GROUNDLINE TREATMENT OF POLES USING BORON RODS

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ABSTRACT

The boron distribution in western red cedar and lodgepole pine stubs which had been treated 2 years previously by inserting fused disodium octaborate rods into holes drilled at the groundline was determined qualitatively (curcumin spray) and quantitatively (ICP). The amount of boron diffused increased with increasing wood moisture content above the fibre saturation level with the highest concentrations being found just below the groundline. Boron leaching losses from the pole stubs into the surrounding soil and ground water were found to be negligible compared to fish LC_{50} values.

1. Introduction

Boron compounds, usually in the form of boron salts, have long been known and used as effective wood preservatives for lumber. The treatments are ecologically attractive since the mammalian toxicity is very low compared to other chemical wood preservatives (Dickinson and Murphy 1989; Eisler 1990). Unfortunately, these treatments were not suitable for use in utility poles because the fungal protection provided was relatively short lived due to the high water solubility of the boron compounds.

However, the development of solid "boron" rods (Beckgaard 1980) consisting of fused anhydrous disodium octaborate (commercially available as IMPEL or TIMBOR rods) which are placed into holes drilled into the wood, provides a much slower, controlled chemical release and longer protection of the wood from fungal attack. The material is inert until the wood moisture content reaches 25% to 30% (the same levels at which most fungal attack begins) and then begins to dissolve and diffuse through the wood. The preservative rods have been evaluated in applications such as window joinery and railway ties (Blow and Summers 1985; Dietz and Schmidt 1988; Ruddick and Kundzewicz 1991; Beauford et al 1992). A number of laboratory and field investigations involving wood poles have been carried out on a variety of wood species in Sweden and England and more recently in North America (Greaves et al 1982; Friis-Hansen 1987; Dickinson et al 1988; Dickinson et al 1989; Henningsson et al 1989; Morrell et al 1990; Morrell 1992) with promising results. However, information was required specifically on the performance of the borate rods in species used by B.C. Hydro under B.C. climatic conditions.

The objective of this project was to evaluate boron rods for remedial groundline treatment of western red cedar and lodgepole pine poles. The parameters to be investigated included:

- diffusion of boron in the wood
- leaching to the environment
- longevity of the treatment

2. Methodology

Twenty-seven pole stubs, 15 western red cedar [WRC] and 12 lodgepole pine [LPP] located in a test plot at Powertech Labs Inc. in Surrey B.C., were selected for the investigation (Figure 1). The 2 meter stubs, which are buried 1 m below ground, were installed 10 years previously for a 1983 CEA project to evaluate groundline preservatives. The stubs selected had been cut from full length creosote or pentachlorophenol (PCP) treated WRC and PCP treated LPP poles. In addition to the original preservative treatment, the stubs had also been treated at the groundline with a heavy P9 petroleum grease using the pressure spade method.

Prior to the initiation of the current investigation in 1993, the stub tops were coated with an asphaltic sealant to prevent moisture ingress and background soil samples were obtained about 18 inches deep next to the selected stubs. One-half inch diameter holes were drilled into the stubs directly at the groundline downward at an angle of 45 degrees to the vertical. Background wood samples were obtained from the drilling debris. Impel rods measuring 12 mm x 100 mm, each containing 35.1 gm boric acid equivalents (BAE), were then inserted into the holes at a depth and frequency depending upon the stub diameter as recommended by the manufacturer. Stubs having a diameter 240 mm or greater (most of the WRC stubs) were treated with 4 rods at 90 degree intervals to a depth of 170 mm whereas the smaller diameter stubs (most of the LPP stubs) were treated with 3 rods at 120 degree intervals to a depth of 150 mm. The rods were tamped into place and the holes were then sealed with tapered hardwood plugs.

After periods of 12 months and 24 months, a number of the stubs were removed from the ground for testing. Soil samples were obtained at 3 locations 18 inches below the surface in each post hole to evaluate boron losses from the stubs. If present, water samples were also obtained from the post holes.

The stubs were washed and then cross sectioned using a band saw into 6 - 100 mm thick slabs starting from the groundline. The cross sections were labelled from +300 (top slab above groundline) to -200 (bottom slab below groundline).

The water content at the slab surfaces was determined using a moisture meter. To obtain a qualitative estimation of the boron diffusion through the wood, the surfaces were sprayed with curcumin reagent (Edlund 1982) which reacts with boron to produce a light pink to dark red coloration depending upon the boron concentration. On completion of the colour development, the results were documented by photography. The cross sections from several stubs were also temporarily reassembled and cut lengthwise. In addition, 2 stubs were also cut lengthwise from below the bottom cross section to the base of the pole. The vertical sections were then sprayed and photographed.

Two stubs of each species were selected for quantitative boron analyses and moisture determinations. Core samples 5 mm in diameter were obtained through each cross section at 9 locations in a grid pattern. The borings were oven dried at 105°C and then ground to 20 mesh using a Wiley mill. An 0.4 gm portion of each boring was digested with 10 ml of 0.5 N sulfuric acid for 30 minutes in an ultrasonic bath, filtered using Whatman #41 paper and made up to 25 ml with distilled, deionized water prior to analysis by Inductively Coupled Plasma Emission Spectroscopy (ICP).

The soil samples were first dried and sieved. One gram subsamples < 8 mesh were then digested with 2 ml of concentrated nitric acid and 6 ml of concentrated hydrochloric acid. The solution was diluted to 25 ml using distilled, deionized water prior to ICP analysis.

The water samples were filtered and the filtrates were analyzed by ICP.

3. Results and Discussion

3.1 Pole Sectioning

During the sectioning of the stubs, a number of intact rods as well as several metal spikes were encountered. After 1 year, the rods appeared to be intact, i.e. there appeared to be little dissolution of the solid disodium octaborate into "mobile" boric acid although the analytical results indicated that significant diffusion had occurred. After the 2nd year, some loss of solids from the rods was evident and the exposed material was brittle but the outer shell of the rods were largely intact.

3.2 Qualitative Boron Analyses

Figure 2 shows the grid sampling pattern for the moisture measurements and quantitative boron analyses. Photographs of the curcumin stained cross sections and vertical sections are shown in Figures 3-9.

The coloured dots marking the sampling points are indicative of the moisture contents determined by meter analysis:

White	<25%
Blue	25 - 30% (fibre saturation)
Yellow	30+%

The colour intensity of the curcumin stained wood increased with the increasing boron concentration:

Colour	Boric Acid Equivalents kg/m^3
not detected to faint pink	0.0 - 0.1
pale pink	0.1 - 0.3
pink	0.3 - 1.0
red	>1.0

Previous investigations (Edlund 1982; Blow 1985) have found that in some cases, eg in areas previously attacked by fungi, curcumin is not a reliable indicator of boron concentration. However, we found that, in general, the colour intensity, boron concentration (ICP) and wood moisture content showed good correlations.

Areas showing little or no coloration had moisture contents below the fibre saturation level (25 - 30%). Although there was insufficient boron in these areas to protect against fungal attack (1.5 kg/m^3 BAE is generally considered to be the minimum required for effectiveness [Beckgaard 1980]), such an attack is unlikely because fungi generally require environments with higher moisture contents. The lack of boron movement at low moisture contents has been cited as an advantage since the rods will not be depleted until moisture conditions favourable for fungal attack exist.

In most cases, the diffusion appears to initiate in the heartwood region where the rod tips converge as can be seen in the -100 mm section, Pole No. 195, (Figure 6), and then spreads to other regions depending upon the moisture content and distribution. In Pole No. 110, (Figure 4), one of the drier specimens, boron diffusion is evident in the heartwood region and is also visible in a "spoke" pattern directly above and below the 4 rods used to treat this pole.

The amount of boron diffusion showed considerable variation between poles of the same species depending upon the moisture concentration and distribution. Diffusion was much more pronounced in the below ground sections for both species than in those located above ground. The highest concentrations were generally found in the 0 to -100 mm section immediately below the groundline, i.e. the area most susceptible to attack. Boron concentrations were intensified in the immediate areas of checks which would be susceptible to fungal attack because of a lack of a protective P9 grease barrier.

Boron diffusion continued past the -300 mm level in some of the WRC and LPP stubs (Figure 9). The diffusion appeared to be less pronounced in the LPP stubs but continued past 600 mm and approached 900 mm in some WRC stubs.

3.3 Quantitative Boron Analyses

The quantitative boron values obtained by ICP analysis of the wood cores generally showed a good correlation with the qualitative staining results. The concentrations varied appreciably among poles of the same specie, but, in almost all cases, the highest concentrations were found in the 0 to -100 mm sections. The highest boron concentrations were generally in the heartwood region of this section and reached values as high as 30 kg/m^3 BAE.

The boron distribution as a function of wood moisture content are given in Figures 10 and 11. The relationship was found to be linear for each of the stubs for moisture contents above fibre saturation but the slopes of the lines varied widely particularly for the WRC stubs. The first year results for cedar also showed this non-uniform behaviour. Based on the average moisture contents, one would have expected higher boron concentrations in pole #111 (ave. MC = 87%) than in pole # 113 (ave. MC = 63%). The reason for the apparent discrepancy is the moisture distribution close to the rod locations. Pole # 113 had much higher moisture levels in the heartwood areas close to the rods whereas, in pole #111, the moisture levels were lower in the core sections but much higher in the outer sapwood areas particularly in the lower sections some distance away from the rods.

The moisture distributions were much more uniform in the LPP stubs and similar slopes were obtained in the graphs of both poles after 2 years (Figure 11). The 1st year data also showed a similar uniformity between poles but the lines had slightly steeper slopes than the 2nd year data.

Plots were also made of the average boron distribution within the stubs (Figures 12 - 16). The highest concentrations were found within the region most susceptible to attack, i.e., the sections immediately below the groundline. Figure 12 shows that even at a relatively low moisture concentration (pole 110, ave. M.C = 25%), this section contained greater than the 1.5 kg/m^3 BAE required for fungal protection. Considerably higher levels of boron and a broader distribution, slightly skewed in the lower sections, were found in the other WRC stubs containing higher moisture concentrations. Comparison of the WRC data after years 1 and 2 (Figure 13) showed that higher boron levels were achieved after the first year, however, the moisture contents of these stubs were much higher than those of the 2nd year samples.

The boron distribution in the LPP stubs after 2 years, shown in Figure 14, was closer to a normal gaussian distribution than the WRC plots because of a more uniform moisture distribution. The boron concentrations were found to be higher in the 2nd year than in the first which would be expected, since the moisture contents were similar and diffusion would increase with time (Figure 15).

Figure 16, a graph of the average of all the WRC and LPP data (both years), showed that similar amounts and distribution of boron diffusion occurred in both species.

3.4 Boron Leachates

The boron concentrations were more predominant in the immediate areas of checks which are susceptible to fungal attack. These areas, in many cases, were not protected with P9 grease and boron losses to the surrounding soil likely occurred, particularly in areas having large checks. In addition, in some of the sound sections of wood, the photographs show boron diffusion continued through the sapwood to the P9 grease layer. It is likely that some boron migrated through to the soil particularly in areas which contained little grease.

The test site conditions were particularly favourable to induce leaching. The site is situated over a field drainage system and during the wetter months, the water level in the system is ≈25 inches below ground level. This means that the bottom 12 inches of the stubs were continually exposed to water during this period. In addition, a number of areas within the site contained small pools of surface water during the wetter months. As this water diffused downward, boron at the stub surfaces could have been washed into the drainage system.

However, results of analyses on the soil samples showed no significant increase in the boron concentrations (Table 1). Note that the detection limit for the ICP analytical method was reduced prior to the analyses of the second year samples. The presence of high iron concentrations in the test site impeded the analysis, however, after an inter-element correction was applied, the detection limit was reduced to 5 ppm.

Boron was found in the water present in some of the post holes after the 1st year (no water was present during the 2nd year sampling) but the concentrations were very low, ranging from 0.9 to 16 mg/L and averaging 6.5 mg/L. The boron losses are not expected to be significant or pose a threat to the environment because of the prolonged release of boron into the wood, the gradual dispersion of the boron from the wood into large quantities of ground water and the very low toxicity of boron compounds. For example, the LC_{50} value (lethal concentration at which 50% of the exposed specimens die) for boric acid is cited at 100 mg/L for rainbow trout and 113 mg/L for juvenile salmon (Eisler 1990) whereas the LC_{50} value for pentachlorophenol, a commonly used goundline remedial treatment, is 0.078 mg/L (Can. Tech. Rpt on Fish Aquatic Sci. 1984).

4. Conclusions

There was good diffusion of boron through the groundline region of western red cedar and lodgepole pine stubs which had been remedially treated with fused disodium octaborate rods. The highest boron concentrations were found in the region immediately below the groundline which is particularly susceptible to fungal attack.

The diffusion was very dependent on the moisture content of the poles, however, at wood moisture contents above the fibre saturation level, the concentration of boron which diffused into the wood was more than required to protect the wood against fungal attack.

Leaching losses of boron into the surrounding soil and ground water were insignificant relative to fish toxicity data.

5. Recommendations

The monitoring program should be continued to determine the longevity of the boron rod treatment.

The study should be expanded to include the evaluation of a slower release boron source, diboron trioxide, for wetter climatic areas and a faster acting preservative, disodium octaborate/glycol paste, for remedial treatment of poles in drier regions.

6. Acknowledgements

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7. References

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Table 1

Boron Leaching Results

	Time	Samples	Concentration
Soil	Background	27	<10 mg/kg
	1 year	8 1	<10 mg/kg 11 mg/kg
	2 years	5	<5 mg/kg
Water	1 year	5	0.9 - 16 mg/L Average = 6.5 mg/L

LC_{50}	Rainbow Trout	100 mg B/L
	Coho Salmon	113 mg B/L

Figure 1. Pole Test Site in Surrey, BC

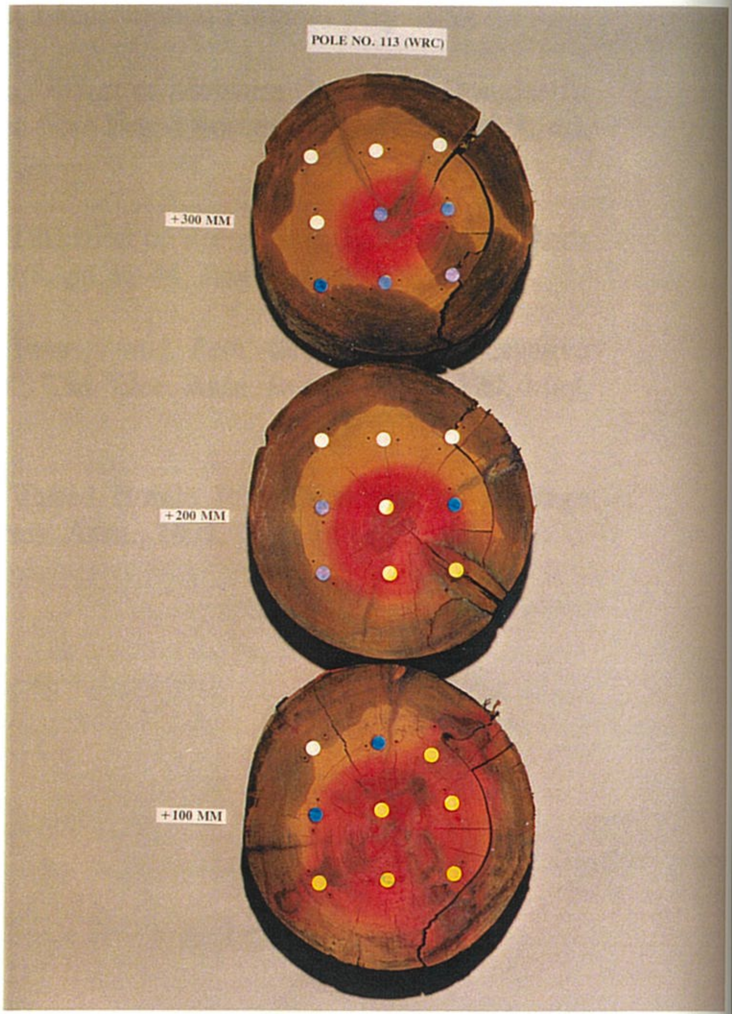

Figure 2. Grid Sampling Pattern

Moisture Distribution

White = <25%
Blue = 25 - 30%
Yellow = >30%

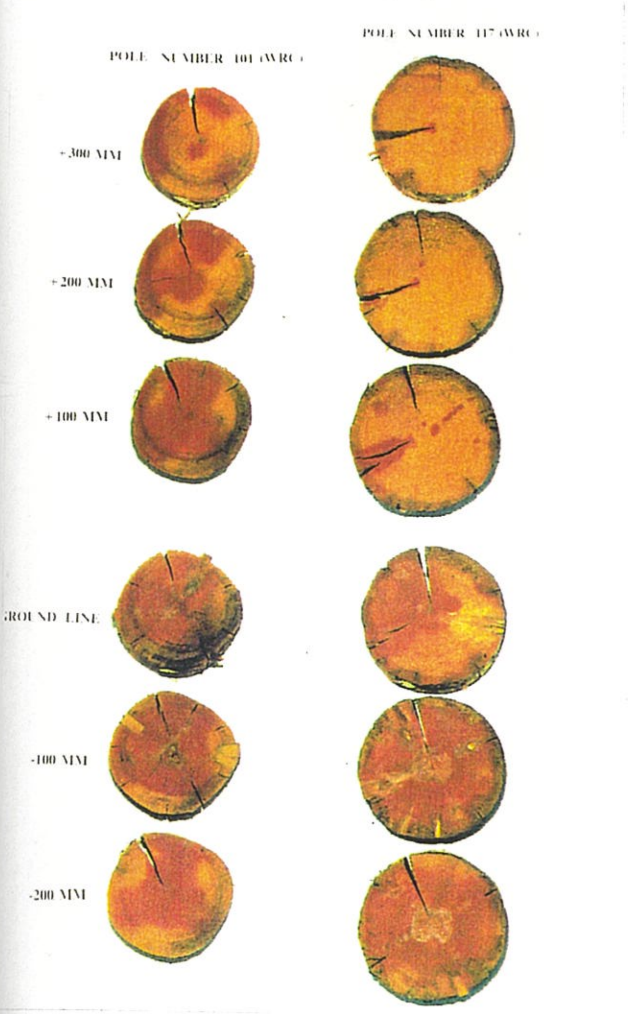

Figure 3. WRC Cross Sections After 1 Year

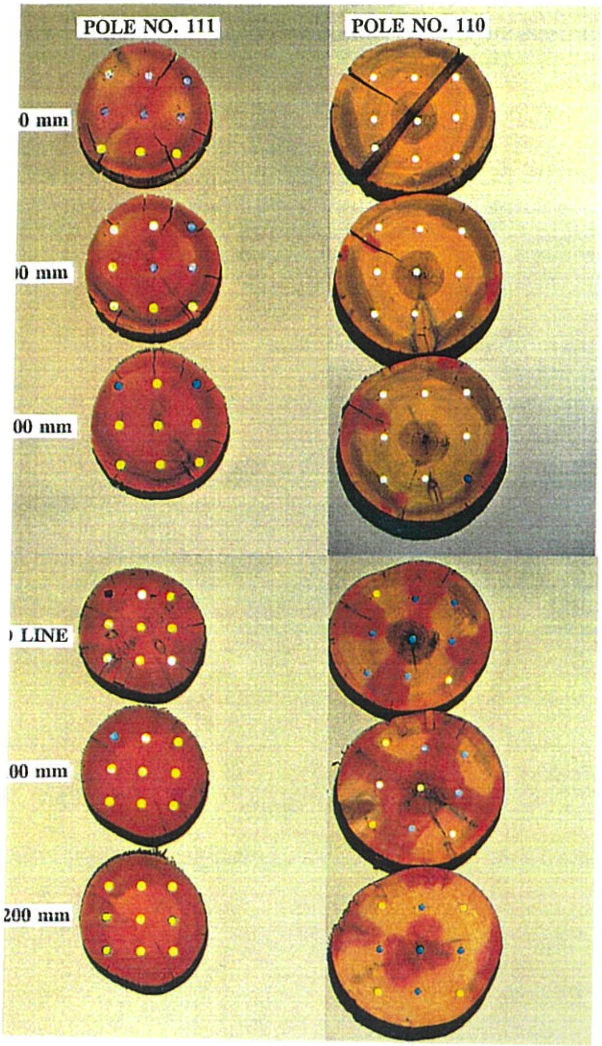

Figure 4. WRC Cross Sections After 2 Years

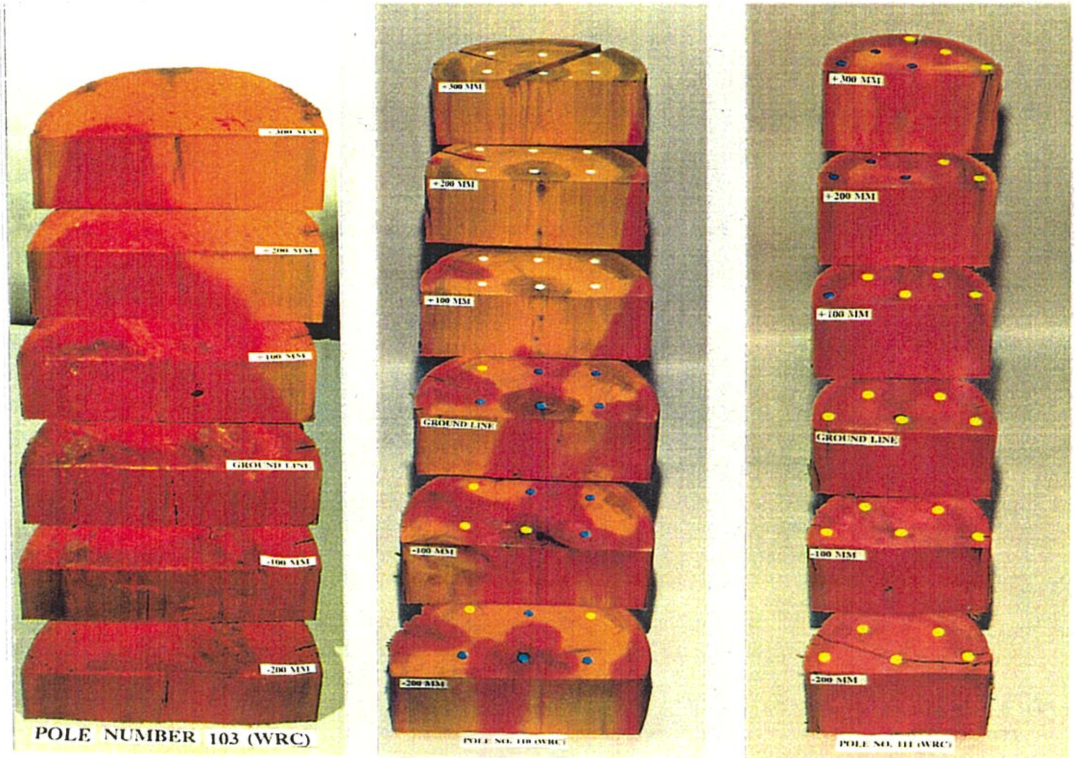

Figure 5. WRC Vertical Sections After 1 & 2 Years

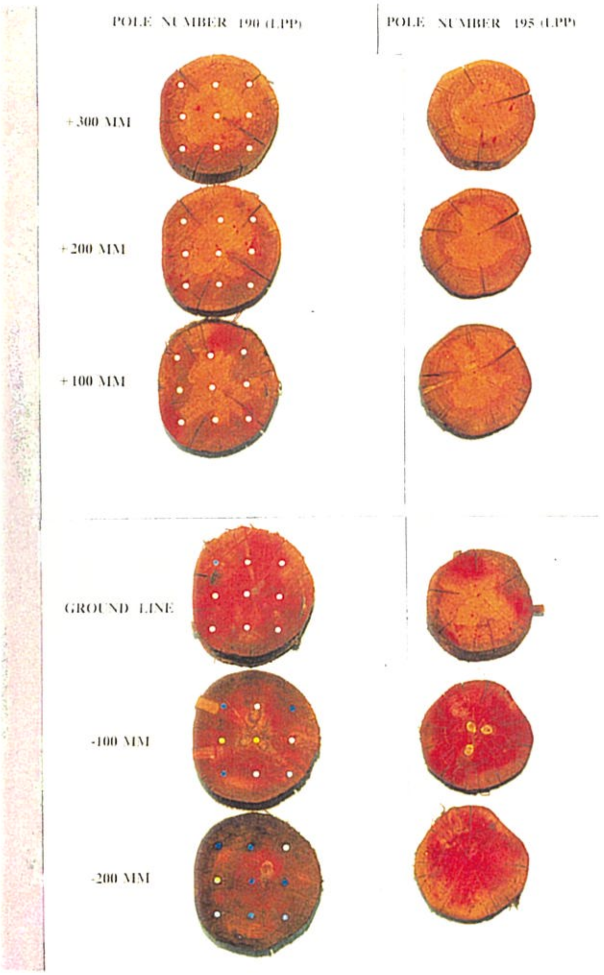

Figure 6. LPP Cross Sections After 1 Year

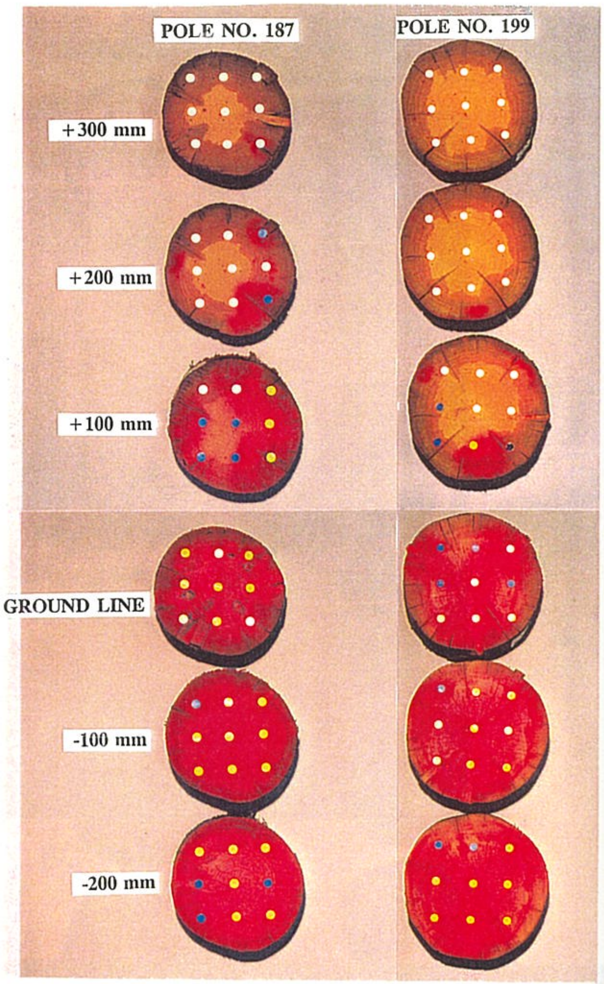

Figure 7. LPP Cross Sections After 2 Years

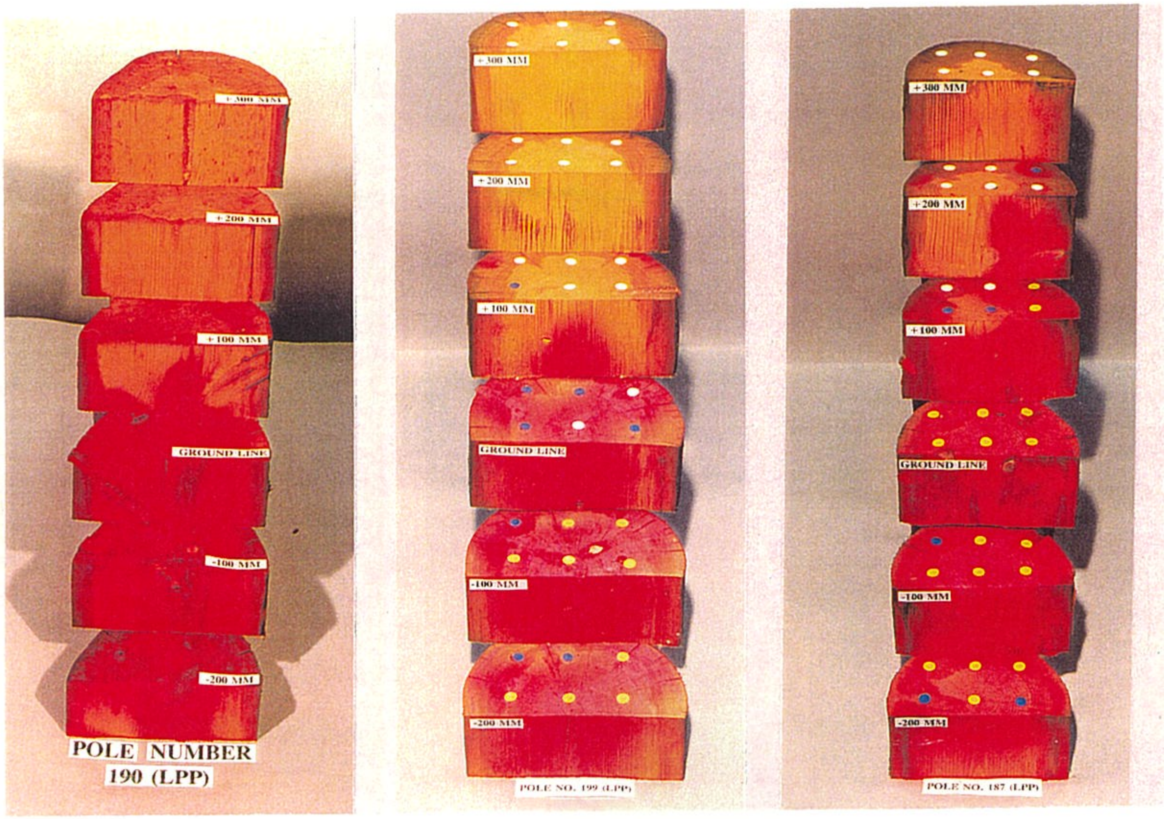

Figure 8. LPP Vertical Sections After 1 & 2 Years

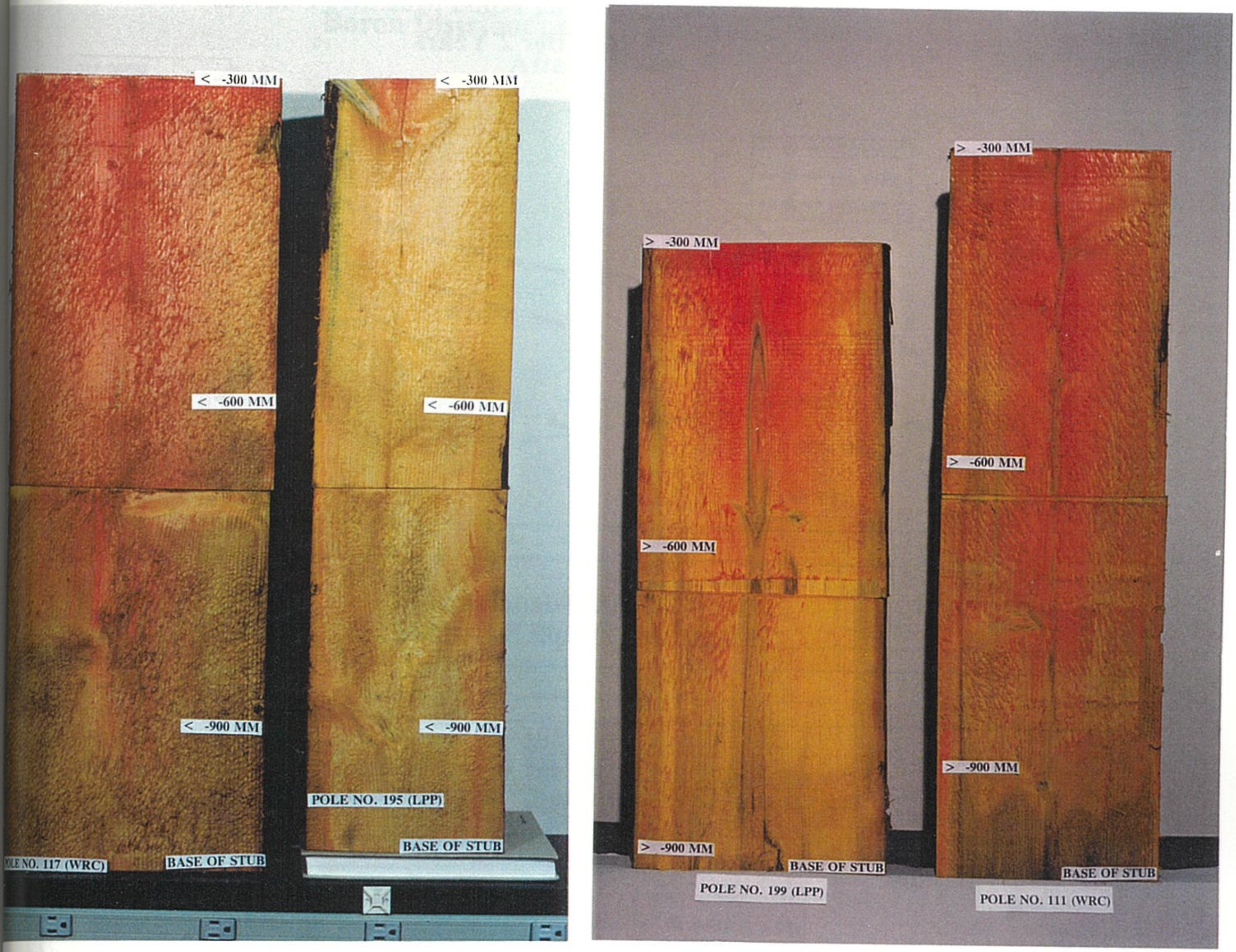

Figure 9. Lower Portion of the Stub After 1 & 2 Years

Figure 10
Boron Distribution versus Wood Moisture Content
WRC After 2 Years

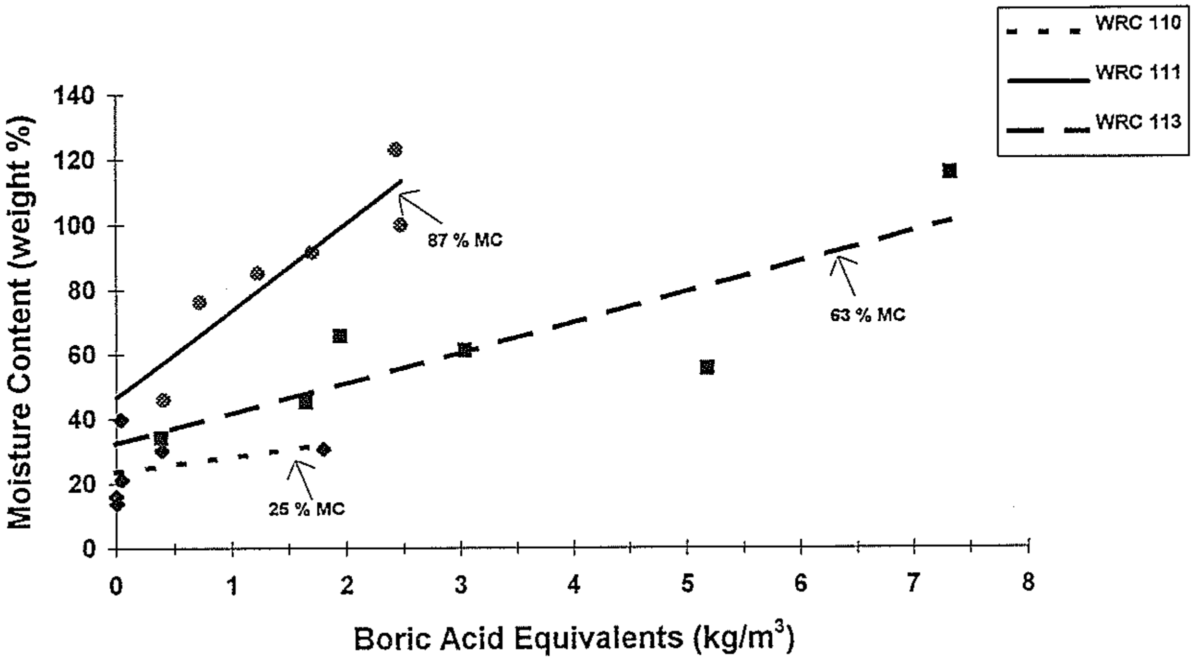

Figure 11
Boron Distribution versus Wood Moisture Content
LP After 2 Years

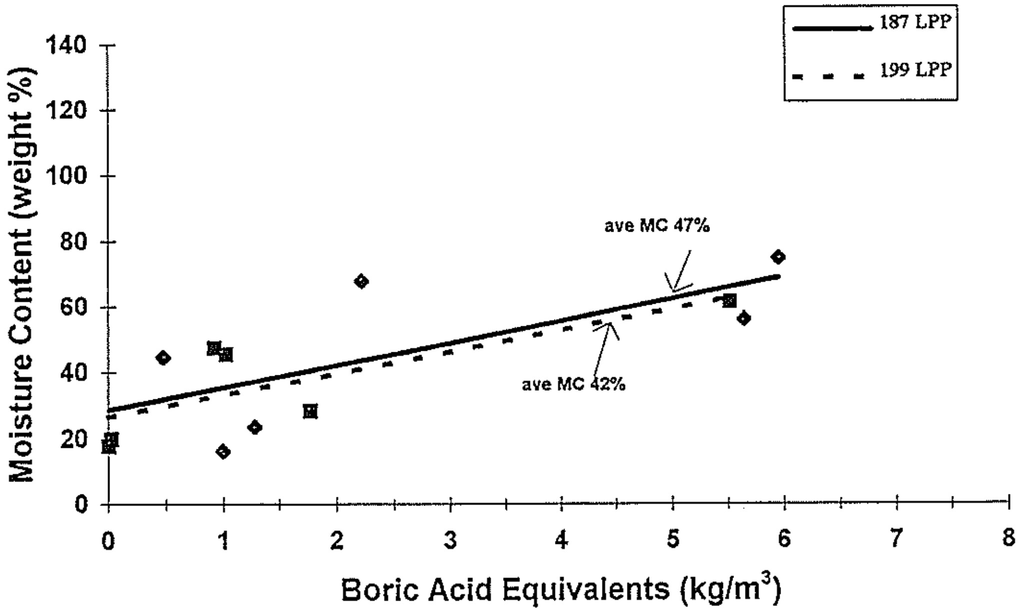

Figure 12
Boron Distribution in WRC Stub Sections After 2 Years

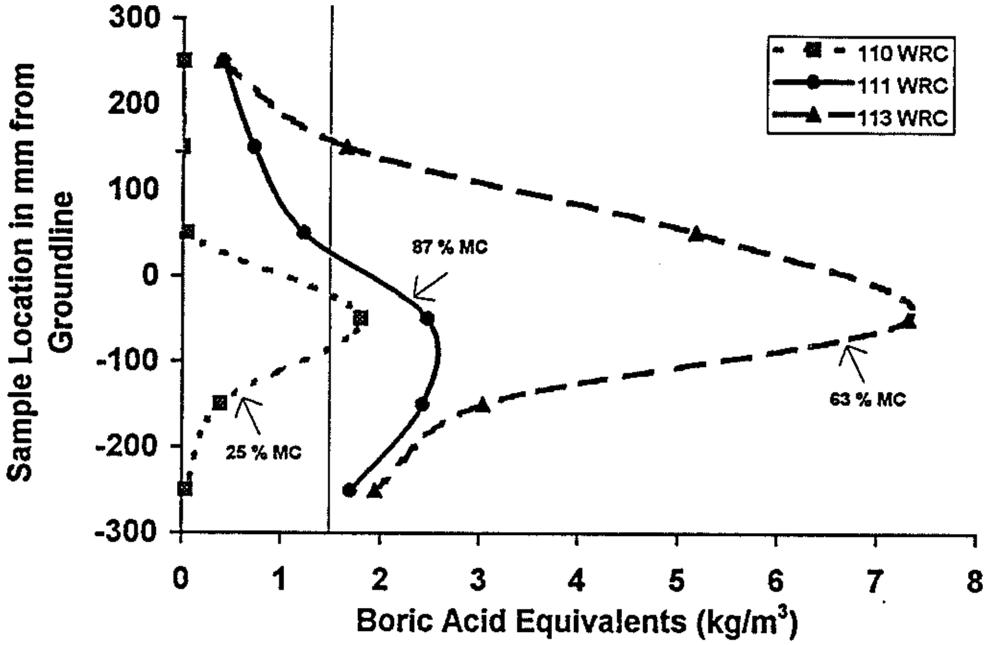

Figure 13
Average Boron Distribution in WRC Stub Sections After 1 & 2 Years

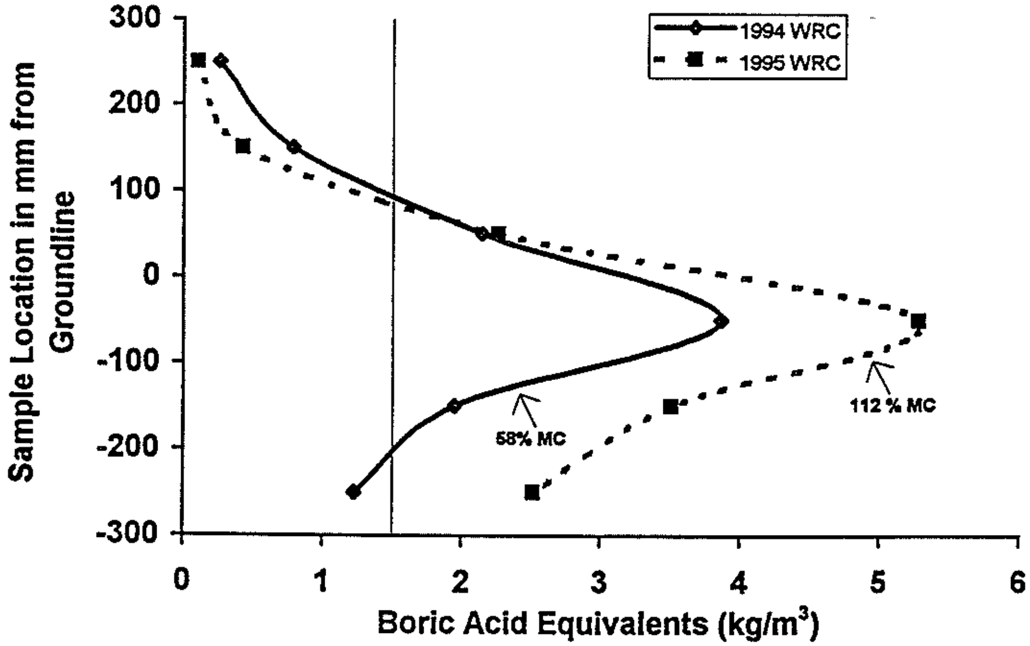

Figure 14
Boron Distribution in LP Stub Sections
After 2 Years

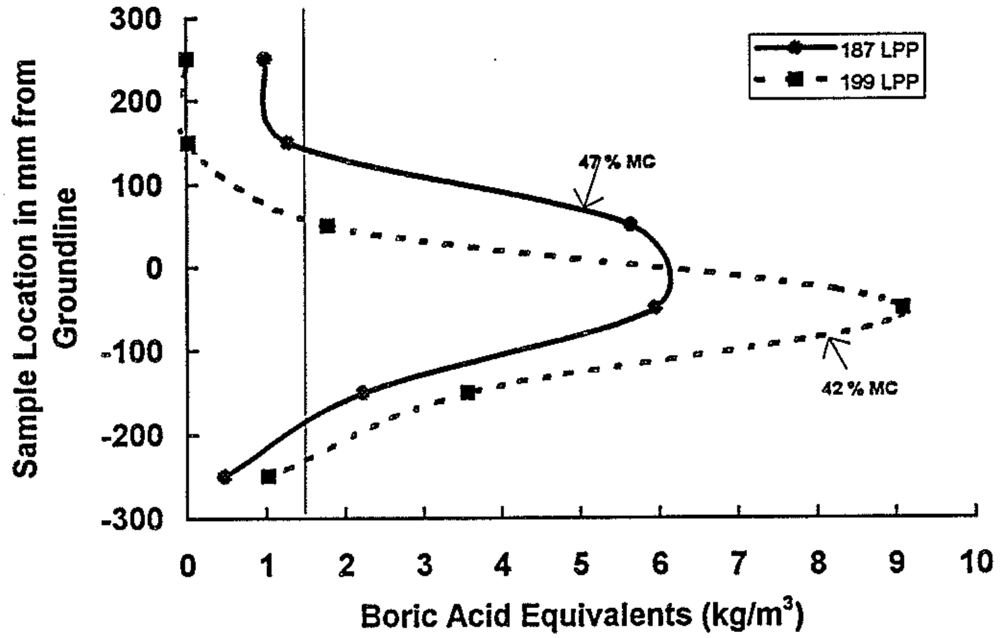

Figure 15
Average Boron Distribution in LP Stub Sections
After 1 & 2 Years

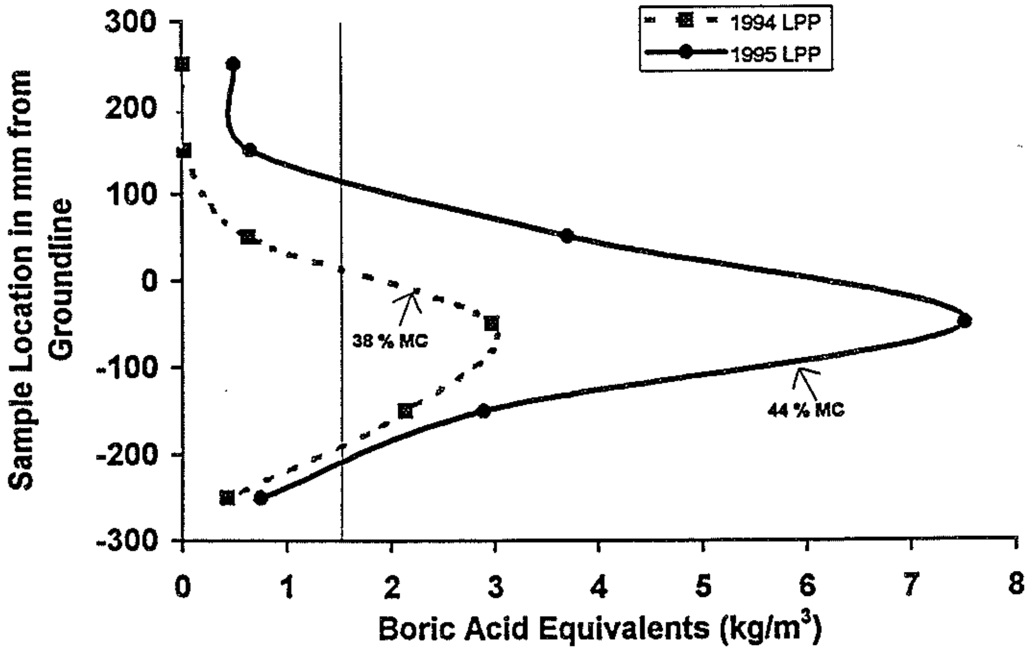

Figure 16
Average Boron Distribution in Stub Sections