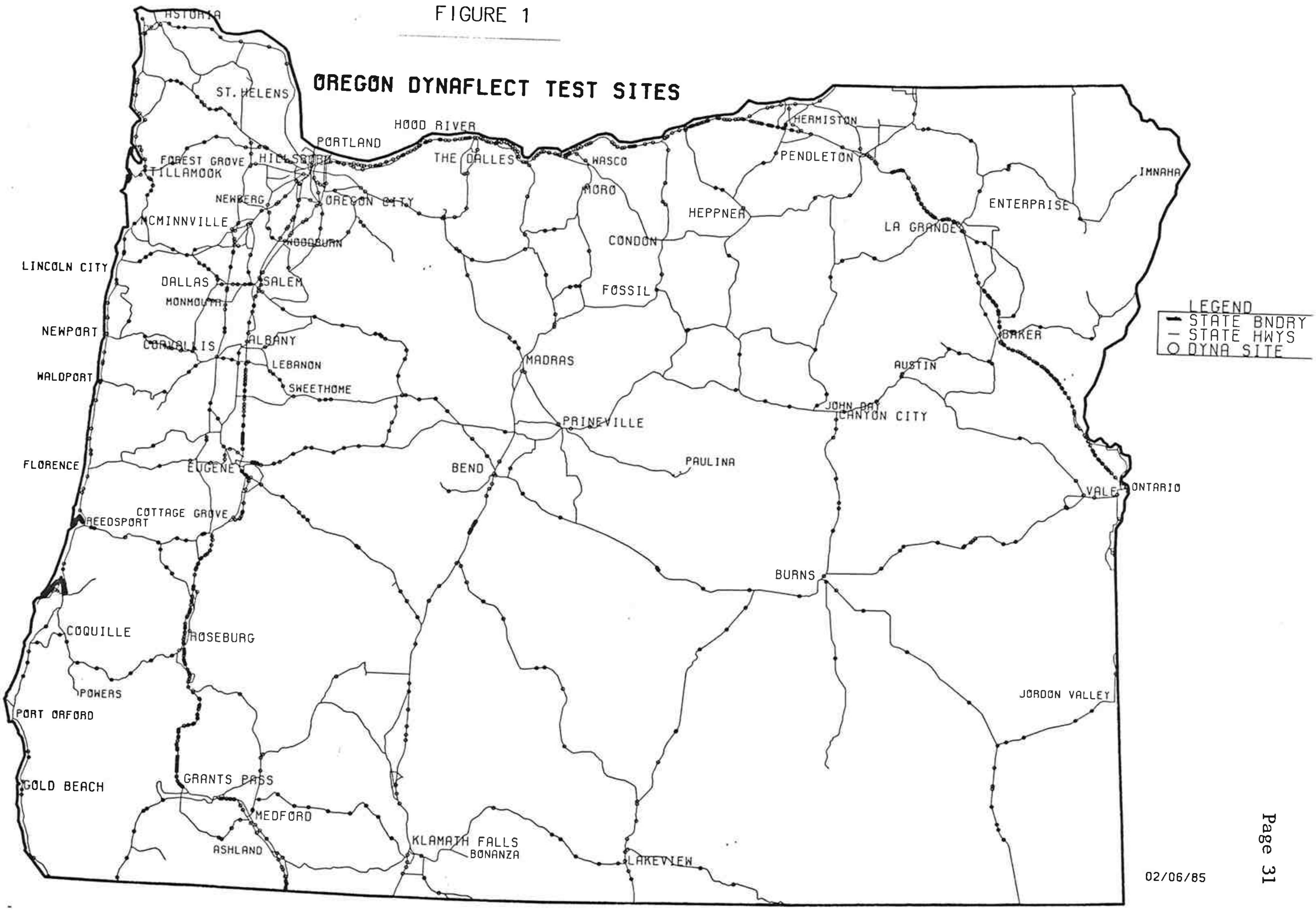
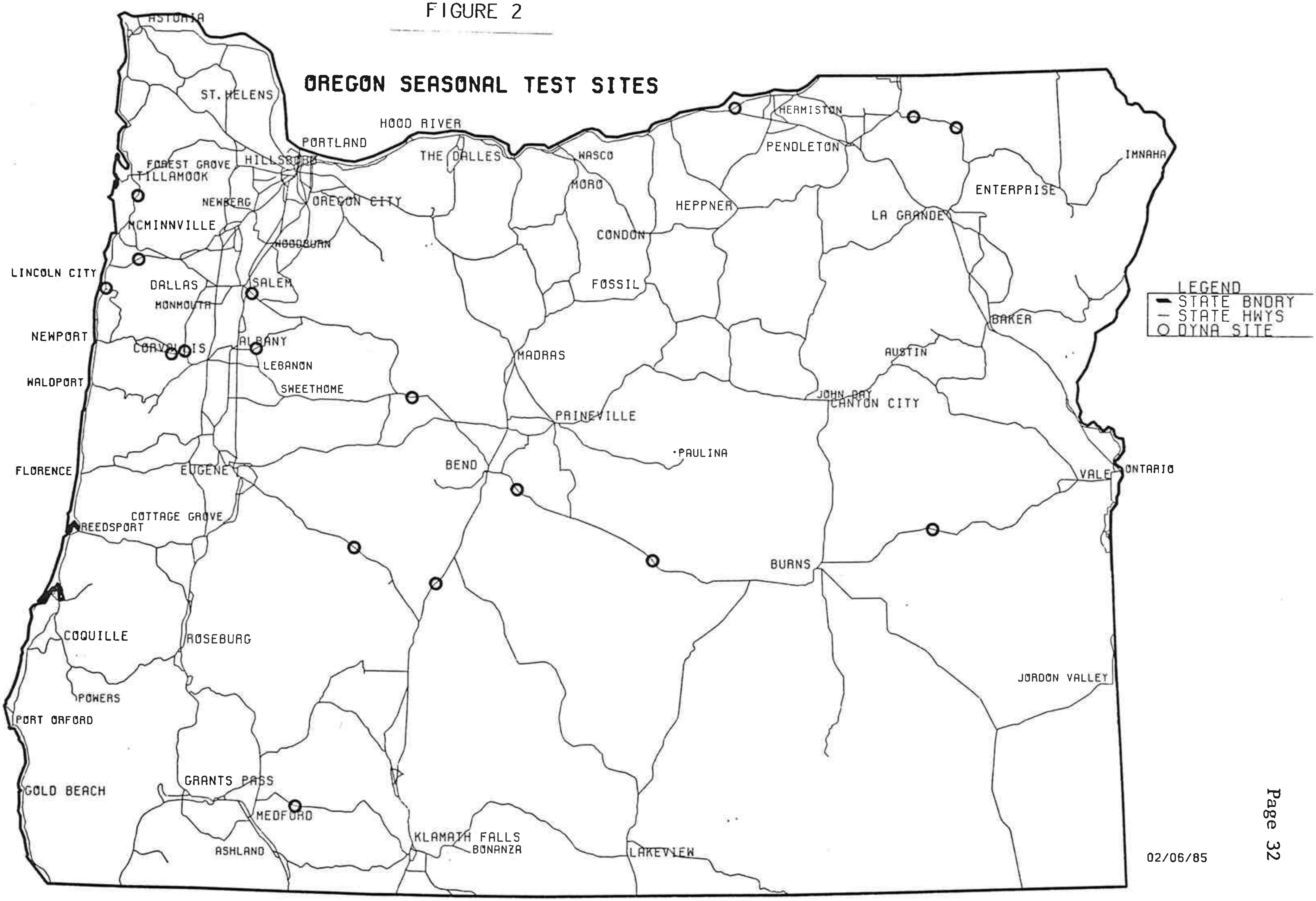

ØREGØN DYNAFLECT TEST SITES
LEGEND
STATE BNDRY
STATE HWYS
DYNA SITE
ASTORIA
ST. HELENS
PORTLAND
HOOD RIVER
HILLSBORO
FOREST GROVE
TILLAMOOK
NEWBERG
OREGON CITY
THE DALLES
WASCO
MORO
HERMISTON
PENDLETON
IMNAHA
ENTERPRISE
LA GRANDE
HEPPNER
CONDON
FOSSIL
MCMINNVILLE
WOODBURN
LINCOLN CITY
DALLAS
SALEM
MONMOUTH
NEWPORT
CORVALLIS
ALBANY
LEBANON
WALDPORT
SWEETHOME
MADRAS
BAKER
AUSTIN
JOHN DAY
CANYON CITY
PRINEVILLE
PAULINA
FLORENCE
EUGENE
BEND
VALE
ONTARIO
COTTAGE GROVE
REEDSPORT
BURNS
COQUILLE
ROSEBURG
POWERS
PORT ORFORD
JORDON VALLEY
GOLD BEACH
GRANTS PASS
MEDFORD
ASHLAND
KLAMATH FALLS
BONANZA
LAKEVIEW
02/06/85

FIGURE 2

OREGON SEASONAL TEST SITES



02/06/85

FIGURE 3

MAINT COST TRACKING TEST SITES

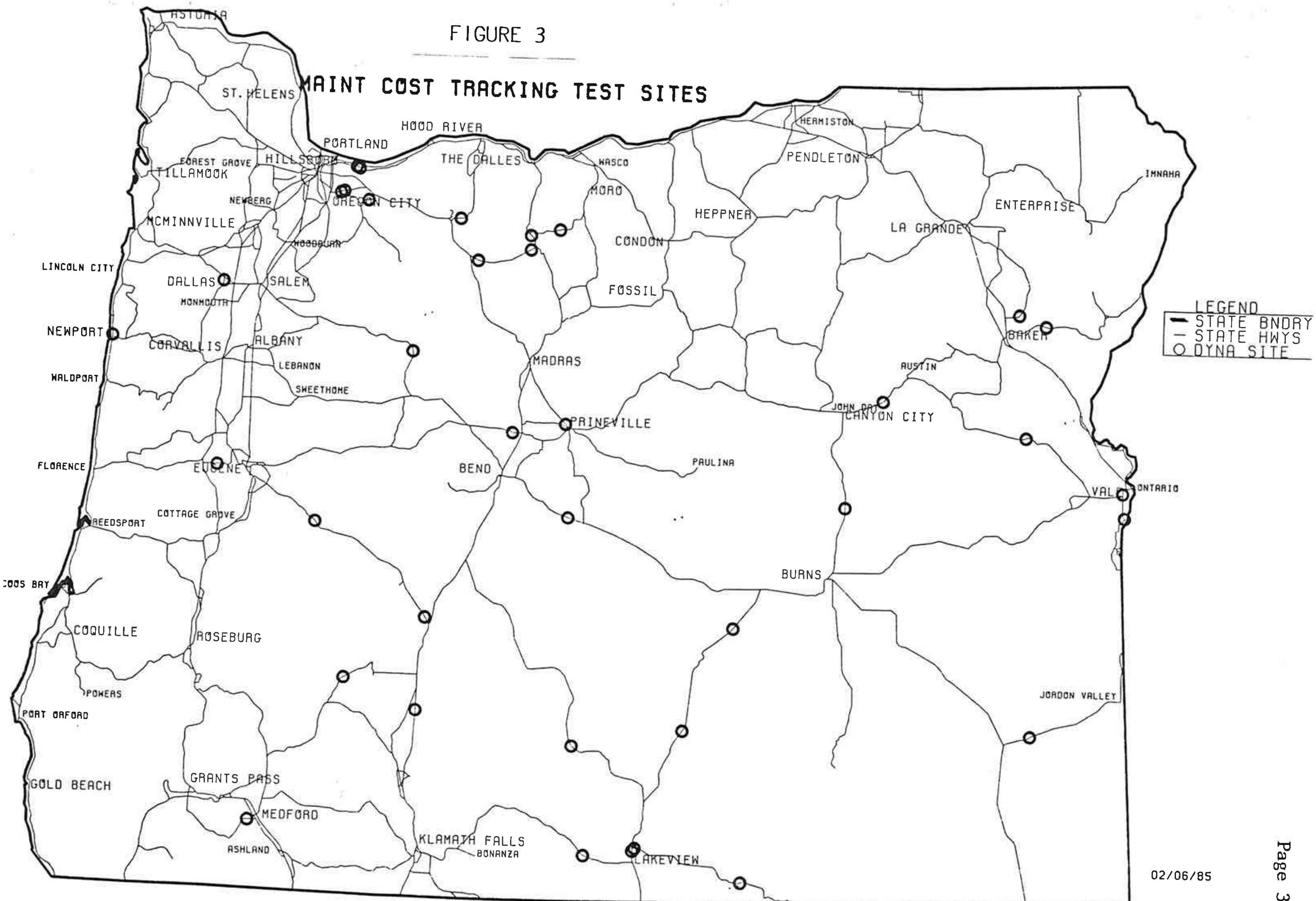
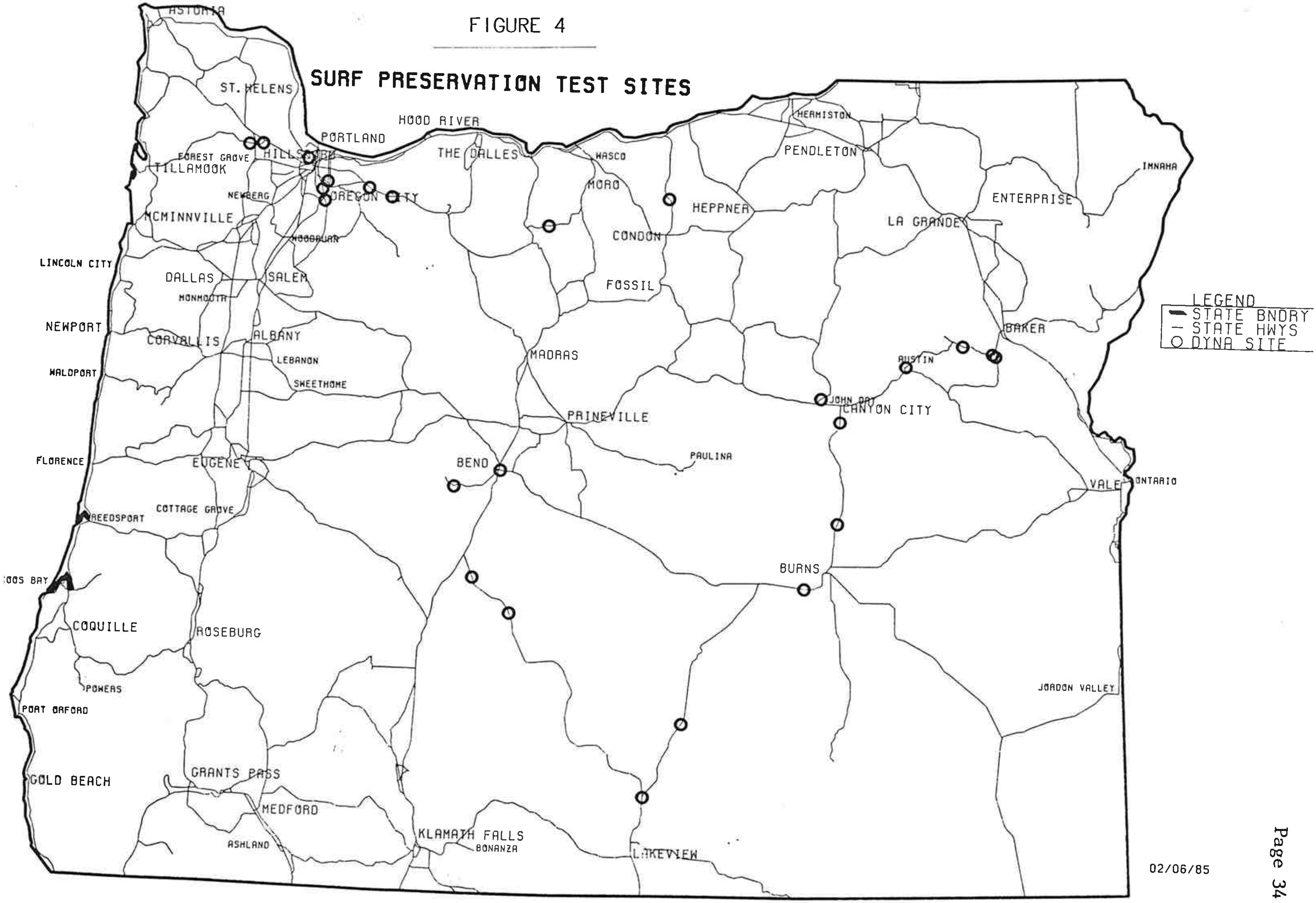


FIGURE 4

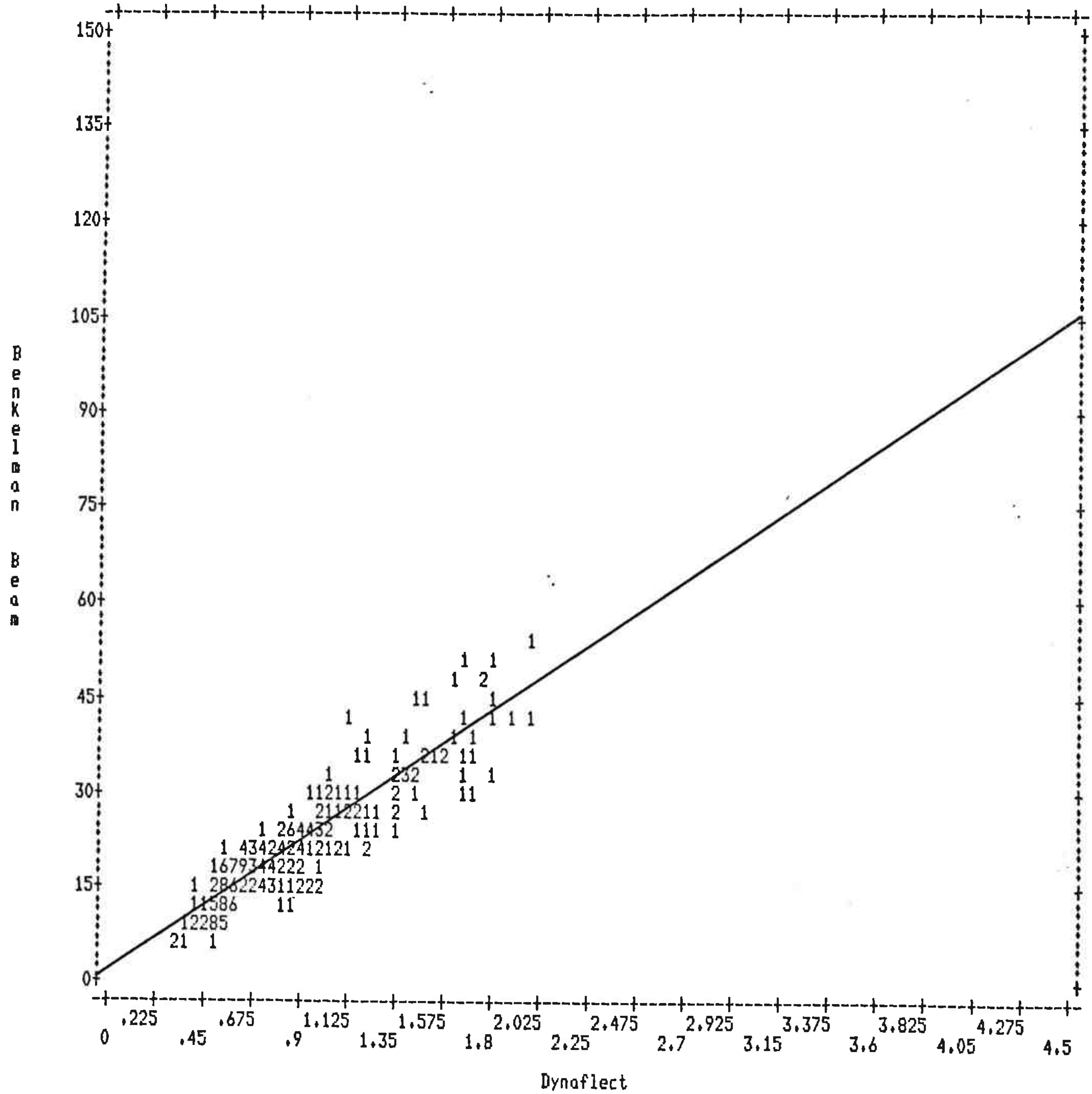
SURF PRESERVATION TEST SITES



02/06/85

FIGURE 5

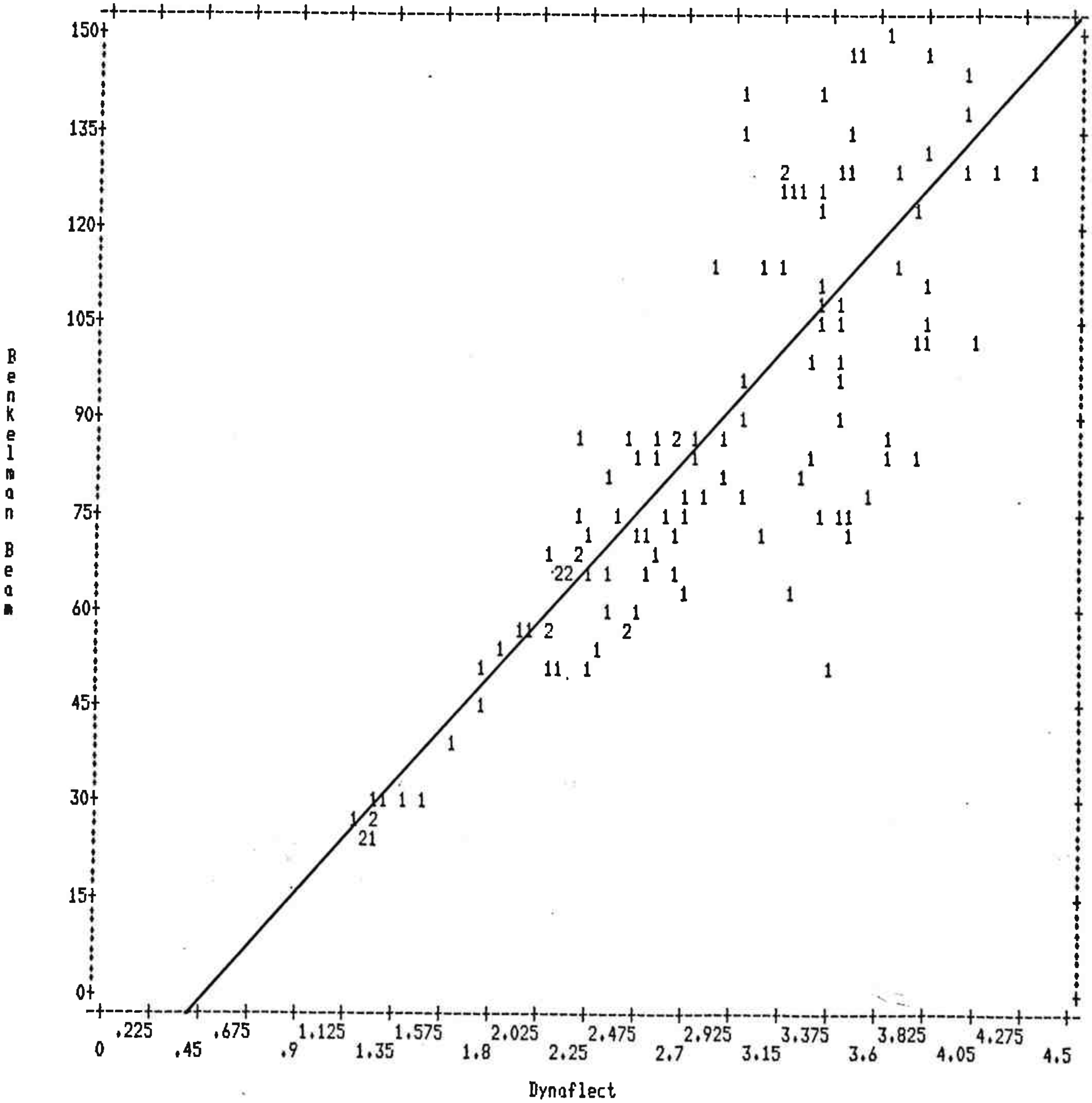
Plot of Old Corrected Dynalfect vs. Old Corrected Benkelman Beam



Benkelman = 22.73(Dynaflect) + 1.34

FIGURE 6

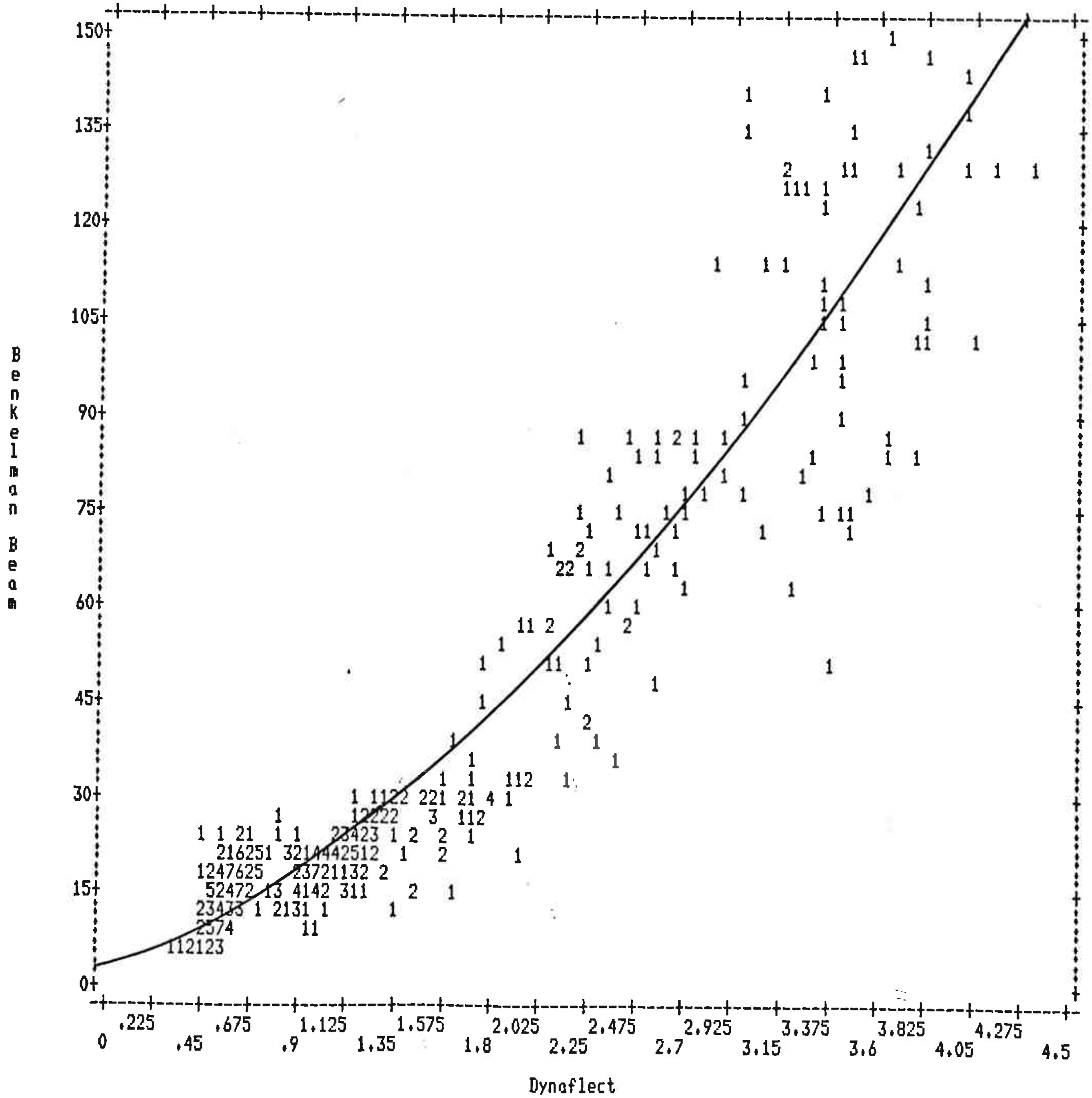
Plot of New Dynaflect (Temp. Corr. 2) vs. New Benkelman Beam (Temp. Corr. 2)



Benkelman = 36.71(Dynaflect) - 15.99

FIGURE 7

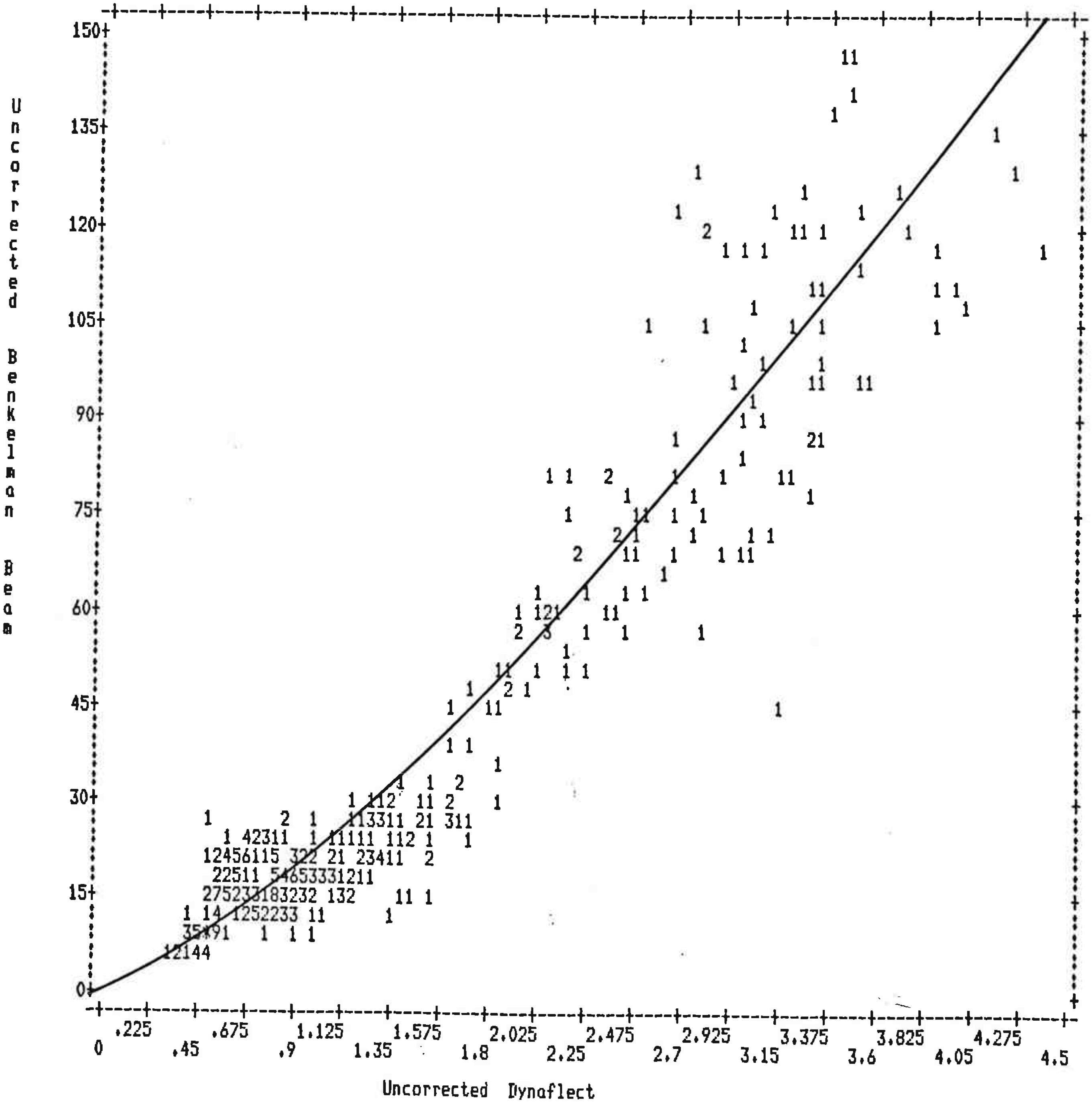
Dynaflect (Temp. Corr. 2) vs. Benkelman Beam (Temp. Corr. 2) Beam



Benkelman = 4.83(Dynaflect2) + 13.99(Dynaflect) + 1.95

FIGURE 8

Plot of Uncorrected Dynaflect (Old and New) vs. Uncorrected Benkelman Beam (Old and New)



Benkelman = 3.38(Dynaflect2) + 18.78(Dynaflect) - 0.87

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