EVALUATING FIVE YEARS OF SOIL HYDROLOGIC RESPONSE FOLLOWING THE 2009 LOCKHEED FIRE IN THE COASTAL SANTA CRUZ MOUNTAINS OF CALIFORNIA

A Thesis
Presented to
The Faculty of California Polytechnic State University,
San Luis Obispo

In Partial Fulfillment
Of the Requirements for the Degree
Masters of Science in Forestry Sciences

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December, 2014

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ABSTRACT

Evaluating five years of soil hydrologic response following the 2009 Lockheed Fire in the coastal Santa Cruz Mountains of California

Mary Theresa Crable

The Lockheed Fire burned 31 km^2 (7,660 acres) of the Scotts Creek watershed in August 2009. 4.5 km^2 (1,100 acres) of California Polytechnic State University's educational and research facility at Swanton Pacific Ranch. The burned region presented an opportunity for studying the hydrologic response of burned soils in the Santa Cruz Mountains where there is insufficient post-fire studies regarding fire-effects on watershed processes such as infiltration and near-surface runoff. Soil infiltration and soil water repellency were evaluated with rainfall simulations, Mini-disk Infiltrometer (MDI) and water drop penetration time tests (WDPT) at sites represented by variations in burn severity, soils, and vegetation types throughout the Scotts Creek watershed each year for 5 years following the burn. Mixed-effects modeling was utilized on the 3 datasets to evaluate if changes could be detected in infiltration rates and water repellency following the fire. Rainfall simulations and WDPT tests showed that the fire did not have a statistically-significant impact on infiltration rates or soil water repellency, whereas the MDI tests detected a statistically-significant impact on post-fire infiltration. While the MDI results showed that fire had a significant impact on the hydrologic response over time, questions arose regarding challenges associated with sampling suggesting the method may not be pursued on steep slopes with high surface rock fragments or in the presence of large soil macropores. It is recognized that additional understanding would be gained from having multiple replications at each site every year and tests could be conducted on a subwatershed scale to account for the naturally occurring variability of larger watersheds.

Keywords: soil water repellency, infiltration, hydrologic response, near-surface runoff, burn severity, soil burn severity, rainfall simulations, water drop penetration times, Mini-disk Infiltrometer.

ACKNOWLEDGMENTS

I would like to acknowledge my mother and sister, first and foremost, for encouraging[1] me to pursue a graduate degree. I would also like to thank Ed Crable and Roger Chin, my fathers, for always supporting me and pushing me to reach personal and professional goals.

Next, I would like to acknowledge and give a tremendous thanks to Brian Dietterick for providing me with the opportunity[2] to conduct this valuable post-fire research as well as take part in holding down the Little Creek Project. I would like to thank Karen Vaughan and Chris Dicus for making time in their busy schedules on numerous occasions to review and discus my thesis. I truly appreciate the guidance and support provided by each of you throughout this program.

I would like to acknowledge all of the interns who collected data prior to my time on this project, and I would to thank all of the interns who helped either myself, Dylan Theobald, John Hardy, or Ashley Brubaker collect field data. Thanks everyone!

I would like to acknowledge Drew Perkins and Drew Loganbill[3]; the pair of you taught me everything I know about the Little Creek Project.

Julie Dufresne[4], if it were not for this graduate program, I would have never found my best friend[5]. Excuse me, best friends (Marley[6]).

Last, but certainly not least, I would like to acknowledge and give a tremendous thanks to all of the Swanton Pacific Ranch staff[7] for being supportive in every way possible. I will cherish every moment I spent with all of you and I shall remember the good times fondly.

This research was funded through the CSU Agricultural Research Initiative, the USDA McIntire-Stennis grant program, Cal Fire, and Swanton Pacific Ranch.

[1] Encouraging = harassing. I am grateful for your “encouragement” because I have truly found what I love to do. Thanks you two!
[2] Provide me with opportunity = TRUSTING me.
[3] The “Drizzles.”
[4] To be pronounced Doo-frez-knee.
[5] Outside of family members.
[6] To be pronounced Mar Mar.
[7] Sierra Alpha, Golf Charley, Sierra Bravo, Sierra Whisky, Sierra Lima, Charlie Delta, Charlie Mexico, Papa Delta, Indigo Kilo, Charlie Nebraska, Alpha Bravo, Sierra Charlie, Joy Llama, Nebraska Mexico, PartAy Alpha, Joy Whisky, Romeo Sierra, and Romeo Mexico.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 : INTRODUCTION

Soil infiltration rates are widely studied around the world for the purposes of land management. In California, a considerable amount of research focuses on post-fire soil infiltration rates because of the potential for increased runoff and overland flow as a result of fire-induced effects that reduce the infiltration capacity of burned regions. Such effects that may result in decreased infiltration rates include loss of canopy and surface cover, fire-induced soil water repellency, and soil sealing. Erosional events such as rilling, mass wasting, and debris flows, and possibly debris torrents, may arise due to an increase in overland flow following a fire (Wells, 1987; Wohl and Pearthree, 1991). While there is an abundance of literature from decades of research on the post-fire effects on soil hydrologic properties or on fire-induced mass wasting, there is insufficient data regarding the effect of fire on hydrologic processes within the Santa Cruz Mountains. What makes this area particularly intriguing is the vegetative gradient from mixed coniferous redwood dominated forests in the lowlands in lower-slope positions to the chaparral on the mid-upper slopes to knobcone dominating the higher, more xeric slope positions. A watershed of this nature would presumably produce varying responses in the soil hydrologic processes following wildfire.

The Lockheed Fire burned 31 km^2 (7,660 acres) of a predominantly forested landscape in the Coastal Mountains of Santa Cruz County in August of 2009. Although devastating to landowners, wildfire is an important ecosystem process and has been absent in this area since the 1948 Pine Mountain Fire. This burn presented a unique opportunity for studying the soil hydrologic processes of burned soils and provided an opportunity to improve our understanding of a post-fire watershed response.

Nearly 4.5 km^2 (1,100 acres) of Cal Poly's Swanton Pacific Ranch was in the burn area. Swanton Pacific Ranch is held by the Cal Poly Corporation for education and research purposes of the California Polytechnic State University, San Luis Obispo. In addition to being a working ranch that supports livestock, forestry, and crop operations, the 13 km^2 (3,280 acres) property provides both faculty and students the opportunity to better understand land management influences and natural disturbances on ecosystem processes.

Following the wildfire, several projects were instituted in order to gain a better understanding of the watershed processes. This project offers an evaluation of soil infiltration rates, near-surface runoff and fire-induced water repellency. Soil infiltration and soil water repellency were evaluated with rainfall simulations, Mini-disk Infiltrometer and water drop penetration time tests. These tests were performed at sites across a range of burn severities, soils, and vegetation types throughout the Scotts Creek watershed each of the first five years following the burn.

1.1 Study objectives and goals:

This thesis analyzes the results of three field tests utilized to analyze if a fire-induced effect on soil hydrologic properties exists. The tests include 1) rainfall simulations, 2) Mini-disk Infiltrometers, and 3) water drop penetration times. The objectives of this study were:

1. Evaluate changes in infiltration and near-surface runoff using rainfall simulations.
2. Evaluate changes in soil water repellency using Mini-disk Infiltrometers.
3. Evaluate changes in penetration times using water drop penetration times.

The goals are to identify if temporal trends in hydrologic processes, namely infiltration, are evident and whether those trends can be statistically proven to be a result of the 2009 Lockheed Fire. This work provides both baseline data for future soil/water relations research as well as recommendations on how to effectively collect data using rainfall simulations, Mini-disk Infiltrometers and water drop penetration time tests. Understanding how a fire affects the hydrologic function of this watershed via rainfall simulations, Mini-disk Infiltrometers and /or water drop penetration time tests will help resource managers, landowners and other decision makers in regards to mitigation efforts immediately following the wildfire.

CHAPTER 2 : BACKGROUND

2.1 Study Location

This study occurred within the Scotts Creek watershed in Western Santa Cruz County, California (Figure 2-1.) The 190 km^2 (46,950 acres) coastal watershed is located north of Santa Cruz, CA and drains to the Pacific Ocean. Specifically, experimentation was carried out within Mill Creek, Boyer Creek, and Little Creek watersheds, subwatersheds to Scotts Creek watershed. Access to these sites was granted by Swanton Pacific Ranch, Lockheed Martin and the former Cemex property, known as San Vicente Redwoods, that is now owned by four conservation groups that include, the Land Trust of Santa Cruz County, Peninsula Open Space Trust, Sempervirens Fund, and Save the Redwoods League.

2.1.1 Climate

The Santa Cruz Mountains have a Mediterranean climate with year-round, coastal fog. Winters are mild and wet with the majority of rainfall occurring during this time. Summers tend to be warm and dry with a fairly consistent fog bank at lower elevations along the coast. The mean annual precipitation at the lowest elevation in the Scotts Creek watershed is 76.2 cm. The mean annual precipitation ranges from 102-127 cm along the ridgelines (Scotts Creek Watershed Assessment, 2005).

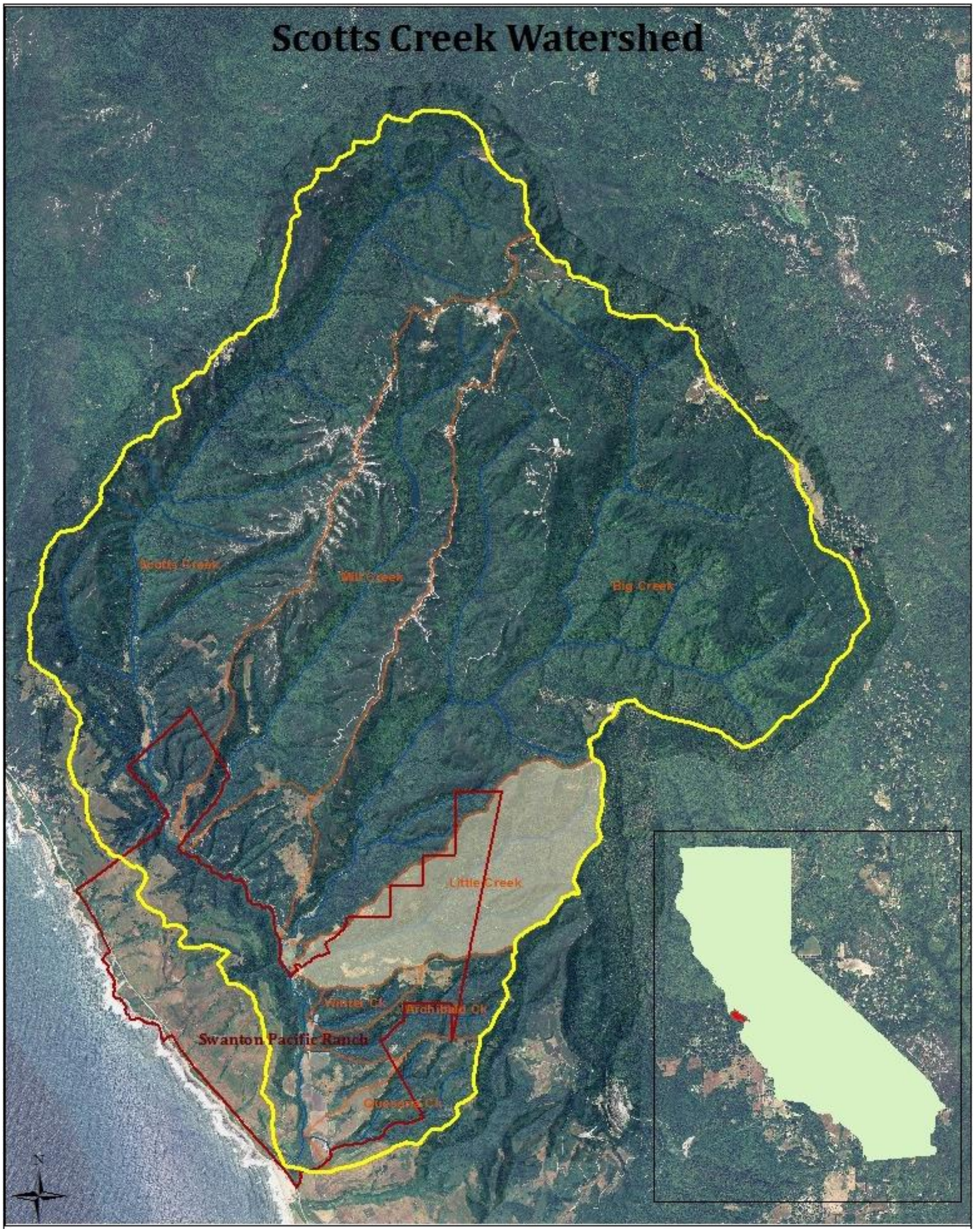


Figure 2-1: Scotts Creek (yellow) and Little Creek (shaded) watershed boundaries, Swanton Pacific Ranch (red).

2.1.2 Geology and Soils

The Scotts Creek watershed resides in the tectonically-active Coast Ranges. Steep, narrow valleys characterize much of the watershed and its subwatersheds. This is due to the rapid uplift of the region in combination with the continual down cutting of streams and erosional events such as landsliding, debris torrents and rotational slumps.

The watershed overlies the Salinian block which is composed of three main rock types: quartz diorite (Cretaceous), Santa Margarita Sandstone, and Santa Cruz Mudstone (Upper Miocene). The quartz diorite and some metamorphic marble and schist (Mesozoic or Paleozoic) make up the basement rock while the Santa Margarita Sandstone and Santa Cruz Mudstone makeup the overlying cover rock (Figure 2-2). As a result of the continuous uplifting, the Salinian block has been tilted ocean-ward and has been subject to surficial wind and rain erosion. The northeastern portion of the watershed is dominated by exposed granite while the rest of the watershed maintains a patchy distribution of sedimentary rock overlying the granite (Taskey, 2010).

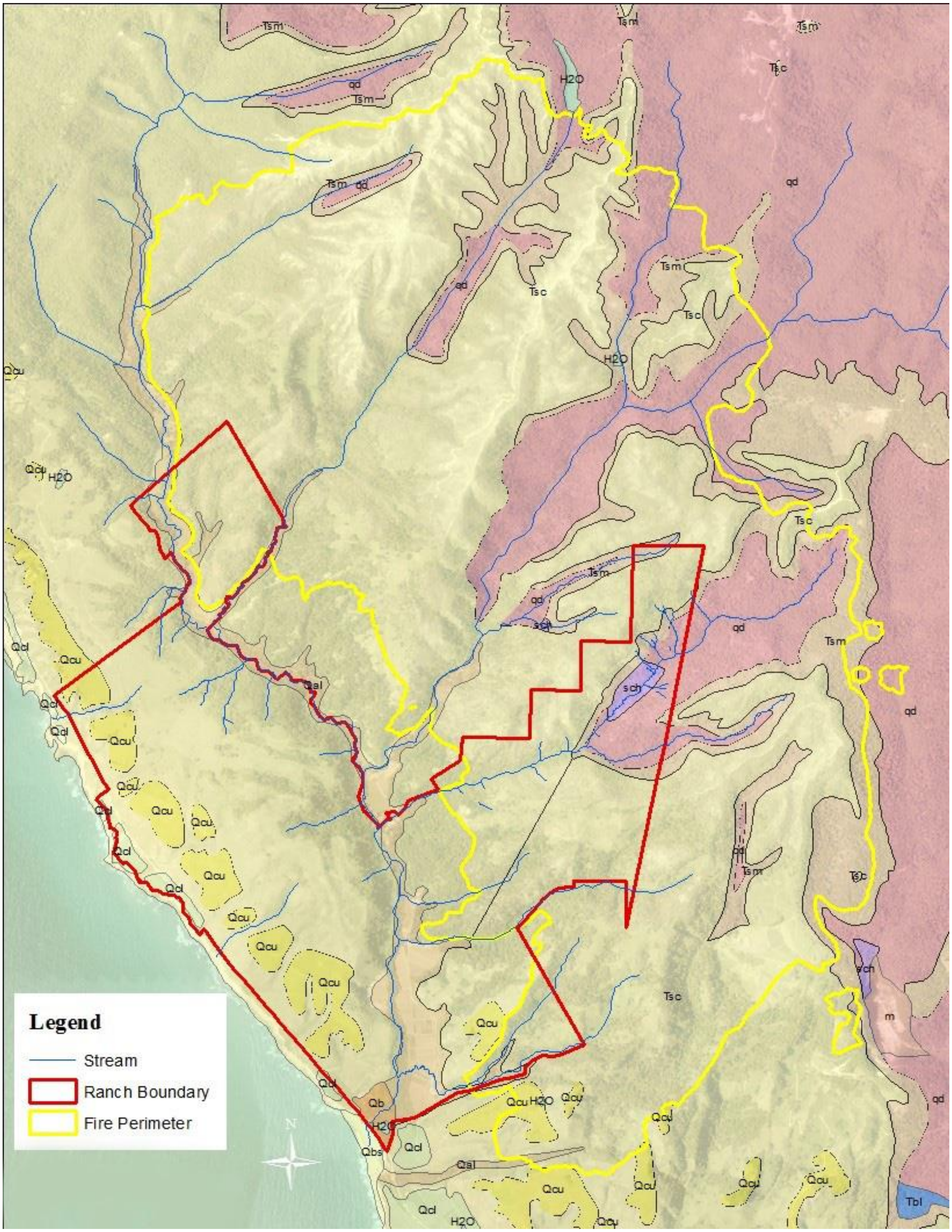


Figure 2-2: Geologic map with the fire perimeter (yellow) and ranch boundary (red) within the Scotts Creek watershed. Qd- quartz diorite (pink), Tsm-Santa Margarita sandstone (beige), Tsc-Santa Cruz mudstone (light yellow).

Pedogenesis in the Scotts Creek watershed is strongly influenced by slope position, slope steepness and parent material (Taskey, 2010). There are numerous soil types within the Scotts Creek watershed, with soils derived from granite, sandstone and mudstone. Test sites represented variations among the soil parent materials.

The soil map unit and soil names are 113—Ben Lomond-Catelli-Sur complex, 30 to 75 percent slopes; 173—Sur-Catelli complex, 50 to 75 percent slopes; and 153—Maymen-Rock outcrop complex, 50 to 75 percent slopes (Figure 2-3). Table 2-1 lists the dominant soil types where field tests were conducted.

Table 2-1: Soil Series names and Family Classifications of soils mapped at site locations (Soil Survey of Santa Cruz County, California).

Soil Series Name	Family Classification
Ben Lomond-Catelli-Sur Complex	Coarse-loamy, mixed, super active, mesic Pachic Ultic haploxerolls-Coarse-loamy, mixed, superactive, mesic Ultic Haploxerolls-Loamy-skeletal, mixed, superactive, mesic Entic Haploxerolls
Sur-Catelli Complex	Skeletal, mixed, superactive, mesic Entic Haploxerolls-Coarse-loamy, mixed, superactive, mesic Ultic Haploxerolls.
Maymen-Rock outcrop complex	Loamy, mixed, active, mesic, shallow Typic Dystroxerepts-Rock outcrop

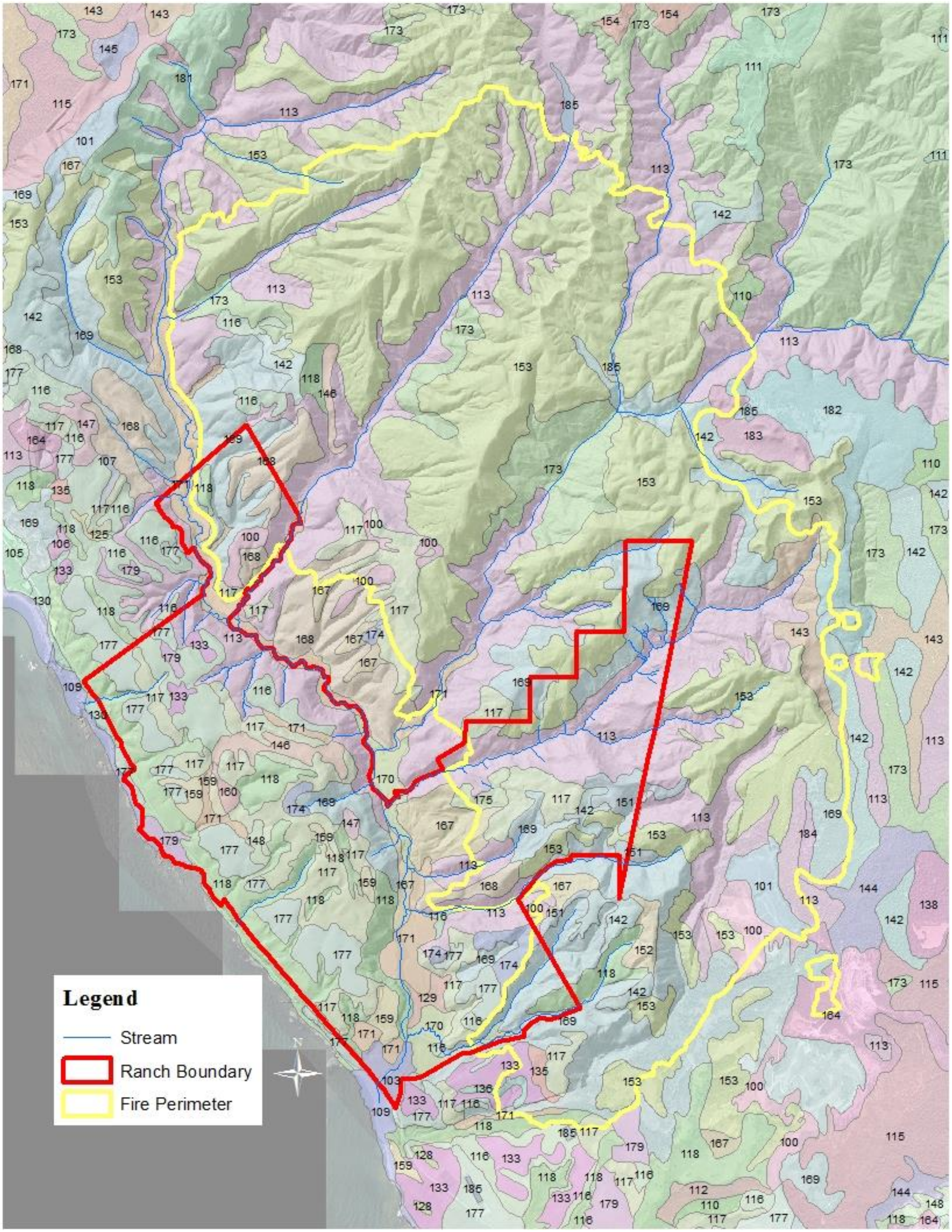


Figure 2-3: Soils of the Scotts Creek watershed with the fire perimeter in yellow and the ranch boundary in red.

2.1.3 Vegetation

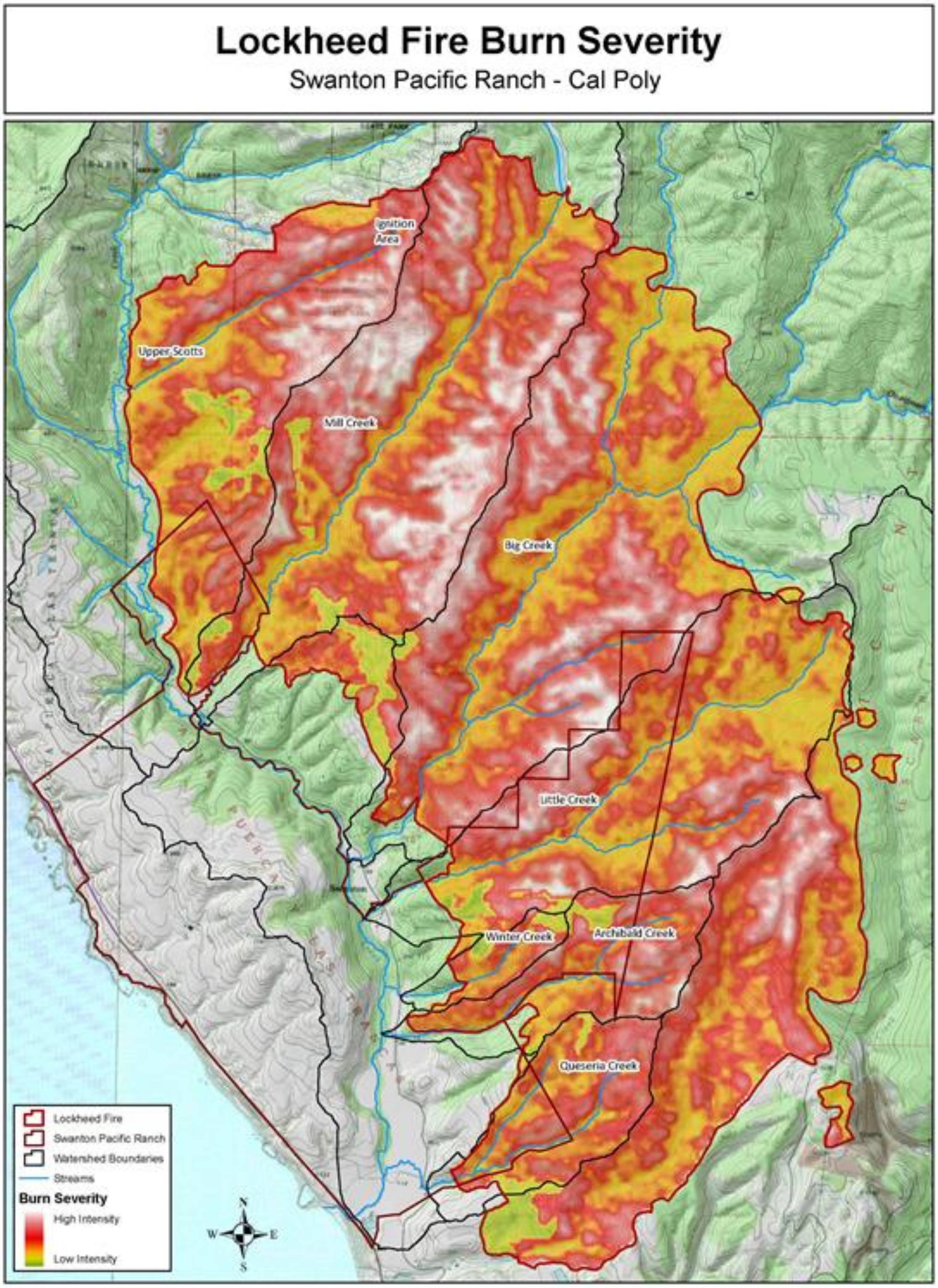
The Scotts Creek watershed contains a very diverse array of plant communities and forest types. This area that was once clearcut for its valuable redwood lumber, at the turn of the 19th century, now supports over 600 native plant species (West, 2014).

Adjacent to streams, the watershed supports a lush riparian plant community with an overstory of red alder (*Alnus rubra*), big-leaf maple (*Acer macrophyllum)* and California box elder (*Acer negundo* var. *californicum*), and an understory composed of arroyo willow (*Salix lasiolepis*), yellow willow (*Salix lutea*), blackberry (*Rubus ursinus*), thimbleberry (*Rubus parviflorus*), salmonberry (*Rubus spectabilis*), nightshade (*Atropa belladonna*), rush (*Juncus*), sedges (*Carex*) and poison oak (*Toxicodendron diversilobum*). Moving away from the streams laterally, the plant community transitions into mixed conifer stands of redwood (*Sequoia sempervirens*) and Douglas fir (*Pseudotsuga menziesii* var. *menziesii*) and mixed hardwood and conifer stands consisting of Douglas fir, tanoak (*Lithocarpus densiflorus*), coast live oak (*Quercus agrifolia* var. *agrifolia*), California bay laurel and some interspersed madrone (*Arbutus menziesii*). The ridgelines tend to be dominated by chaparral species and knobcone pine (*Pinus attenuata*) forests. Manzanita (*Arctostaphylos*), chamise (*Adenostoma fasciculatum*), bush poppy (*Dendromecon rigida*), chaparral pea (*Pickeringia montana* var. *montana*), and huckleberry (*Vaccinium ovatum*) compose the understory vegetation while the overstory consists of primarily knobcone pine and some redwood.

2.2 The Lockheed Fire

The Lockheed Fire began at 7:12 the evening of August 12, 2009. A total of 31.642 km^2 (7,819 acres) burned by the time the wildfire was 100% contained on August 23, 2009. The majority of the burn occurred within the Scotts Creek watershed with a small percentage of the San Vicente watershed burned. Strong winds the day of the fire and a preceding dry winter combined with heavy fuel loads and ladder fuels had a large influence on the extent and severity of the burn. The fire spread rapidly throughout the watershed including riparian vegetation at lower elevations, redwood and mixed conifer stands at mid-slope elevations and completely consuming most knobcone pine and manzanita stands on the ridgelines.

A team of specialists from Cal Fire, Big Creek Lumber Company and Cal Poly evaluated burn severity by using ground observations, photos taken from a helicopter, and a Burned Area Reflectance Classification (BARC) map which is a satellite-derived map of the post-fire vegetation condition. The BARC map was the basis for the burn severity map and was fine-tuned as necessary using team members' field observations (Figure 2-4).



Area Burned	Acres	Percent
Lockheed Fire Total	7,819	--
Scotts Creek Watershed	6,735	35%
Swanton Pacific Ranch	1,142	35%

Burn Severity from USFS BARC
Fire perimeter from CALFIRE
September 8, 2009
DP, RW

Figure 2-4: Burn severity map from the 2009 Lockheed Fire.

Burn severity was highest on the ridgelines which are comprised predominantly of knobcone pine and chaparral species. Moderate severity was interspersed with the high and lower severity burn classifications in the upper, mid and lower slopes, and generally consisting of redwood and mixed conifer vegetative communities. Some areas of the coast redwood and Douglas fir forest type were fully consumed and were classified as high severity. Streamside vegetation including overstory trees, shrubs and ground cover experienced lower fire intensities and that resulted in low severity soil burn conditions. The percentage of each burn severity over the entire burned area is 14% very high, 37% high, 43% moderate, and 6% low. The breakdown of percent burned of individual subwatershed is presented in Table 2-2. A description of each burn severity classification can be found in Appendix A. Burn severity by vegetation type is presented in Table 2-3 to further illustrate the correlation between burn severity and specific vegetation types.

Table 2-2: Total percent burned of each subwatershed and percent of each burn severity within individual subwatersheds Cal Fire, 2009).

Watershed	Total Acreage	Acreage burned	% Burned	Very High Severity	High Severity	Moderate Severity	Low Severity
Boyer	1,354	432.0	31.9	13.8	31.8	47.6	6.80
Little Creek	1,306	1200	91.9	11.2	30.9	52.7	5.30
Mill Creek	2,404	1626	67.6	25.0	38.1	32.6	4.2
Lower Scotts	1503	150	10.0	2.0	30.6	27.2	40.1
Upper Scotts	5207	583	11.2	2.8	31.7	52.2	13.3
Entire Scotts Creek	19,001	6755	36.0	n/a	n/a	n/a	n/a

Table 2-3: Soil burn severity by vegetation type (Cal Fire, 2009).

Vegetation Type	Area Burned (ha)	Very High Severity (ha)	High Severity (ha)	Moderate Severity (ha)	Low Severity (ha)
Redwood Forest	979	17.4	240	667	55.6
Mixed Conifer Forest	790	37.6	283	448	21.0
Chaparral (including knobcone)	981	372	489	112	8.9
Coastal Scrub	217	6.9	124	78.9	6.9
Grassland	138	0	21.9	8.9	108
Agriculture	17.0	0	4.0	11.3	0.8
Monterey Pine	15.0	0	6.9	7.3	0.8
Quarry/Town	1.6	0	0	0.4	1.2
Oak Woodland	6.1	0	1.2	4.9	0

CHAPTER 3 : LITERATURE REVIEW

Infiltration is the downward entry of water into soil (Hillel, 2004; Brady and Weil, 2009). In a watershed, infiltration depends on precipitation, soil properties, vegetation and topography. Precipitation will reach the soil surface directly from the sky or indirectly from plants. Water is then stored in soil macropores and micropores until it is returned to the atmosphere through evaporation and transpiration, or discharged as surface runoff or subsurface flow (Brady and Weil, 2009). In the event that water can no longer infiltrate, surface runoff will occur (Knighton, 1998).

The two types of surface runoff are saturation overland flow and infiltration excess overland flow. Saturation overland flow takes place when soil water storage is at capacity and additional water becomes runoff. Infiltration excess occurs when the precipitation rate is greater than the infiltration rate (Knighton, 1998). Following a fire, infiltration and runoff rates may be affected.

3.1 Factors leading to fire-induced changes in soil hydrologic properties

The fire-induced conditions that lead to physical changes in soil hydrologic processes are loss of duff, live vegetation and canopy cover in addition to soil sealing, ash deposition, surface roughness, and fire-induced hydrophobicity. Burn severity can significantly influence these post-fire conditions. Burn severity is a measure of organic matter loss or deposition of ash from aboveground combustion of biomass (Keeley, 2009). Rainfall simulations, Mini-disk

Infiltrometers and water drop penetration time tests can be used for evaluating post-fire effects on infiltration and runoff rates, and soil water repellency.

3.1.1 Loss of Duff

Forests soils tend to have greater infiltration rates because of the high percentage of macropores generated by old root channels, and/or burrows and tunnels made by animals, insects and worms and have the ability to exceed rainfall rates of 12 centimeters per hour (Fisher and Binkley, 2000; Ice *et* al., 2004; Rothacher *et al.*, 1976). In addition, mature forests have thick O horizons underlain by deep soils, both of which rapidly absorb water like a sponge (Fisher and Binkley, 2000). As a result, undisturbed, mature forest soils generally have little surface runoff and the thick O horizon protects the soil surface from rainfall impact thus lessening soil particle detachment and overall erosion during storms (Fisher and Binkley, 2000).

The reduction or complete incineration of the O horizon during a fire lowers the overall water storage capacity of the landscape. The O horizon has the ability to absorb several times its own mass therefore the reduction or removal of this horizon may contribute to an increase in post-fire runoff (Fisher and Binkley, 2000; Pierson *et al.*, 2008). Fire-induced soil water repellency is often described as having been formed by the combustion of the litter and duff in the O horizon that can lead to the development of a hydrophobic layer within the top 5 cm of mineral soil and has high spatial variability (DeBano, 2000b; Robichaud *et al.*, 2008; Robichaud and Hungerford, 2000; Doerr and Moody, 2004). The addition of a hydrophobic layer restricts water movement downward through the soil profile thereby reducing the water holding capacity of the soil. A reduction in water holding capacity contributes to saturation excess overland flow (DeBano, 2000a; Ice *et al*., 2004; Robichaud *et al.*, 2008; Larsen *et al*., 2009). Not only does the

combustion of organic litter and duff lead to fire-induced water repellent layers, but the destruction of these overlying organic layers exposes bare soil to rainfall impact that can lead to erosion through particle detachment and the formation of surface crusts and seals (Onda *et al*., 2008; McIntyre, 1958). Such fire induced changes have resulted in decreased infiltration capacities and increased overland flow (Shakesby and Doerr, 2005; Onda *et al*., 2008).

3.1.2 Loss of Vegetation

The removal of ground and canopy cover is a primary cause of increased surface runoff rates following a fire (Helvey, 1980; Pierson *et al.*, 2008). Vegetation consumption reduces evapotranspiration losses which cause water storage capacities to remain high in the years following a wildfire. Elevated soil water storage capacities do not allow for additional precipitation to infiltrate, therefore, saturation excess overland flow occurs (Helvey, 1980). The regenerative process may take several years depending on burn severity and vegetation characteristics. Vegetation is important in balancing soil water storage. As vegetation growth progresses following a fire, moisture will be removed from the soil via plant roots and over time, the soil water holding capacity will increase (Helvey, 1980).

3.1.3 Soil sealing

Post-fire soil sealing can contribute to significant increases in infiltration excess overland flow. Reduced surface cover subjects bare ground to processes that cause soil sealing. Two types of seals can form: structural and depositional. Structural seals develop as a result of soil compaction, slaking, pore clogging, and destruction of soil aggregates by direct rainfall impact.

Depositional seals form by the settling of fine particles carried in runoff (Assouline and Maulem, 2000). The onset of a major storm event the first winter in a severely-burned watershed has the ability to drastically change the soil surface by compressing and eroding the ash layer thereby causing a seal (Onda *et al*., 2008) Seals can range in thickness from 0.1mm to several centimeters, and have a hydraulic conductivity (rate at which water can move through the soil) several magnitudes lower than underlying soils (Assouline, 2004; McIntyre, 1958). The inability of water to infiltrate the upper soil layers will lead to increases in infiltration excess overland flow. The difficulty of water to permeate the seal leads to increased post-fire runoff rates (Larsen *et. al.*, 2009).

3.1.4 Ash deposition

Ash has a strong effect on infiltration and runoff rates following a fire. Depending on the amount, it can protect against soil sealing, absorb a lot of water because of its particle size and lead to a decrease in runoff rates (Mallik *et al.*, 1984; Cerda and Doerr, 2008). The extent and thickness of the ashy layer is largely influenced by the amount of fuel and burn severity. Burn severity can range from unburned, where plants are unaltered from lack of heating, to severely burned, where surface litter is replaced with ash (Keeley, 2009). Immediately following a high severity wildfire, the thick ash layer protects bare soil from rainfall impact and absorbs water. Runoff rates are low during the first storm until the ash layer is completely saturated and the wetting front reaches the hydrophobic layer after which subsurface flow will continue laterally and infiltration excess flow will occur on the surface (Cerda and Doerr, 2008; Onda *et al*., 2008). Consequently, the time frame in which ash may significantly reduce runoff is in terms of days

(Woods and Balfour, 2008). Because it is highly susceptible to wind and water erosion, the ash layer can be carried away within a short period following the fire (Cerda and Doerr, 2008).

Ash can also reduce infiltration rates. When the thick ash layer dissipates, any remaining ash particles may clog soil pores in the upper soil layer causing a structural seal (Lavee *et al.,* 1995). Should any remaining ash become hydrated with water, it will expand significantly enhance the formation of a structural seal (Etiegni and Campbell, 1991). The addition of ash can also change the proportion of macropores and micropores depending upon soil texture thus reducing percolation, but increasing water holding capacity (Mallik *et al.,* 1984).

3.1.5 Surface roughness

On lower severity burn sites, surface roughness is a fire-induced condition that contributes to mitigating increased runoff rates. Partial consumption of surface litter and ground cover does not necessarily produce the same thick ash layers as a high severity burn, but remnants of charred organic matter, such as branches, and rock fragments protect against rainfall impact. As a result, post-fire surface roughness reduces soil sealing thereby promoting a higher rate of infiltration to take place. Surface roughness increases depression storage and decreases runoff velocities, which provides water with the chance and time to infiltrate (Lavee *et al.*, 1995). This roughness is similar to unburned conditions. Litter and vegetation increase water storage and shield against the erosional forces of rainfall impact. Fire removes this protective covering and barriers to overland flow (Pierson *et al.,* 2008). When total consumption of surface cover occurs on severely burned sites and the resulting thick ash layer has been eroded, a site with low surface roughness is expected to have higher runoff rates than unburned sites (Lavee *et al.*, 1995).

3.1.6 Hydrophobicity

Fire-induced hydrophobicity (same as soil water repellency) is another factor that influences infiltration and runoff rates. Hydrophobic soils are formed by the accumulation of waxy organic substances from plants around soil particles. During a fire, the waxy substances are vaporized and the pulsating heat may force substances down through the soil where they cool and coalesce with other precipitates on to soil particles forming an impervious layer (DeBano *et al.,* 1976). They can be found on the soil surface or a few to several centimeters down, parallel to the surface in variable thicknesses. The strength of hydrophobicity depends on the soil temperature. Weak soil water repellency occurs at lower burning temperatures, 175ºC, and intense water repellency occurs between 175ºC and 200ºC burning temperatures. Hydrophobicity is broken down at temperatures exceeding the latter. Hydrophobic layers reduce the infiltration and percolation depth of soils; therefore, soils will become saturated sooner in a storm event and saturation excess runoff will occur (DeBano *et al.,* 1976). However, instances where natural hydrophobicity is strong, burning may reduce the strength of the hydrophobic layer allowing water to infiltrate more readily and reduce runoff (Pierson *et al.,* 2008).

3.2 Evaluating soil hydrologic processes

3.2.1 Rainfall simulation experiments

Physical rainfall simulations are a tool used to measure runoff rates following a fire (Johansen *et al*., 2001; Benavides-Solario and MacDonald, 2001). Specialized equipment are designed to apply controlled rainfall amounts and intensities for evaluating the effects of cover, soil sealing, ash deposition, surface roughness, and hydrophobicity (Larsen *et al*., 2009). Simulators are

particularly useful for measuring the soil hydrologic condition following disturbance such as wildfire. Soil physical and chemical properties exhibit a high degree of spatial variability throughout a watershed and the addition of fire may increase this variability (Lavee *et al.*, 1995; Robichaud and Hungerford, 2000; Sposito, 2004). Therefore, simulators can be useful tools because of the ability to control rainfall intensity, duration, and volume of the output. Precipitation variability that occurs naturally during a storm event is limited. An overall rainfall simulator design to fit all field and/or laboratory conditions is not available, therefore each simulation is conducted on a research-specific basis (Bowyer and Burt, 1989). Project design takes into account the purpose of the research, natural rainfall characteristics of the location, along with available resources and ability to attain or custom build a simulator. In order to accurately measure runoff, multiple simulations are conducted.

3.2.2 Mini-disk Infiltrometer and water drop penetration time tests

The Mini-disk Infiltrometer (MDI) and water drop penetration time (WDPT) tests are methods utilized in the field to classify the soil water repellency (none, weak, strong) following prescribed and wild fires (Robichaud *et al.*, 2008; Lewis *et al.*, 2006). These two tests are typically conducted alongside one another because they are similar in their purpose and it time effect way to test soil with two methods. Although similar in their purpose, the MDI is credited with being less subjective and easier to perform than the WDPT. The MDI also provides an infiltration rate in addition to evaluating soil water repellency.

3.3 Summary

Post-fire conditions alter infiltration and runoff rates. Not every fire will have dramatic effects on a watershed, but burn severity and environmental factors greatly influence many hydrologic changes that occur following a fire (Ryan *et al.*, 2011). Surface cover loss, soil sealing, ash deposition, surface roughness and hydrophobicity independently, or combined, alter waters ability to enter a soil either by enhancing or reducing that ability. Conducting rainfall simulations and utilizing additional methods such as the Mini-disk Infiltrometer and water drop penetration time tests are suitable for evaluating post-fire effects on soil hydrologic processes.

CHAPTER 4 : METHODS AND MATERIALS

4.1 Study Design

Rainfall simulations, Mini-disk Infiltrometers (MDI) and water drop penetration time (WDPT) tests were performed in the field at various locations throughout the Scotts Creek watershed following the Lockheed Fire. These tests were conducted in order to evaluate the changes in infiltration rates, hydrologic- responses (ratio of total runoff (L) to total rainfall (L)), and soil water repellency of soils burned at different severities. In addition to burn severity, test sites represented variations in soil parent material, percent slope, dominant vegetation type and aspect (Tables 4-1 and 4-2). Some control sites were established and tested in order to make the comparison between burned and unburned sites. Data collection using these three techniques began in the fall of 2009 and has been conducted annually during summers through 2013.

Table 4-1: Rainfall simulation sites listed by number, soil parent material, percent slope, vegetation type, dominant vegetation type, burn severity and aspect.

Site Number	Soil Parent Material	Slope (%)	Veg Type	Dominant Veg Type	Burn Severity	Aspect
2	MS	60	RW	RW	N	NE
4	MS	65-88	RW/DF	RW	N	SE
5	MS/SS	47-65	RW/DF	RW	M	SE
6	Granitic	40-52	RW/DF	RW	L	NW
7	MS	45-54	RW/TO	RW	M	NW
8	MS	47-60	KP/MZ	KP	H	S
9	MS/SS	55-65	KP/MZ	KP	N	S
10	MS	27-45	KP/MZ	KP	H	NE
11	MS	17-40	KP/MZ	KP	N	NW
12	Granitic	38-46	TO	TO	N	SE
13	MS	50-65	TO	TO	H	NW
14	MS	70-72	RW/TO	RW	M	NW
15	MS	35-38	KP/MZ	KP	H	N

Table 4-2: MDI and WDPT test sites listed by number, slope position, vegetation type, dominant vegetation type, burn severity and aspect.

Site Number	Soil Parent Material	Slope Position	Vegetation. Type	Dominant Veg. Type	Burn Severity	Aspect
1	MS	Lower	RW	RW Dom	H	SE
2	MS/SS	Lower	RW/DF	RW Dom	M	SE
3	Granitic	Lower	RW	RW Dom	M	NW
4	MS	Upper	RW/TO	RW/Dom	H	N
5	MS	Lower	RW/TO	RW/Dom	M	W
6	MS	Upper	TO	TO	H	N
7	MS	Upper	KP/MZ	KP/MZ	H	N
8	MS	Upper	KP/MZ	KP/MZ	H	SE
9	Granitic	Lower	RW/TO	RW Dom	L	SE
10	MS	Upper	KP/MZ	KP/MZ	H	S
11	Granitic	Upper	RW/TO	RW Dom	M	NW
12	MS	Upper	KP/MZ	KP/MZ	H	S
13	Granitic	Lower	RW	RW Dom	M	S
14	MS	Lower	RW	RW Dom	N	S
15	MS	Upper	KP/MZ	KP/MZ	H	S/E
16	MS	Mid-slope	KP/MZ	KP/MZ	H	SE
17	MS	Mid/Lower	KP/MZ	KP/MZ	H	SE
18	MS	Upper	KP/MZ	KP/MZ	H	SE
19	MS	Lower	KP/MZ	KP/MZ	H	SE
20	MS	Upper	KP/MZ	KP/MZ	H	NW
21	MS/SS	Lower	RW/TO	RW Dom	M/L	N
22	SS	Upper	KP/MZ	KP/MZ	M/H	N
23	MS	Upper	RW/TO	RW Dom	H	N

4.1.1 Rainfall simulation setup

A portable rainfall simulator was utilized to test infiltration rates and the hydrologic response of soils because the simulator has the ability to mimic natural rainfall in a field setting. Thirteen rainfall simulation locations are distributed throughout Little Creek and the greater Scotts Creek watersheds (Figure 4-1). Eight sites were established in 2009 and repeated each year through 2013. Four additional sites were added in 2010 and repeated each year through 2013. Specific site descriptions for all thirteen locations can be found in Appendix B.

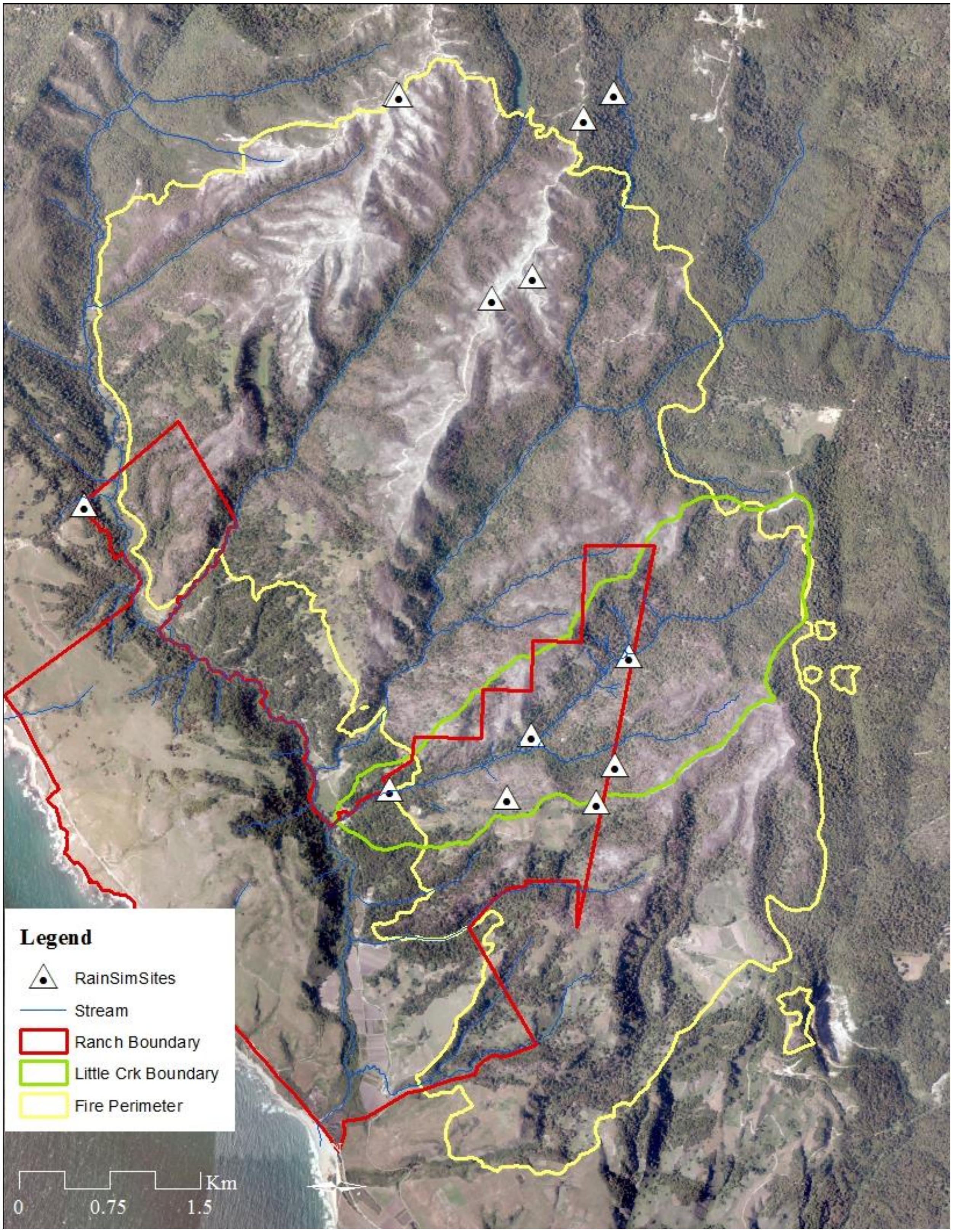


Figure 4-1: Rainfall simulation locations within the Scotts Creek watershed. Ranch boundary is outlined in red, the Little Creek watershed is outlined in green and the fire perimeter is outlined in yellow.

A modified Purdue-style rainfall simulator that was fabricated in Moscow, ID at the Rocky Mountain Research Station by the USDA Forest Service was generously loaned to our research team (Figure 4-2). The simulator stands three meters above the soil surface on three adjustable fiberglass legs. The sprayer sweeps across a fixed opening and was set to maintain a spraying rate about 5 cm (2 in) per hour. Five centimeters per hour is greater than the typical high rainfall intensity for this area. This rate was chosen because it is an intensity that would produce a significant hydrologic response in soils with properties altered by fire. The simulator stands in the open air where rainfall is subject to wind, however, simulations were conducted with little to no wind. Water was supplied to the simulator through a garden hose that was attached to a gas-powered water pump which received water from a fifty-gallon barrel full of water. The oscillating motion of the simulator was powered by a 2000-watt generator and a control box that was used to turn the simulator on and off as well as turn the oscillating motion on and off.

The plot size is 1 m long by 1 m wide. The border (outside frame of the plot) is made of sheet metal. During setup, the sheet metal is driven down vertically into the soil profile several centimeters in depth. This is to prevent water from seeping into the plot through the back or two sides. Plastic was placed around the perimeter of the sheet metal as another preventative measure to help ensure water was not entering laterally through the two sides and top of the plot.

Figure 4-2: Rainfall simulator on the tripod above the 1x1 m plot enclosed by a trough in the front.

The front of the plot was confined by a trapezoidal trough designed to catch the near-surface runoff[8]. The goal was to capture near-surface runoff, the lateral subsurface or surface flow that may be shunted off laterally downslope due to fire-induced soil water repellency within the profile. This depth was estimated to be at the most 10 cm below the soil surface. Thus, the trough is inserted 8 and 10 cm below the soil surface and driven laterally into the soil so that the angle of the trough matched the angle of the existing natural slope. When near-surface runoff is present, it is captured in the trough along the downslope edge of the plot and then funneled into an outlet tube and then into a five gallon bucket. Any water percolating down below the 8-10 cm is regarded as water infiltrated to depth below where a fire-induced hydrophobic layer would normally be found. The infiltrated amount (expressed as a rate or a volume) is accounted for by the taking the difference between the rainfall rate and the near-surface runoff rate. Finding this difference provides an estimate of the infiltration rate which can also be regarded as a deep percolation rate to distinguish it from the water entering the soil surface but confined as near-surface runoff.

The rainfall intensity was determined by measuring the volume of rainfall that accumulated in a 1x1 m metal calibration pan that was placed over the plot. The pressure of the simulator could be adjusted to either increase or decrease the rainfall intensity in order to achieve as close to 5 cm (2 in) per hour. Once a consistent volume and rainfall intensity was obtained during the calibration process, the calibration pan was removed to begin the simulation. Simulations would be run for a minimum of 40 minutes to a maximum of 70 minutes[9]. The near-surface runoff collected in the 5 gallon bucket was recorded every 2 minutes using a ruler.

[8] Near-surface runoff refers to the top 7 centimeters of soil where runoff is occurring because this is the depth at which runoff can impact the surface soil through mobilization.
[9] Simulation times varied because of time constraints.

Following simulations, plots were disrupted in order to evaluate any fire-induced hydrophobicity by observing subsurface hydrologic flow paths.

4.1.2 MDI and WDPT setup

MDI and WDPT tests were utilized as time efficient means of evaluating soil water repellency by measuring infiltration volumes and penetration times. There are twenty-three sites distributed throughout the Little Creek watershed (Figure 4-3). All twenty-three sites were established in 2009 and tested annually until the amount of regrowth did not allow for sites to be accessed safely. These two tests were performed every 6.1 m (20 ft) along a 30.5 m (100 ft) transect. At each of the five locations along the transect, three replicate tests were conducted at 1 and 3 cm using the MDI. WDPT tests were conducted at 1, 2, and 3 cm at each of the five locations along the transect, using a water dropper. Specific site descriptions for all twenty-three locations can be found in Appendix C.

The MDI, created by Decagon Devices, Inc. in Pullman, Washington, is a portable, handheld device used to assess soil infiltration capacity in the field (Figure 4-4). The MDI measures the volume of water that has passed from the instrument into the soil over a 1 minute time interval thereby providing a total infiltration volume. An infiltration rate can be found utilizing this method, however, for the purposes of this project, total infiltration volume was analyzed. Following a wildfire, the MDI has proven to be very useful for a rapid field assessment of infiltration capacity and soil water repellency based upon the mean infiltration rate of test sites (Robichaud *et al.*, 2008).

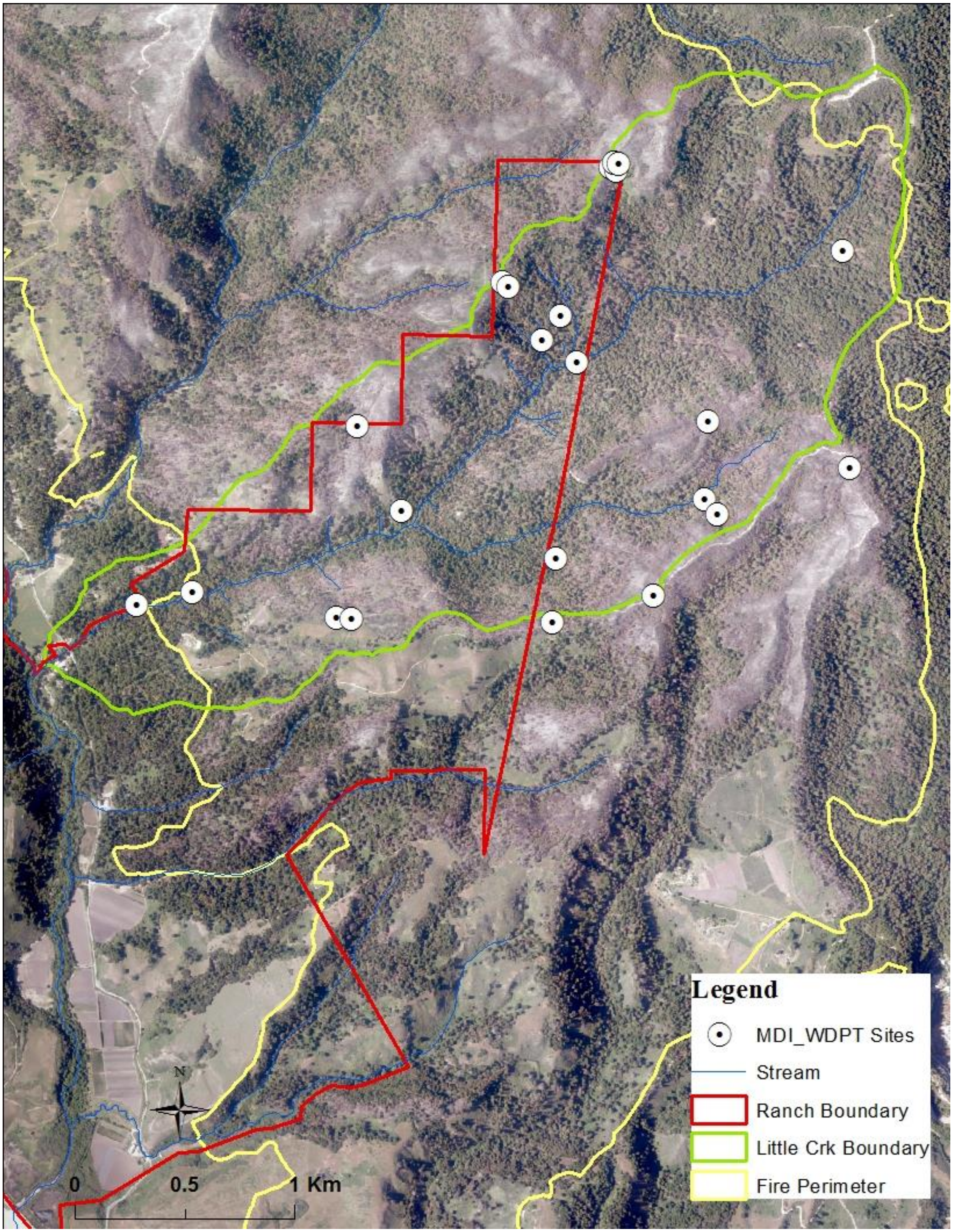


Figure 4-3: Soil infiltration sites located in the Little Creek watershed (green). The ranch boundary is outlined in red and the fire perimeter is outlined in yellow.

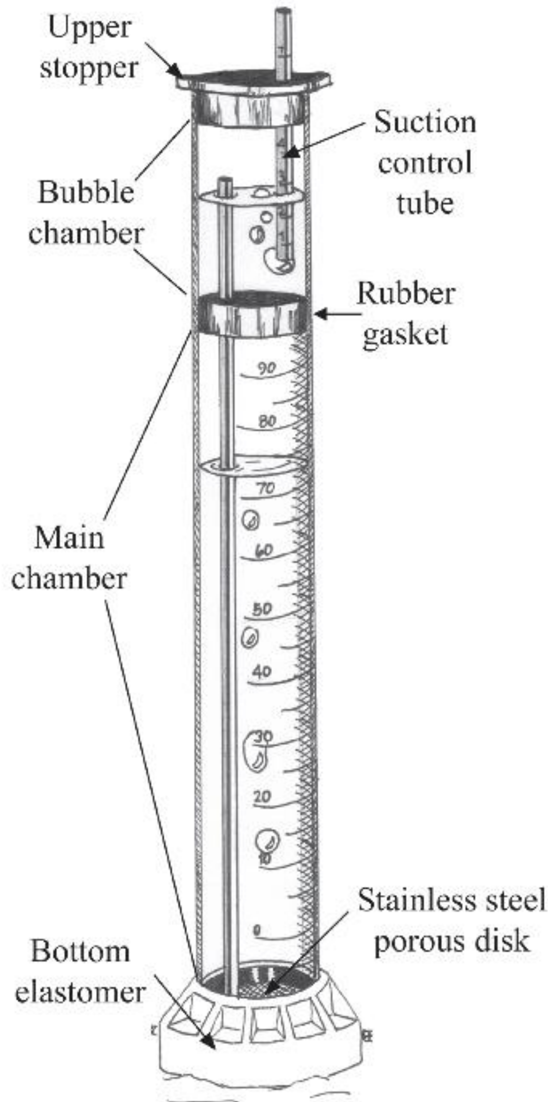


Figure 4-4: Diagram of the Mini-Disk Infiltrometer from Decagon Devices Inc.

4.2 Procedure

4.2.1 Rainfall simulation procedure

For a complete procedure on how rainfall simulations were carried out in the field and for a complete list of the equipment utilized by field technicians, see Appendix D: Instructions for conducting rainfall simulations.

4.2.2 MDI and WDPT procedure

For complete procedures on how MDI and WDPT tests were conducted in the field and for a complete list of the equipment used for each test, see Appendix E: Instructions for conducting Mini-disk Infiltrometer and water drop penetration time tests.

4.3 Data Analysis

4.3.1 Preliminary analysis

Microsoft Excel™ 2007 was utilized for data entry, quality control, and preliminary analysis for rainfall simulation, MDI, and WDPT datasets. Preliminary analysis for the rainfall simulations consisted of finding the infiltration rate and hydrologic response[10] of each rainfall simulation. Preliminary analysis for the MDI dataset consisted of finding the average infiltration volume of the three replicate tests at each position and depth along the transect, and using the mean value to classify the soil water repellency. Preliminary analysis for the water drop penetration times dataset consisted of finding the average penetration time at each position and depth along the transect and using the mean value to classify the soil water repellency.

[10] The hydrologic response is the ratio of total measured runoff (L) to total simulated rainfall (L).

4.3.1.1 Calculating rainfall simulation infiltration rate and hydrologic response

Equation 1 was developed in Microsoft Excel™ 2007. During simulations, runoff data or water depth, was collected and measured at two minute intervals from the start to the end of the simulation. The runoff rate was found by converting the water depth to a runoff volume using equation 1.

$$\text{Runoff Volume (L)} = 0.009712{*}WD^2 + (1.377{*}WD)$$

$$\text{Where WD = water depth in bucket in cm.} \qquad (1)$$

Equation 1 was derived by finding the relationship between the depth of the bucket to the volume of water inside the bucket. This was accomplished by adding 500 mL of water sequentially into the bucket and recording each depth.

The near-surface runoff volumes and the simulated rainfall rates are then plotted against time and a regression line is added to the runoff values in order to define an average runoff rate. Next, taking the difference between the runoff rate and simulated rainfall rate provides an infiltration rate. Again, infiltration rate means that water percolates deeper in the soil profile (below the level we would assume would be uniformly wetted if fire-induced soil water repellency exists). The hydrologic response, was found by taking the ratio of total runoff in L to total simulated rainfall in L thus it is also referred to as the runoff ratio. Figure 4-1 shows an example plot of runoff and rainfall volume against time with the derived linear regression equation for runoff volume. Annual rainfall simulation data, raw data and graphs, can be found in Appendix F.

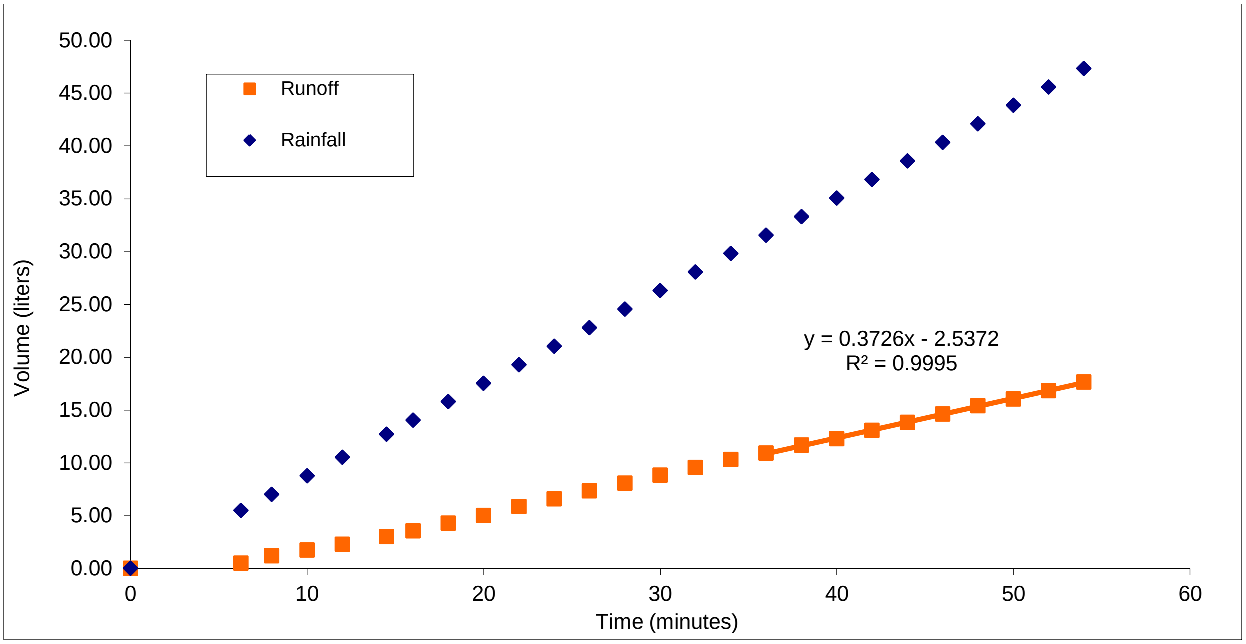


Figure 4-5: Example plot of runoff volume and rainfall volume for site 6-Upper North Fork.

The purpose of the regression line is to identify if and when steady state runoff is achieved. Steady state runoff occurs when the infiltration capacity[11] of the soil is met and infiltration occurs at a constant rate from which it can decrease no more even with the continuous addition of water (Hillel, 2004). When attempting to ascertain whether fire had an effect on soil infiltration, it is important to find the steady state runoff rates so that comparisons could be made pertaining to the infiltration capacities of the soil. Fire-induced water repellent layers can decrease the infiltration capacity (the three dimension depth at which water can infiltrate and percolate) of soil thus decreasing time to runoff and increasing runoff rates (DeBano *et al.*, 1967).

[11] Capacity is used to denote an amount or volume. Although capacity is met, water is still moving through the profile via gravitational potential thus infiltration can still occur.

4.3.1.2 Classifying soil water repellency for MDI tests

Microsoft Excel™ 2007 was utilized to find the mean of the infiltration volume for three field replicates and to classify the soil water repellency based upon the calculated mean. Table 4-3 is an example of the field data in excel with the soil water repellency classified.

Soil water repellency was classified based on the mean volume. When the infiltration volume exceeded 8 mL, soils were classified as being not repellent. Soils were classified as weak when the infiltration volume was between 3-8 mL, and strong when the infiltration volume was between 0-3 mL (Robichaud *et al.*, 2008). See Appendix G for annual MDI field data and soil water repellency classifications.

Table 4-3: Data and water repellency classification of MDI field test at site 1.

Date	Site	ID/TM[12]	Severity[13]	Aspect[14]	Slope Position[15]	Depth (cm)	Test 1 vol (mL)	Test 2 vol (mL)	Test 3 vol (mL)	Mean (mL)	Repellency
12/2/09	1	1/20	H	SE	L	1	0	18	2	6.67	Weak
12/2/09	1	1/20	H	SE	L	3	0.3	11	9	6.77	Weak
12/2/09	1	1/40	H	SE	L	1	0	0	1	0.33	Strong
12/2/09	1	1/40	H	SE	L	3	2.5	1	1	1.50	Strong
12/2/09	1	1/60	H	SE	L	1	0.5	0	0	0.17	Strong
12/2/09	1	1/60	H	SE	L	3	0	0	0.8	0.27	Strong
12/2/09	1	1/80	H	SE	L	1	1	0	0	0.33	Strong
12/2/09	1	1/80	H	SE	L	3	0	0.5	0	0.17	Strong
12/2/09	1	1/100	H	SE	L	1	2	1	1	1.33	Strong
12/2/09	1	1/100	H	SE	L	3	2	2	1.5	1.83	Strong

[12] ID indicates the site location and TM indicates the transect mark which is either 20, 40, 60, 80, or 100 feet away from the start of the transect at 0 feet.
[13] Severity can either be N= none, L= low, M= moderate or H= high and was classified by the BAER team.
[14] Aspect indicates the four cardinal directions N= North, E =East, S = South, and W= West, and the four ordinal directions NE, SE, NW and SW.
[15] Position indicates the position along the hillside that the plot is located. L=low, M=mid , U=upper

4.3.1.3 Classifying soil water repellency for WDPT tests

Microsoft Excel™ 2007 was utilized to classify the water repellency based off of penetration times. Table 4-4 is an example of repellency times recorded and classified at site 1. When penetration times were less than 5 seconds the soil was classified as wettable. Soils were classified as slightly repellent when times were between 5-60 seconds, moderately repellent when times were between 60-400 seconds and highly repellent when times were over 400 seconds[16]. See Appendix H for annual field data and soil water repellency classifications.

Table 4-4: Data and water repellency classification of WDPT field test at site 1.

Date	Site	ID/TM	Severity	Aspect	Position	Depth (cm)	Time (seconds)	Water repellency
10/14/2010	1	1/20	H	SE	L	1	305	moderate
10/14/2010	1	1/20	H	SE	L	2	305	moderate
10/14/2010	1	1/20	H	SE	L	3	20	slight
10/14/2010	1	1/40	H	SE	L	1	60	slight
10/14/2010	1	1/40	H	SE	L	2	20	slight
10/14/2010	1	1/40	H	SE	L	3	10	slight
10/14/2010	1	1/60	H	SE	L	1	305	moderate
10/14/2010	1	1/60	H	SE	L	2	305	moderate
10/14/2010	1	1/60	H	SE	L	3	305	moderate
10/14/2010	1	1/80	H	SE	L	1	305	moderate
10/14/2010	1	1/80	H	SE	L	2	305	moderate
10/14/2010	1	1/80	H	SE	L	3	305	moderate
10/14/2010	1	1/100	H	SE	L	1	305	moderate
10/14/2010	1	1/100	H	SE	L	2	305	moderate
10/14/2010	1	1/100	H	SE	L	3	305	moderate

4.3.2 Statistical analysis: Mixed-effects modeling

Following the preliminary analysis, further data analysis was conducted by Mr. Jack Lewis, USFS Pacific Southwest Research Station Mathematical Statistician (retired) with the use of the

[16] This is a modified version from the USDA Forest researchers (DeBano, 1983) as provided by Robichaud *et. al.*, 2008)

R language, an environment for statistical computing and graphics (R Development Core Team, 2010). Mixed effects models were used within the R framework to analyze all three datasets, rainfall simulations, MDI, and WDPT tests for the following reasons:

1. Mixed-effects models have the ability to model a variety of unbalanced experimental design involving grouped data, nested data, or repeated measures.
2. These models account for a combination of continuous and categorical variables.
3. Mixed effect models account for fixed and random effects.

All three studies exhibit these three characteristics. First, the annual data collected is not statistically independent from previous year's data; data collected from the same location on successive occasions is not independent, for instance, site 1 is compared to site 1 each year. Therefore, the data from site 1 in 2009 is more likely to be similar to data from site 1 in subsequent years rather than being similar to data from another site thus it is not statistically independent. As well, nesting of transects, as with the MDI and WDPT tests, develops additional dependencies; observations at a specific position within a transect tend to be more similar than observations at other positions within the transect. Furthermore, the three datasets contain continuous and categorical data. Lastly, all three datasets contain both fixed effects, variables that remain unchanged throughout the testing period such as burn severity, soil parent material, dominant vegetation type and percent slope, as well as random effects, which are those attributes that were randomly assigned during the setup of the project such as site number. Therefore, mixed-effects modeling was used because this approach accounts for repeated measurements at multiple sites and transects within the same sites as well as a variety of variables that are either fixed or random.

Variables within mixed-effect models are categorized as either "fixed" or "random" effects. Fixed-effects are the variables tested within the model for having a statistically-significant impact on infiltration rates, infiltration volumes and penetration times at the conventional rejection level of $\alpha = 0.05$. Random effects are typically nuisance variables that were typically randomly chosen but must be accounted for in the model. Additionally, for each model, an interaction between time and each fixed-effect is tested in order to determine if the change over time can be attributed to the fixed-effect that time is interacted with in the model.

4.3.2.1 Statistical model for rainfall simulations

A modified version of a body weight model (Model 1) proposed by Pinheiro and Bates (2000, eq 5.20, p 222) is the basis for the rainfall simulation model created by Jack Lewis.

$$
\begin{aligned}
y_{ij} &= (\beta_0 + \gamma_{02}S_{2i} + \gamma_{03}S_{3i} + \gamma_{04}S_{4i} + b_{0i}) \\
&+ (\beta_1 + \gamma_{12}S_{2i} + \gamma_{13}S_{3i} + \gamma_{14}S_{4i} + b_{1i})t_{ij} + \varepsilon_{ij} \\
\mathbf{b}_i &= \begin{bmatrix} b_{0i} \\ b_{1i} \end{bmatrix} \sim \mathbb{N}(0, \boldsymbol{\psi}), \quad \varepsilon_{ij} \sim \mathbb{N}(0, \sigma^2)
\end{aligned}
$$

Model 1

where y_{ij} is the response (infiltration rate or hydrologic response) of the j^{th} observation at site i; t_{ij} is the time (day number or year) of the j^{th} observation at site i; S_{ki} is a binary variable taking the value 1 if the i^{th} site was burned at severity level k (2=low, 3=moderate, 4=high), otherwise $S_{ki} = 0$; β_0 and β_1 are the average intercept and average slope for unburned sites; γ_{0k} and γ_{1k} are the average difference in intercept and slope respectively, between unburned sites and those with burn severity k; b_i is the vector of normally distributed within-site (residual) error, assumed

independent for different i, j and independent of the random effects. The 3 variance parameters estimated are $\boldsymbol{\psi}$, a vector of length 2, consisting of the variances of b_{0i} and b_{1i}; σ^2, the within-site error variance. This model assumes that the burn severity is invariant for a given site (Lewis, 2013).

The responses analyzed are infiltration rates and hydrologic responses over the five-year period. The fixed effects tested for rainfall simulations were time (years), burn severity, percent slope, and dominant vegetation type. Burn severity was classified as unburned (N), low (L) moderate (M), and high (H). The three dominant vegetation types tested are redwood dominant (RW), tanoak (TO) and a combination of knobcone pine and manzanita (KP/MZ). These fixed-effects were treated as site-invariant because these characteristics remained the same every year although the plots were not located in precisely the same location each year.

The influence each fixed-effect had on infiltration rates and hydrologic responses was analyzed discretely. The goal of the study is to see if there was a fire induced effect on infiltration rates and hydrologic responses over a period of five years, therefore the interaction between burn severity and time was tested. If this interaction term is found to be significant, it could be inferred that the change over time is attributed to the fire. The change over time alone can be attributed to a multitude of factors, therefore, time was interacted with all fixed-effects in order to distinguish which variable influenced any change over time.

4.3.2.1.1 Burn dichotomy

Additional analysis was performed in order to test the maximum fire effect and any fire effect on infiltration rates and hydrologic responses by dividing sites into two burn dichotomies and

analyzing each burn dichotomy. The two burn dichotomies developed and tested as predictors in model 1 are “Hot burn versus all others” and “Unburned versus all others.” The “Hot burn versus all others” partitions out the high severity sites and tests high severity sites against all other sites which includes unburned, low and moderate burn severity sites. The second dichotomy tested unburned sites against all other sites which includes low, moderate and high burn severity sites.

4.3.2.1.2 Little Creek watershed

Additional analyses were performed on rainfall simulation sites located solely in the Little Creek watershed. The Little Creek watershed has been part of a long-term study designed to evaluate water quality and channel conditions, before, during, and after selective timber harvest. Additional analysis was performed solely on the Little Creek rainfall simulation sites in order to document fire related effects with respect to changes in infiltration rates and near-surface runoff. The reasons for this separate analysis include: 1) adds to understanding of fire effects to support Little Creek monitoring work, 2) includes sites that represent broad conditions within a single watershed boundary, and 3) excludes sites chosen because of pre-observed conditions of widespread strong natural soil water repellency.

Model 1 was utilized and the same fixed-effects were tested for this additional analysis. However, two p-values were generated from the model: sequential and marginal. The sequential p-value indicates the significance of each term as it is added to the model sequentially, for instance a model that only includes that term and the terms before it. Marginal p-values are the conventional p-value ($p < 0.05$) which indicate the significance of each term in the complete model. The raw rainfall simulation data utilized in R can be found in Appendix I. The R code and output for rainfall simulation analysis can be found in Appendix J.

4.3.2.2 Statistical model for MDI and WDPT

As with the rainfall simulation data, mixed-effects modeling was used to analyze both the MDI and WDPT datasets. This section will provide a detailed explanation of the mixed effects model used for both the MDI and WDPT datasets. While both the MDI and WDPT datasets are structured similar to that of the rainfall simulations, these datasets are slightly more complex because transects are nested and depth is an additional explanatory variable. Thus, the same general model used to analyze rainfall simulation data can be used for MDI and WDPT datasets, but with some additional terms to account for depth and transect location. Jack Lewis modified the continuous-time mixed effects Model 1 to account for transect location with the addition of subscript *m* and a random effect for the *m*th location within each site (Model 2).

$$
\begin{gathered}
y_{ijm} = (\beta_0 + \gamma_{02}S_{2i} + \gamma_{03}S_{3i} + \gamma_{04}S_{4i} + b_{0i} + c_{0im}) \\
+ (\beta_1 + \gamma_{12}S_{2i} + \gamma_{13}S_{3i} + \gamma_{14}S_{4i} + b_{1i} + c_{1im})t_{ijm} + \varepsilon_{ijm} \\
\mathbf{b}_i = \begin{bmatrix} b_{0i} \\ b_{1i} \end{bmatrix} \sim \mathbb{N}(0, \boldsymbol{\psi}),\ \mathbf{c}_{im} = \begin{bmatrix} c_{0im} \\ c_{1im} \end{bmatrix} \sim \mathbb{N}(0, \boldsymbol{\Phi}),\ \varepsilon_{ijm} \sim \mathbb{N}(0, \sigma^2)
\end{gathered}
$$

Model 2

where y_{ijm} is the (possibly) transformed response (infiltration volume or penetration time of the j^{th} observation at transect location *m* at site *i*; t_{ijm} is the time (day number or year) of the j^{th} observation at transect location *m* at site *i*; S_{ki} is a binary variable taking the value 1 if the i^{th} site was burned at severity level *k* (2=low, 3=moderate, 4=high), otherwise S_{ki} =0; β_0 and β_1 are the average intercept and average slope for unburned sites; γ_{0k} and γ_{1k} are the average difference in intercept and average slope, respectively, between unburned sites and those with burn severity *k*; b_i is the vector of normally distributed random effects, assumed independent for different *i*; b_{0i} and b_{1i} are the perturbations on the intercept and slope, respectively, for the site *i*; c_{0im} and c_{1im} are the perturbations on the intercept and slope, respectively, for transect location *m*

at site i; ε_{ijmn} is the normally distributed within-a-point location (residual) error, assumed independent for different i, j, m and independent of random effects. The 5 variance parameters estimated are $\boldsymbol{\psi}$, a vector of length two, consisting of the variances of b_{0i} and b_{1i}; Φ a vector of length 2 consisting of variances of c_{0im} and c_{1im}; and σ^2, the within-a-point-location error variance. This model will focus on the hypothesis involving the γ_{1k} parameters, which characterize the time trends. In particular we want to test whether these parameters are all the same or whether they depend on k, the burn severity (Lewis, 2013).

To test the depth effect, another set of terms was added to the model (Model 2-a). Since burn severity could depend on depth, or vice versa, the interaction between depth and burn severity must be modeled.

$$+\left(\beta_2+\gamma_{22}S_{2i}+\gamma_{23}S_{3i}+\gamma_{24}S_{4i}+b_{2i}+c_{2im}\right)d_{ijm}$$

$$\mathbf{b}_i=\begin{bmatrix}b_{0i}\\b_{1i}\\b_{2i}\end{bmatrix}\sim\mathbb{N}\left(0,\boldsymbol{\psi}\right),\ \mathbf{c}_{im}=\begin{bmatrix}c_{0im}\\c_{1im}\\c_{2im}\end{bmatrix}\sim\mathbb{N}\left(0,\boldsymbol{\Phi}\right),\ \varepsilon_{ijm}\sim\mathbb{N}\left(0,\sigma^2\right)$$

Model 2-a

where d_{ijm} is the depth of the jth observation at transect location m at site i. The new slope parameters γ_{2k} describe the fixed effect of depth for each burn severity, and a new random effects are included for the perturbations in slope due to site and transect location within site. Having a new random effect to b_i and c_{im}, the number of variance parameters increases from 5 to 7; $\boldsymbol{\psi}$ (3x1), Φ (3 x 1), and σ must be estimated (Lewis, 2013) .

If site and transect location had been modeled as fixed effects, it would have required estimating 115 slopes and 115 intercepts (for 5 transect locations at each of 23 sites). By instead modeling them as random effects the number of parameters to be estimated is limited to 7, while properly accounting for the groupings in the data.

The significance of fixed effects was evaluated using conditional F tests as described in

Pinheiro and Bates (2000, pp 89-92). The tests are conditioned on the estimates of the random effects variance-covariance parameters (Lewis, 2013).

4.3.2.2.1 MDI test variables

The fixed-effects tested in Model 2 were burn severity, soil parent material, dominant vegetation type, day number (from 12/31/2008), and the interactions between burn severity and time, soil parent material and time, and dominant vegetation type and time. The significance of the interaction between burn severity and time is of greatest concern for this analysis because it will suggest whether or not the fire had an effect on the response being analyzed, which is post-fire infiltration volumes. Yet, testing the additional, naturally occurring variables will shed some light on whether such variables had an influence on post-fire hydrologic processes. The random effects are site number and transect location.

Burn severity, soil parent material, and dominant vegetation type were treated as site-invariant because these characteristics remained the same every year although the transects were not located in precisely the same location each year. Because there is not an equal number of sites in each burn severity classification, two simplified burn classes were developed, “Cool” and “Hot.” “Cool” incorporates unburned (N), and moderate to low (ML) sites while “Hot” incorporates moderate (M), moderate to high (MH) and high (H) burn severities. The three dominant vegetation types tested are a combination of redwood and Douglas fir (RW/DF), a combination of redwood and tanoak (RW/TO) and tanoak (TO). The three soil parent materials are granitic, mudstone (MS), and a mixture of mudstone and sandstone (MS/SS). In these models, the time trend for the square root of the response (mean infiltration volume) is assumed to be linear.

Additionally, square root and logarithmic transformations were used in order to linearize the data. Both transformed datasets were modeled but the logarithmic model produced a better fit whereas residuals from the square root model were skewed.

The zeroes in the dataset (replications where no water infiltrated into the soil from the MDI) were problematic for computing logarithms therefore the zeroes were replaced with 0.10mL. The lowest non-zero value recorded is 0.17 mL therefore 0.10 was used in lieu of 0. The R code and output for the MDI analysis can be found in Appendix K.

4.3.2.2.2 WDPT test variables

The fixed-effects tested were burn severity, soil parent material, dominant vegetation type, day number (from 12/31/2008), and the interactions between burn severity and day number, dominant vegetation type and day number, and soil parent material and day number. The significance of the interaction between burn severity and time is of greatest concern for this analysis because it will suggest whether or not the fire had an effect on the response being analyzed, which is post-fire penetration times. As previously mentioned, testing the additional fixed-effects, such as soil parent material and dominant vegetation type, will help determine whether site characteristics had an influence on penetration times. The random effects are site number and transect location.

Burn severity, dominant vegetation type and soil parent material were treated as site-invariant because these characteristics remained the same every year although the transects were not located in precisely the same location each year. The same classifications for simplified burn classes, dominant vegetation types and soil parent materials used in the MDI analysis are used for WDPT analysis.

Continuous penetration times for the water drop tests were transformed using square roots and logarithms with the intent of normalizing the residuals distribution. As a note, the 164 zeroes in the dataset were recoded to 0.5 seconds for the logarithmic transformation so that they could be retained in the analysis. While the mixed-effects model for the square root transformed response was able to compute the effect of depth, the mixed effects model for the log transformed response did not include the effect of site on the depth coefficient due to computational reasons. The R code and output for WDPT analysis can be found in appendix L.

CHAPTER 5 : DATA AND STATISTICAL RESULTS

5.1 Scotts Creek watershed rainfall simulation data and results

5.1.1 Scotts Creek watershed rainfall simulation sites sampled each year

Rainfall simulations were conducted at 13 sites for 5 years, but not necessarily at each site every year (refer to Figure 4-1 in Chapter 4 for specific locations). All, but one, of the simulations were conducted during the months of July through November. One simulation was conducted in February 2013, at site 12-Upper Boyer Creek, but is included in the 2012 dataset. The total number of complete simulations is 55. However, two simulations were carried out within 10 meters of one another at site 12-Boyer Unburned in July 2013 in order to compare the results of the two simulations. Results were similar, therefore, the infiltration rates and hydrologic responses were averaged to produce a single observation reducing the total sample size to 54. Table 5-1 shows rainfall simulations by site and years conducted.

The number indicates how many simulations were conducted that year at the specified site. Sites containing a 0 indicate no simulations were performed that year. There are a few reasons. Several sites were not established immediately following the burn, but they were established in 2010. Sites established in 2010 were site 2-Swanton Road, site 12-Upper Boyer, site 13-Lions Flat, site 14-Hillslope, and site 15-Mill/Boyer. Additional locations that contain a 0 were not visited because of time constraints or the amount of vegetative regrowth did not allow re-entry.

Table 5-1: Rainfall simulations by site and year conducted. The number below the year indicates the amount of times a simulations was conducted that year.

Site Number	Site Name	Veg Type[17]	Burn Severity[18]	2009	2010	2011	2012	2013
2	Swanton Rd.	RW	N	0	0	1	1	1
4	L.C. Unburned	RW/DF	N	1	1	1	1	0
5	Cabins	RW/DF	M	1	1	1	1	1
6	Upper North Fork	RW/DF	L	1	1	1	1	1
7	South Fork	RW/TO	M	1	1	1	1	1
8	Boyer	KP/MZ	H	1	1	1	1	1
9	Mill Unburned	KP/MZ	N	1	1	1	1	1
10	Scotts/Mill Burned	KP/MZ	H	1	1	1	1	1
11	Scotts/Mill Unburned	KP/MZ	N	1	1	1	1	1
12	Upper Boyer Unburned	TO	N	0	1	1	0	2
13	Lions Flat	TO	H	0	1	1	1	0
14	Hillslope	RW/TO	M	0	0	1	1	0
15	Mill/Boyer Burned	KP/MZ	H	0	1	1	0	1

5.1.2 Scotts Creek watershed rainfall simulation data

Figure 5-1 displays infiltration rate ($\frac{\mathrm{L}}{\mathrm{min}}$) as a function of time (years) for all thirteen rainfall simulation sites. In general, there is an increasing trend present at all sights meaning that infiltration has increased since the fire regardless of burn severity. Some trends are stronger than others but the more notable observation is that infiltration rates at some sites peak in 2012 and decline in 2013.

[17] RW= Redwood, DF= Douglas fir, TO= tanoak, KP= knobcone pine and MZ= Manzanita
[18] Soil Burn Severity: N=None, L=Low, M=Moderate, H=High

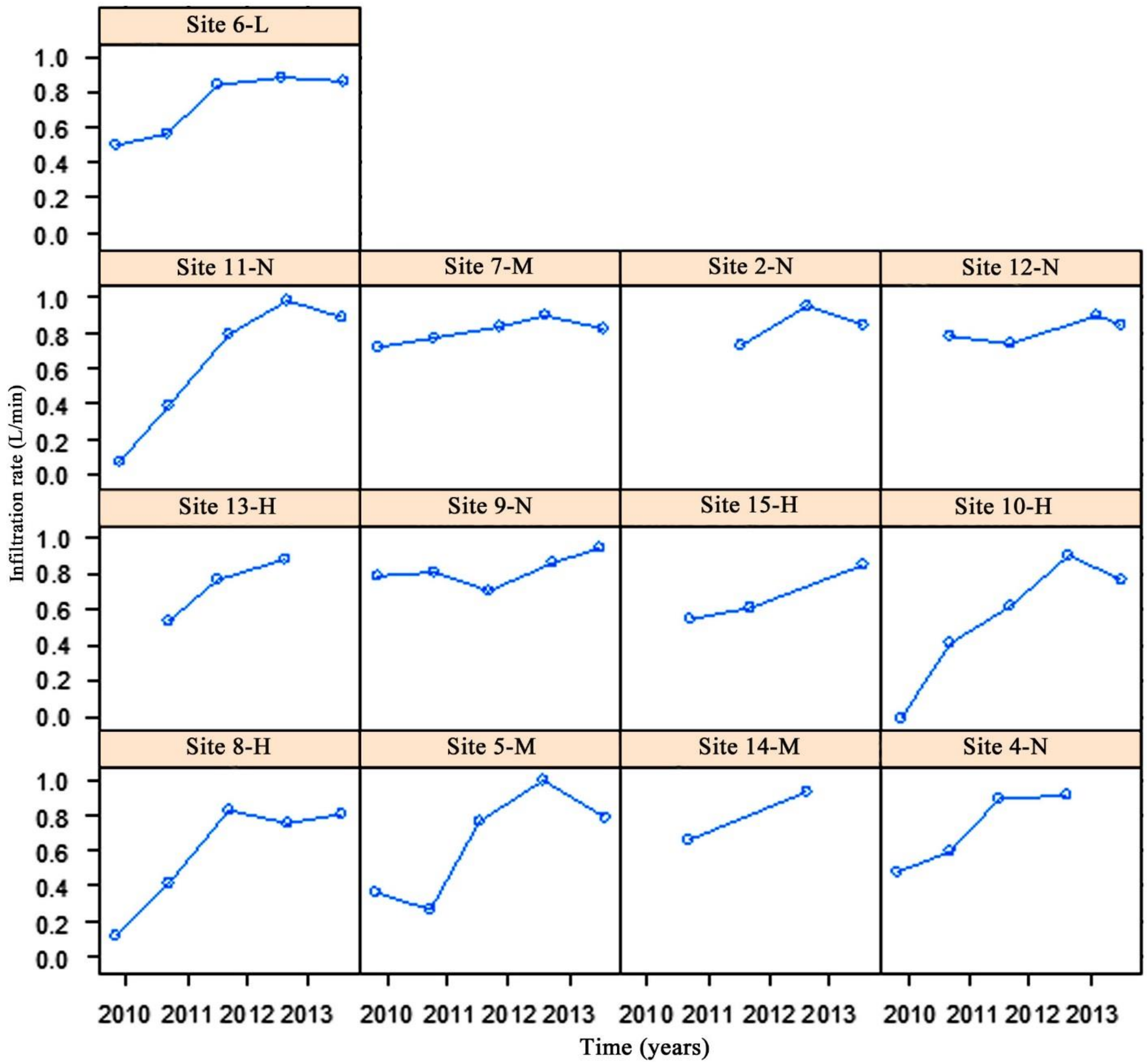


Figure 5-1: Infiltration rate (L/min) as a function of time (years) of each site with a letter that signifies the burn severity classification. N=unburned, L=low, M=moderate, and H=high.

Figure 5-2 displays the hydrologic response as a function of time (years) by each site. Graphs in Figure 5-2 displays a decreasing trend, illustrating that hydrologic response (ratio of total runoff (L) to total rainfall (L)) has decreased over time at almost all of the sites. In particular, sites 7 and 8 show the hydrologic response to be lowest in 2012 and increased in 2013.

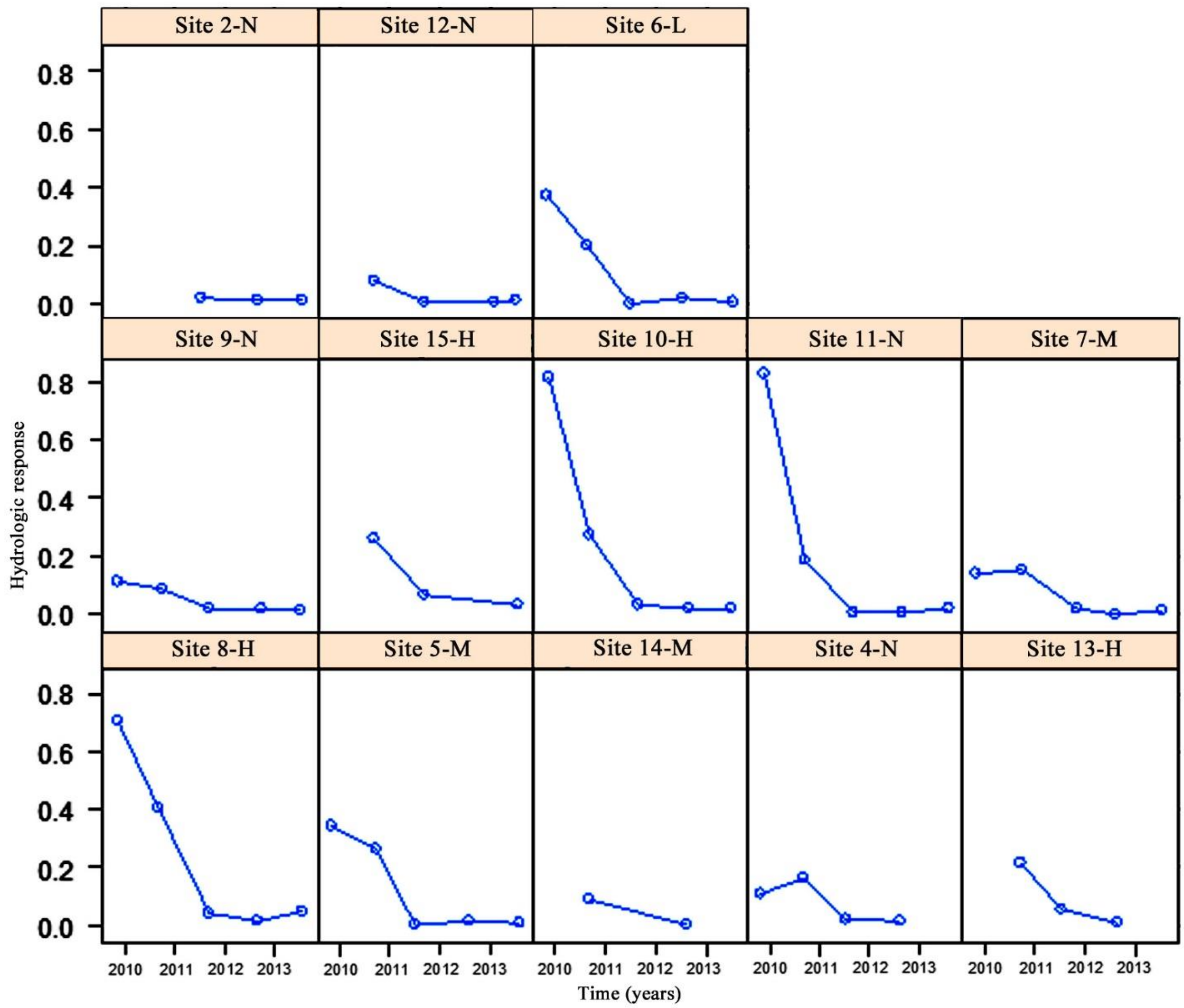


Figure 5-2: Hydrologic response as a function of time (years) for each site location with a letter that signifies the burn severity classification. N=unburned, L=low, M=moderate, and H=high.

5.1.2.1 Burn severity

Figure 5-3 displays the infiltration rate ($\frac{\mathrm{L}}{\mathrm{min}}$) for each burn severity classification as a function of time (days). Sites are color coded and divided by burn severity classifications. Strong increasing trends in infiltration at the high burn severity sites and one unburned site from 2009 to 2010 are visible in Figure 5-3. The remaining unburned, low and moderate sites exhibit an

increase in infiltration over time as well, but are weaker from 2009 to 2010. Similar to Figure 5-1, there is a peak in infiltration in 2012 that is followed by a decline in 2013 at most of the sites.

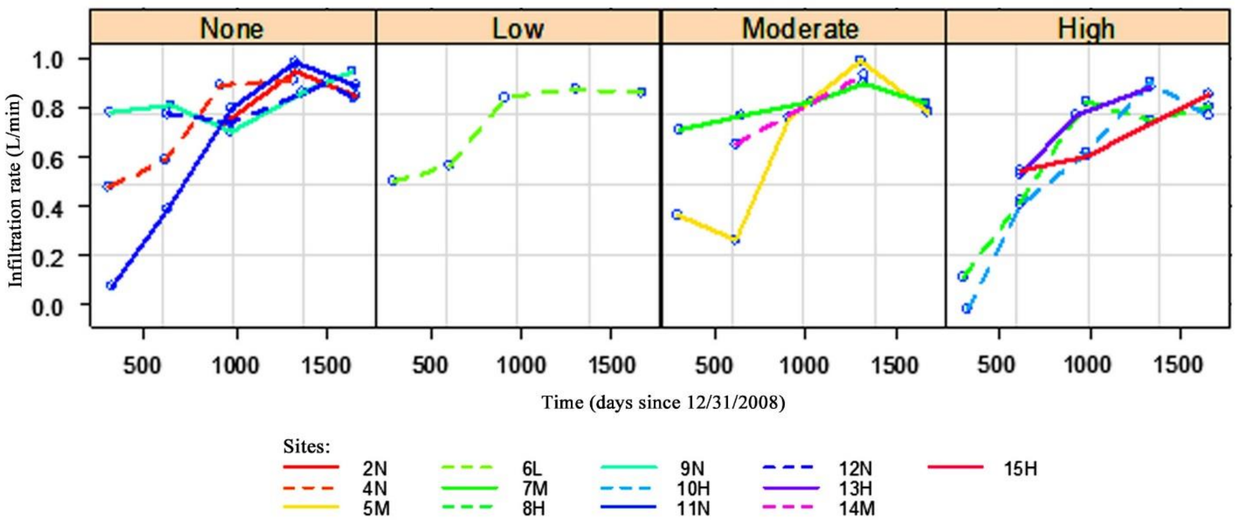


Figure 5-3: Infiltration rates (L/min) of different burn severity classes as a function of time (days since 12/31/2008).

Figure 5-4 displays the hydrologic response for each burn severity classification as a function of time (days). A strong, decreasing trend is evident at high severity sites from 2009 to 2010 as a result of high runoff volumes at site 8-Boyer and site 10-Scotts/Mill. Oddly enough, however, there is a strong decreasing trend from 2009 to 2010 at site 11-Scotts/Mill which is an unburned site. Field notes following the simulation at site 11-Scotts/Mill indicated natural soil water repellency was suspected.

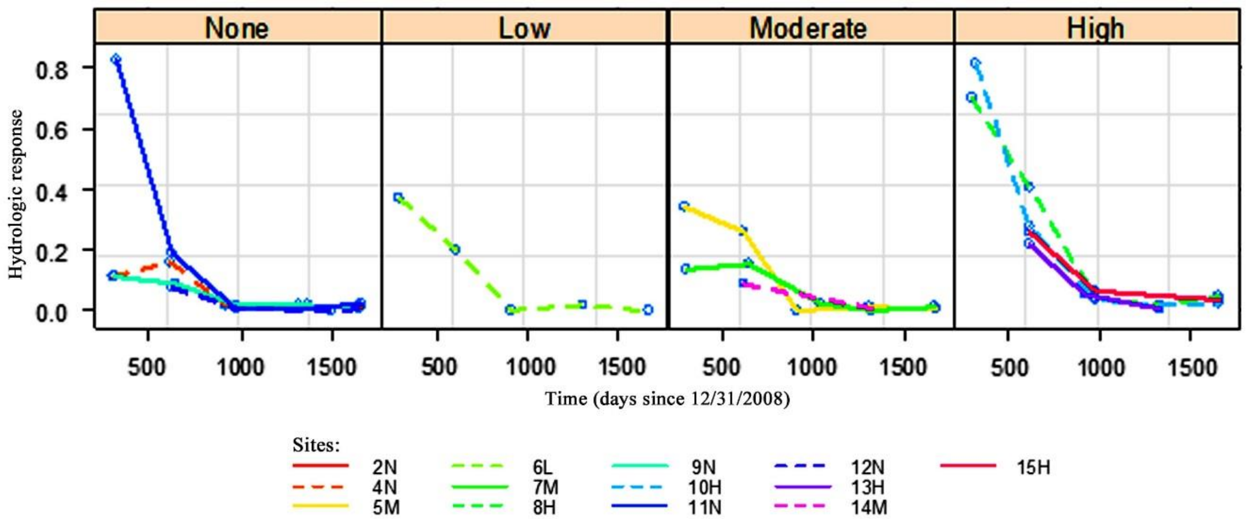


Figure 5-4: Hydrologic response of different burn severity classifications as a function of time (days since 12/31/2008).

5.1.2.2 Dominant vegetation type

Figure 5-5 displays infiltration rates by dominant vegetation type as a function of time (years). This graph depicts the knobcone pine vegetation type having the strongest increasing trend of the three vegetation types. Yet, the tanoak site, site 13-Lion's Flat does not contain 2009 data since this site was established in 2010, one year following the burn.

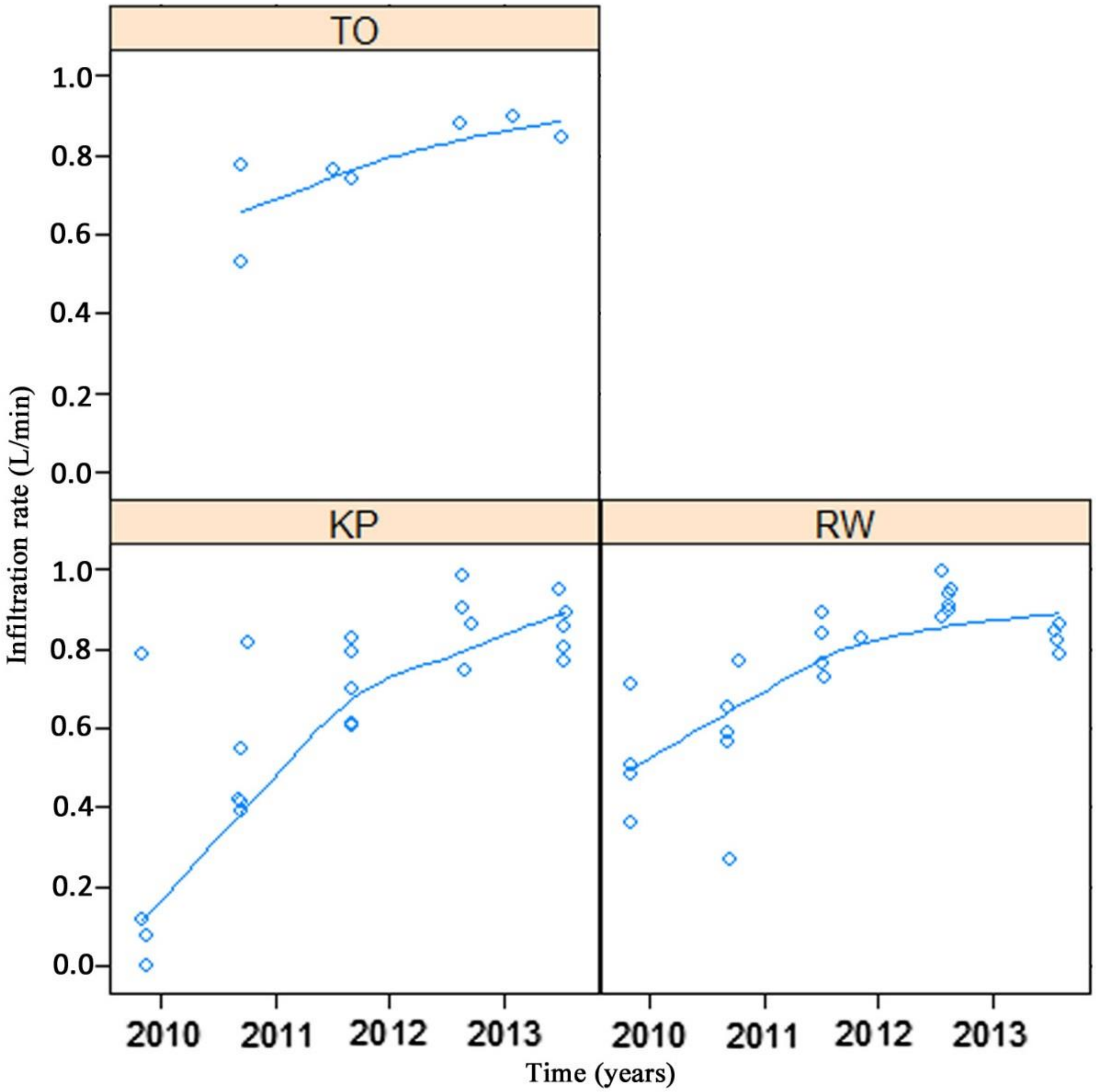


Figure 5-5: Infiltration rates based on vegetation type for the Scotts Creek watershed as a function of time (years). TO= tanoak, KP= knobcone pine and RW= redwood.

Figure 5-6 displays the hydrologic response by dominant vegetation type as a function of time (years). A decreasing trend in hydrologic response is present at all dominant vegetation types yet the knobcone pine sites have the greatest hydrologic response in 2009.

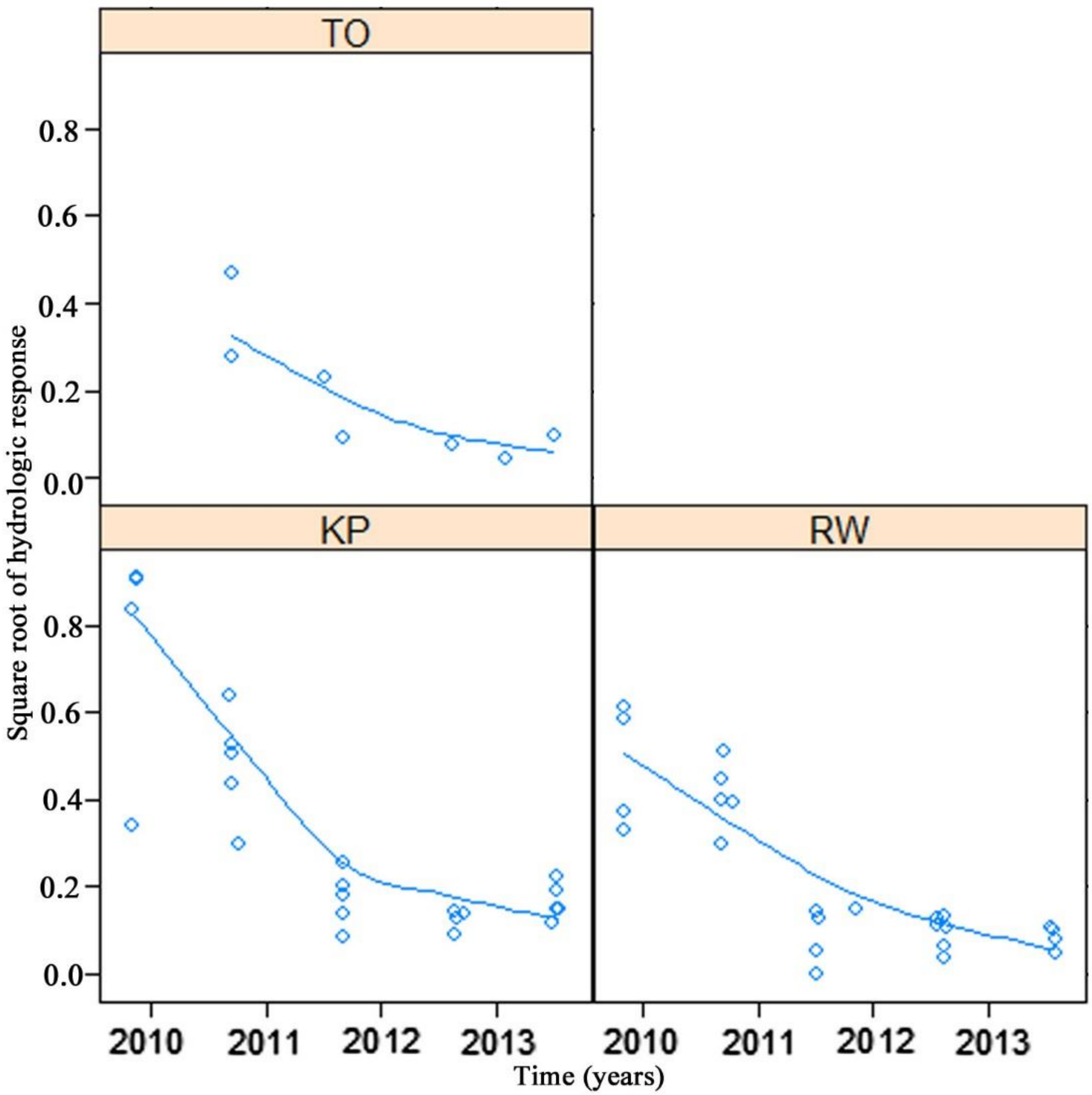


Figure 5-6: Square root of hydrologic response based vegetation type in the Scotts Creek watershed as a function of time (years). TO= tanoak, KP= knobcone pine and RW= redwood.

5.1.2.3 Percent Slope

Figure 5-7 displays the annual infiltration rates for all rainfall simulation sites as a function of percent slope. The trend line for the 2009 graph shows that infiltration increases with an increase

in slope. The trend lines of the remaining graphs are fairly linear suggesting infiltration is less affected by slope in the years following the fire.

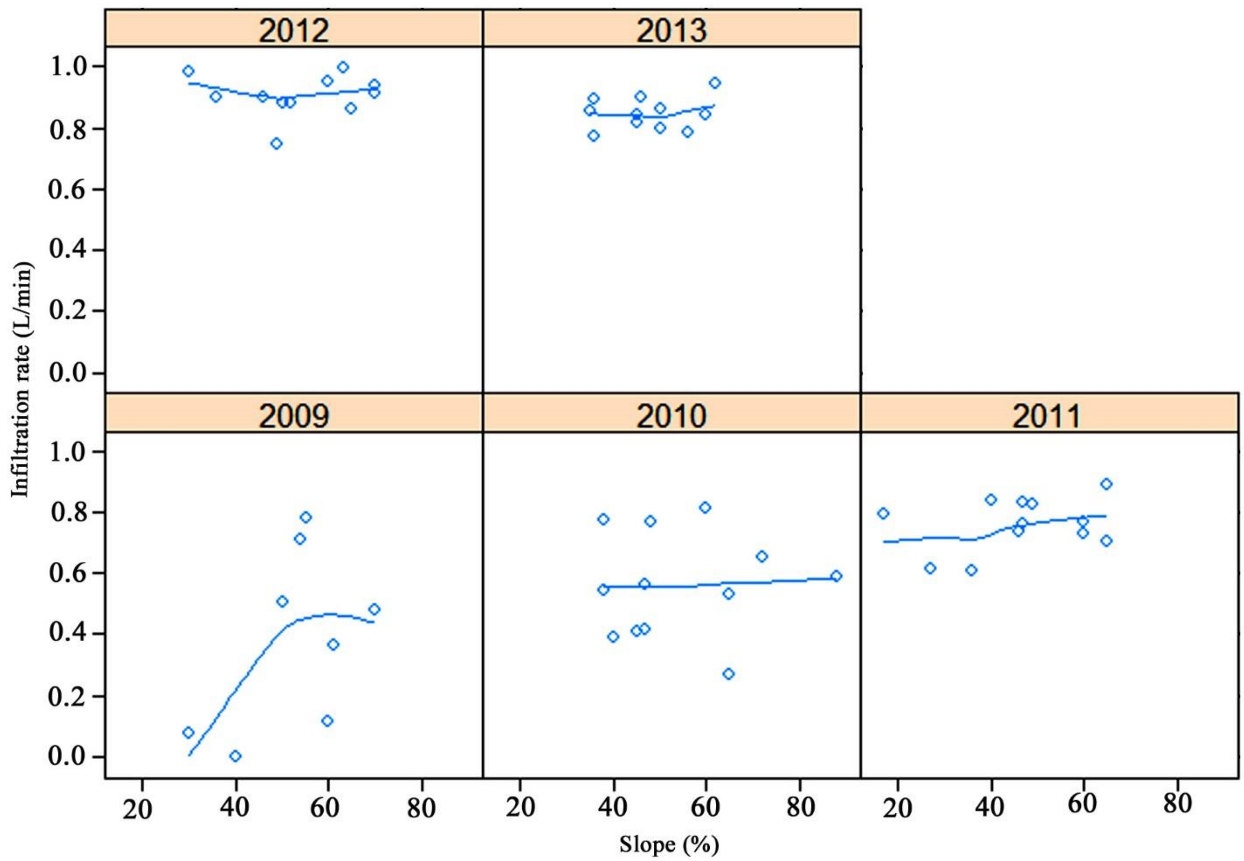


Figure 5-7: Annual infiltration rates (L/min) of all sites as a function of slope (%).

Figure 5-8 displays the annual square root of hydrologic responses for all rainfall simulation sites as a function of percent slope. The trend line for the 2009 graph shows that near-surface runoff decreases with an increase in slope. The trend lines in the remaining graphs, 2010 to 2013, do not necessarily suggest slope influences runoff because trend lines are neither increasing nor decreasing.

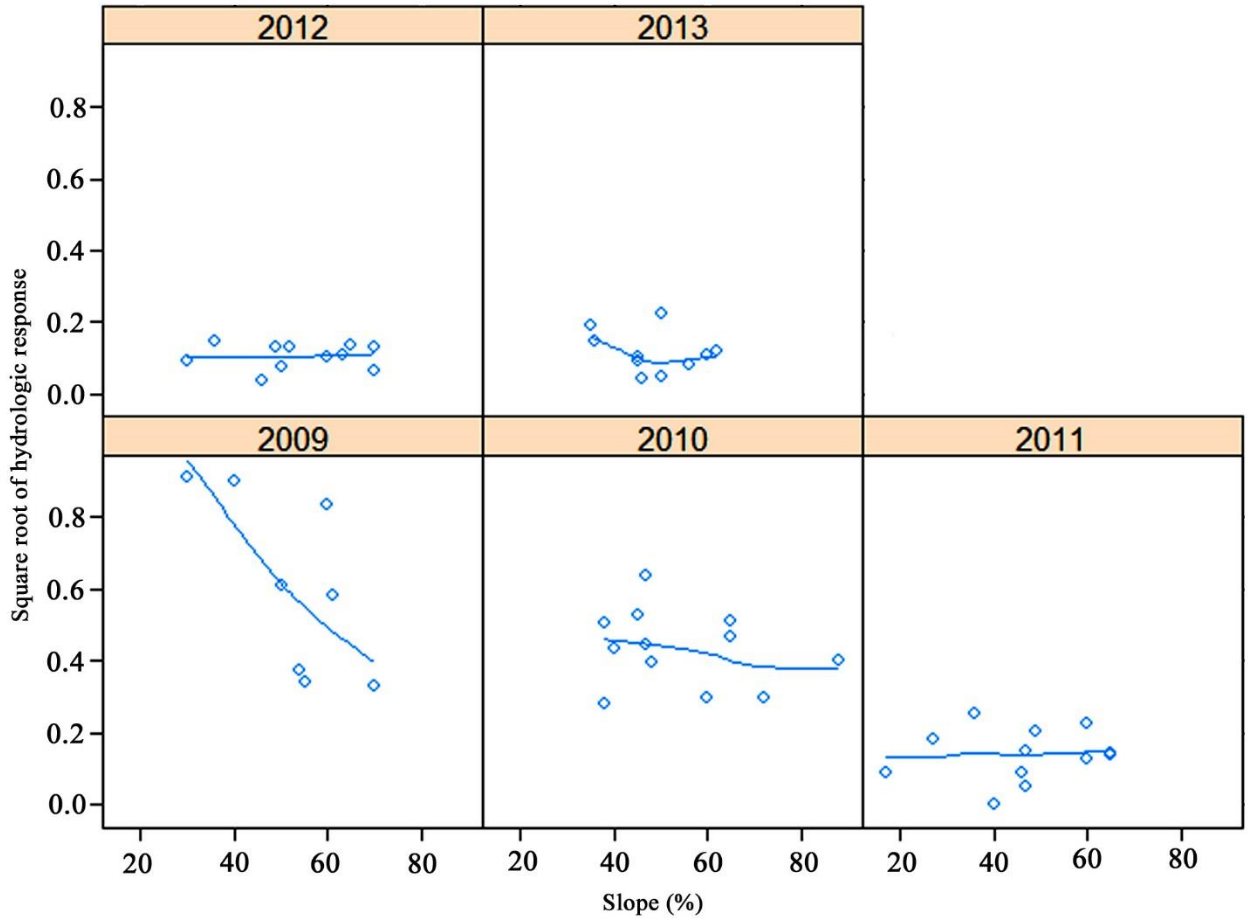


Figure 5-8: Annual square root of hydrologic response as a function of slope (%).

5.1.3 Statistical results for rainfall simulations in the Scotts Creek watershed

5.1.3.1 Burn severity

Figure 5-9 is the residual distribution from model 1 with infiltration rate as the response. Residuals are slightly skewed away from the regression line but overall the residual distribution is fairly linear. In this model, time was highly significant (p=0.0052) but burn severity (p=0.32) and the interaction between burn severity and time (p=0.72) were not significant predictors, thus supporting that the fire did not have an effect on infiltration rates.

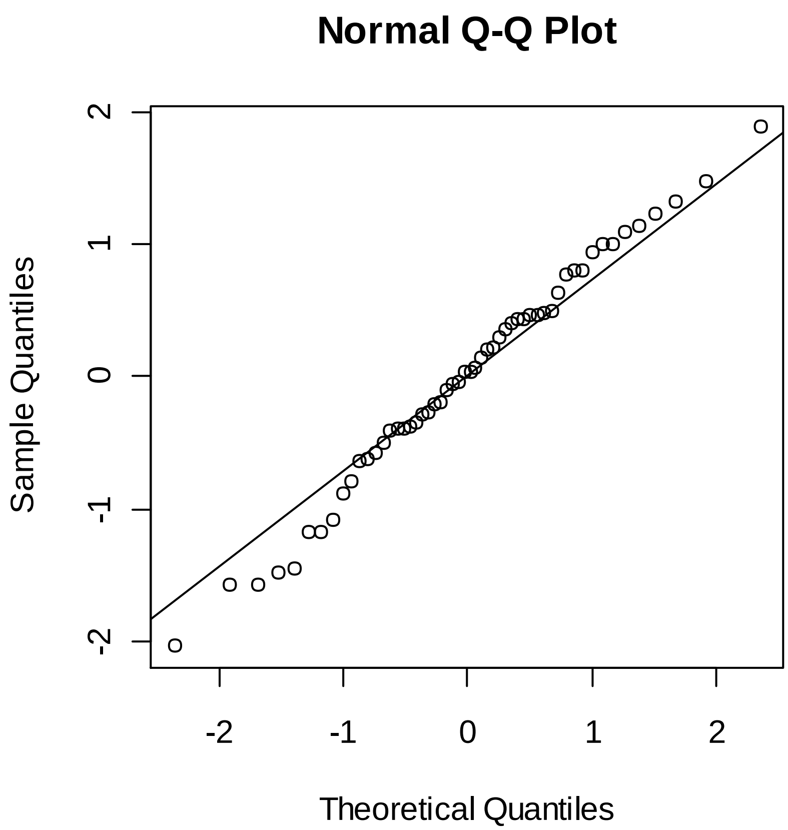


Figure 5-9: Residual distribution from model 1 with infiltration rates as the response.

In analyzing hydrologic responses, residuals in the initial linear model were skewed, therefore, a square root transformation was applied in order to linearize the data. Figure 5-10 is the residual distribution from the square root of hydrologic responses. Model 1 with the transformed data showed that time was highly significant ($p<0.001$) however, burn severity ($p=0.2288$) and its interaction with time ($p=0.4610$) were not statistically-significant thus strengthening the notion that the fire did not have an effect on the post-fire hydrologic response.

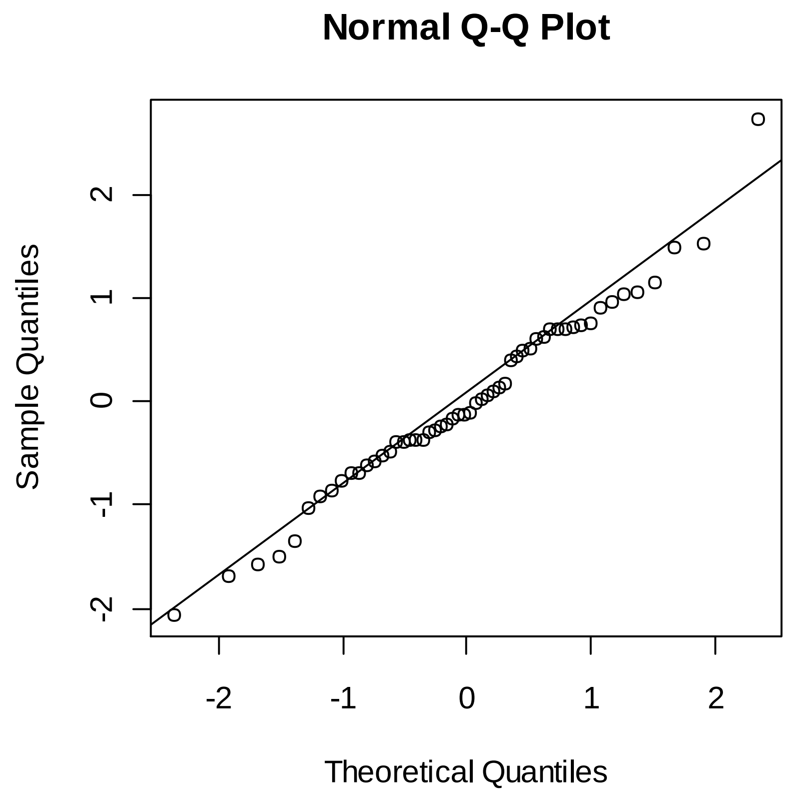


Figure 5-10: Residual distribution from model 1 with square root of hydrologic response as the response.

5.1.3.2 Vegetation and percent slope

Time was a significant predictor when testing the effect of vegetation and percent slope on infiltration rates and the hydrologic response, however, neither dominant vegetation type, slope nor the interactions between the two fixed effects and time were significant. From this model it can be inferred that there was not a particular dominant vegetation type or percent slope that impacted infiltration rates or hydrologic responses significantly more than any other vegetation type or percent slope following the fire.

5.1.3.3 Burn Dichotomy

Testing the burn severity classes alone did not reveal statistically-significant findings, therefore, additional analysis was performed in order to test the maximum fire effect and any fire effect on infiltration rates and runoff by using burn dichotomies. With infiltration rates as the response in the "Hot burn versus all others" model, time was highly significant ($p<0.0001$) while burn severity ($p=0.095$) and the interaction between burn severity and time ($p=0.208$) are not statistically-significant predictors. Regarding square root of hydrologic responses, time was highly significant ($p<0.0001$) and burn severity was slightly significant ($p=0.023$). However, the interaction between burn severity and time ($p=0.123$) was not significant.

Upon analyzing infiltration rates, the second burn dichotomy, "Unburned sites versus all others" revealed that time was highly significant ($p<0.0001$) but burn severity ($p=0.419$) and the interaction between burn severity and time ($p=0.596$) were not. Regarding the square root of the hydrologic responses, time was highly significant ($p<0.0001$) while burn severity ($p=0.164$) and the interaction between burn severity and time ($p=0.211$) were not.

5.2 Little Creek watershed rainfall simulation data results

5.2.1 Little Creek watershed rainfall simulation data

5.2.1.1 Burn severity

The six sites that were partitioned out and re-examined as a group are site 4-Little Creek (unburned), site 5-Cabins (moderate), site 6-Upper North Fork (low), site 7-South Fork (moderate), site 13-Lions Flat (high), and site 14-Hillslope (moderate). The influence of burn

severity, vegetation type and percent slope on infiltration rates and hydrologic responses were re-examined solely on the 6 sites using mixed-effects modeling as described in Section 4.3.2.1.

The dataset contains 1 unburned site, 1 low, 3 moderate, and 1 high severity sites. As is visible in Figure 5-11, infiltration rates increase over time (days since 12/31/2008) at all of the sites. There are two observations that stand out at site 5 in 2009 and 2010 because they have such low infiltration rates compared to the rest of the data including site 13, a high severity site. However, site 13 was established in 2010 and was not surveyed in 2013 due to the amount of vegetative regrowth, thus investigating the full scope of change over time for site 13 was not possible.

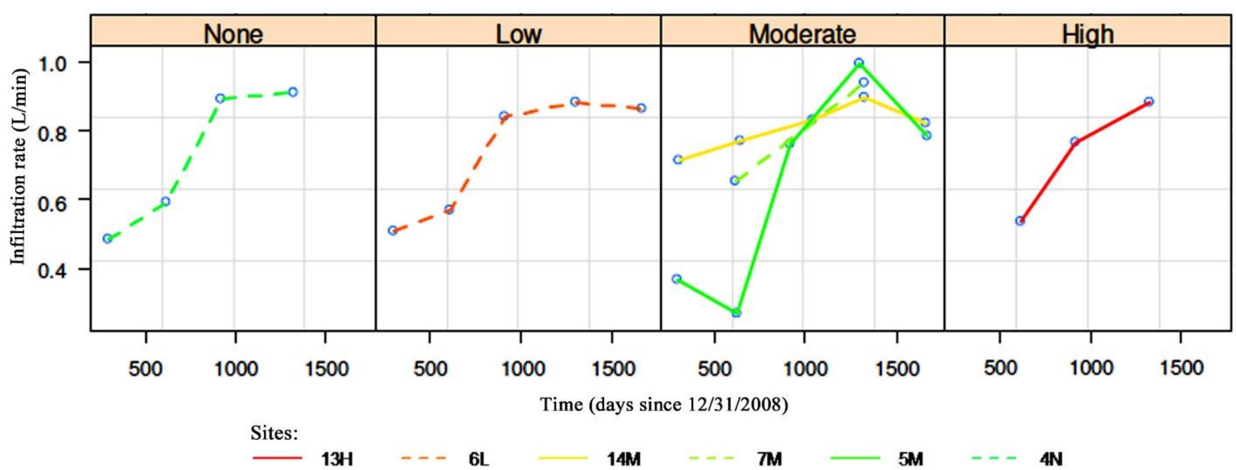


Figure 5-11: Infiltration rates (L/min) for each of the Little Creek rainfall simulation sites by burn severity as a function of time (days since 12/31/2008). Suffixes adjacent to site numbers indicated burn severity classification.

Figure 5-12 displays the hydrologic responses by burn severity classification as a function of time (days since 12/31/2008). There is a decreasing trend at all locations. Near-surface runoff at the low and moderate sites is high in 2009 and similar to site 13, a high severity site, in 2010. There does not appear to be a distinct difference among the four burn severities for either infiltration rates or hydrologic responses as shown by Figures 5-11 and 5-12.

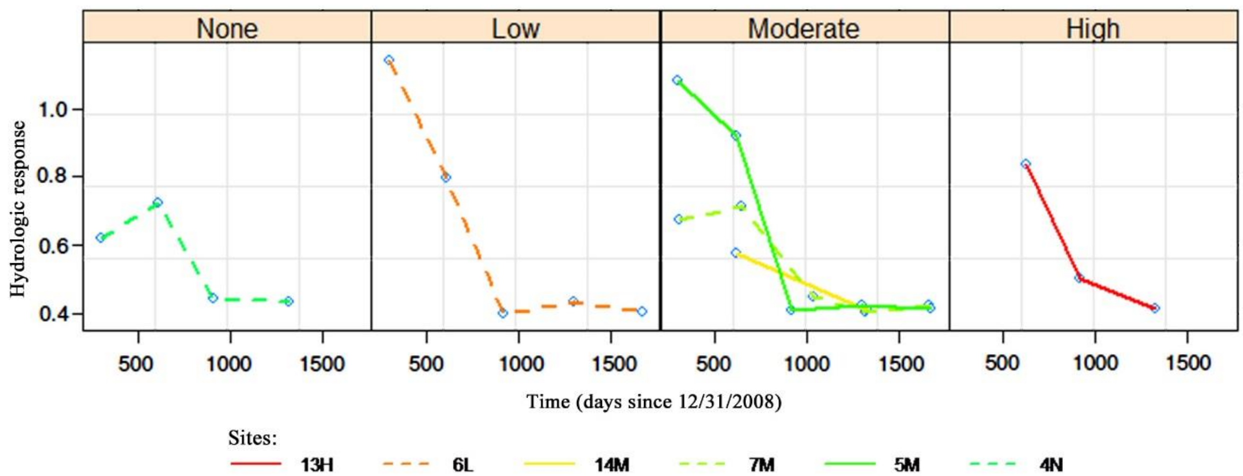


Figure 5-12: Hydrologic responses for each of the Little Creek rainfall simulation sites by burn severity over time (days since 12/31/2008). Suffixes on site number indicates burn severity classification.

5.2.1.2 Dominant vegetation type

Figure 5-13 displays infiltration rate by vegetation type as a function of time (years). There is a strong increasing trend for the first three years of the RW/DF classification. As well as an increasing trend in infiltration for the RW/TO and TO vegetation types.

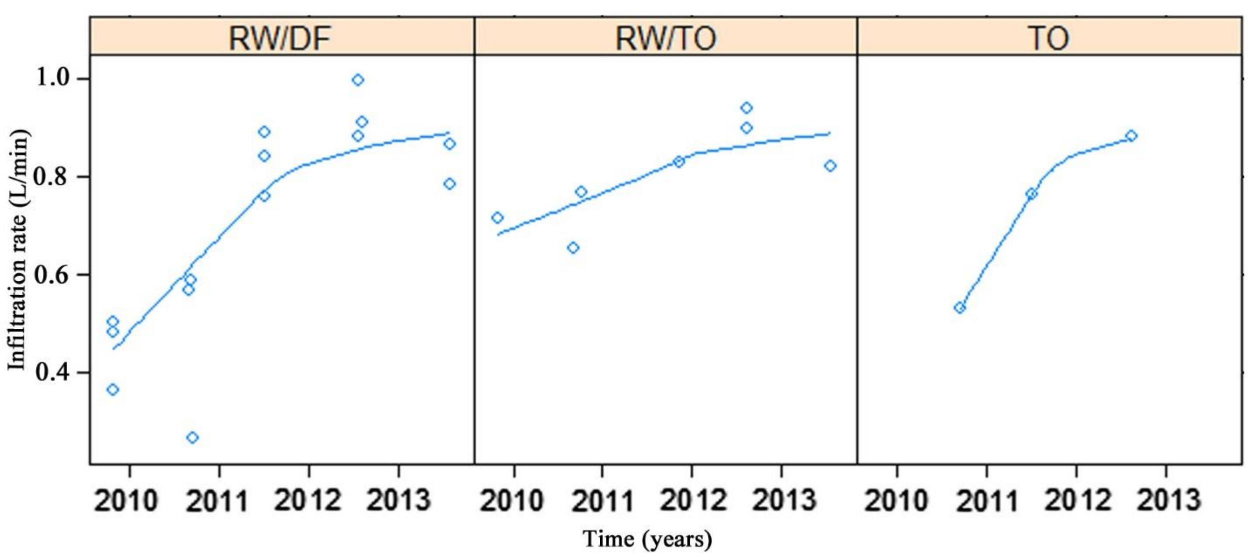


Figure 5-13: Infiltration rates of each vegetation types as a function of time (years). RW/DF= redwood/Douglas fir, RW/TO= redwood/ tanoak, and TO= tanoak.

Figure 5-14 displays the square root of hydrologic responses by vegetation type as a function of time (years). There is a decreasing trend present at all sites showing that the hydrologic responses decreased following the fire. Yet, based upon the Figure 5-13 and 5-14, there does not appear to be a distinct difference among the three vegetation types for both infiltration rates and hydrologic responses.

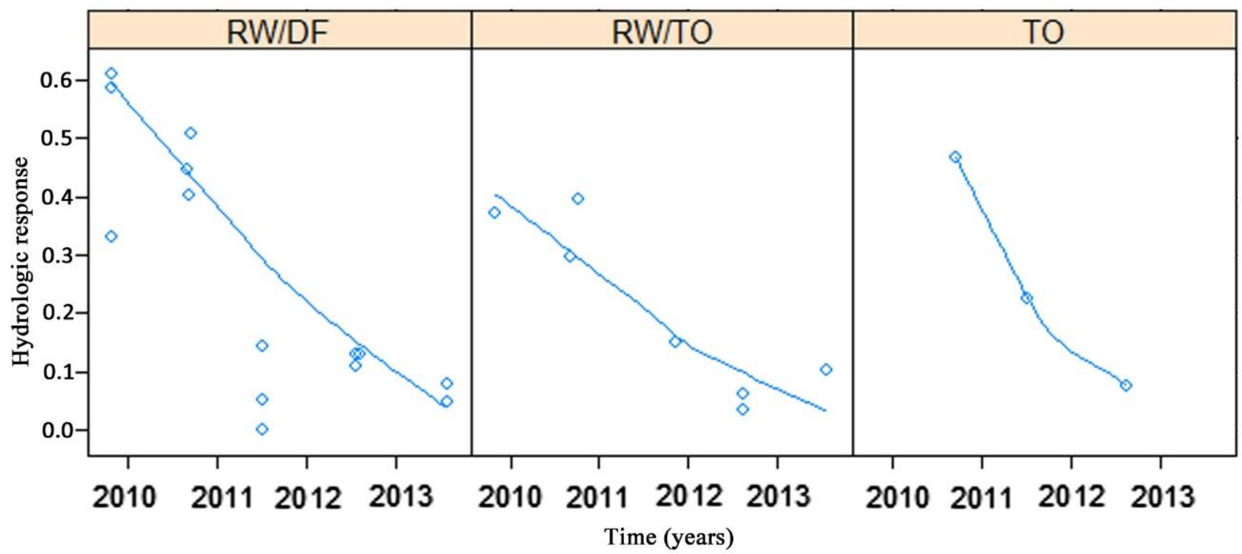


Figure 5-14: Hydrologic responses of each vegetation type as a function of time (years). RW/DF= redwood/Douglas fir, RW/TO= redwood/ tanoak, and TO= tanoak.

5.2.1.3 Percent Slope

Figure 5-15 displays the annual infiltration rates of the six Little Creek sites as a function of slope (%). Trend lines in each of the graphs does not suggest change in slope greatly affects infiltration rates.

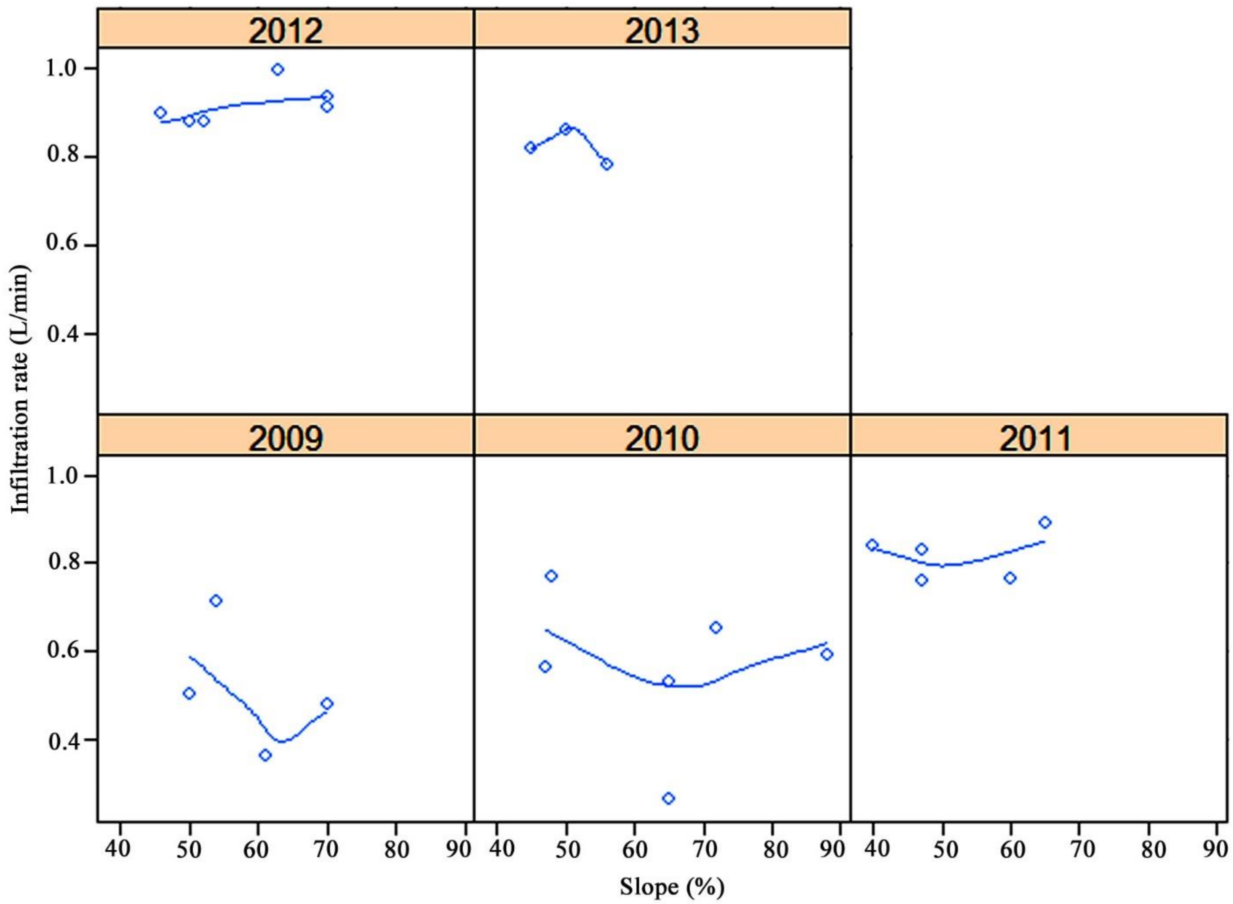


Figure 5-15: Annual infiltration rate (L/min) of six Little Creek sites as a function of slope (%).

Figure 5-16 displays the annual square root of hydrologic responses as a function of slope (%). Although trend lines are not linear, trend lines do not strongly suggest that near-surface runoff is altered by changes in percent slope.

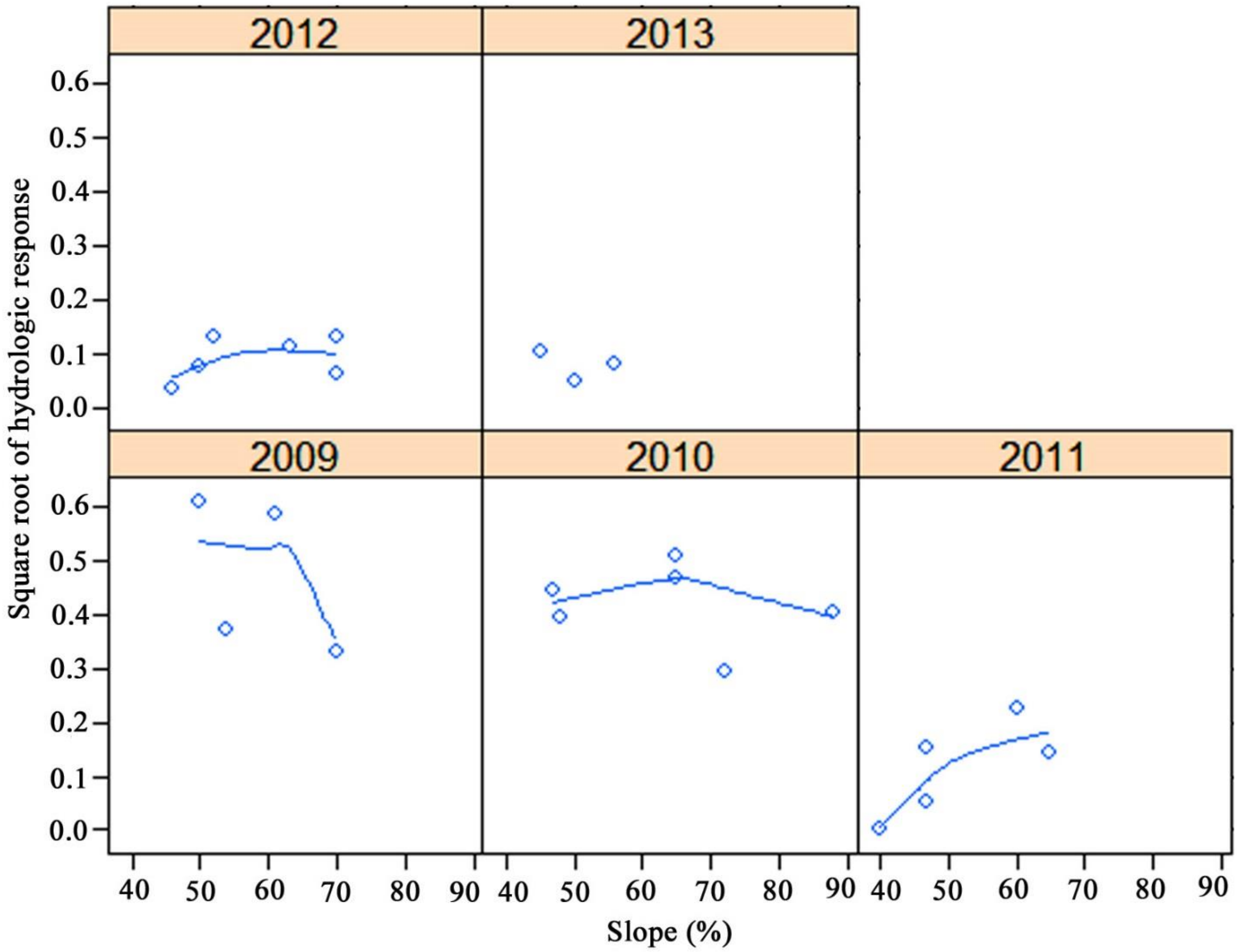


Figure 5-16: Annual square root of hydrologic response of six Little Creek sites as a function of slope (%).

5.2.2 Statistical results for rainfall simulations in the Little Creek watershed

With infiltration rate as the response, the residual distribution was fairly linear except for two lower lying outliers from site 5-Cabins (Figure 5-17). Time is highly significant (p=0.0035) sequentially[19], however, burn severity (p=0.8549) and the interaction between burn severity and time are not statistically-significant. Marginally[20], time (p=0.0691), burn severity (p=0.9474) and

[19] Sequential p-values indicate the significance of each term as it is added sequentially to the model, i.e. in a model that includes only that term and the ones before it.

[20] Marginal p-values are the conventional p-value ($p < 0.05$) which indicate the significance of each term in the complete model.

the interaction between burn severity and time (p=0.8632) were not significant predictors regarding infiltration rates at the 6 Little Creek sites.

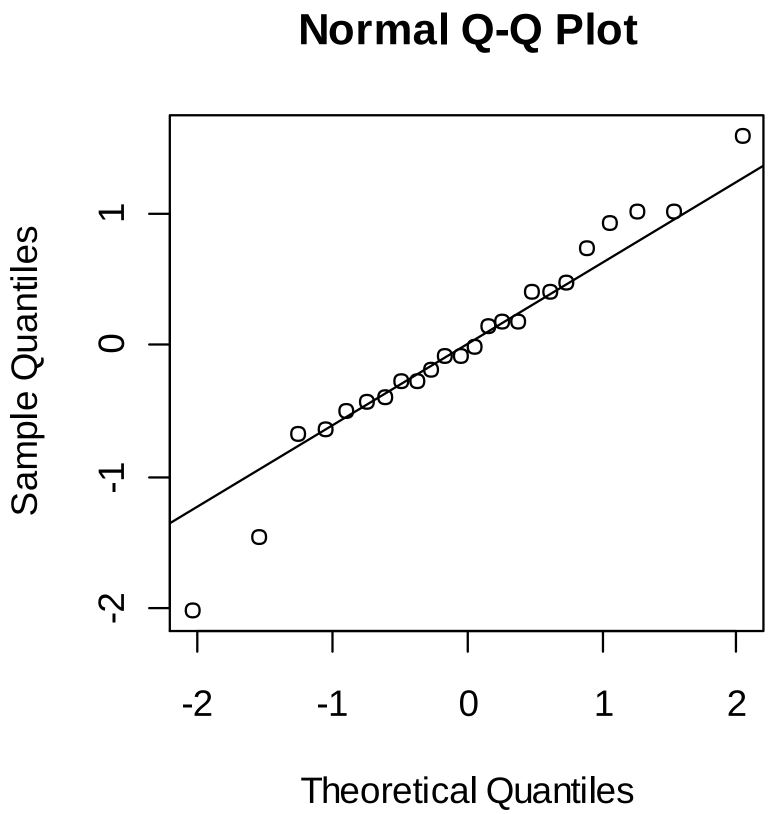


Figure 5-17: Residual distribution from model 1 with infiltration rate as the response.

In the prior analysis containing all thirteen sites, a square root transformation was applied to hydrologic responses. A square root transformation was applied to the Little Creek sites to retain consistency although an improvement in the residual distribution was not obvious upon applying the transformation. Figure 5-18 shows the residual distribution of model 1 for the square root of hydrologic responses for the six Little Creek sites. Sequentially, time ($p<0.0001$) was highly significant while burn severity (p=0.8856) and the interaction between burn severity and time (p=0.7302) were not. Marginally, time (p=0.0003) was a significant predictor, but burn severity (p=0.6769) and the interaction between burn severity and time (p=0.7302) were not.

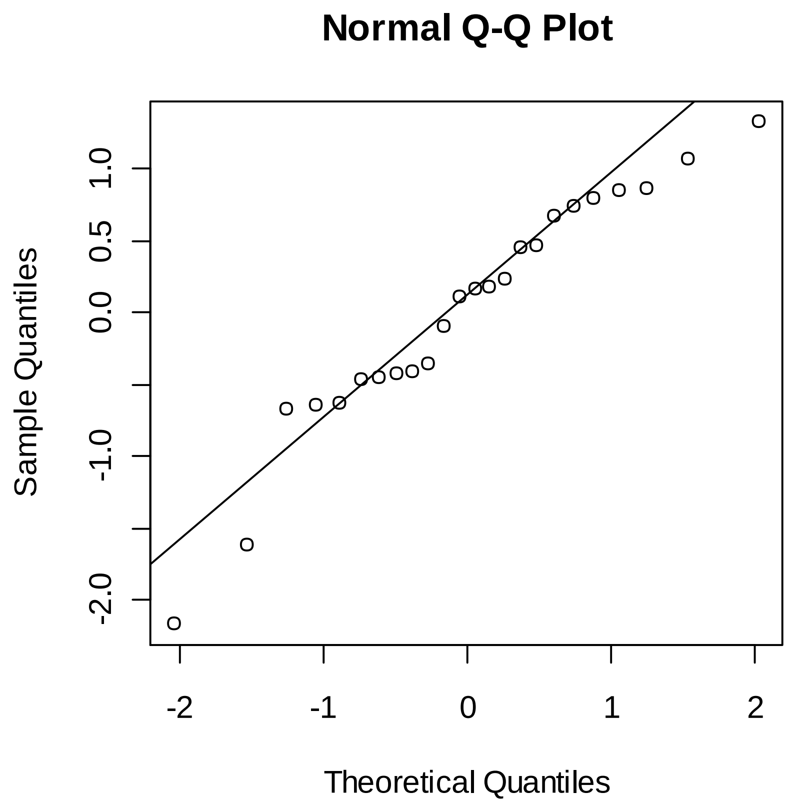


Figure 5-18: Residual distribution from model 1 with square root of hydrologic response as the response.

5.2.2.1 Vegetation

With infiltration rates as the response, time is highly significant both sequentially (p<0.0001) and marginally (p=0.0003), but vegetation type was neither sequentially (p=0.5044) nor marginally (p=0.2248) significant and the interaction between vegetation type and time was neither sequentially (p=0.2064) nor marginally (p=0.2064) significant. Regarding the square root of hydrologic responses, time was highly significant sequentially (p<0.0001) and marginally (p=0.0001). However, vegetation type was neither sequentially (p=0.8417) nor marginally (p=1.5194) significant. Similarly, the interaction between vegetation and time was neither sequentially (p=0.5352) nor marginally (p=0.5352) significant. These results suggest that

vegetation type did not influence a change in infiltration or near-surface runoff following the Lockheed Fire.

5.2.2.2 Percent Slope

With infiltration rate as the response, slope and the interaction between slope and time are significant predictors marginally (p=0.0208) whereas time is not a significant predictor marginally (p=0.1132). Sequentially, time (p=0.0001) and the interaction between slope and time (p=0.0192) are significant predictors but slope alone (p=0.6494) is not.

Regarding the square root of the hydrologic responses, time is a significant predictor sequentially (p=0.0001), but is not a significant predictor marginally (p = 0.8300). Slope is neither sequentially (p=0.1603) nor marginally (p=0.2470) significant and the interaction between slope and time is neither sequentially (p=0.4966) nor marginally (p=0.4966) a significant predictor.

5.3 Mini-disk Infiltrometer data and results

5.3.1 MDI sites sampled each year

MDI tests were conducted at 23 sites for five years, but not necessarily at each site every year (refer to Figure 4-3 for specific locations). Tests were conducted during the summer months and early fall. The total number of complete MDI replications is 913. Table 5-2 shows the amount of annual MDI measurements recorded each year.

Table 5-2: Number of annual MDI measurements recorded. Burn severity classifications are N= None, M/L= Moderate/Low, M= Moderate, H/M= High/Moderate, and H=High.

Site Number	Burn Severity	2009	2010	2011	2012	2013
1	H	10	10	10	12	12
2	M	10	10	12	12	0
3	M	10	10	12	12	12
4	H	10	10	10	10	0
5	M	10	8	0	12	12
6	H	10	0	12	12	0
7	H	10	10	12	12	0
8	H	10	10	10	12	0
9	M	10	10	12	12	12
10	H	10	10	0	12	12
11	M	10	8	0	12	12
12	H	20	10	10	12	0
13	M	13	0	12	12	0
14	N	10	10	8	0	0
15	H	10	0	0	12	12
16	MH	10	0	0	0	0
17	MH	10	0	0	0	0
18	H	10	10	1	0	0
19	M	10	10	0	0	0
20	H	10	10	10	12	12
21	ML	10	10	10	12	12
22	MH	10	10	10	12	12
23	H	10	10	0	12	0

The number of measurements for any given site and year is normally the number of transect locations multiplied by the number of depths measured. Some sites were discontinued after either the first or second year of testing due to their close proximity to other sites. Site 16 and 17 were no longer tested after 2009 because they were in close proximity to sites 15 and 8. Site 19 was no longer tested after 2010 due its proximity to site 18.

5.3.2 MDI Data

Figures 5-19 displays the mean infiltration volume of three measurements as a function of time measured in days since 12/31/2008 for each individual site at 1 cm depth. The number indicates the site number and the letter signifies the soil burn severity classification.

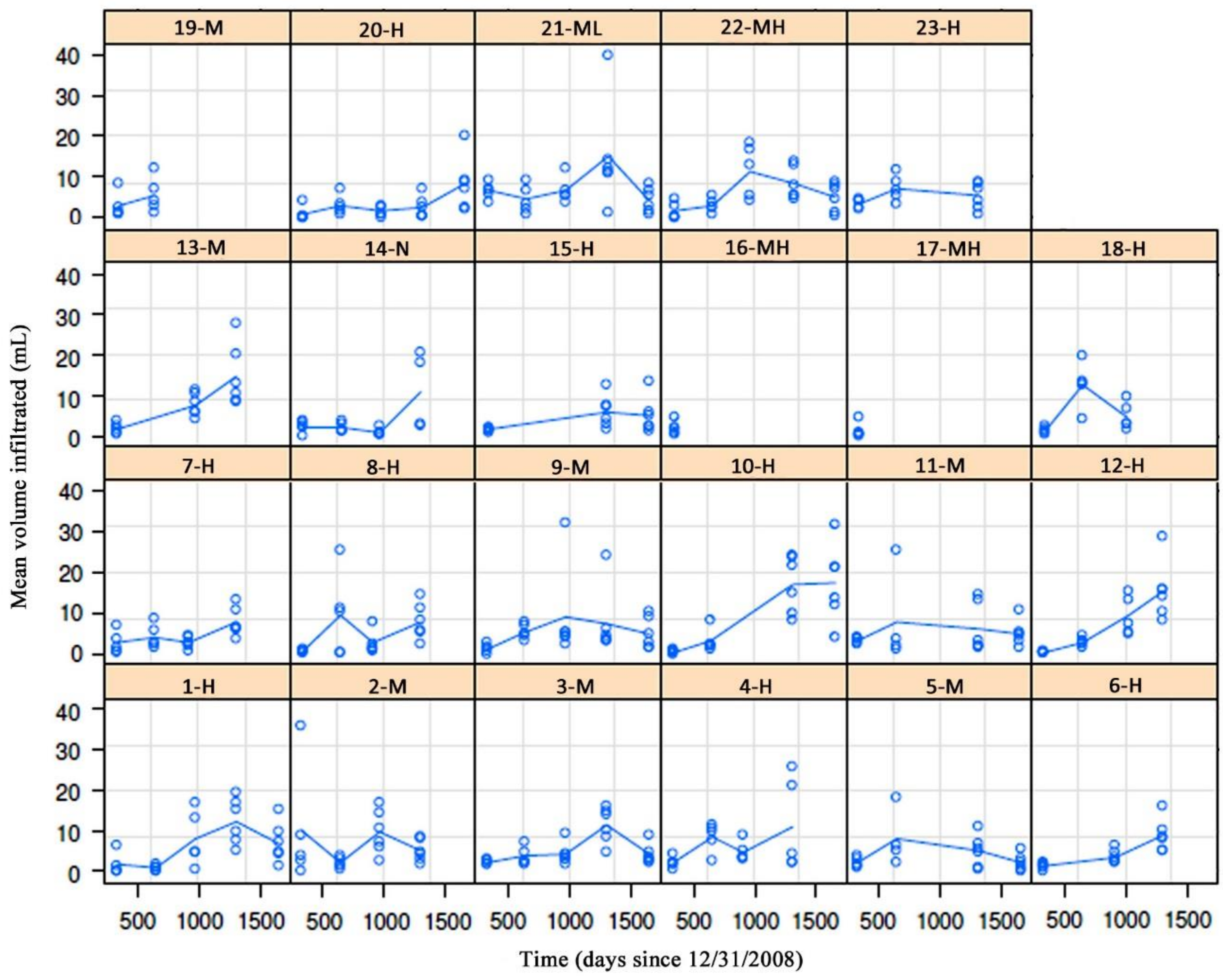


Figure 5-19: Annual MDI mean infiltration volumes (mL) as a function of time (days since 12/31/2008) by site number at 1 cm depth. The number represents the site number and the letter represents a burn severity classification: H=High, MH=Moderate to High, M=Moderate, ML=Moderate to Low, N=Unburned.

Figure 5-20 displays the mean infiltration volume of three measurements as a function of time measured in days since 12/31/2008 for each individual site at 3 cm depth. When visually

comparing figures 5-19 and 5-20, there does not appear to be a distinct difference in mean infiltration volumes between 1 and 3 cm depths.

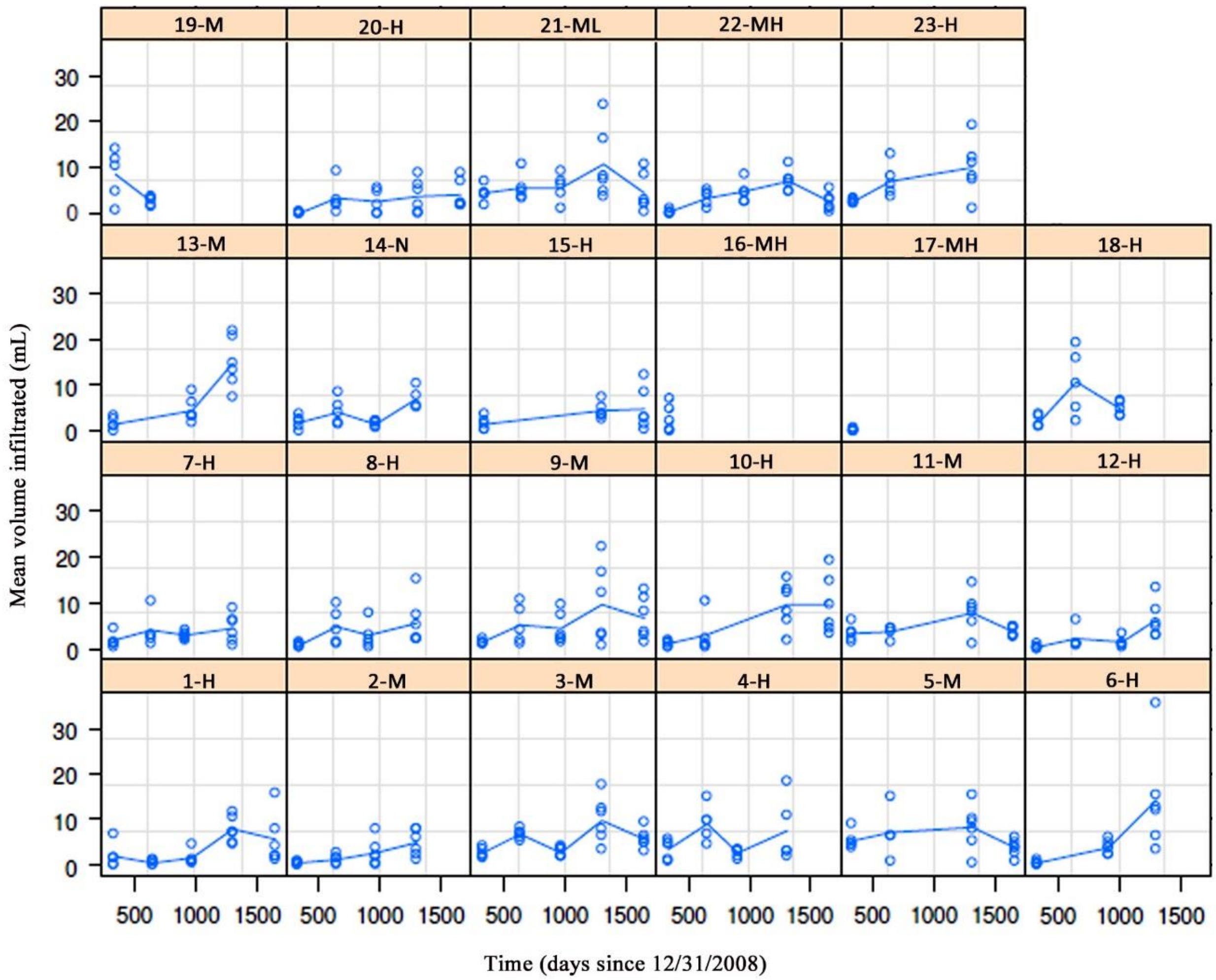


Figure 5-20: Annual MDI mean infiltration volumes (mL) as a function of time (days since 12/31/2008) by site number at 3 cm depth. The number represents the site number and the letter represents a burn severity classification: H=High, MH=Moderate to High, M=Moderate, ML=Moderate to Low, N=Unburned.

5.3.2.1 Burn Severity

Figure 5-21 displays the mean infiltration volume by year and simplified burn classification as a function of time (years). This graph shows that mean infiltration volume does not appear to be related to depth as a result of trend lines that are neither strongly increasing nor decreasing.

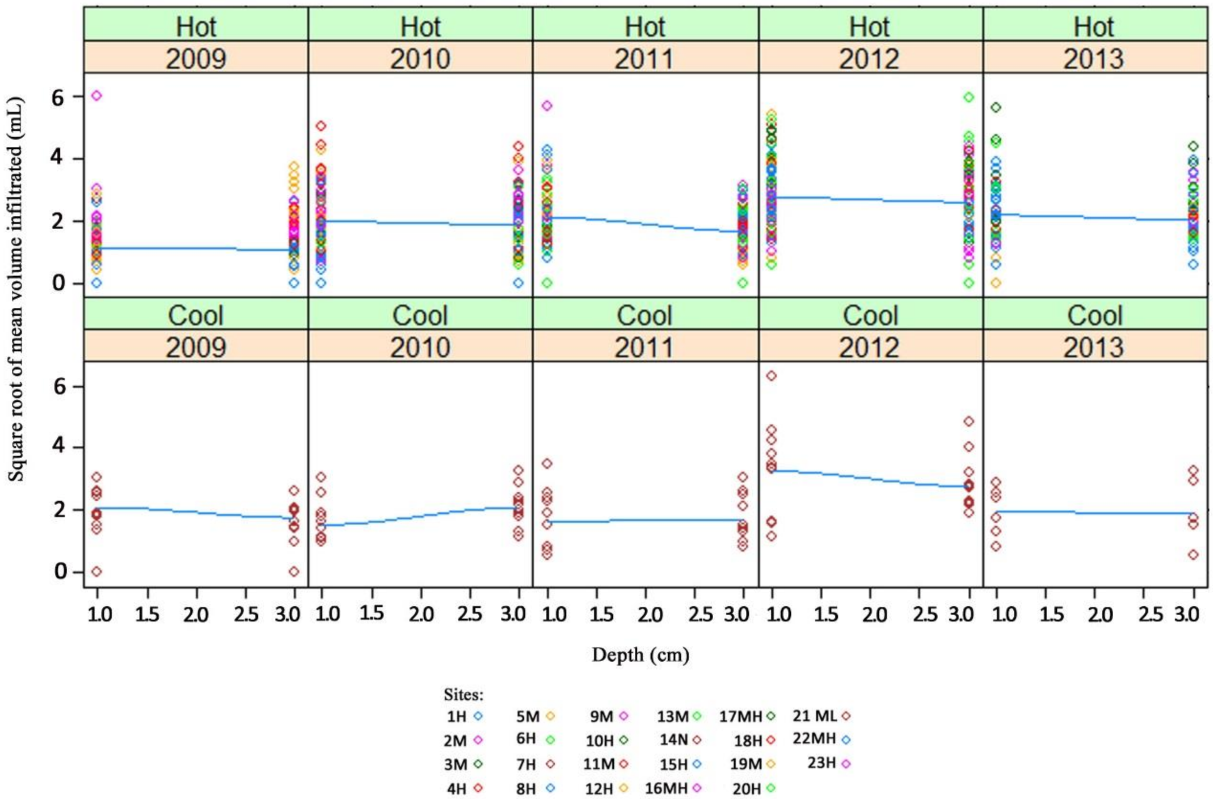


Figure 5-21: MDI mean volume infiltrated in (mL) as a function of depth (cm) for each year and simplified burn severity classification. For the simplified burn classes, "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML. Volumes have been transformed for this display using square roots. Curves are fitted by loess (degree=1, span =1)

Figure 5-22 shows annual mean infiltration volumes by depth and simplified burn severity classification as a function of time (years). The trend lines show maximum infiltration volumes occur in 2012 regardless of depth or burn severity classification.

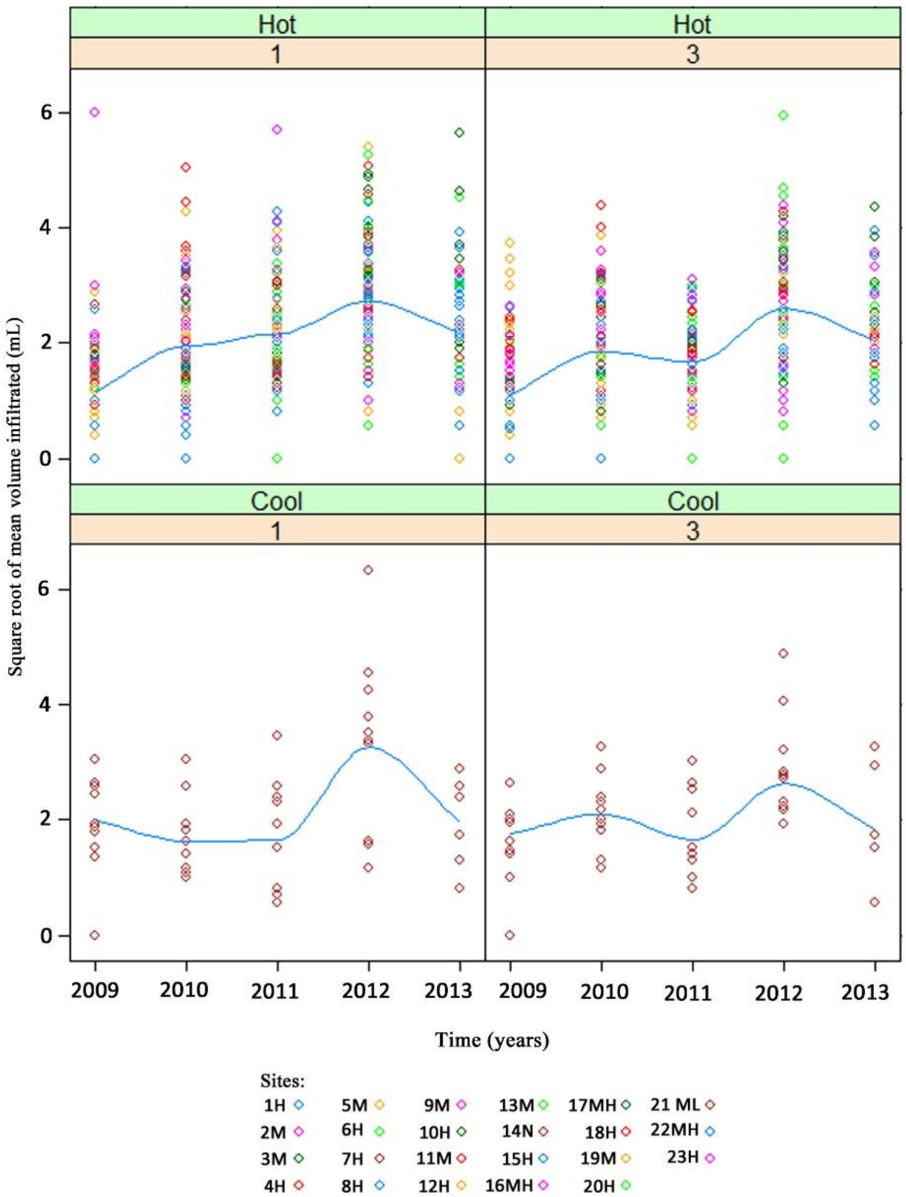


Figure 5-22: MDI mean infiltration volume (mL) as a function of time (years) for each depth (cm) and simplified burn classification. For simplified burn classes, "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML. Volumes have been transformed for this display using square roots. Curves are fitted by loess (degree=1, span =0.5)

Figure 5-23 is a temporal display of the original burn severity classifications for each site. The moderate, moderate/high and high classifications show an increasing trend in infiltration volumes with a maximum in 2012 and leveling out or decline in 2013. The unburned sites and moderate/low sites show a less definitive increase in 2012 and decline in 2013.

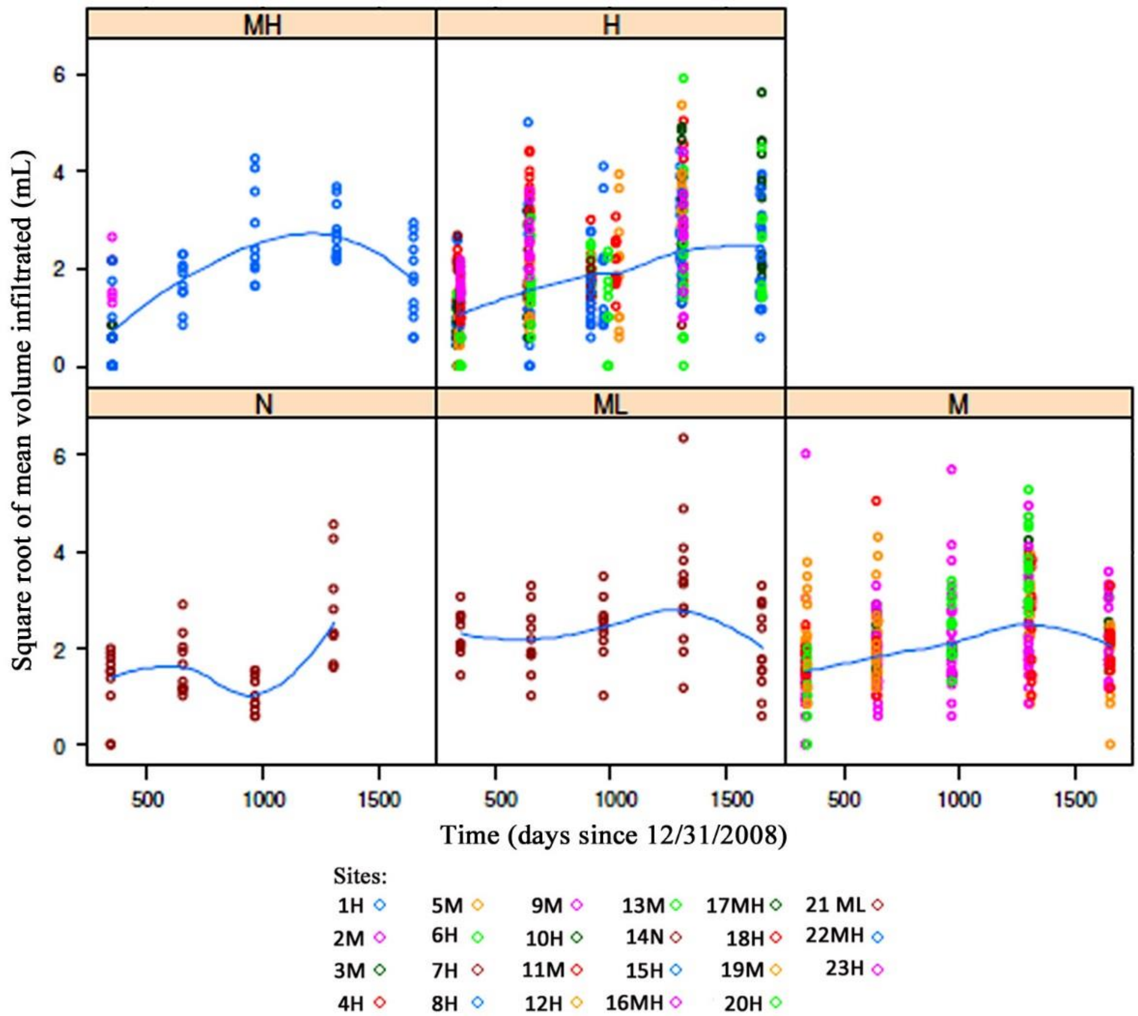


Figure 5-23: MDI mean infiltration volume as a function of day number for each burn severity class. Burn severity classifications are N= None, M/L= Moderate/Low, M= Moderate, H/M= High/Moderate, and H=High. Volumes have been transformed for this display using square roots. Curves are fitted by loess (degree=2, span =1)

5.3.2.2 Soil parent material

Figure 5-24 displays the square root of mean infiltration volume by depth, simplified burn class, and soil parent material as a function of time (years). Temporal trends are visible but not evident to suggest one soil parent material has grater or lower infiltration volumes from the remaining soil parent materials types.

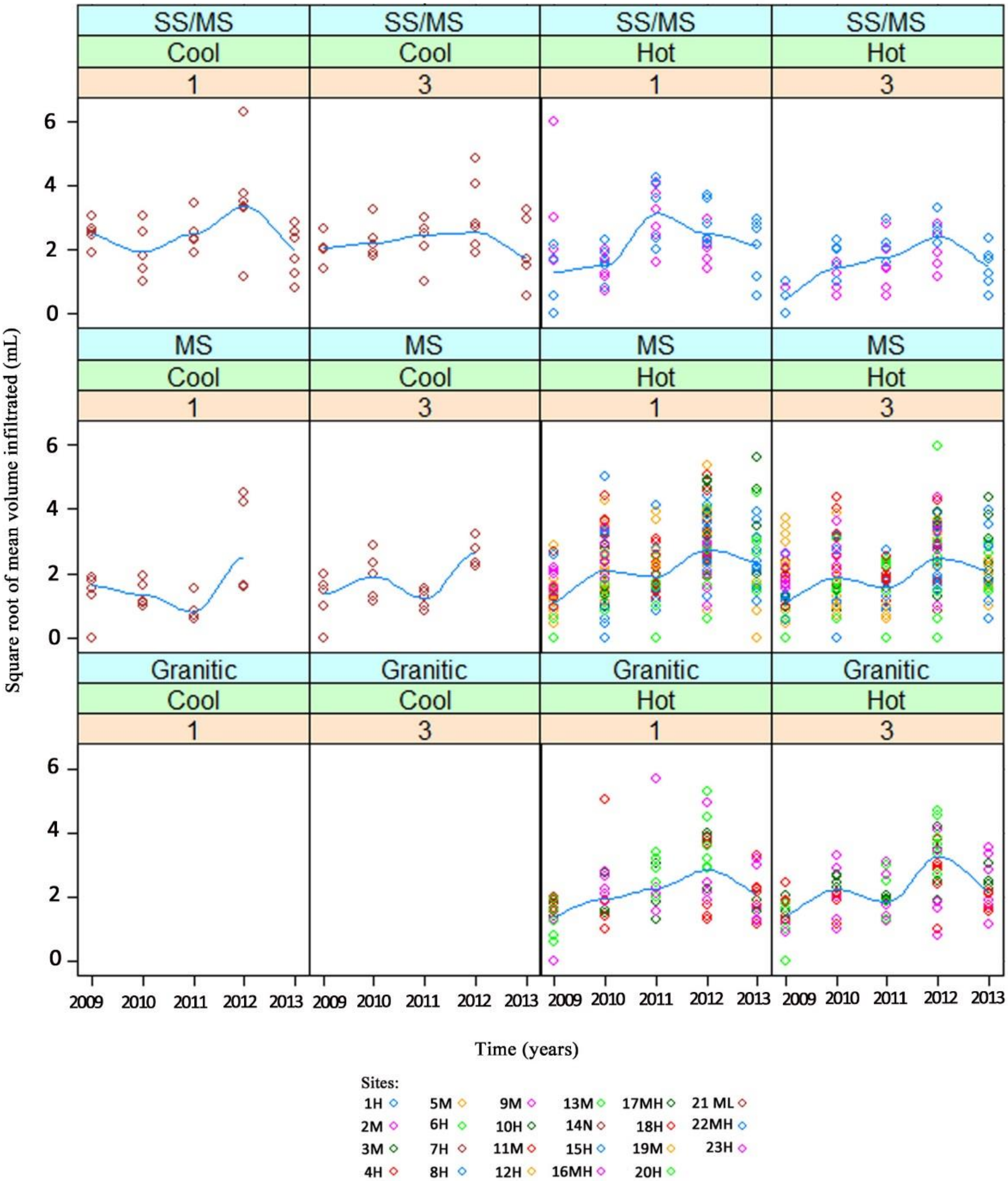


Figure 5-24: Square root of mean infiltration volume (mL) by depth (cm), simplified burn class, and soil parent material as a function of time (years). For simplified burn classes, "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML. For soil parent material MS= mudstone and MS/SS = mixture of mudstone and sandstone.

Figure 5-25 displays the square root of mean infiltration volume by soil type and simplified burn severity classification as a function of time (years).

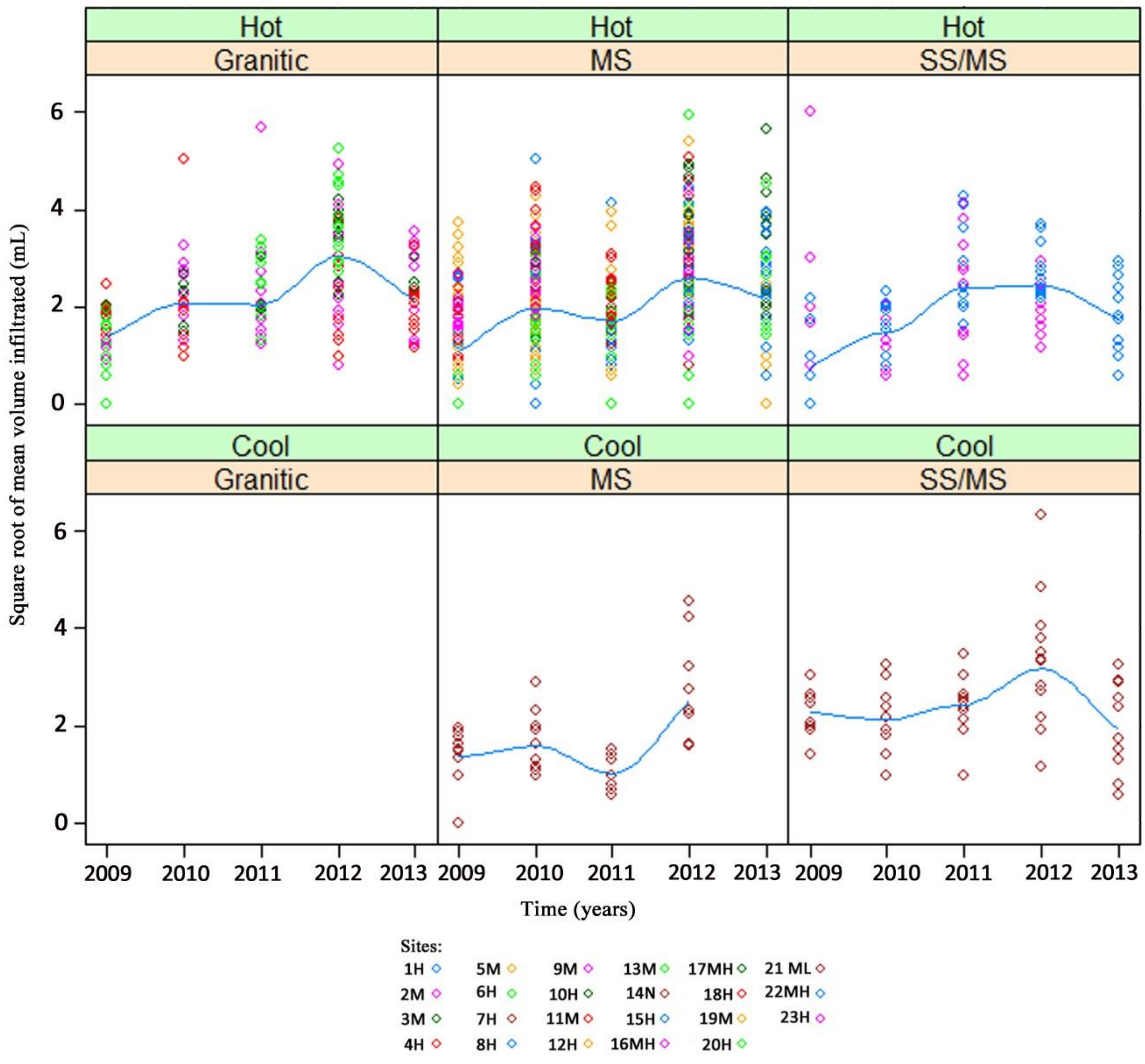


Figure 5-25: Square root of mean infiltration volume (mL) by soil type, simplified burn class and depth (cm) as a function of time (years). For simplified burn classes "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML. For soil parent material MS= mudstone, and MS/SS = mudstone/sandstone.

Table 5-3 provides the mean annual infiltration volumes for each of the three soil types. The lowest and greatest mean infiltration volumes change from year to year thus providing additional evidence that soil parent material is not a suitable predictor for infiltration volumes.

Table 5-3: Mean infiltration volume by year and soil type.

Year	Granitic	Mudstone	Sandstone/Mudstone
2009	2.37	1.90	3.96
2010	5.42	5.19	3.32
2011	5.44	3.45	6.80
2012	10.24	8.25	8.53
2013	5.03	6.74	4.10

5.3.2.3 Dominant vegetation type

Figure 5-26 displays the square root of mean volume infiltrated by dominant vegetation type and simplified burn severity classification as a function of time (years).The knobcone pine and manzanita sites were all high burn severity sites therefore there are none of these sites in the "Cool" simplified burn class. Both vegetation types show a trend of increasing infiltration over time and neither vegetation type or burn severity classifications appears to have a stronger influence than the others.

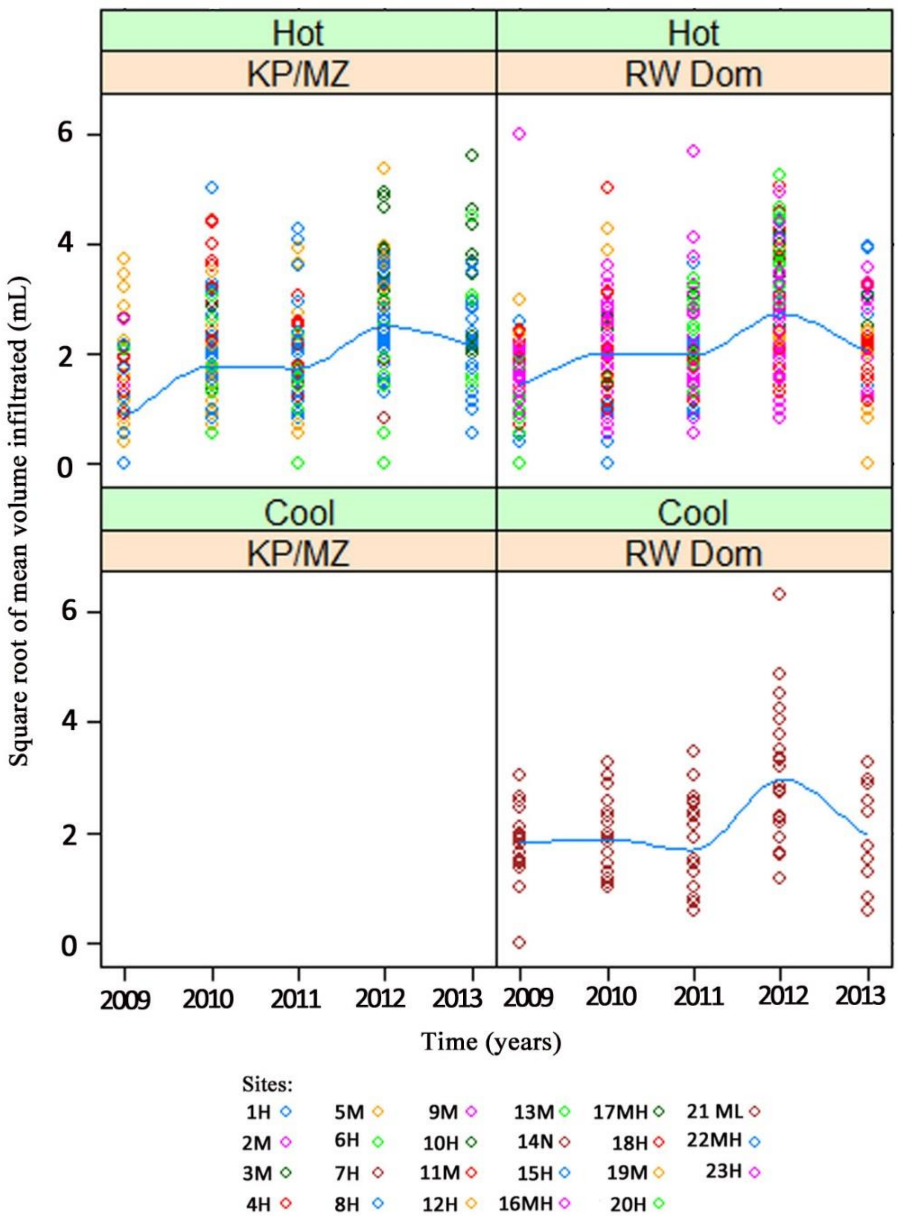


Figure 5-26: Square root of infiltration volume by dominant vegetation type and simplified burn classification as a function of time (years). For simplified burn class "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML. For dominant vegetation type KP/MZ= knobcone pine/ manzanita and RW= redwood dominant.

5.3.3 Statistical results for the MDI tests

5.3.3.1 Burn severity

This model for the log-transformed response had a more Gaussian distribution and showed that day number ($p=0.044$), burn severity ($p=0.0017$), depth ($p=0.004$), and the interaction between day number and burn severity ($p<0.0001$) were all significant (Figure 5-27). This model explains 50% of the variation in the logarithm of MDI volume. The coefficient is negative for depth, suggesting infiltration is reduced at greater depths. The interaction between burn severity and depth and was not found to be significant ($p=0.17$).

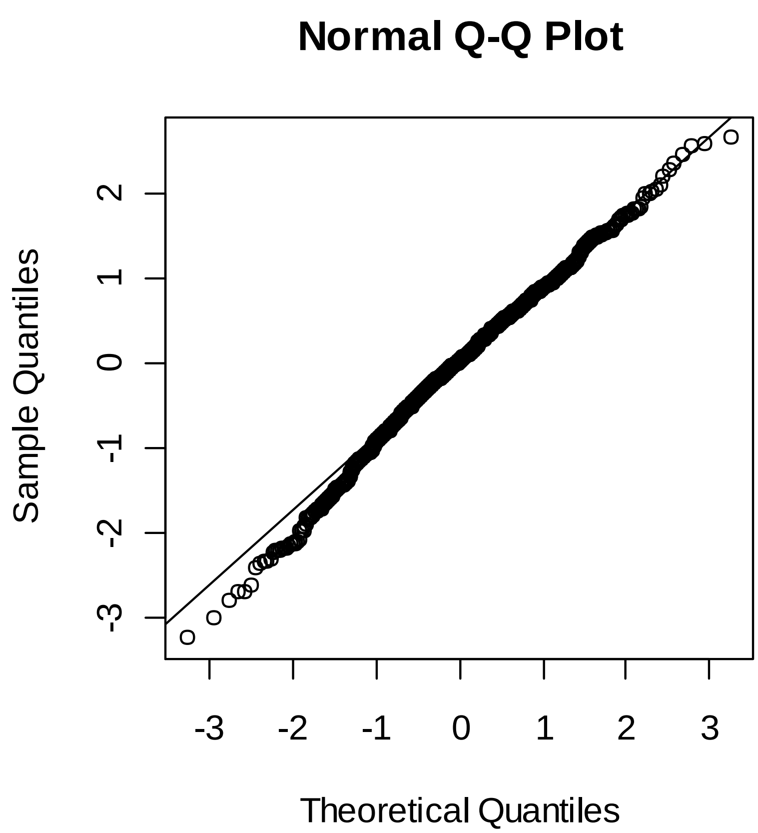


Figure 5-27: Logarithmic transformed residual distribution for model of MDI.

5.3.3.2 Soil parent material

The three soil parent materials were added to model 2 as fixed effects. While parent soil material is the attribute of most concern, additional fixed effects in the model are day number (time), depth, burn severity and the interaction between burn severity and time. The significance of the latter four fixed effects was tested and only day number ($p<0.0001$) and depth ($p=0.0434$) were found to be significant therefore burn severity and the interaction between burn severity and time were removed from the model. Nevertheless, soil parent material ($p=0.4994$), the interaction between soil parent material and day number ($p=0.5285$), and the interaction between soil parent material and depth ($p=0.3062$) were significant predictors. Depth alone ($p=0.7634$) was not a significant predictor either.

5.3.3.3 Dominant Vegetation Type

The same mixed-effects model for the logarithm of mean infiltration volume was refitted without the tanoak site and included the random effect of site on depth. With the random effect of depth, day number ($p<0.0001$) and depth (0.0467) were significant while vegetation ($p=0.080$) and the interaction between vegetation and day number ($p=0.076$) were not significant.

One more mixed-effects model was fitted to the aggregated dataset for vegetation type. The model analyzed the infiltration volumes averaged across depth and transect per site location by taking into account day number and year. Vegetation was not significant when modeled with day number ($p=0.1762$) nor was it significant when modeled with year ($p=0.2330$).

5.4 Water Drop Penetration Time Tests

5.4.1 WDPT sites sampled each year

WDPT tests were conducted at 23 sites for a total of four years starting in 2010 (refer to Figure 4-3 in Chapter 4 for specific locations). The 2009 WDPT field data was misplaced. Therefore, 2009 data is not included in this analysis. In 2011, the 2 cm depth was not tested. Tests were conducted during the summer months and early fall but not necessarily at each site every year. The total number of observations for water drop tests is 740. Table 5-4 shows the annual number of measurements recorded at each site location. The number of measurements for any given site and year is normally the number of transect locations multiplied by the number of depths measured.

Table 5-4: Number of annual WDPT measurements recorded. Burn severity classifications are None=N, Moderate/Low=M/L, Moderate=M, High/Moderate=H/M, and High=H.

Site Number	Burn Severity	2010	2011	2012	2013
1	H	15	10	18	18
2	M	15	12	18	0
3	M	15	12	18	18
4	H	15	8	15	0
5	M	15	0	18	18
6	H	0	10	18	0
7	H	15	12	18	0
8	H	15	9	18	0
9	M	15	12	18	18
10	H	15	0	18	18
11	M	12	0	18	18
12	H	15	4	18	0
13	M	0	12	18	0
14	N	15	10	18	0
15	H	0	0	18	18
16	MH	0	0	0	0
17	MH	0	0	0	0
18	H	15	1	0	0
19	M	15	0	0	0
20	H	15	7	32	4
21	ML	12	8	18	18
22	MH	15	10	18	18
23	H	15	0	18	0

5.4.2 WDPT Data

5.4.2.1 Burn severity

Penetration times are displayed on a square root scale to help visualize any trends. The response analyzed is the continuous penetration time as opposed to a hydrophobic classification. Figure 5-28 is a fundamental display of penetration times as a function of time for each individual site. Strong trends are not visibly apparent at 1 cm depth.

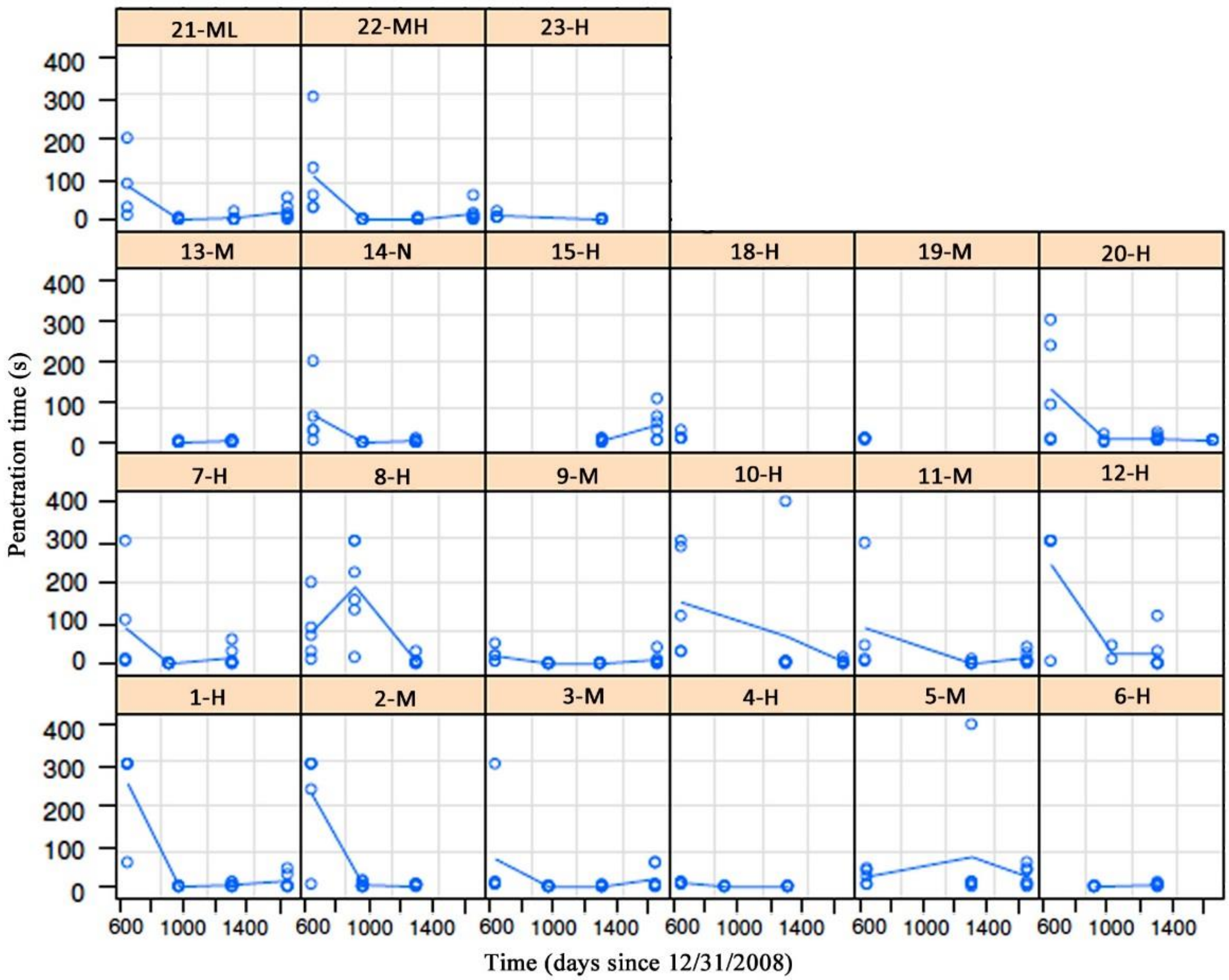


Figure 5-28: Annual water drop penetration times (s) of sites as a function of day number (since 12/31/2008) at 1 cm depth.

Figure 5-29 and Figure 5-30 are also fundamental displays of penetration times as a function of time (days) for each individual site. Figure 5-29 displays data from 2cm depth and figure 5-30 displays data from 3cm depth. Again, for both of these figures, there is no discernible trend visible.

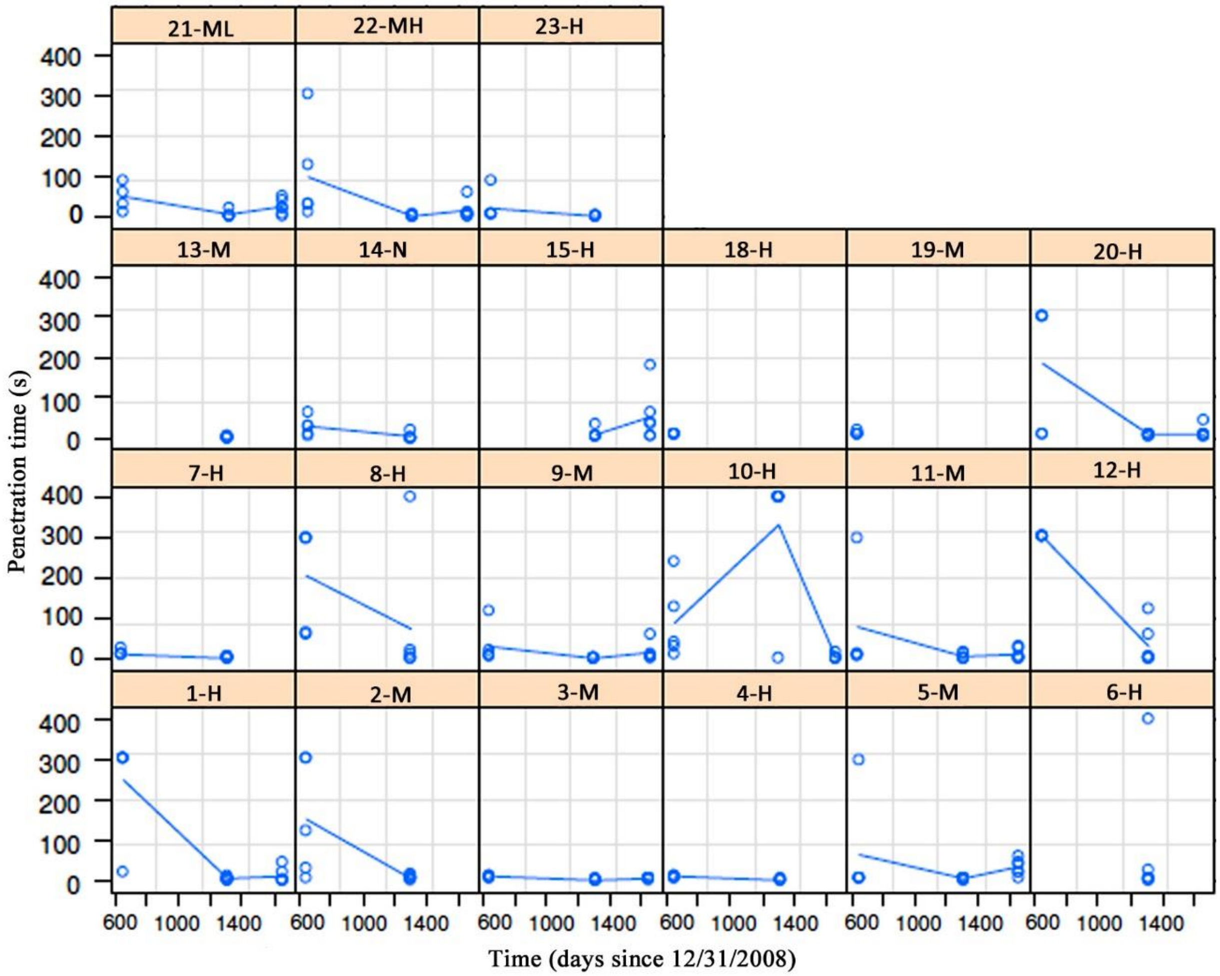


Figure 5-29: Annual water drop penetration times (s) of sites as a function of day number (since 12/31/2008) at 2 cm depth.

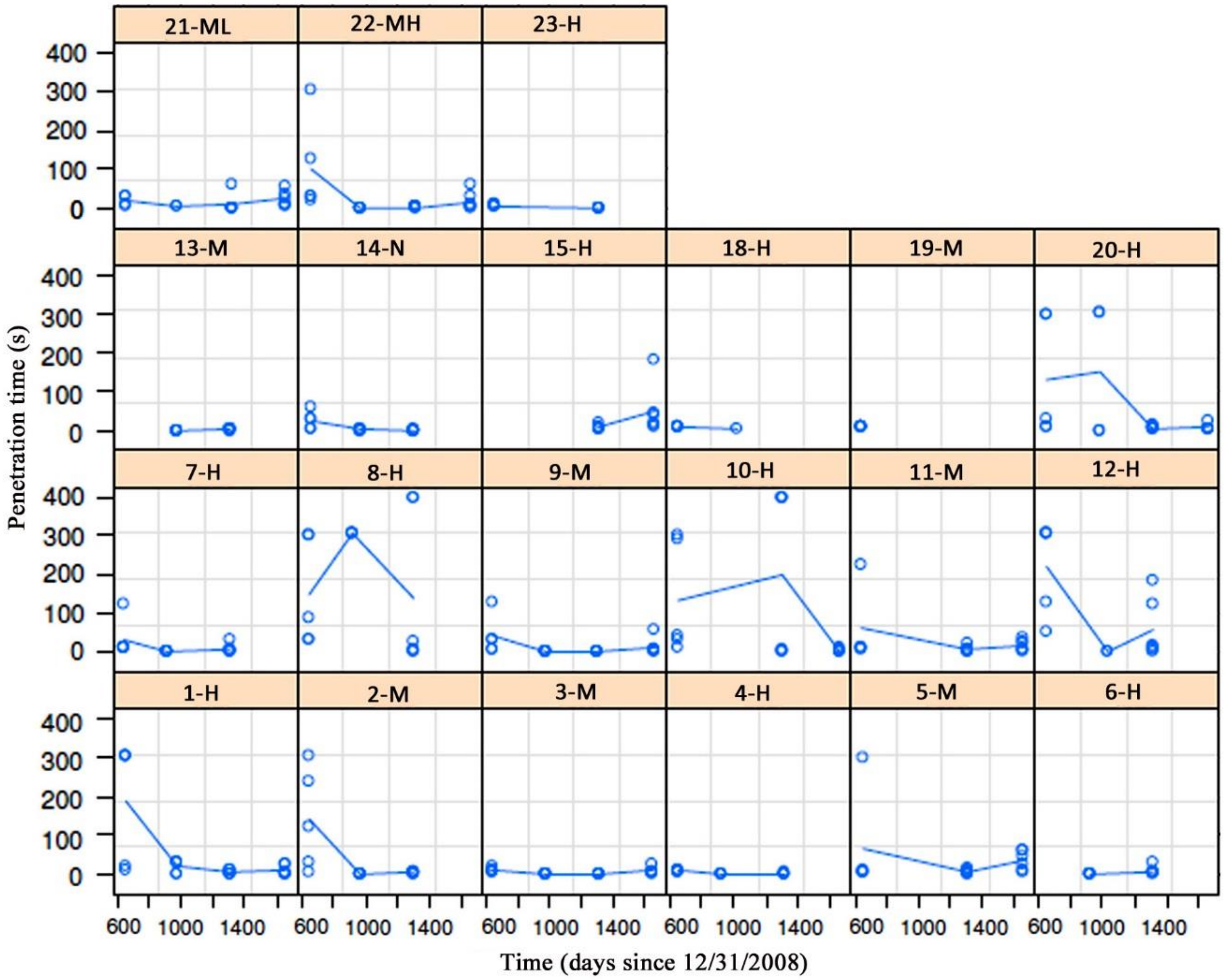


Figure 5-30: Annual water drop penetration times (s) of sites as a function of day number (since 12/31/2008) at 3 cm depth.

Figure 5-31 is displayed on a square root scale to aid the visualization of trends. There appears to be greater/higher infiltration times in 2010 for the hot simplified burn class. Penetration times seem unrelated to depth. There is only one penetration time greater than 100 seconds in the cool simplified burn class while there are many in the hot burn class.

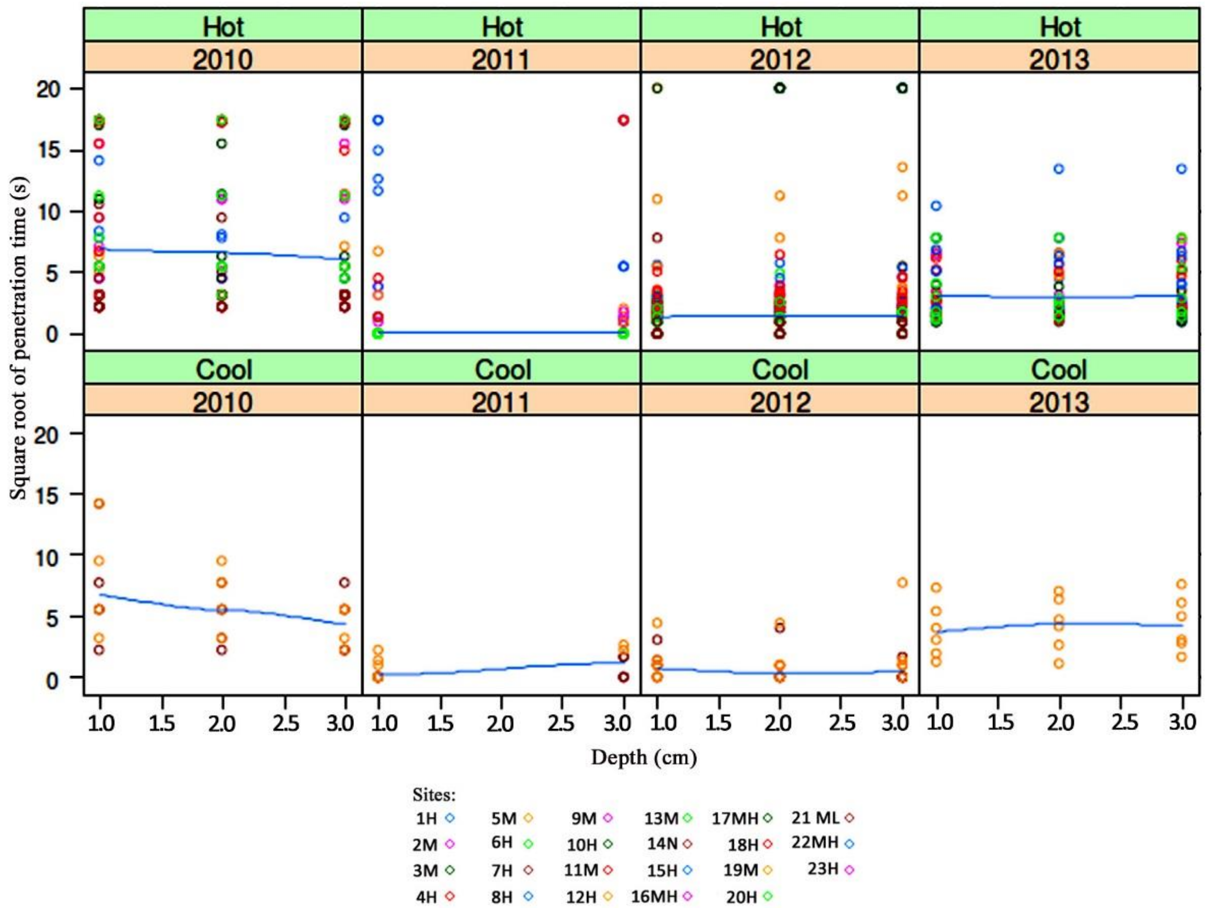


Figure 5-31: Square root of water drop penetration times (s) as a function of depth for each year and simplified burn classification. "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML. Curves are fitted by loess (degree=1, span =1)

Figure 5-32 shows penetration times in seconds as a function of year at 1, 2, and 3 cm depths for the simplified burn classes. The penetration times have been transformed using square roots to display trends. Once more greatest penetration times are shown in 2010 for both modified burn severity classes. "Hot" burns have longer penetration times regardless of depth.

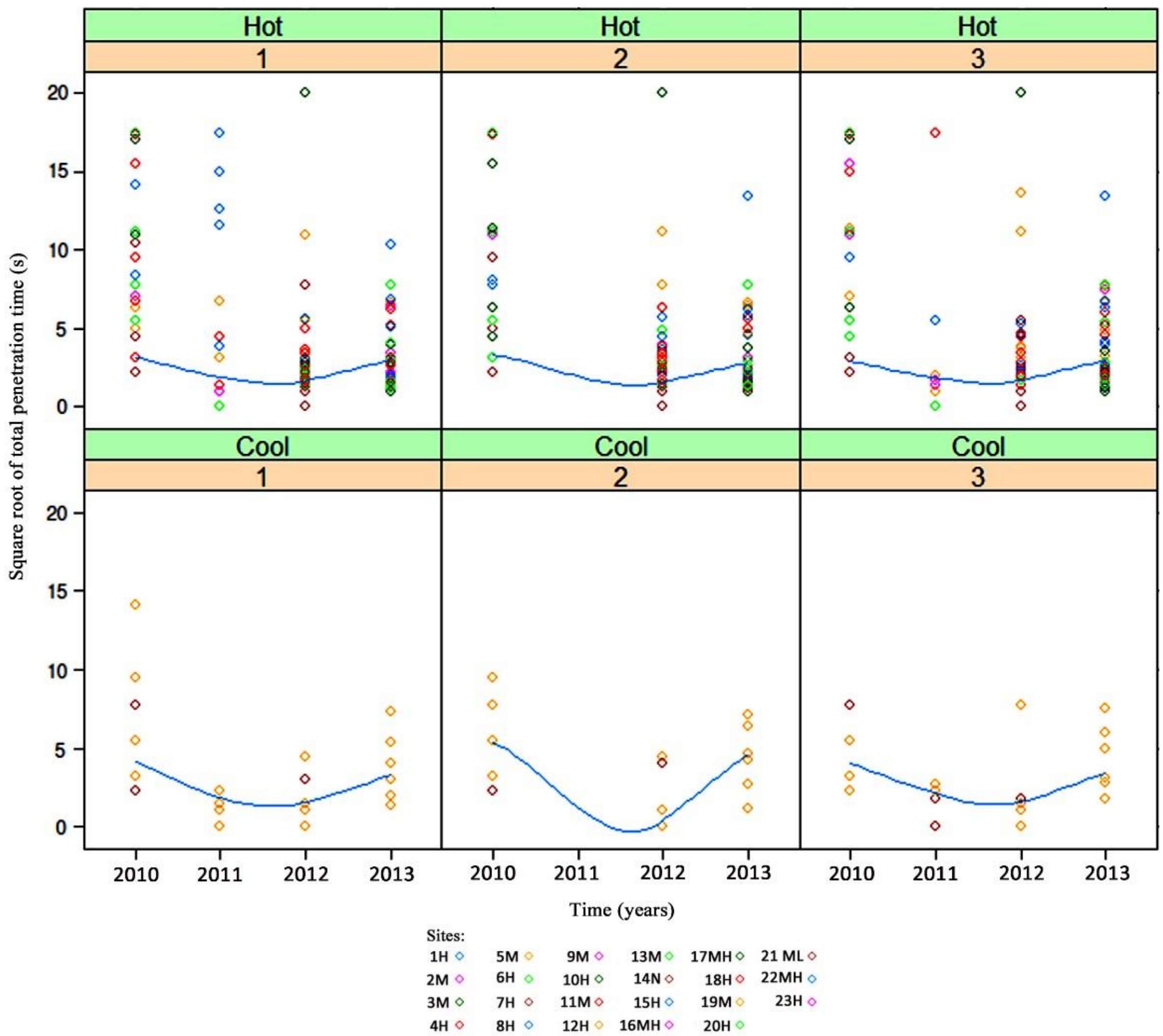


Figure 5-32: Square root of water drop penetration times (s) as a function of time (years) for each depth (cm) and simplified burn classification. For simplified burn classes, "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML. Penetration time has been transformed for this display using square roots. Curves are fitted by loess (degree=1 and span =1)

Figure 5-33 is a breakdown of penetration times for the original burn severity classification as a function of time regardless of depth. Similar trends are present at each soil burn severity classification; penetration times are lowest between the 2011 and 2012 data followed by an increase in penetration times in 2013.

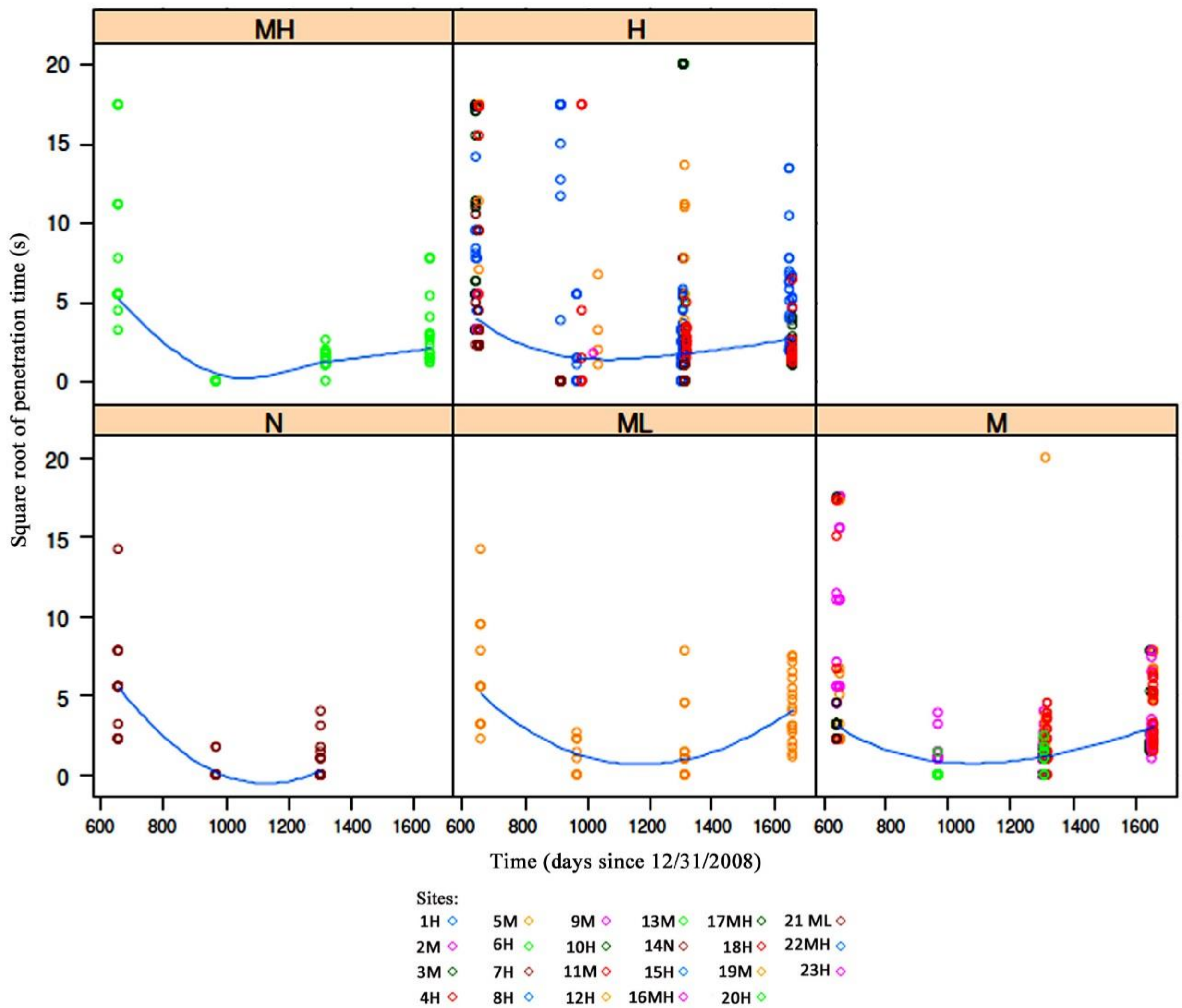


Figure 5-33: Square root of water drop penetration times (s) as a function of time (day number since 12/31/2008) for each burn severity class. . Burn severity classifications are N= None, M/L= Moderate/Low, M= Moderate, H/M= High/Moderate, and H=High. Penetration time has been transformed for this display using square roots. Curves are fitted by loess (degree=2, span =1.25)

5.4.2.2 Soil parent material

Graphical displays of penetration times by soil parent material do not differ greatly than penetration times by burn severity classification. Figure 5-34 displays trends in penetration times by burn severity classification and soil type as a function of time. Penetration times are greatest in 2010, lower in 2011 and 2012 and then increase in 2013.

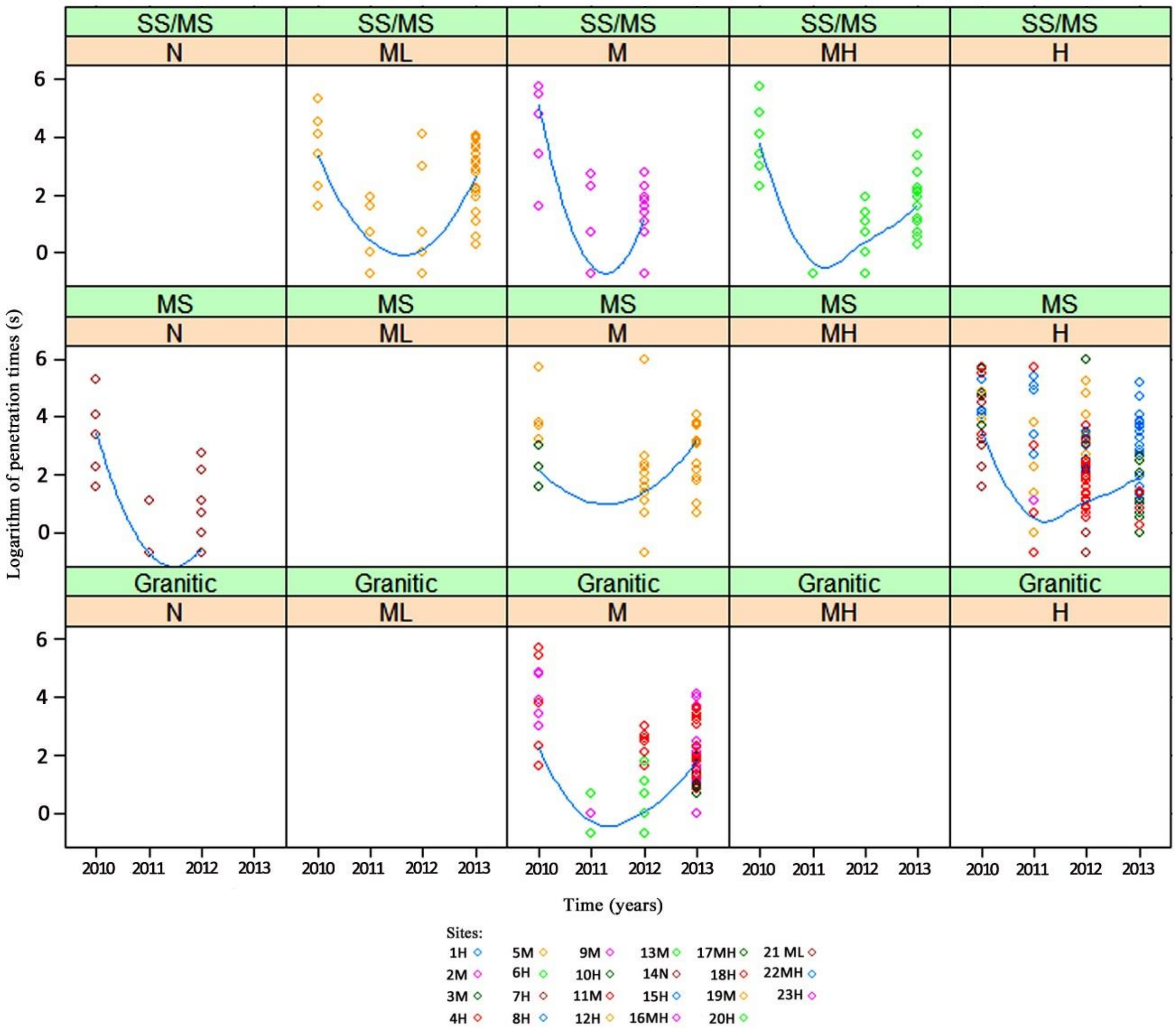


Figure 5-34: Logarithm of water drop penetration times (s) by burn severity class and soil type as a function of time (years). Burn severity classifications are N= None, M/L= Moderate/Low, M= Moderate, H/M= High/Moderate, and H=High. For soil parent material, MS= mudstone and SS/MS= sandstone/mudstone.

Figure 5-35 displays the logarithm of penetration times by soil parent material and simplified burn classification as a function of time (years). There are no sites located in the "cool" burn severity classification with a granitic parent material (bottom left) therefore that portion of the graph does not contain data. The general trend in Figure 5-35 is lowest penetration times occurring between 2011 and 2012 and then an increase in penetration times in 2013.

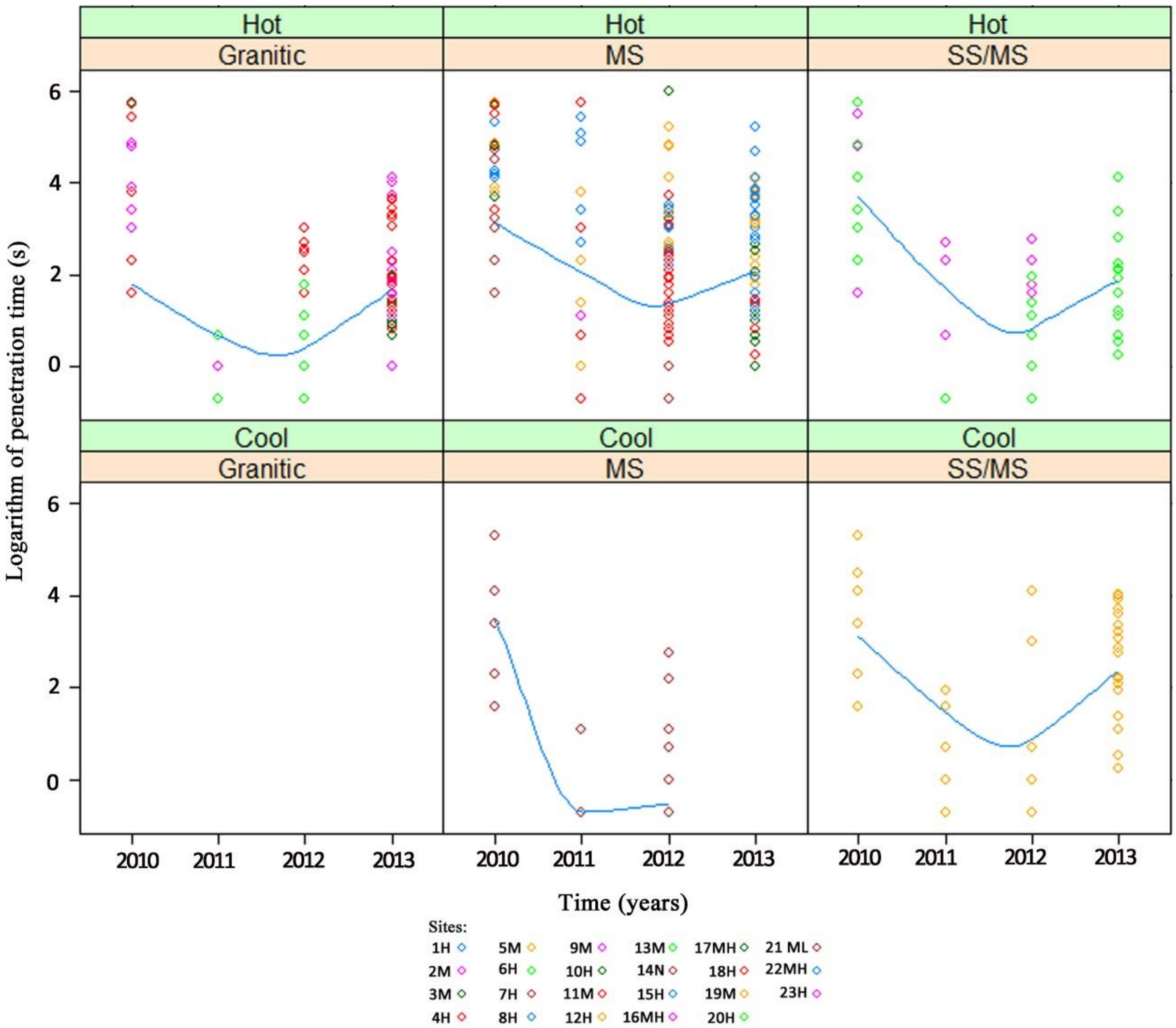


Figure 5-35: Logarithm of water drop penetration times (s) by soil parent material and simplified burn severity classification as a function of time. For soil parent material, MS= mudstone and SS/MS= sandstone/mudstone. For simplified burn classes, "Hot" incorporates burn severity classes M, MH, and H. "Cool" incorporates N and ML.

Figure 5-36 displays the logarithm of penetration times by soil parent material irrespective of soil burn severity classification and depth, as a function of time (days since 12/31/2008).

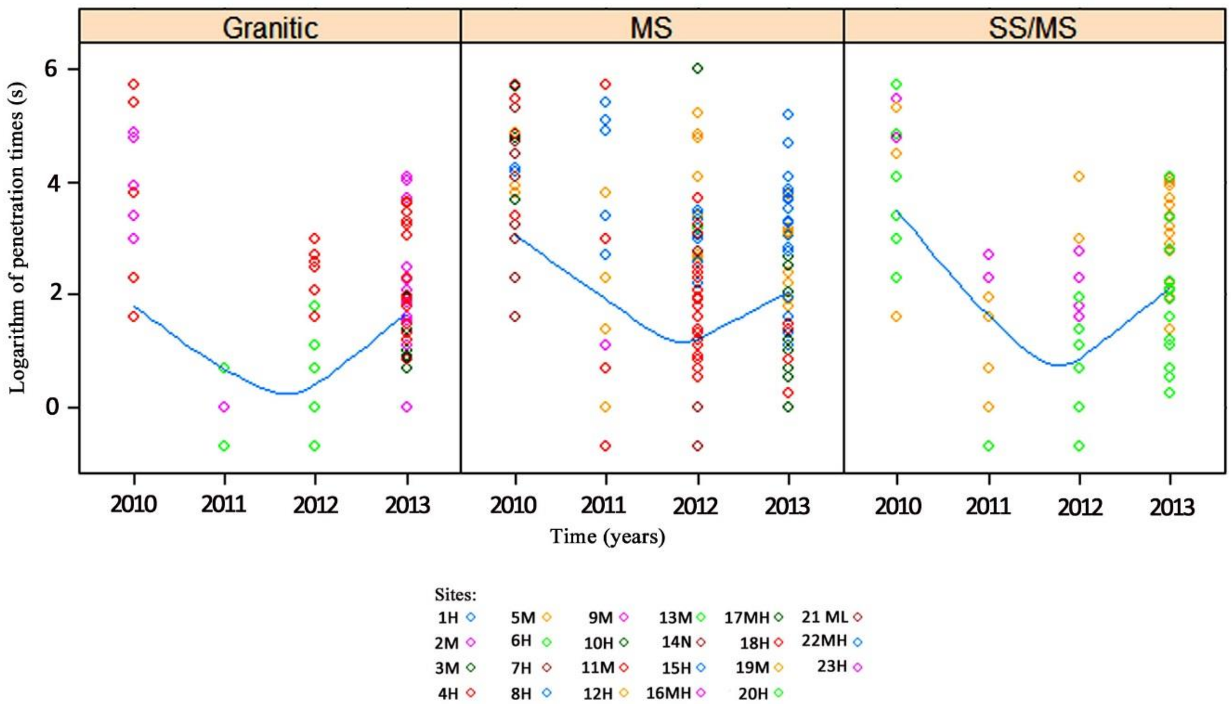


Figure 5-36: Logarithm of water drop penetration times (s) by soil type irrespective of burn severity and depth, as a function of time (days since 12/31/2008). For soil parent material, MS= mudstone and SS/MS= sandstone/mudstone.

Table 5-5 shows the mean annual water drop penetration time (seconds) by soil type. The granitic soil types have the lowest penetration times every year when compared to the other two soil parent materials.

Table 5-5: Mean annual water drop penetration time (s) by soil type.

Year	Granitic	Mudstone	Sandstone/Mudstone
2010	43.3	90.3	113.8
2011	0.4	40.2	1.6
2012	2.1	32.2	4.3
2013	13.0	22.9	18.7

5.4.2.3 Dominant vegetation type

The knobcone pine and manzanita sites appear to have greater penetration times than the redwood dominant sites (Figure 5-37). There does not appear to be a difference among the burn

severity groups of the redwood dominant sites where as there is some noticeable difference among the moderate/high and high knobcone pine/manzanita sites. In spite of that, there is an absence of the lesser severity sites to compare the higher severity penetration times with for the knobcone pine/manzanita sites. The reason being that the knobcone pine/manzanita vegetation type throughout the Little Creek Watershed, for the most part, did not undergo low or moderately low burn severity.

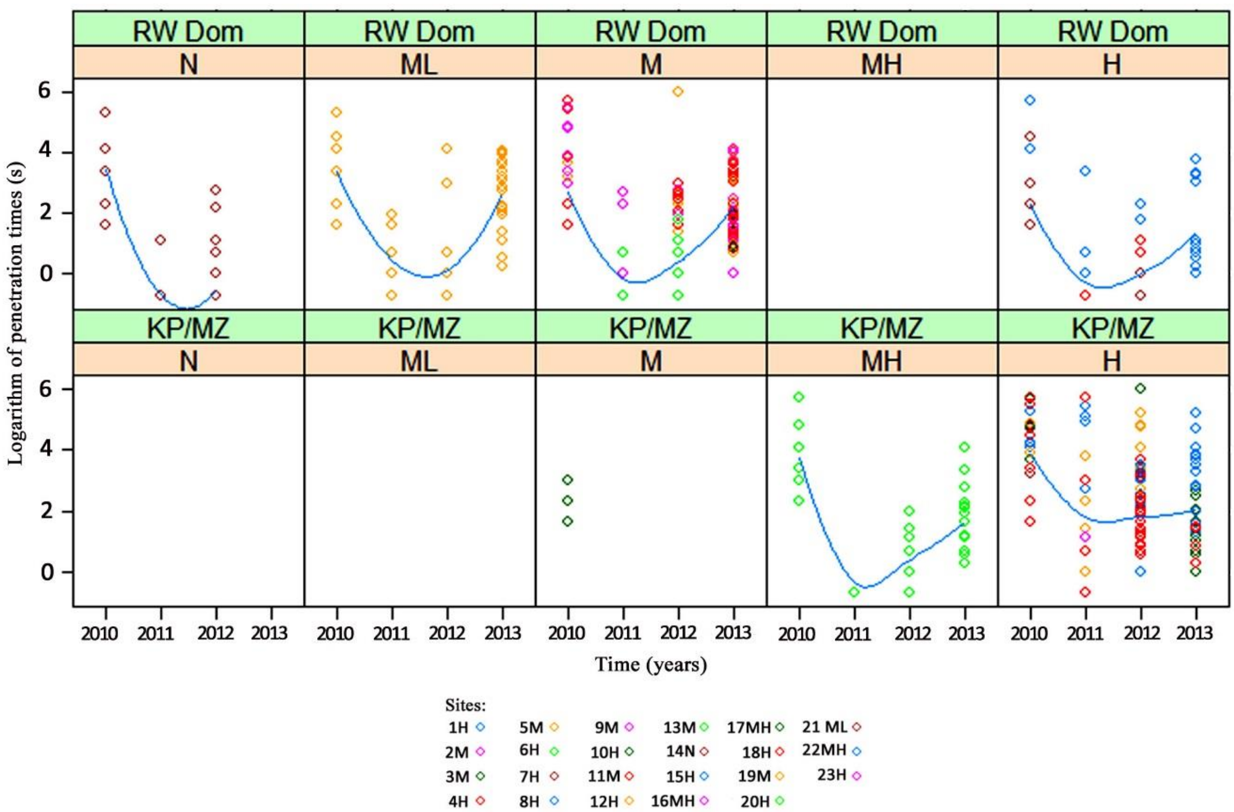


Figure 5-37: Logarithm of water drop penetration times (s) by burn severity classification and dominant vegetation type as a function of time (years). Burn severity classifications are N=None, M/L=Moderate/Low, M=Moderate, H/M=High/Moderate, and H=High. For dominant vegetation type KP/MZ= knobcone pine/ manzanita and RW= redwood dominant.

Figure 5-38 compares knobcone pine and manzanita vegetation type data to the redwood dominant vegetation type data irrespective of burn severity and depth. There are more data point with high penetration times in the knobcone pine and manzanita vegetation type, but the trends

are not indicative that one vegetation type might have a stronger influence on penetration times than the other vegetation type.

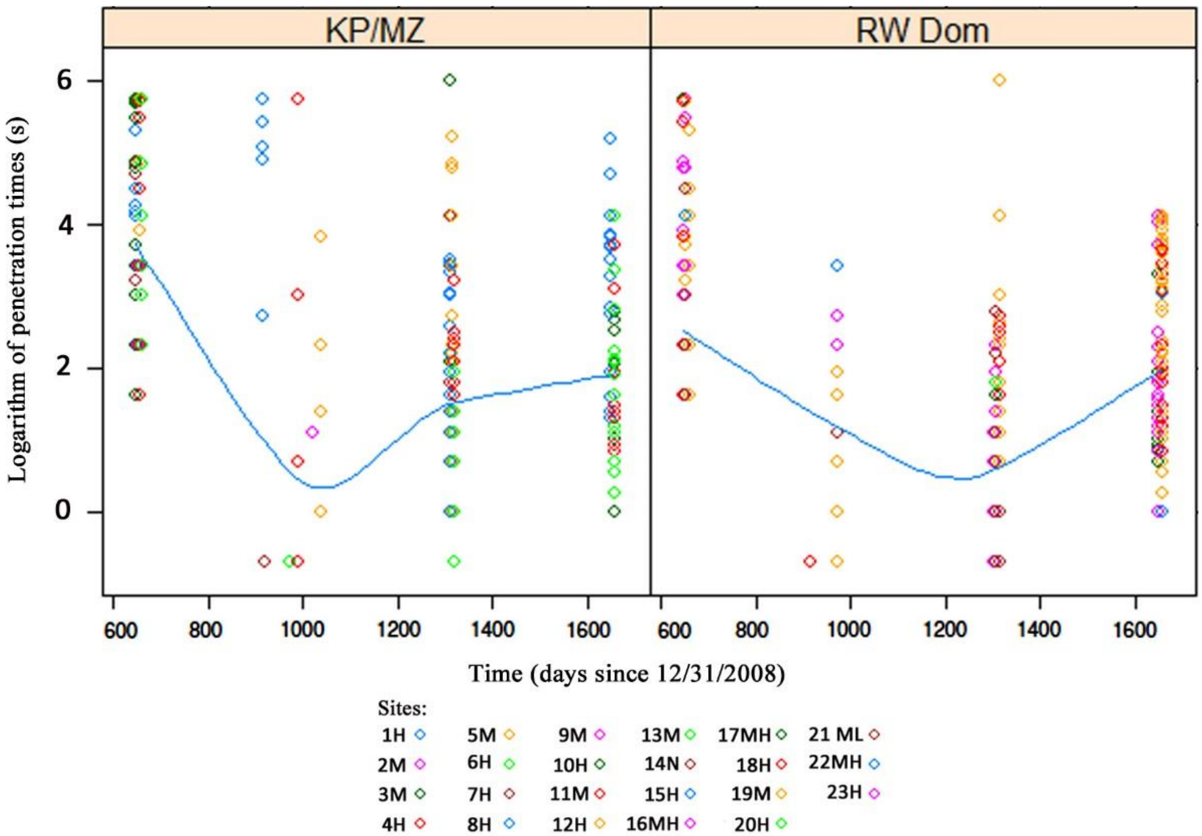


Figure 5-38: Logarithm of water drop penetration times (s) by dominant vegetation type, irrespective of burn severity classification and depth, as a function of time (days since 12/31/2008). Dominant vegetation types are KP/MZ=knobcone pine/manzanita, and RW Dom=redwood dominant.

5.4.3 Statistical results for the WDPT tests

5.4.3.1 Burn severity

The square root of penetration times was first modeled as a linear function of time However, the linear trend modeled showed that depth ($p<0.566$), burn severity ($p=0.151$) and the interaction between burn severity and day number ($p=0.104$) were not significant, Therefore, penetration

times were modeled as a quadratic function, which contains a square root transformation, because the square root transformation was better fitted to the data than the linear function. In this model, square of day number (p=0.02) was significant, depth was not significant (p<0.487), but burn severity (p=0.014) and its interactions with the linear (day number) (p=0.002) and quadratic (square root of day number) terms (p=0.002) were significant. However, the residuals distribution from this model is extremely long in the tails (Figure 5-39) rendering the significance test highly suspect.

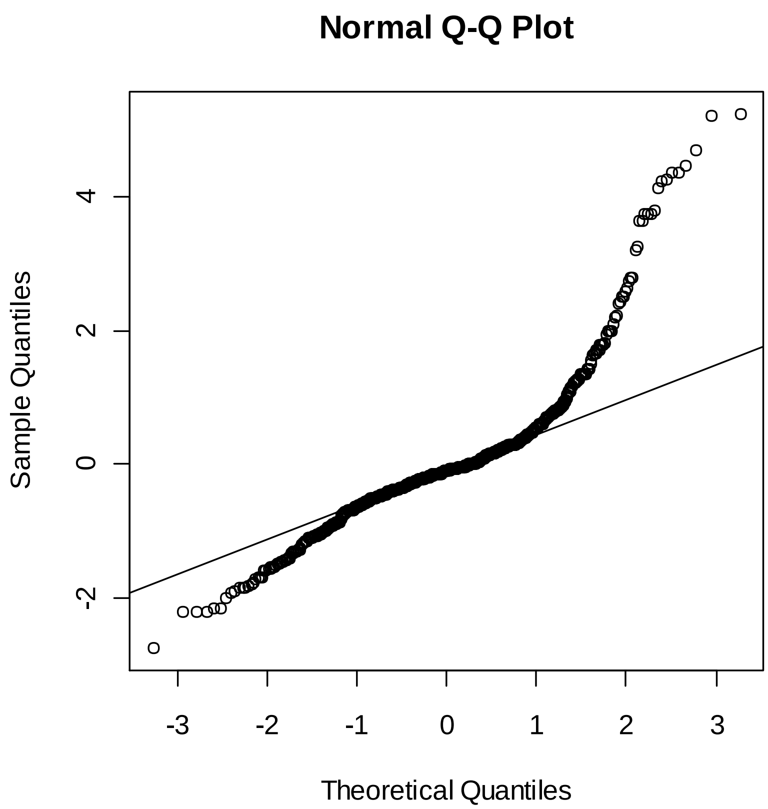


Figure 5-39: Square root transformed residual distribution for model of WDPT.

The logarithm transformation did improve the residual distribution but did not entirely normalize it. The distribution is significantly right skewed (Figure 5-40). In the model with the log-transformed response, the quadratic term (square of day number) appeared to be highly

significant ($p<0.0001$), but burn severity ($p=0.185$) and the interaction between burn severity and day number ($p=0.144$) were not significant. The interaction between burn severity and the square of day number could not be tested, as singularities arose in solving the model. However it is the interaction between burn severity and the linear term (day number) that is probably of greater interest as this is the term that would best explain differences in rate of recovery after burning. The model whose residuals are depicted in Figure 5-40 explains 63% of the variation in the logarithm of WDPT.

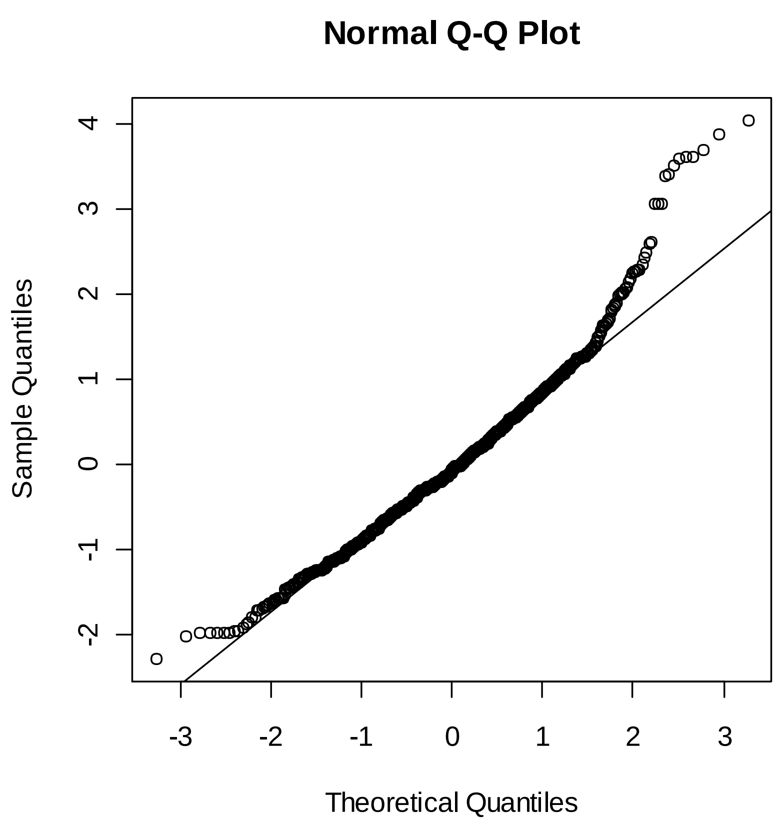


Figure 5-40: Logarithmic transformed residual distribution for model of WDPT.

5.4.3.2 Soil parent material

The aforementioned quadratic trend mixed-effects model for the logarithm of water drop penetration times (Figure 5-40) was altered to include soil parent material and the interaction between soil parent material and day number, and the interaction between soil parent material and square of day number. The random effect of site on depth was dropped in order for the model to work. In this model, all fixed effects, soil parent material and the interactions between soil parent material and day number, and soil parent material and square of day number, were highly significant ($p < 0.0001$), thereby implying that the temporal pattern of penetration times varies by soil parent material. Yet, the significance may be overestimated as a result of omitting the random effect of site number on depth.

Since results from the quadratic trend model were suspect, a new aggregated dataset was generated that contained penetration times averaged across depth and transects thus providing one observation per site per year. A simpler mixed-effects model was fitted to the aggregated dataset that tested soil parent material and time in years. Neither soil parent material nor time were found to be significant predictors of penetration times.

5.4.3.3 Dominant vegetation type

Dominant vegetation type and the interaction between vegetation type and day number (days since 12/31/2008), and the interaction between dominant vegetation type and square of day number were added to the model. In order for the model to function, the random effect of depth had to be dropped from the model. All fixed effects were significant ($p<0.001$) after having dropped the random effect of depth. However, once again the significance may be overestimated as a result of dropping depth and other random effects from the model.

Since depth provided computation issues, a new mixed-effects model was fitted to the aggregated dataset which contained one observation per site, per year. In this model, dominant vegetation type was not significant and the interactions between vegetation type and day number, and between vegetation type and square of day number, could not be tested because singularities arose in fitting the model. As a result, one more model was fitted using time as the categorical variable year, but again, vegetation type was not significant as singularities arose when testing the interaction between vegetation type and year.

CHAPTER 6 : DISCUSSION

Low infiltration rates immediately following a fire have been attributed to fire-induced hydrophobicity, soil sealing, and surface compaction via rainfall impact on bare soils (DeBano, 2000a; Robichaud, 2000; Doerr *et al.*; Pierson *et al.*, 2001; Ice *et al.*, 2004; Assouline, 2004). Within a year following a burn, infiltration rates typically begin to increase as a result of regrowth, restored duff layer, breakdown of a hydrophobic layer, and/or the wetting of a hydrophobic layer (Robichaud, 2000; Larsen *et al.*2009; MacDonald and Huffman, 2004; Onda *et al*., 2008). Similar response to soil hydrologic processes was presumed to occur within the Scotts Creek watershed following the 2009 Lockheed Fire. Rainfall simulations, Mini-disk Infiltrometers (MDI) and water drop penetration time tests (WDPT) were the three methods employed to measure infiltration annually from 2009 to 2013. While it was suspected that the Lockheed Fire would have an influence on infiltration, only MDI tests detected a statistically-significant difference in average infiltration volumes over the five-year period as a result of the fire. Statistical analysis conducted on the rainfall simulation dataset showed that there was a statistically-significant difference in the rate of change in infiltration rates and near-surface runoff over the five-year period, but the change over time was not influenced by the Lockheed Fire. As well, the statistical analysis conducted on the WDPT dataset showed that there was a statistically-significant difference in the rate of change in penetration times over the five-year period, but the change over time can not be attributed to the Lockheed Fire.

Results regarding temporal trends, burn severity, soil parent material, and dominant vegetation type for the rainfall simulations, MDI and WDPT tests will be discussed in this

section. Observations made during experimentation are presented in order to offer further explanation of the data and statistical results. Lastly, limitations and recommendations for future experimentation. of the three tests are addressed.

6.1 Rainfall simulations

6.1.1 Scotts Creek watershed rainfall simulations

6.1.1.1 Temporal trends

Thirteen rainfall simulation sites were distributed throughout the Scotts Creek watershed. In an attempt to account for the variability associated with a fire of this magnitude and the natural variability of the landscape, rainfall simulation sites were represented by variations in burn severity and dominant vegetation type. Trends were present in the graphical displays showing that infiltration rates and hydrologic responses changed over time regardless of burn severity classification or vegetation type. This suggests that neither burn severity nor vegetation type strongly influenced the response variables over the five-year testing period.

6.1.1.2 Burn severity trends

There is a discernible increasing trend in infiltration rates and a discernible decreasing trend in hydrologic responses (ratio of runoff (L) to rainfall (L)) at all rainfall simulation sites, including the unburned sites, over the five-year testing period. Four of the five unburned sites displayed similar trends, with regards to infiltration rates and hydrologic responses, as the low and moderate burn severity sites. However, Site 11, mirrored the infiltration rates and the

hydrologic responses of high severity burned sites. This result was unexpected, but is not necessarily uncommon because chaparral vegetation is a plant community often associated with natural soil water repellency due to the leaching of hydrophobic compounds from organic surface matter (Doerr *et al*., 2000). WDPT tests on two sagebrush sites found strongly repellent soils in unburned conditions compared to sites that were severely burned because burning had decreased the strength of soil water repellency by breaking down the repellent layer as opposed to strengthening it (Pierson *et al*., 2008). Therefore, it is not abnormal for an unburned site located in a chaparral community to produce high near-surface runoff and retain a low infiltration rate.

Additionally, the lack of a thick litter/duff layer could explain the high near-surface runoff at Site 11 in 2009. The upper portion of the Scotts Creek watershed is referred to as the "chalks" because of the widespread off-white soil at the Scotts Creek/Mill Creek ridgeline. This area exhibits low vegetated density when compared to the Little Creek ridgelines, thus the accumulation of duff is slow. While two of the unburned sagebrush sites studied by Pierson *et al*. (2008) reported unburned sites with high runoff due to natural hydrophobicity but additional unburned sagebrush sites with 100% surface cover had high infiltration rates as a result of the water being stored in the ground litter regardless of the soil being strongly hydrophobic beneath the litter layer. While site 11 was suspected to be naturally hydrophobic, the lack of duff may have contributed to high near-surface runoff rates as well.

6.1.1.3 Statistical analysis- Burn severity

The effects of time, burn severity and the interaction between burn severity and time on infiltration rates and hydrologic responses were analyzed using mixed-effects modeling. Time was a highly-significant predictor for infiltration rates and the hydrologic response indicating that there was a statistically-significant difference in the average infiltration rate and hydrologic response among years. This is reasonable given that the unburned sites contained similar time trends as the burned sites. Burn severity was not a statistically-significant predictor for infiltration rates or hydrologic responses. This implies that burned sites are no different than unburned sites in regards to infiltration rates and hydrologic responses thus suggesting no fire effect. Similarly, the interaction between burn severity and time is not a significant predictor implying that the statistically-significant change in infiltration rates and hydrologic response among years cannot be attributed to the fire.

6.1.1.4 Statistical Analysis- Dichotomous burn contrasts

Burn severity is the variable utilized in the model as an indicator of a fire effect. However, there was some difficulty distinguishing between degrees of burn severity because ground observations suggested that the fire did not burn the landscape homogenously. Instead, the fire appeared to burn the landscape in a mosaic fashion. Hence, the two burn dichotomies were generated in order to test a maximum fire effect and any fire effect.

When considering the two dichotomous burn contrasts, “Hot burn versus all others” and “Unburned versus all others,” time is a highly-significant predictor for both infiltration rates and hydrologic responses. The indicators that would illuminate any fire effect, burn severity and the

interaction between burn severity and time were not significant except for one instance. Burn severity was slightly significant ($p= 0.023$) in predicting the hydrologic response. In this particular model, burn severity was classified as “Hot versus all others” which means that data from high severity burn sites was compared to no burn, low and moderate burn sites. Although burn severity is slightly significant, there are naturally-occurring soil physical characteristics at the high-burn severity sites that aid in understanding why the hydrologic response was statistically-significant.

All of the high-burn severity sites are located on the ridgelines where the soil depth to bedrock is very shallow, rocks are largely present on the soil surface and duff/leaf litter is scarce. Ridgelines of this watershed are noted for having a chaparral vegetation type (knobcone pine and manzanita) and naturally-occurring hydrophobic soils were suspected during experimentation for instance at site 11-Scott/Mill which is an unburned site. Site 11 as an unburned site is an outlier and will be addressed later in the discussion. Moving downward into the watershed, soils became more developed; the soil depth to bedrock can be significantly deeper, and duff and litter was widespread and thicker. Thus when considering near-surface runoff, the ridgeline sites generated more near-surface runoff than sites lower in the watershed likely due to the difference in water holding capabilities of the litter/duff layer. Rainfall simulation field notes indicated that the litter/duff layers were moist and retained the simulated rainfall where a litter/duff layer was present. The absence of a thick, contiguous litter/duff layer explains why there was more near-surface runoff at the high severity burned sites. Therefore, although burn severity is a slightly-significant predictor in the dichotomous burn classification model, naturally-occurring physical characteristics of the landscape such as mineral soil depth, vegetation type, and elevation within the watershed provide an alternate reason as to why the hydrologic response (near-surface

runoff) was significantly different on high severity sites versus all other sites. By chance, all high severity sites are located on the ridgelines where many of these physical characters are likely similar at all sites.

6.1.1.5 Statistical Analysis-The outlier

As previously mentioned, site 11-Scott/Mill unburned, showed similar temporal trends as the high burn severity sites regarding infiltration rates and hydrologic responses. Field notes indicated that natural soil water repellency was suspected after screeding away the upper 2.5 centimeters of soil; it was common to find that the soil matrix was mostly dry below with some evidence of preferential pathways by which water would infiltrate deeper within the profile. Over 50% of the plot was dry below the top 2.5 centimeters. The remaining unburned sites did not have as pronounced of an increase in infiltration and decrease in the hydrologic response as Site 11 from 2009 to 2010. Hence, the 2009 Site 11 observation is an outlier[21]. Removing Site 11 from the analysis does not change the findings for infiltration rate. On the other hand, burn severity and the interaction between burn severity and time become significant predictors for the hydrologic response. Yet removing Site 11 is not justifiable and provides a less robust dataset.

6.1.1.6 Statistical Analysis-Vegetation type

Vegetation type is one attribute that was suspected to have a significant influence on post-fire hydrologic processes, however, this analysis showed that there was not a statistically-significant

[21] Outlier denotes an observation that does not fit into a postulated model that has a specific set of implicit or explicit assumptions, or has some other ‘surprising’ characteristics. Thus, what may be considered an outlier in one model may not be considered an outlier in another model.

difference in infiltration rates or hydrologic responses based upon dominant vegetation type. Yet, Figures 5-5 and 5-6 show stronger trends for the knobcone pine/manzanita vegetation type. The trends in Figures 5-5 and 5-6 are similar to the trends for infiltration and runoff based upon burn severity classification at high severity sites because knobcone pine and manzanita are the dominant chaparral vegetation that occupies the ridgelines. While the trend exists, the absence of significant findings may be attributed to the fact that data is missing from 2009 at two ridgeline sites, Sites 15 and 13. Soils are highly vulnerable immediately following a burn in chaparral therefore the lack of 2009 data may have limited the ability to show a more significant fire-induced effect (DeBano *et al*., 1979).

6.1.2 Little Creek watershed rainfall simulations

The separate analysis performed on six Little Creek rainfall simulation sites was conducted to eliminate the upper Scotts Creek sites that exhibit naturally-occurring soil water repellency. The six Little Creek sites represent variations in soil burn severity and percent slope as well as a range vegetation types.

6.1.2.1 Temporal trends and statistical analyses

Trends were present at all sites within the Little Creek watershed regarding infiltration rates and hydrologic responses when displayed by burn severity classification, vegetation type and slope as a function of time. However, only sequential[22] p-values indicated that time was a significant predictor of infiltration rates and hydrologic responses when modeled with the effect of burn severity, dominant vegetation type, and percent slope, and the interactions between burn severity

[22] The sequential p-value indicates the significance of each term as it is added to the model sequentially.

and time, vegetation type and time, and percent slope and time. This suggests there is a statistically-significant difference in the average infiltration rate and hydrologic response among years.

While time was a significant predictor, burn severity and the interaction between burn severity and time were not statistically-significant predictors of infiltration rates and hydrologic responses suggesting there is no detectable fire-induced changes to the hydrologic process within the Little Creek watershed. Statistical analysis showed that vegetation type is not a statistically-significant predictor of infiltration rates or hydrologic responses indicating there is no difference in the hydrologic processes among vegetation types. The lack of statistically-significant findings may be attributed to gaps within the dataset; 2009 observations for sites 14 and 13, 2011 observation for site 14, and 2013 observations for sites 4, 14 and 13.

The effect of percent slope on infiltration rates was statistically-significant suggesting that higher infiltration rates occurred at lower percent slopes over the course of the study. However, percent slope was not a statistically-significant predictor of hydrologic responses over the course of the study. Slope steepness is positively correlated to near-surface runoff, thus, as slope steepness decreases, incoming rainwater has more opportunity to infiltrate deeper into the soil matrix.

6.2 Mini-disk Infiltrometer and water drop penetration time tests

6.2.1 Temporal Trends

Twenty-three MDI and WDPT sites were distributed throughout the Little Creek watershed. These sites represent variations in soil burn severities, vegetation and soil types. Mini-disk Infiltrometers measured the volume of water (mL) that infiltrated over a period of 30 seconds while water drop tests measured the total amount of time (in seconds) for applied water droplets to infiltrate into the soil. Temporal trends are present in the MDI dataset when considering burn severity, soil parent material and vegetation type. However, temporal trends are similar regardless of burn severity, soil parent material, or vegetation type. Similar results were observed for the water drop tests; there are not dramatic differences in the dataset, suggesting one variable does not have a stronger influence on the hydrologic processes than others in the grouping. While trends suggest there is no difference among burn severity, soil parent material, or vegetation type, a fire effect within the Little Creek watershed is dependent on the statistical significance of burn severity and the interaction between burn severity and time.

6.2.2 Statistical analysis

MDI tests showed that there was a statistically-significant difference in infiltration volumes between the burned and unburned sites, thereby supporting a fire effect on the hydrologic response of soils within the Little Creek watershed. Conversely, the WDPT tests showed that there is no significant difference in penetration times between burned and unburned sites even though these WDPT tests were conducted alongside the infiltrometer tests.

The difference in findings between the MDI and WDPT tests could be attributed to a variety of reasons. First, and perhaps most importantly, 2009 WDPT data is missing from the analysis because of a clerical error. Although there is debate on the strength and persistence of fire-induced hydrophobicity, experiments carried out in upper Michigan and coniferous forests in Montana found water repellency had disappeared within 1 year after burning (Reeder and Jurgensen, 1979; DeByle, 1973.) Thus, not having the 2009 WDPT data may have limited our ability to detect a significant change in post-fire infiltration.

Additionally, there was less consistency in the data collection for the WDPT tests. The methodology specified that there be 3 replications at 1, 2, and 3 cm depths at five positions along a transect. However, that did not necessarily get carried out at every site. In 2011, the 2 cm depth was not tested for unknown reasons. The absence of the 2009 data combined with the varied number of replications at each depth for the WDPT tests may be a contributing factor to explain why this test did not show a fire-induced effect.

Although the MDI showed significant changes in the soil hydrologic response, there was only 1 unburned site out of 23 sites total to compare with the burned sites. Furthermore, data not was collected from the unburned site in 2013 because of safety concerns with a wasp nest at the site. Had this non-burn site been tested, there is potential that this data could have bolstered the WDPT dataset and potentially contributed to a significant finding between the burn and unburned sites.

6.3 Limitations

There are overlapping limitations associated with the rainfall simulations, Mini-disk Infiltrometer, and water drop penetration time tests, therefore, each test is discussed in one section with the goal of explaining the varied results among the three tests.

6.3.1 Small sample size and unbalanced datasets

A couple of reasons noted for lacking a statistically-significant effect is having a small sample size or not having enough replications (Crawley, 2005). While there are thirteen rainfall simulation sites, simulations were not performed at every site each year. The reasons being that some sites were not established in 2009, time constraints, and accessibility as a result of the amount of regrowth. Two rainfall simulation sites in particular, site 15-Mill/Boyer burned and site 12-Lion’s Flat, were not established in 2009, but are located in a high burn severity region on the ridgelines. Collecting data from rainfall simulation sites in 2009 could have provided data similar to that of other high severity sites, Likewise, MDI and WDPT tests were not consistently conducted throughout the course of the study. Furthermore, there is only one unburned site to make comparisons to and that site was not tested in 2013. If MDI and WDPT data had been collected from the only unburned site, and had there been consistency in collecting data from all sites, there is a chance that the statistical analysis would have be strengthened and improved our understanding of a fire effect.

Additionally, thirteen rainfall simulation sites for this study may not have been a sufficient amount of sites to investigate a fire effect in a topographically- and geologically-diverse watershed such as the Scott Creek watershed. Visually pre and post-fire, the Scotts and

Mill ridgelines exhibited different characteristics than the Little Creek ridgelines. As previously mentioned, the Scotts/Mill ridgelines are referred to as the “chalks” because of the amount of visible ground surface which happens to be off-white. Pre-fire vegetation was present on the Scott/Mill ridgeline, but scattered such that the ground surface was prevalent when viewed aerially. Based upon post-fire observations, the amount of regrowth and plant diversity on the Scotts/Mill ridgelines does not compare to that of the Little Creek watershed. Within the five years following the burn, ridgelines in the Little Creek watershed contain an abundance of vegetation making it difficult to see the ground surface. As a result of such differences among the project sites, the Little Creek sites were partitioned from the rest of the Scotts Creek sites and analyzed separately because of the chance that sites within a smaller subwatershed would contain less variability than the sites located in the upper portion of the Scotts Creek watershed. However, the supplementary sample contained only six sites. Benavides-Solario and MacDonald (2001) reported finding from a total of 26 simulation plots[23] distributed among three different fires and Pierson *et al*. reported findings from over 50 simulation plots dispersed over three different locations.

Computational issues arose during the analysis as a result of having unbalanced the datasets regarding burn severity, soil parent material, and vegetation type. Having an unbalanced dataset resulted in combining sites into simplified burn classification and dominant vegetation types. Thus, it is important to represent all variables equally during experimentation.

[23] This experiment had 11 high severity, 4 moderate severity, and 8 low severity or unburned sites.

6.3.2 Spatial and procedural variability

Permanent plots for rainfall simulations and permanent transects for MDI and WDPT testing were not established during the setup of this project. In order for flow paths to be observed and to observe the presence of water repellent layers, rainfall simulation plots were disturbed following the simulation. Likewise, MDI and WDPT transects were disturbed at the soil surface as part of testing. Due to the disturbance factor and the amount of regrowth, preserving rainfall simulation plots and transects to be sampled in subsequent years was not manageable. As a result, detecting the change over the five-year period at the initial plot and transect locations was missed.

Yet, creating a new plot for rainfall simulations or setting out new transects for MDI and WDPT tests at every site each year may have helped account for the naturally-occurring variability of the landscape within sites. The spatial variability of soil water repellency is high following forest fires and may vary at a 10 centimeter scale (Lewis *et al*., 2006). Moderately-burned areas are typically a mosaic of burn severities, thus have a mixture of strong and weak water repellency (Robichaud and Hungerford, 2000; Robichaud *et al*., 2008). Water drop tests in the Little Creek watershed confirmed that soil water repellency was highly variable during field tests. One drop would be placed on the soil and completely infiltrate while another adjacently placed drop never infiltrated. For that reason, it was beneficial to establish new simulation plots and new MDI and WDPT transects annually in order to account for landscape variability.

However, without having established permanent plots, there is room for error when constructing a new plot for rainfall simulations. Constructing a new plot is not an easy feat particularly in rocky soils like that of the ridgelines. If the plot is not constructed correctly, there is an increased chance for error during data collection. For instance, a bad seal between the

trough and soil can result in near-surface runoff leakage underneath the trough. Leaks became apparent after the simulation was complete, never during. Breaking down the equipment and removing the trough was the only way to be certain of a leak. If leaks were detected, that site was tested again. If the trough was installed flat instead of with the slope of the ground surface, near-surface runoff collected in the trough and did not exit thus providing an inaccurate runoff value. Aside from the trough, setting up the border provided difficulties in rocky soil or in thick duff layers which made it challenging to vertically insert the border at a mineral soil depth of 6-8 centimeters. If the border is not inserted to the correct depth, there is a chance that exterior water could enter the plot and generate false results. Establishing a permanent plot would have minimized installation errors and would have allowed for documenting the change over time on that particular plot of land as opposed to comparing different plots from the same site to one another from year to year.

The MDI procedures suggests that spatial variability is accounted for during testing. This requires that the three replicate tests be conducted immediately adjacent to one another without being on top of, or beneath, a previous test in order to compensate for measurement variability (Robichaud et al, 2008). However, performing tests in this manner was not easily accomplished considering the nature of the sloped, rocky soils. For example, when scraping the soil aside to reach either 1 or 3 centimeters, rocks were exposed and in the test location. The Mini-disk Infiltrometer is meant to be placed flush and level with the mineral soil surface not on top of rocks and if the rock is removed, a large macropore or hole is created. Furthermore, rocks prohibited unbiased testing because testing had to shift away from the transect in order to find a rock-free zone.

A highly-sloped landscape was found to be problematic for conducting the MDI and WDPT tests. The Mini-disk Infiltrometer must be placed upright to function properly (Robichaud et al., 2008). The instructions provide additional directions for conducting MDI and WDPT test on slopes greater than 50 percent which are to cut a level shelf as close as possible to the desired depth. However, depth is not uniform across the benched surface because the depth is deeper at the hinge versus the toe of the bench. This discrepancy combined with rocky soils generated questions of the accuracy and representativeness of the data from this test.

Lastly, although the goal in conducting each of these three tests is to limit the variability and error by conducting each test the same way every time, the spatial and temporal variation along with the various field technicians made consistency one of the most significant challenges in carrying out each test from one year to the next.

6.4 Recommendations

These recommendations are made with the intent of aiding future researchers whose goal is to study post-fire effects on soil hydrologic processes using rainfall simulations, Mini-disk Infiltrometers and/or water drop penetration time tests. In the event that researchers face time or financial constraints during the field season, these recommendations may be of use to ensure that field sampling consistency is achieved.

One recommendation is to equally represent test variables and classifications within test variables to avoid computational errors from arising as a result of having an unbalanced dataset. For instance when analyzing the effects of burn severity (none, low, moderate and high) and vegetation types (redwood and tanoak), there should be similar numbers of unburned, low,

moderate, and high severity sites with redwood and tanoak vegetation types equally represented among each burn severity classifications.

Next, for a long-term field study, such as this one, it is key to maintain consistency during data collection from year to year. In the case of this project, time and staff constraints occasionally inhibited testing. Therefore, it will likely be more efficient and effective to conduct post-fire research on a more localized subwatershed scale.

As well, natural and fire-induced variability associated with an entire watershed is high. Therefore, in order to account for time and staffing constraints as well as natural variability of the landscape, it is recommended that sites be concentrated within a subwatershed as opposed to being distributed throughout an entire watershed. When testing at a smaller scale, multiple replications should be conducted at a site each year in order to account for microsite variability and limit the influence of any outliers. Lastly, a permanent plot or transect is recommended as well to observe how that plot or transect changed over time. Concentrating the sampling to a localized area and conducting multiple replications will allow for better comparisons to be made among sites. If resources permit, expanding beyond a subwatershed level to collect data from other burned regions is recommended as long as those regions are adequately sampled. These recommendations should aid in minimizing confounding factors that may lead to inconclusive findings.

CHAPTER 7 : CONCLUSION

Rainfall simulations, Mini-disk Infiltrometer and water drop penetration time tests were employed to test whether there was a fire-induced effect on the hydrologic processes namely infiltration and runoff, following the 2009 Lockheed Fire. Rainfall simulations and water drop penetration time tests detected a significant change in infiltration rates, the hydrologic response and penetration times over time, however, simulations and water drop tests did not detect a significant difference in the rate of change between burned versus unburned sites. Alternatively, significant changes between the burned and unburned sites were detected using the Mini-disk Infiltrometer, thereby suggesting that the significant change in infiltration volumes over time can be attributed to the Lockheed Fire.

The influence of soil parent material and vegetation type on the hydrologic processes over the course of the study were tested in order to determine whether any variance could be explained by a specific soil parent material or dominant vegetation type. A variety of models were generated in order to test both the effect of soil parent material and vegetation type. However, the statistics are not strong in supporting that soil parent material or vegetation type had a strong influence on the hydrologic processes (infiltration rates, the hydrologic response, infiltration volumes or penetration times).

While there are a variety of variables with subclasses tested for having a significant influence on the hydrologic processes following the fire, the lack of significant findings can be attributed to inconsistencies in the datasets as a result of not having each effect evaluated for this study, equally represented throughout the testing period. Hence, while visible trends were

present in each dataset, perhaps the inconsistencies in data collection limited the abilities of the mixed-effects modeling to detect a fire effect, especially for the rainfall simulations and water drop penetration time tests.

It is challenging to have perfectly controlled experiments in a natural, field setting. Evaluating the post-fire effects within the Scotts Creek watershed using rainfall simulations, Mini-disk Infiltrometer and water drop penetration time test has provided meaningful results regarding post-fire effects on soil hydrologic processes, limitations of each method, and recommendations for future researchers who choose to use these methods.

Future work pertaining to near-surface hydrology in the Scotts Creek should aim to better understand the trends over time that were seen at nearly all sites for each test by conducting multiple simulations at a site per year, conduct testing at a subwatershed scale, and maintain a balanced dataset by having equal amounts of the variable and subcategories represented in the datasets. A key part to understanding the influence of fire on soils lies within the physical characteristics of the sites including vegetation communities, soils, geology, antecedent moisture content, and duff depth, which, independent of fire, highly influence infiltration and runoff.

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APPENDICES

Appendix A. Soil Burn Severity Descriptive Classes as described by Parsons and Robichaud (2003)

Parsons (2003) defines soil burn severity as “the fire-caused changes to soil hydrologic function, as evidenced by soil characteristics and surface fuel and duff consumption.”

Burn Severity Characteristics (adapted from Parsons, 2003):
Low:
Surface fire with no extension into the tree canopy
Slight or no modification of vegetation structure
Nearly all mature plants survive
Consumption of fine fuels and litter
Unburned islands of vegetation remain
Duff intact
No or slight soil heating

Moderate:
Long stems remaining in the chaparral
Fire extension into the tree canopy of a small number of individual trees
Moderate stand modification
Most mature plants survive, but some mortality
Needles on trees may be scorched
Consumption of fine fuels and litter
Duff layer partially consumed
Some soil heating
Some areas may be more of a mosaic of low to high severity that are lumped into the Moderate rating

High:
Chaparral mostly consumed
Most tree canopies scorched
Most small plants, litter and duff consumed
High mortality of mature plants, including trees
Some larger diameter fuels remain

Very High:
Chaparral consumption with many burned out stumps and burls
Complete consumption of the tree canopies of the majority of the trees within an area
Complete consumption of small plants, litter and duff
Almost total consumption of mature plants
May be significant soil heating

Appendix B. Descriptions of the Rainfall Simulation Sites

Site 2: Swanton Road

Site 2 is located adjacent to Swanton Road approximately 1 mile from the Old Seaside Schoolhouse at the first turnout. The dominant vegetation type is redwood overstory and sparse redwood sorrel understory. A thick, 3-5 inch redwood duff layer overlies mineral soil. The soil parent material is mudstone. The slope of the site is 60 percent. This site was not burned.

Site 4: L.C. Unburned

Site 4 is located above the gate at the entrance of Little Creek road. The plot is adjacent to the mainstem of Little Creek under a redwood/Douglas fir dominant forest type. The understory is composed of hedge nettle, blackberry and redwood sorrel. The soil parent material is Santa Cruz mudstone. Slope ranges from 65-88 percent.

Site 5: Cabins

Site 5 is located below the confluence and near the Spafford Cabin on Little Creek Road. The dominant forest type is Redwood/Douglas fir. The soil parent material is sandstone/mudstone. Slope ranges from 47-65 percent. The fire burn severity is moderate. Following the fire, blackberry, ceanothus and hedge nettle grew vigorously are the current understory vegetation.

Site 6: Upper North Fork

Site 6 is located approximately 5 meters upslope from the Upper North Fork flume station. The dominant forest type is redwood/Douglas fir. The soil parent material is sandstone/mudstone. The slope ranges from 40-50 percent. The burn severity is low. Following the fire, ceanothus, redwood sorrel, and hedge nettle make up the current understory.

Site 7: South Fork

Site 7 is located near the landing at the bottom of the south fork road of Little Creek. The dominant vegetation type is Redwood with some tanoak and the soil parent material is mudstone. The slope of the site ranges from 45-54 percent. The burn severity is moderate.

Site 8: Boyer Burned

Site 8 is located on Lockheed Martin Property adjacent to the road on the Boyer/Mill creek ridgeline. The dominant vegetation type is knobcone/Manzanita. The soil parent material is mudstone. The average slope of the site is 47-60 percent. The burn severity is high.

Site 9: Mill Unburned

Site 9 is located near the road that follows the mill creek and Boyer Creek ridgeline. The dominant forest type is knobcone pine and manzanita. The soil parent material is granitic. The percent slope ranges from 55 to 65 percent. This site was not burned.

Site 10: Scotts/Mill Burned

Site 10 is located on the road that follows the Scott's creek and mill creek ridgeline. The dominant forest type is knobcone pine and manzanita. The soil parent material is mudstone and the slope of the site ranges from 27 to 45 percent. This site has a high burn severity rating.

Site 11: Scotts/Mill Unburned

Site 11 is located across from site 10. The dominant vegetation type is knobcone pine and manzanita. The soil parent material is mudstone and the percent the slope of the site ranges from 17 to 40 percent. This site was not burned.

Site: Upper Boyer Unburned

Site 12 is located along the Boyer creek and Mill creek ridgeline. The dominant vegetation type is tanoak. The soil parent material is granitic and the slope of the site ranges from 38 to 46 percent. This site was not burned.

Site 13: Lions Flat

Site 13 is located along the Little Creek and Archibald creek ridgeline. The dominant vegetation type is redwood and tanoak and the soil parent material is mudstone. The percent slope of the site ranges from 60 to 65 percent. The burn severity of this site is high.

Site 14: Hillslope Erosion Study

Site 14 is located downslope of the south fork road adjacent to the rain gauge. The burn severity is moderate and the dominant vegetation type is redwood/tanoak. The soil parent material is mudstone and the slope of the site ranges from 70 to 72 percent.

Site 15: Mill/Boyer Burned

Site 15 is located along the Mill and Boyer creek ridgline. The burn severity is high and the dominant vegetation type is knobcone pine and Manzanita. The soil parent material is mudstone and the slope of the site ranges from 35-38 percent.

Appendix C. Description of Mini-disk Infiltrometer and Water Drop Penetration Time Test Sites

Site 1

Site 1 is located near the four wheel drive road of Little Creek. The site is just downslope of Little Creek road. The aspect is south east facing and the slope position is low. The soil burn severity is high as well as the overall burn severity.

Site 2

Site two is located in Little Creek upslope of the Spafford cabin. The aspect is south east facing and the slope position is low. The soil burn severity is high and the overall burn severity is moderate.

Site 3

Site 3 is located upslope of the Upper North Fork flume monitoring station in Little Creek. The burn severity is moderate and the site is on a north-west facing slope. The slope position is low.

Site 4

Site 4 is located near the hillslope erosion study site located on the southern ridgeline of little creek. The burn severity is high and the site is located on a north facing slope. The site is located on the upper slope of the hillside.

Site 5

Site 5 is located about 200 feet upslope of the south fork road in Little Creek above the landing. The burn severity is moderate and the site is on a west facing slope. The slope position is low.

Site 6

Site 6 is located a few hundred feet east of the yellow gate dividing San Vicente Redwoods and Swanton properties on Sea View Ridge Road. The burn severity is high and the aspect is north. The position of the site is upper slope.

Site 7

Site 7 is located on adjacent to a saddle on the top of Sea View Ridge road. The burn severity is high and the aspect is north. The slope position is upper slope.

Site 8

Site 8 is located just below the Ridgeline Smith rain gauge. The burn severity is high and the aspect is south east facing. The slope position in upper slope.

Site 9

Site 9 is located in between the General Smith Road and a skid trail near Upper Tributary 1. The burn severity is moderate and the aspect is south east facing. The slope position is low.

Site 10

Site 10 is located downslope of the Ridge Line south fork rain gauge. The burn severity is high and the aspect is south facing. The slope position is upper slope

Site 11

Site 11 is located 100 feet south of the Ridge Line north fork rain gauge and 50 feet downslope of the road. The burn severity is moderate and the aspect is northwest facing. The slope position is upper slope.

Site12

Site 12 is located on High Hill road between R7 and R8. The burn severity is high and the aspect is south facing. The slope position is upper slope.

Site 13

Site 13 is located upslope of landing 20, above the Timber Exclusion Zone. The burn severity is moderate on a south facing slope. The slope position is low.

Site 14

Site 14 is the only unburned site. It is located 300 feet down from the four wheel drive road. The site is located on a low slope position with a south facing aspect.

Site 15

Site 15 is located adjacent to High Hill ridge road. The burn severity is high and the aspect is south east facing. The slope position is upper slope.

Site 16

Site 16 is about 150 feet downslope of site 15. The burn severity is high/moderate with a south east facing aspect. The slope position is mid-slope.

Site 17

Site 17 is located near the ridgeline Smith rain gauge. The burn severity is high/moderate on a south-east facing aspect. The slope position is midslope.

Site 18

Site 18 is located on High Hill ridge. The burn severity is high and the aspect is south east facing. The slope position is upper slope.

Site 19

Site 19 is located just below site 18. The burn severity is moderate and the aspect is south-east facing. The slope position is low.

Site 20

Site 20 is located on the ridgeline between the north and south forks of Little Creek in a small drainage. The burn severity is high and the aspect is north west facing. The slope position is upper slope.

Site 21

Site 21 is located in the south fork of Little Creek. The burn severity I moderate/low and the aspect is north facing. The slope position is low.

Site 22

Site 22 is located upslope from site 21. The burn severity is high/moderate on a north facing slope. The slope position is upper slope.

Site 23

Site 23 is located adjacent to the hill slope erosion study site. The burn severity is high and the aspect is north facing. The slope position is upper slope.

Appendix D. Instructions for Conducting Rainfall Simulations

Permanent plots were not established during the set-up of this project in 2009 because plots were disrupted after the simulation so that infiltration and percolation paths (from macropores and burnt root paths) along with any soil water repellency could be observed with the hope of further explaining the role fire played on infiltration and runoff rates. Therefore, a new plot location was selected every year. New plots were located within the same general site and had the same aspect, soil type, vegetation type, and a similar in percent slope.

Once a plot location is chosen, the first step is to create the plot using the 3 sided sheet metal and trapezoidal trough making certain that the plot is sturdy and does not shift during the simulation. Simulations are often performed on steep slopes and if the sheet metal and trough are not inserted into the soil well, they can shift from gravity. The outlet tubing which is located at the outlet of the trough, should be stretched out the entire length and the five gallon bucket should be set up at the end of the tubing. A hole for the bucket to sit in is often needed so that the outlet tubing can remain at the natural slope ground. If the outlet tubing is flat, or not correctly sloped, runoff rates are more than likely to be inaccurate. Next, the simulator is placed over the plot with two legs adjacent to the trough and the third leg positioned behind the sheet metal at the top of the plot. Once the plot, five gallon bucket and simulator are setup, the calibration pan is then placed on top of the plot and secured using gorilla tape and stakes to keep it from sliding downhill. The calibration pan should cover the entire plot to ensure that the plot will not get wet during the calibration period. The position of the rainfall simulator over the plot should be adjusted so that there is uniform rainfall over the entire plot. Once there is uniform rainfall over the plot, the rainfall rate is calibrated by collecting the runoff in a 500 mL plastic cylinder over a thirty second period. The volume collected over thirty seconds is considered the calibration

runoff rate. From there the rainfall rate can be calculated. Once the simulator is calibrated to about 2.0 inches per hour, the calibration pan is removed and the simulation can begin.

Simulations should run at least an hour with measurements being taken every two minutes. Runoff measurements are recorded in a field notebook along with other essential notes such as time runoff started, time runoff ended, breeze, bucket emptied or any malfunctions that may have occurred such as the pump running out of gas or rock in the simulator nozzle. In some instances, the five gallon bucket may fill up prior to the end of the simulation therefore it is emptied and set back in place between the 2 minute measurements. The outlet tubing can be held upright allowing runoff to accumulate which can then be poured into the bucket once the bucket is set back into place.

Equipment used for rainfall simulations:

(2) 50 gal Barrels	(7) wooden stakes	(1) calibration pan
(1) 50 gal open barrel	(1) single jack	(1) outflow tubing
(1) 50' hose	(1) generator	(1) bucket
(1) Simulator	(1) water pump	(1) shovel
(1) rectagle Plywood	(1) gallon gas	(1) pick mattock
(1) Trough	(1) loppers	(1) recirculation hose
(1) Plot Boundary	(1) hand saw	(3) legs
(7) rebar stakes	(1) roll of plastic	(1) chainsaw

Equipment for rainfall simulation in the dry box:

(1) extension cord	(1) pencil
(1) yellow cable	(1) infiltration rate sheet
(1) control box	(1) gorilla tape
(1) depth ruler	(1) masking tape
(1) field book	(1) 3 meter tent pole

Appendix E. Instructions for Conducting MDI and WDPT Tests

Permanent transects were not established during the set-up of this project in 2009. Locations within a transect were disturbed in order to conduct the tests requiring a new location for each site to be established each year. A new transect was established each time with the same aspect, soil type, vegetation type and as close to the same percent slope. After establishing the 100 foot transect, the tests were conducted every 6.5 meters (20 feet) along the transect at 1 and 3 centimeters for the MDI, and 1, 2, and 3 cm for the WDPT.

A trowel is used to cut to the soil depth being tested at each location along the transect. Many MDI and WDPT sites are located on steep slopes, therefore relatively flat benches were dug as close as possible to the depth being tested. Sloped surfaces can alter infiltration volumes and can cause water drops to roll downhill. Thus, conducting both tests on a flat surface helped to improve accuracy for the data being collected.

When conducting the MDI test, both chambers of the infiltrometer should be filled with water. The suction control tube in the upper chamber is set to 1 cm. The volume of water in the lower chamber is recorded as the start volume. The infiltrometer is then placed flat against and held perpendicular to the soil surface. Once the soil and infiltrometer come into contact, wait 1 minute before lifting/removing the infiltrometer. Record the end volume amount. This is repeated two more times for a total of three times every 6.5 meters within a transect. Water should be added to the lower chamber as necessary throughout testing.

For water drop tests, a squeeze water bottle filled with water is gently squeezed such that individual droplets are dispensed onto the soil surface. The squeeze bottle nozzle was placed as close to the soil surface in order to minimize the impact of the drop on infiltration times. Time was recorded from the moment the water droplet made contact with the soil surface to the time

the drop had completely infiltrated. Times were recorded up to 400 seconds. After 400 seconds, the drops were considered to have no penetration.

Equipment used for the MDI and WDPT tests:

(2) MDI	(1) roll flagging
(2) liters of water	(1) sharpie
(2)laboratry wash bottle	(2) garden shovel
(1) 100 foot tape	(2) water droppers

Appendix F. Rainfall Simulator Preliminary Data and Graphs

2009

Site 4

Date and time: 10/28/2009 @ 14:45
Slope %: 70
Location: Approximately 600' downstream of 4WD road along Little Creek Road. 30' downslope from road edge below RW clump. Approximately 70' from Little Creek. Unburned.

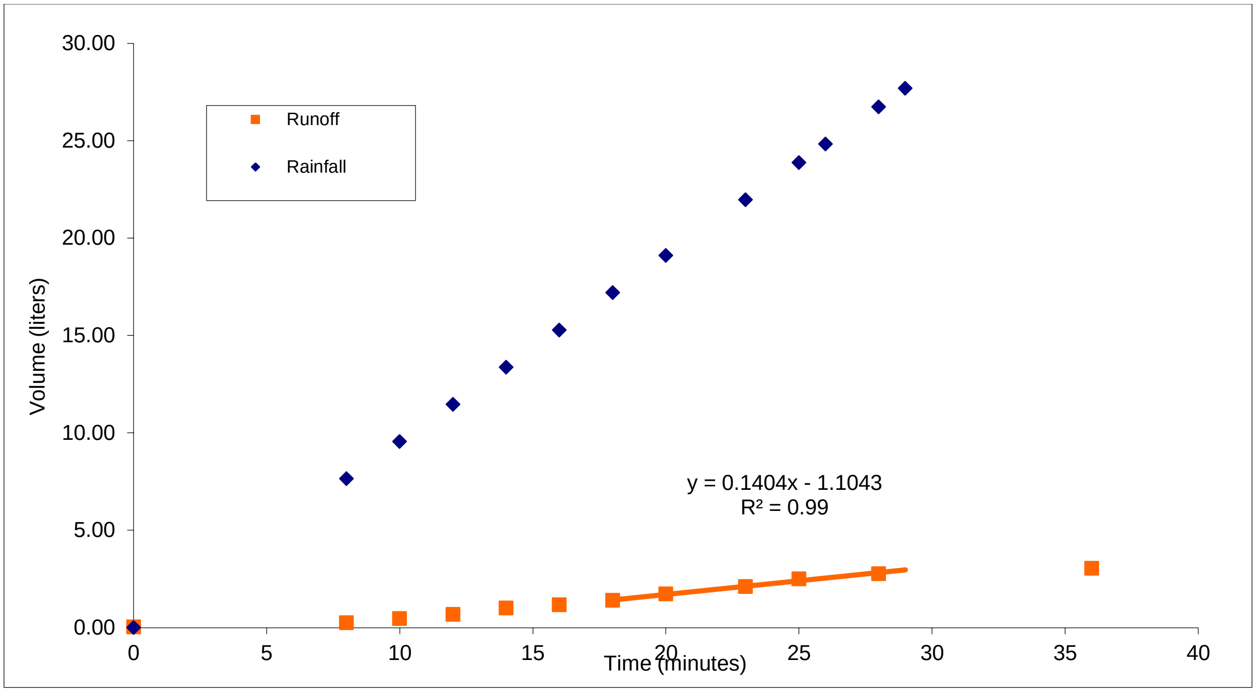
Vegetation: Riparian/Redwood. Redwood, alder, bay, Douglas-fir overstory. Fern, sorrel, poison oak understory.

Soils: 4" thick duff layer. Soil mudstone based and has many gravel to small cobble sized rocks. Many roots.

Calibration:		
Time on	0.5	0.9
Time off	0.5	0.1
Volume 1	310 mL/30s	470 mL/30s
Volume 2	308 mL/30s	467 mL/30s
Volume 3	315 mL/30s	485 mL/30s
Volume 4		488 mL/30s

Slope corrected rainfall	**1.79 in/hr**	**2.75 in/hr**	**rate:**
	0.62 L/min	0.96 L/min	

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	-0.23	0.00	0.03	2.75 in/hr
8	-0.07	7.64	0.25	
10	0.08	9.55	0.46	
12	0.24	11.46	0.68	leveled bucket
14	0.48	13.37	1.01	
16	0.60	15.28	1.17	62mL/30s
18	0.75	17.19	1.39	
20	0.99	19.10	1.72	
23	1.27	21.97	2.11	
25	1.54	23.88	2.49	
26		24.83		65mL/30s
28	1.74	26.74	2.77	
29		27.70		Stop Rain
36	1.94		3.05	



Total Rain:	27.70 L	1.33 in
Total Runoff:	3.05 L	0.15 in
Runoff Ratio:	**0.1101**	

Rainfall Rate:	0.622 L/min	2.75 in/hr
Runoff Rate:	0.140 L/min	0.40 in/hr
Infiltration Rate:	0.482 L/min	**2.35 in/hr**

Results**:** 26 minutes @ 2.75 in/hr: runoff after 6 minutes of rain; most runoff from duff layer, minimal evidence of runoff in soil; soil moist in middle of plot after simulator indicating good infiltration.

Site 5

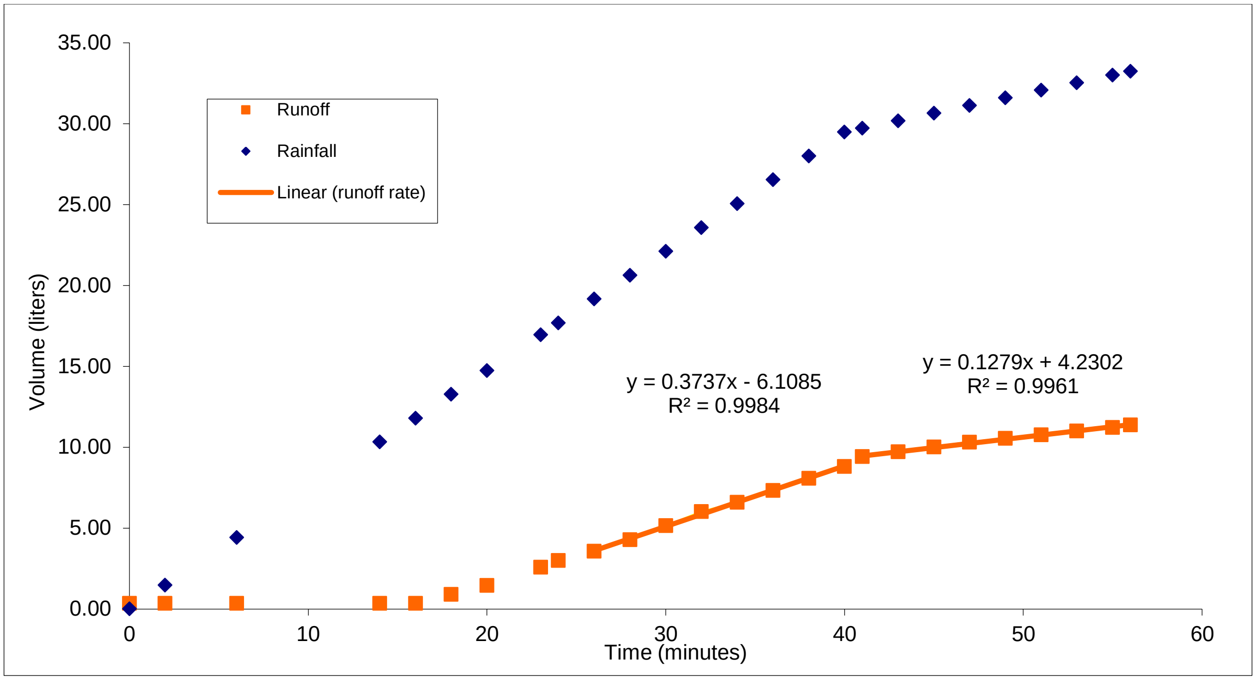
Date and time: 10/29/2009 @11:55
Slope %: 61
Location: 400' up road from crossing R8 on Little Creek Road. 20' upslope from edge of road cut. Near intesection of trail/old road and haul road.
Vegetation: Douglas-fir, bay, oak; south aspect; low to medium burn intensity.
Soils: Sandstone parent material with some mudstone colluvium. 50% coverage by DF/bay/oak leaf litter. 10% rock fragments at surface. Common soil pedestels.

Calibration:

Time on	0.6	0.1
Time off	0.4	0.9
Volume 1	365 mL/30s	118 mL/30s
Volume 2	370 mL/30s	120 mL/30s
Volume 3	370 mL/30s	115 mL/30s

Slope corrected rainfall rate:	**2.04 in/hr**	**0.65 in/hr**
	0.74 L/min	0.24 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.35	rain 2.04 in/hr
2	0	1.47	0.35	
6	0	4.42	0.35	
14	0	10.31	0.35	start runoff - runoff only from top 1" of soil, below 1" dry.
16	0	11.79	0.35	
18	0.4	13.26	0.90	
20	0.8	14.73	1.46	
23	1.6	16.94	2.58	
24	1.9	17.68	3.00	runoff rate 0.94 in/hr
26	2.3	19.15	3.57	
28	2.8	20.63	4.28	
30	3.4	22.10	5.14	soil pedestals observed forming
32	4	23.57	6.01	
34	4.4	25.05	6.59	runoff rate 1.03 in/hr
36	4.9	26.52	7.33	
38	5.4	27.99	8.07	
40	5.9	29.47	8.81	
41	6.3	29.70	9.41	rain 0.65 in/hr
43	6.5	30.17	9.71	
45	6.7	30.64	10.01	
47	6.9	31.11	10.31	
49	7.05	31.58	10.54	
51	7.2	32.06	10.77	
53	7.35	32.53	10.99	
55	7.5	33.00	11.22	
56	7.6	33.23	11.37	



Total Rain:	33.23 L	1.53 in
Total Runoff:	11.37 L	0.52 in
Runoff Ratio:	**0.3423**	

Rainfall Rate:	0.737 L/min	2.04 in/hr
Runoff Rate:	0.374 L/min	1.03 in/hr
Infiltration Rate:	0.363 L/min	**1.00 in/hr**

Rainfall Rate:	0.24 L/min	0.65 in/hr
Runoff Rate:	0.13 L/min	0.35 in/hr
Infiltration Rate:	0.11 L/min	**0.30 in/hr**

Results: Top layer saturated (1" depth) and majority of runoff coming from 1st inch of soil, with little to no surface flow. Below 1" soil was dry.

Site 6

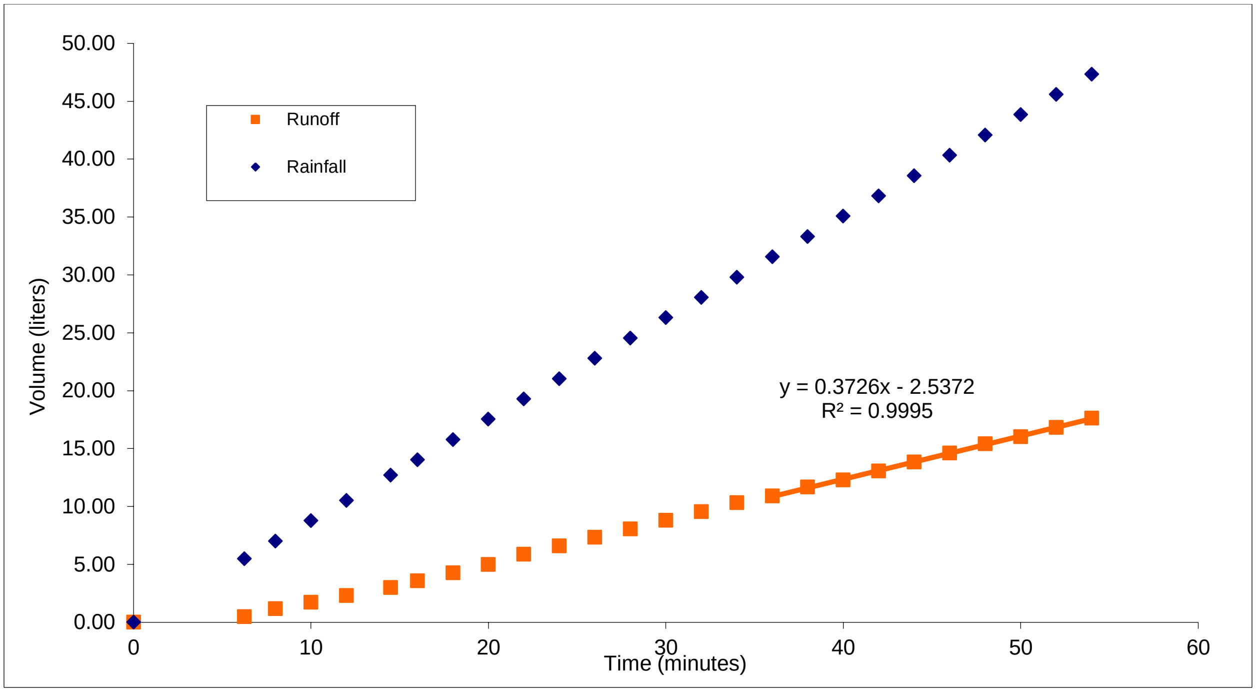
Date and time: 10/30/2009 @ 12:05
Slope %: 50
Area m^2: 0.894
Location: Near UNF bridge directly uphill from top of trail to flume
Vegetation: Redwood/tanoak. Low burn intensity
Soils: decomposed granite. High clay content. Initially moist no dry layer.

Calibration:

Time on	0.8	0.6
Time off	0.2	0.4
Volume 1	616 mL/30s	435 mL/30s
Volume 2	570 mL/30s	438 mL/30s
Volume 3	590 mL/30s	442 mL/30s

Slope corrected rainfall rate:	**3.13 in/hr**	**2.32 in/hr**
	1.18 L/min	0.88 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0		0.00		Start
6.25	0.1	5.48	0.49	
8	0.6	7.01	1.18	
10	1	8.77	1.73	
12	1.4	10.52	2.29	
14.5	1.9	12.71	3.00	
16	2.3	14.03	3.57	
18	2.8	15.78	4.28	
20	3.3	17.53	5.00	
22	3.9	19.29	5.87	
24	4.4	21.04	6.59	
26	4.9	22.79	7.33	
28	5.4	24.55	8.07	
30	5.9	26.30	8.81	
32	6.4	28.05	9.56	
34	6.9	29.81	10.31	
36	7.3	31.56	10.92	
38	7.8	33.31	11.68	
40	8.2	35.07	12.29	
42	8.7	36.82	13.06	
44	9.2	38.57	13.84	
46	9.7	40.33	14.62	
48	10.2	42.08	15.40	
50	10.6	43.83	16.03	
52	11.1	45.59	16.83	
54	11.6	47.34	17.63	Off



Total Rain:	47.34 L	2.08 in
Total Runoff:	17.63 L	0.78 in
Runoff Ratio:	**0.3724**	

Rainfall Rate:	0.877 L/min	2.32 in/hr
Runoff Rate:	0.373 L/min	0.98 in/hr
Infiltration Rate:	0.504 L/min	**1.33 in/hr**

Results: Collector plate 1.5 to 2" deep at downhill end of plot. Observed runoff after 6 mins of rainfall. Some surface flow was evident. Fairly consistent runoff rate.

Site 7

Date and time: 11/2/2009 @13:04
Slope %: 54
Area m^2: 0.88
Location: South fork Little Creek approximately 150 feet uphill from first landing in the redwoods.
Vegetation: Redwood, Tan oak, Douglas-fir. Moderate burn intensity; scorch heights 3-10 ft. locally with 30 ft. plus within 50 ft.
Soils: Mudstone colluvium parent material.

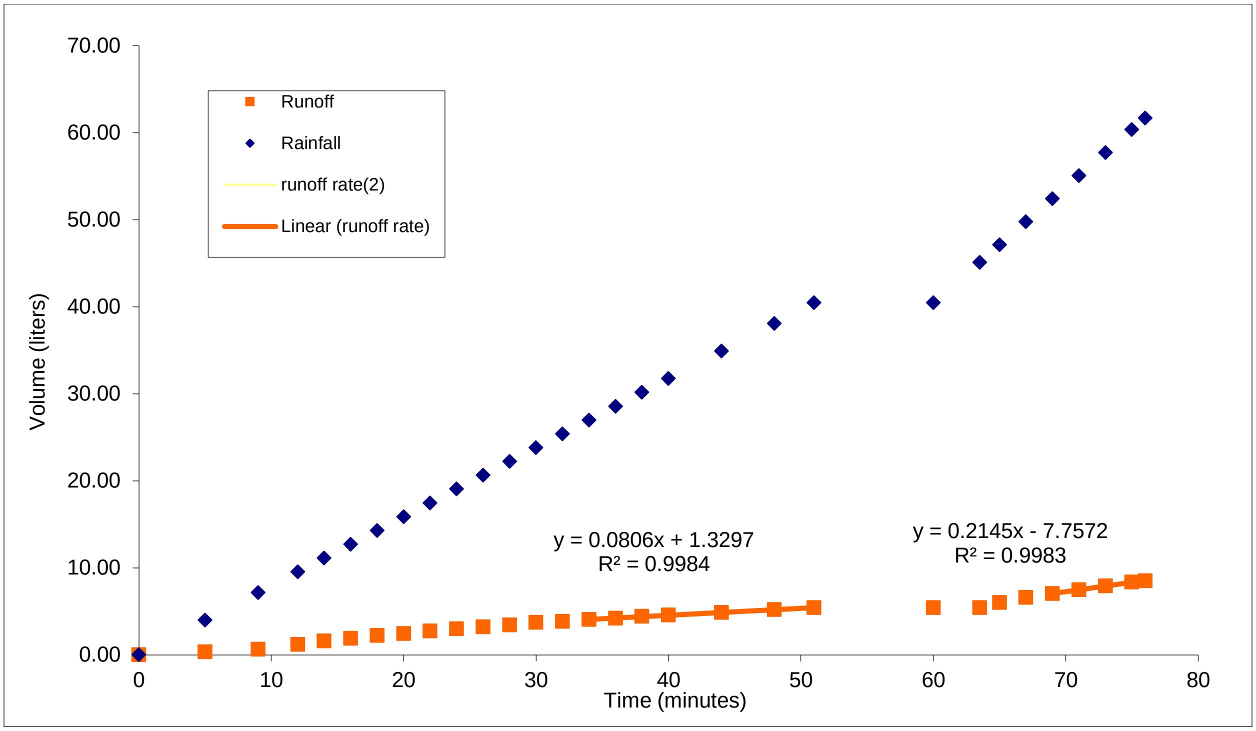
Calibration:

Time on	0.6	0.9
Time off	0.4	0.1
Volume 1	397 mL/30s	670 mL/30s
Volume 2	388 mL/30s	660 mL/30s
Volume 3	405 mL/30s	660 mL/30s

Slope Corrected Rainfall Rate:	**2.13 in/hr**	**3.56 in/hr**
	0.79 L/min	1.33 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0		0.00		Start
5	0	3.97	0.35	
9	0.2	7.14	0.62	
12	0.6	9.52	1.18	
14	0.9	11.11	1.59	
16	1.1	12.69	1.87	
18	1.35	14.28	2.22	
20	1.5	15.87	2.43	
22	1.7	17.45	2.72	
24	1.9	19.04	3.00	
26	2.05	20.63	3.21	
28	2.2	22.21	3.42	
30	2.4	23.80	3.71	
32	2.5	25.39	3.85	
34	2.65	26.97	4.06	
36	2.75	28.56	4.21	
38	2.9	30.15	4.42	
40	3	31.73	4.57	
44	3.2	34.91	4.85	
48	3.45	38.08	5.21	
51	3.6	40.46	5.43	
60	3.6	40.46	5.43	Start 3.56 in/hr
63.5	3.6	45.10	5.43	
65	4	47.09	6.01	

67	4.4	49.75	6.59	
69	4.7	52.40	7.03	
71	5	55.05	7.48	
73	5.3	57.71	7.92	
75	5.6	60.36	8.36	
76	5.7	61.69	8.51	



Total Rain:	61.69 L	2.76 in
Total Runoff:	8.51 L	0.38 in
Runoff Ratio:	**0.1380**	

Rainfall Rate:	0.793 L/min	2.13 in/hr
Runoff Rate:	0.081 L/min	0.22 in/hr
Infiltration Rate:	0.713 L/min	**1.91 in/hr**

Results: Had constant runoff rate after 10 min. No evidence of surface runoff. Site appeared to have good infiltration capacity, although after rainfall about 5% of plot had dry soil, possibly indicating hydrophobicity.

Site 8

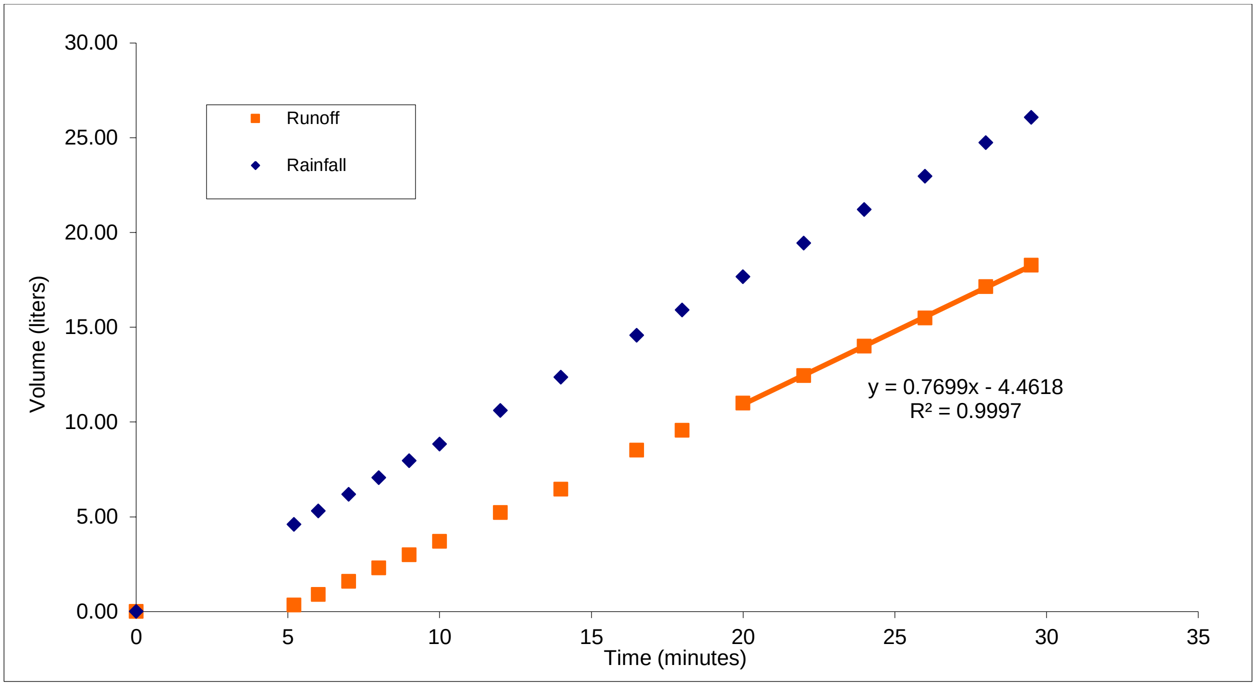
Date and time: 11/04/2009 @ 12:30
Slope %: 60
Area m^2: 0.857
Location: Mill Creek/Boyer Creek ridgeline on south facing slope of Boyer Creek (Lockheed property). Very high burn intensity.
Vegetation: Manzanita, Knobcone pine, scrub oak, (chaparral)
Soils: Shallow mudstone. 95% of surface rock fragments.

Calibration:

Time on	0.8	0.6
Time off	0.2	0.4
Volume 1	420 mL/30s	326 mL/30s
Volume 2	437 mL/30s	345 mL/30s
Volume 3	445 mL/30s	310 mL/30s
Volume 4	452 mL/30s	307 mL/30s
Volume 5	455 mL/30s	319 mL/30s
Volume 6		300 mL/30s

Slope corrected rainfall rate:	**2.43 in/hr**	**1.75 in/hr**
	0.88 L/min	0.64 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0		0.00		runoff @ 2 min
5.2	0	4.59	0.35	
6	0.4	5.30	0.90	
7	0.9	6.19	1.59	
8	1.4	7.07	2.29	
9	1.9	7.95	3.00	
10	2.4	8.84	3.71	
12	3.45	10.60	5.21	
14	4.3	12.37	6.45	
16.5	5.7	14.58	8.51	
18	6.4	15.90	9.56	
20	7.35	17.67	10.99	
22	8.3	19.44	12.45	
24	9.3	21.21	13.99	
26	10.25	22.97	15.48	395 mL/30s @ 27
28	11.3	24.74	17.15	
29.5	12	26.07	18.27	



Total Rain:	26.07 L	1.20 in
Total Runoff:	18.27 L	0.84 in
Runoff Ratio:	**0.7009**	

Rainfall Rate:	0.884 L/min	2.43 in/hr
Runoff Rate:	0.769 L/min	2.12 in/hr
Infiltration Rate:	0.115 L/min	**0.32 in/hr**

Results: Strong evidence of hydrophobicity. Very high runoff rate with little to no infiltration in half inch plus depth of soil. Top half inch of soil removed after rainfall exposing nothing but dry soil.

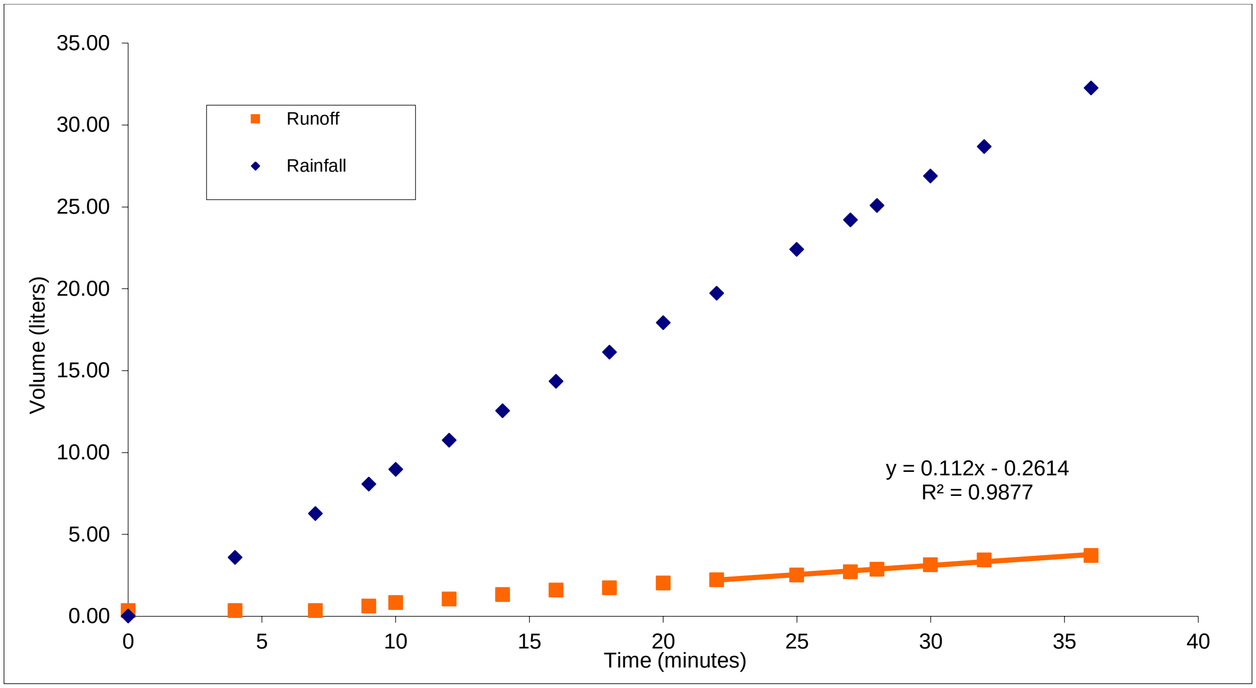
Site 9

Date and time: 11/4/2009 @15:38
Slope %: 55
Area m^2: 0.876
Location: Lockheed ridge on top of Mill Creek and Boyer Creek watersheds on Boyer Creek side. Unburned control site. Near rectangular fenced area.
Vegetation: Manzanita, Knobcone pine, Doug-fir, oak, (chaparral).
Soils: Mudstone/sandstone, possibly at contact of two parent materials. Sandy loam soil.

Calibration:	
Time on	0.8
Time off	0.2
Volume 1	440 mL/30s
Volume 2	470 mL/30s
Volume 3	460 mL/30s
Volume 4	445 mL/30s
Volume 5	425 mL/30s
Volume 6	448 mL/30s

Slope corrected rainfall rate: **2.42 in/hr**
0.90 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.35	
4	0	3.58	0.35	runoff starts
7	0	6.27	0.35	
9	0.2	8.06	0.62	
10	0.35	8.96	0.83	
12	0.5	10.75	1.04	
14	0.7	12.54	1.32	
16	0.9	14.34	1.59	
18	1	16.13	1.73	
20	1.2	17.92	2.01	
22	1.35	19.71	2.22	
25	1.55	22.40	2.51	
27	1.7	24.19	2.72	
28	1.8	25.09	2.86	
30	2	26.88	3.14	
32	2.2	28.67	3.42	
36	2.4	32.26	3.71	



Total Rain:	32.26 L	1.45 in
Total Runoff:	3.71 L	0.17 in
Runoff Ratio:	**0.1150**	

Rainfall Rate:	0.896 L/min	2.42 in/hr
Runoff Rate:	0.112 L/min	0.30 in/hr
Infiltration Rate:	0.784 L/min	**2.11 in/hr**

Results: Low runoff rate indicating higher infiltration through soil. After rainfall simulation top inch of soil removed and 50% dry soil observed showing natural hydrophobicity although rainfall in finding avenues of infiltration.

Site 10

Date and time: 11/18/2009 @12:10
Slope %: 40
Area m^2: 0.928
Location: Mill Creek and Upper Scotts ridge on Mill Creek side. Lockheed or State Parks property. High burn intensity.
Vegetation: Chaparral: Knobcone pine, manzanita, scrub oak.
Soils: Shallow mudstone.

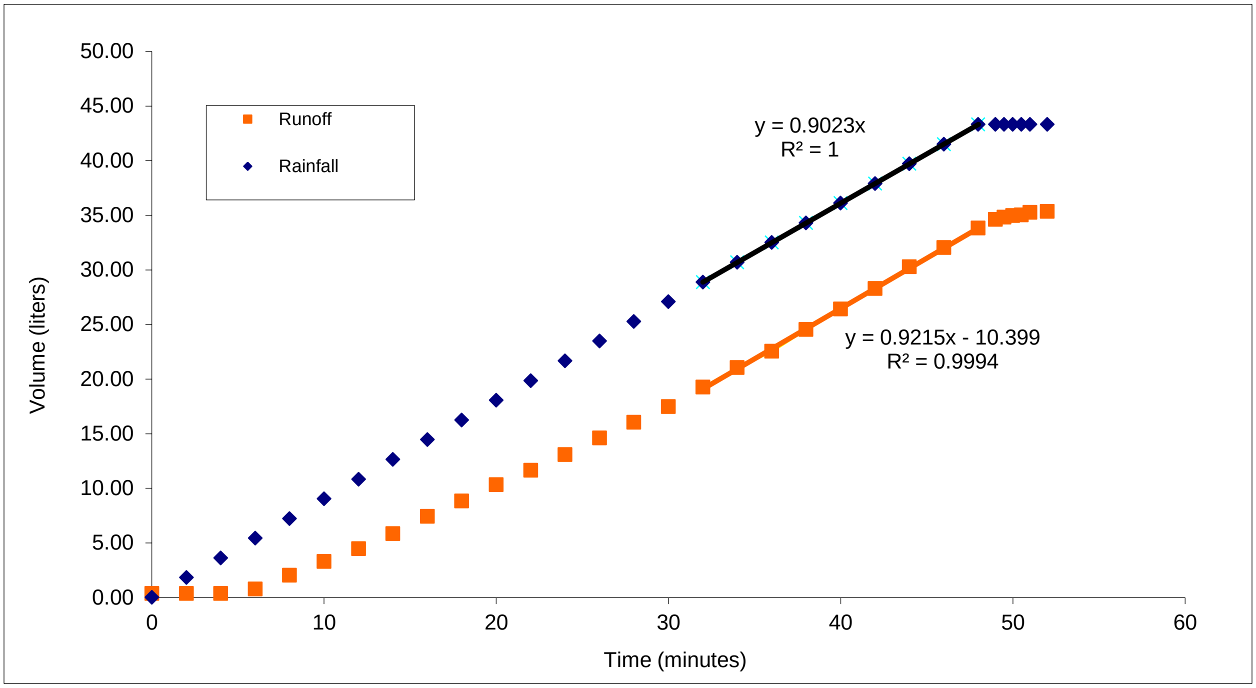
Calibration:

Time on	0.6	0.8	0.7
Time off	0.4	0.2	0.3
Volume 1	330 mL/30s	470 mL/30s	460 mL/30s
Volume 2	295 mL/30s	490 mL/30s	415 mL/30s
Volume 3	322 mL/30s	490 mL/30s	455 mL/30s
Volume 4			450 mL/30s
Volume 5			462 mL/30s
Volume 6			465 mL/30s

Slope corrected rainfall rate:	**1.61 in/hr**	**2.46 in/hr**	**2.30 in/hr**
	0.63 L/min	0.97 L/min	0.90 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.35	Start
2	0	1.80	0.35	drip every 2 sec
4	0	3.61	0.35	small stream
6	0.3	5.41	0.76	steady stream
8	1.2	7.22	2.01	
10	2.1	9.02	3.28	
12	2.93	10.83	4.47	
14	3.88	12.63	5.84	
16	4.95	14.44	7.40	runoff 0.74L/m
18	5.9	16.24	8.81	
20	6.9	18.05	10.31	runoff 0.73L/m
22	7.77	19.85	11.63	
24	8.7	21.66	13.06	
26	9.68	23.46	14.59	
28	10.6	25.27	16.03	
30	11.5	27.07	17.47	
32	12.6	28.87	19.24	
34	13.7	30.68	21.04	
36	14.6	32.48	22.52	
38	15.8	34.29	24.53	

40	16.9	36.09	26.39	
42	18	37.90	28.28	
44	19.15	39.70	30.28	runoff 0.79L/m
46	20.15	41.51	32.04	
48	21.15	43.31	33.82	stop rain
49	21.6	43.31	34.62	
49.5	21.7	43.31	34.80	
50	21.78	43.31	34.95	
50.5	21.82	43.31	35.02	
51	21.95	43.31	35.25	
52	22	43.31	35.34	



Total Rain:	43.31 L	1.84 in
Total Runoff:	35.34 L	1.50 in
Runoff Ratio:	**0.8160**	

Rainfall Rate:	0.902 L/min	2.30 in/hr
Runoff Rate:	0.922 L/min	2.34 in/hr
Infiltration Rate:	-0.019 L/min	**-0.05 in/hr**

Results: Windy: 10-20 mph from NW; Sunny. High runoff rate. No evidence of rills but majority of rainfall runoff from top half inch of soil. After rainfall simulation, top half inch of soil removed and 95% of surface was dry and had strong evidence of hydrophobicity.

Site 11

Date and time: 11/19/2009 @ 11:45
Slope %: 30
Area m^2: 0.958
Location: Mill Creek and Upper Scotts Creek ridge on Scotts side. Lockheed property? Control site - unburned.
Vegetation: Chaparral: knobcone pine, manzanita, oak.
Soils: Mudstone, silty clay loam. Initially slightly moist.

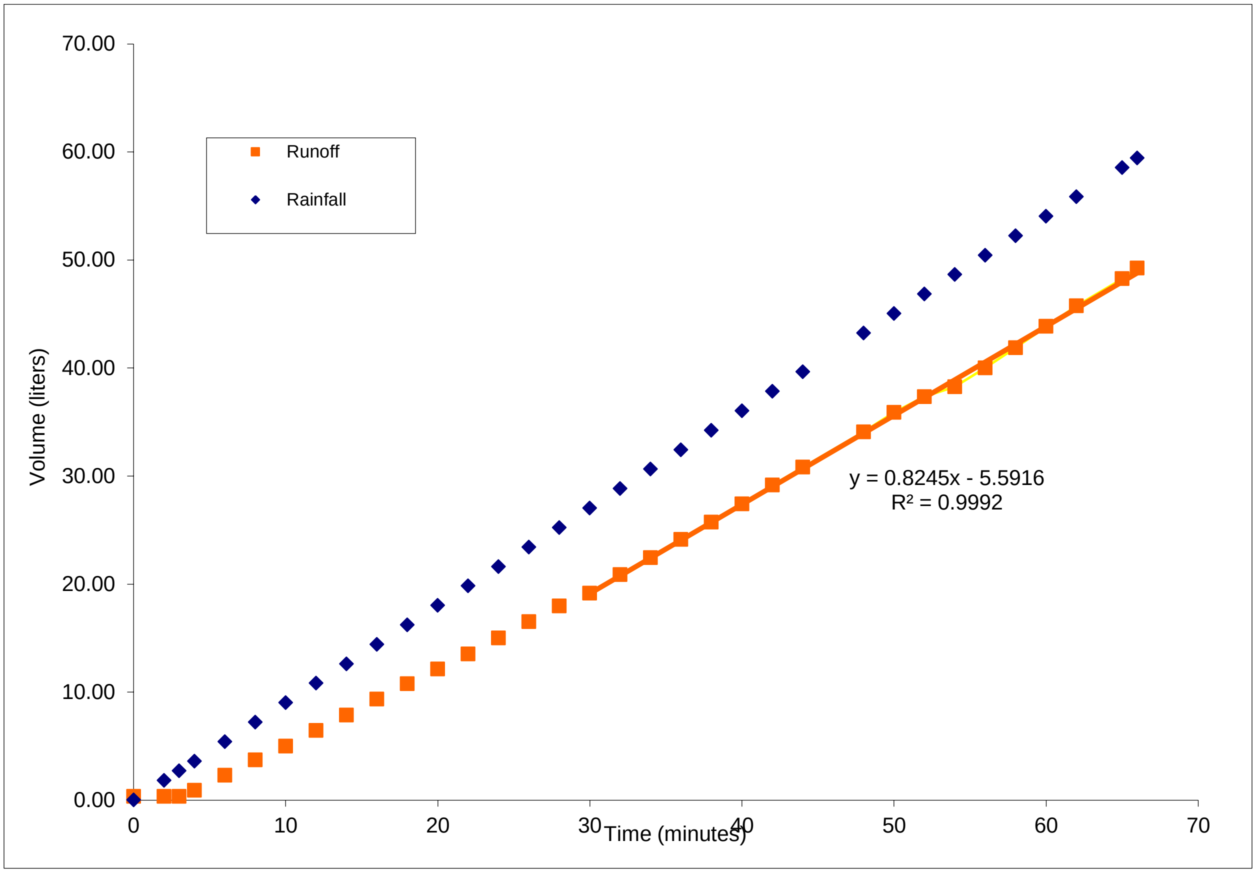
Calibration:

Time on	0.7
Time off	0.3
Volume 1	~~438 mL/30s~~
Volume 2	451 mL/30s
Volume 3	450 mL/30s
Volume 4	450 mL/30s

Slope corrected rainfall rate: **2.22 in/hr**
0.90 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.35	start rain
2	0	1.80	0.35	runoff starts
3	0	2.70	0.35	
4	0.4	3.60	0.90	
6	1.4	5.40	2.29	
8	2.4	7.21	3.71	0.700L/m
10	3.3	9.01	5.00	
12	4.3	10.81	6.45	
14	5.25	12.61	7.84	
16	6.25	14.41	9.33	
18	7.2	16.21	10.77	0.706L/m
20	8.1	18.01	12.14	
22	9	19.81	13.53	
24	9.95	21.62	15.01	
26	10.9	23.42	16.51	
28	11.8	25.22	17.95	0.708L/m
30	12.55	27.02	19.16	
32	13.6	28.82	20.87	
34	14.55	30.62	22.44	
36	15.55	32.42	24.11	
38	16.5	34.23	25.71	
40	17.5	36.03	27.42	
42	18.5	37.83	29.15	0.714L/m

44	19.45	39.63	30.80	
48	21.3	43.23	34.08	
50	22.3	45.03	35.88	
52	23.1	46.83	37.34	
54	23.6	48.64	38.25	
56	24.55	50.44	40.01	0.710L/m
58	25.55	52.24	41.87	
60	26.6	54.04	43.85	
62	27.6	55.84	45.75	0.700L/m
65	28.9	58.54	48.25	
66	29.4	59.44	49.23	end



Total Rain:	59.44 L	2.44 in
Total Runoff:	49.23 L	2.02 in
Runoff Ratio:	**0.8281**	

Rainfall Rate:	0.901 L/min	2.22 in/hr
Runoff Rate:	0.825 L/min	2.03 in/hr
Infiltration Rate:	0.076 L/min	**0.19 in/hr**

Results: High runoff rate although rainfall is still infiltrating slowly. Top inch of soil removed after rainfall simulation and 50% of surface dry. Rainfall rate exceeds infiltration rate. Natural hydrophobicity observed.

2010

<u>Site 4</u>

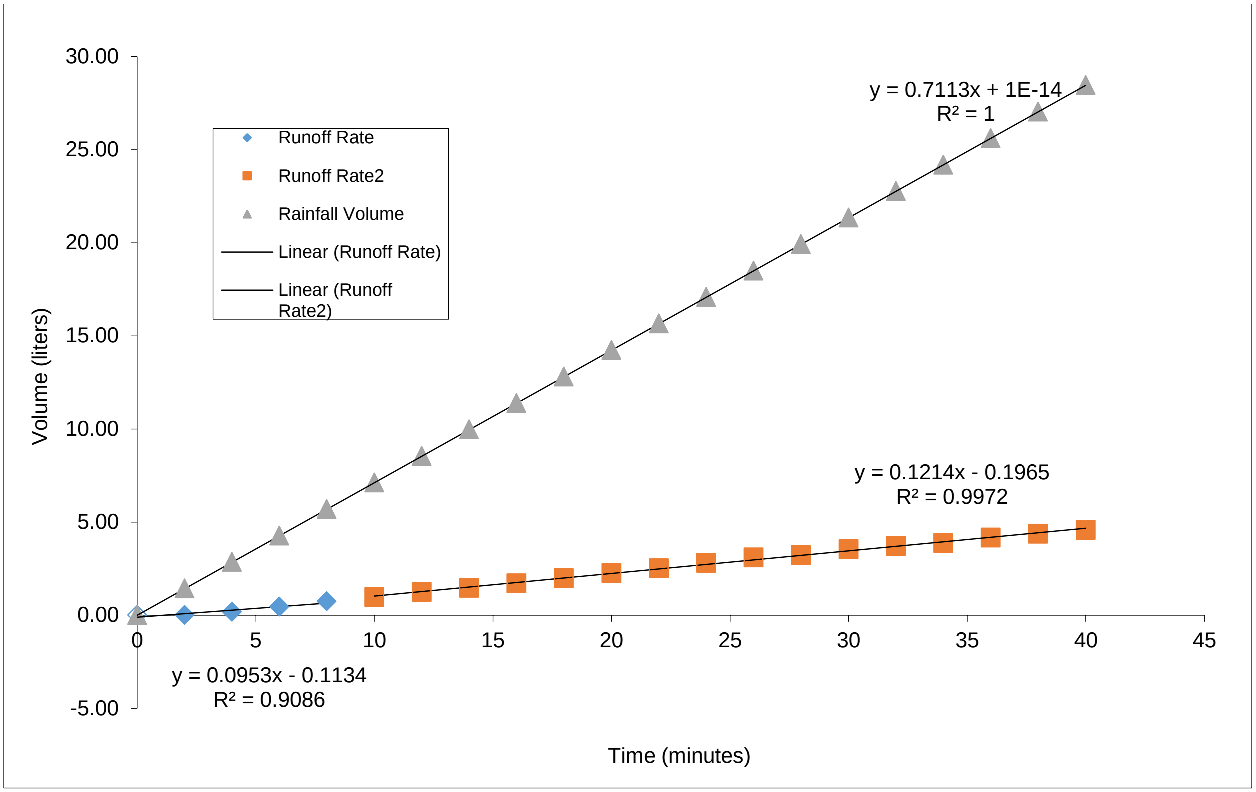
Date: 09/08/2010
Slope %: 88
Area m^2: 0.751
Location: Approximately 600' downstream of 4WD road along Little Creek Road. 30' downslope from road edge below RW clump. Approximately 70' from Little Creek. Unburned
Vegetation: Riparian/Redwood. Redwood, alder, bay, Douglas-fir overstory. Fern, sorrel, poison oak understory.
Soils: 4" thick duff layer. Soil mudstone based and has many gravel to small cobble sized rocks. Many roots.

Calibration:

Volume 1	350 mL/30s
Volume 2	357 mL/30s
Volume 3	360 mL/30s

Slope corrected rainfall rate: **2.24 in/hr**
0.71 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.00	
2	0	1.42	0.00	
4	0.12	2.85	0.17	
6	0.32	4.27	0.44	
8	0.53	5.69	0.73	
10	0.7	7.11	0.97	
12	0.89	8.54	1.23	
14	1.05	9.96	1.46	
16	1.22	11.38	1.69	
18	1.42	12.80	1.97	
20	1.62	14.23	2.26	
22	1.8	15.65	2.51	
24	2.01	17.07	2.81	
26	2.21	18.49	3.09	rate reading 30 s=60mL
28	2.3	19.92	3.22	
30	2.52	21.34	3.53	
32	2.65	22.76	3.72	
34	2.76	24.19	3.87	
36	2.96	25.61	4.16	
38	3.1	27.03	4.36	
40	3.25	28.45	4.58	



Total Rain:	28.45 L	1.49 in
Total Runoff:	4.58 L	0.24 in
Runoff Ratio:	**0.1609**	

Rainfall Rate:	0.711 L/min	2.24 in/hr
Runoff Rate:	0.121 L/min	0.38 in/hr
Infiltration Rate:	0.590 L/min	**1.86 in/hr**

Results: No results recorded in field notes.

Site 5

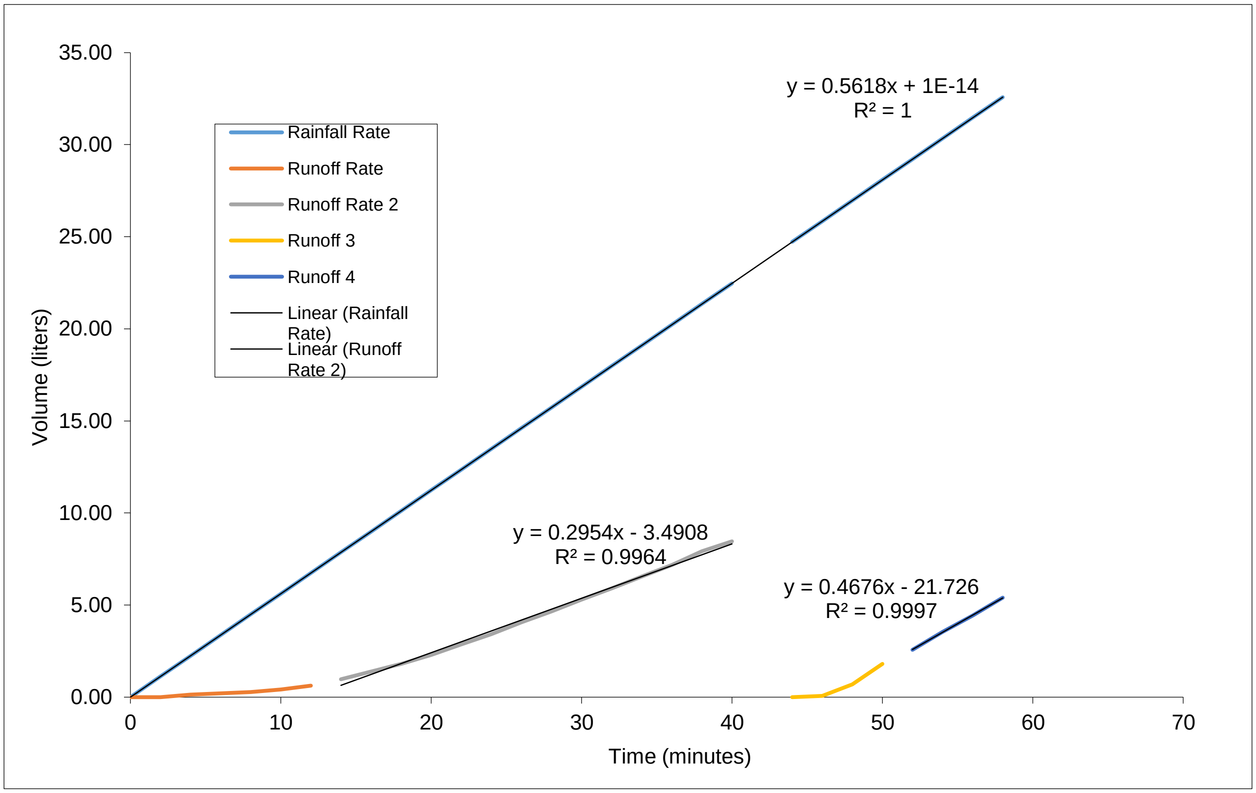
Date and time: 9/15/2010
Slope %: 65
Area m^2: 0.838
Location: 450' up road from crossing R8 on Little Creek Road. 20' upslope from edge of road cut. Near intersection of trail/old road and haul road. (move from previous location to avoid slash
Vegetation: Douglas-fir, bay, oak; south aspect; low to medium burn intensity.
Soils: Sandstone parent material with some mudstone colluvium. 50% coverage by DF/bay/oak leaf litter. 10% rock fragments at surface. Common soil pedestals.

Calibration:		
Time on	0.6	0.9
Time off	0.5	0.1
Volume 1	350 mL/30s	485 mL/30s
Volume 2	330 mL/30s	480 mL/30s
Volume 3	325 mL/30s	465 mL/30s

Slope corrected rainfall rate:	**1.58 in/hr**	**2.25 in/hr**
	0.56 L/min	0.80 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.00	
2	0	1.12	0.00	
4	0.1	2.25	0.14	
6	0.15	3.37	0.21	
8	0.2	4.49	0.28	
10	0.3	5.62	0.41	
12	0.45	6.74	0.62	
14	0.7	7.86	0.97	
16	1	8.99	1.39	
18	1.3	10.11	1.81	
20	1.65	11.24	2.30	
22	2.05	12.36	2.86	
24	2.45	13.48	3.43	
26	2.9	14.61	4.07	
28	3.3	15.73	4.65	
30	3.75	16.85	5.30	
32	4.17	17.98	5.91	
34	4.61	19.10	6.55	
36	5.03	20.22	7.17	
38	5.54	21.35	7.93	
40	5.9	22.47	8.46	

44	0	24.72	0.00	
46	0.05	25.84	0.07	
48	0.5	26.96	0.69	
50	1.3	28.09	1.81	
52	1.85	29.21	2.58	
54	2.53	30.33	3.55	
56	3.15	31.46	4.43	
58	3.82	32.58	5.40	



Total Rain:	32.58 L	1.53 in
Total Runoff:	8.46 L	0.40 in
Runoff Ratio:	**0.2597**	

Rainfall Rate:	0.562 L/min	1.58 in/hr
Runoff Rate:	0.295 L/min	0.70 in/hr
Infiltration Rate:	0.266 L/min	**0.88 in/hr**

Rainfall Rate:	0.80 L/min	2.25 in/hr
Runoff Rate:	0.47 L/min	1.10 in/hr
Infiltration Rate:	0.33 L/min	**1.15 in/hr**

Results: Top layer saturated (1" depth) and majority of runoff coming from 1st inch of soil, with little to no surface flow. Below 1" soil was dry.

Site 6

Date and time: 2/9/2010 @ 11:18
Slope %: 47
Area m^2: 0.905
Location: Near UNF bridge directly above flume on southern side of bank. (moved from previous spot to different aspect because all other soil was disturbed)
Vegetation: Tan oak dominated. Redwood and Doug Fir nearby.
Soils: Granitic soils, horizon on top 1 inch 12% clay, 6 inches down clay increases to around 24 %. Clay is different than above.

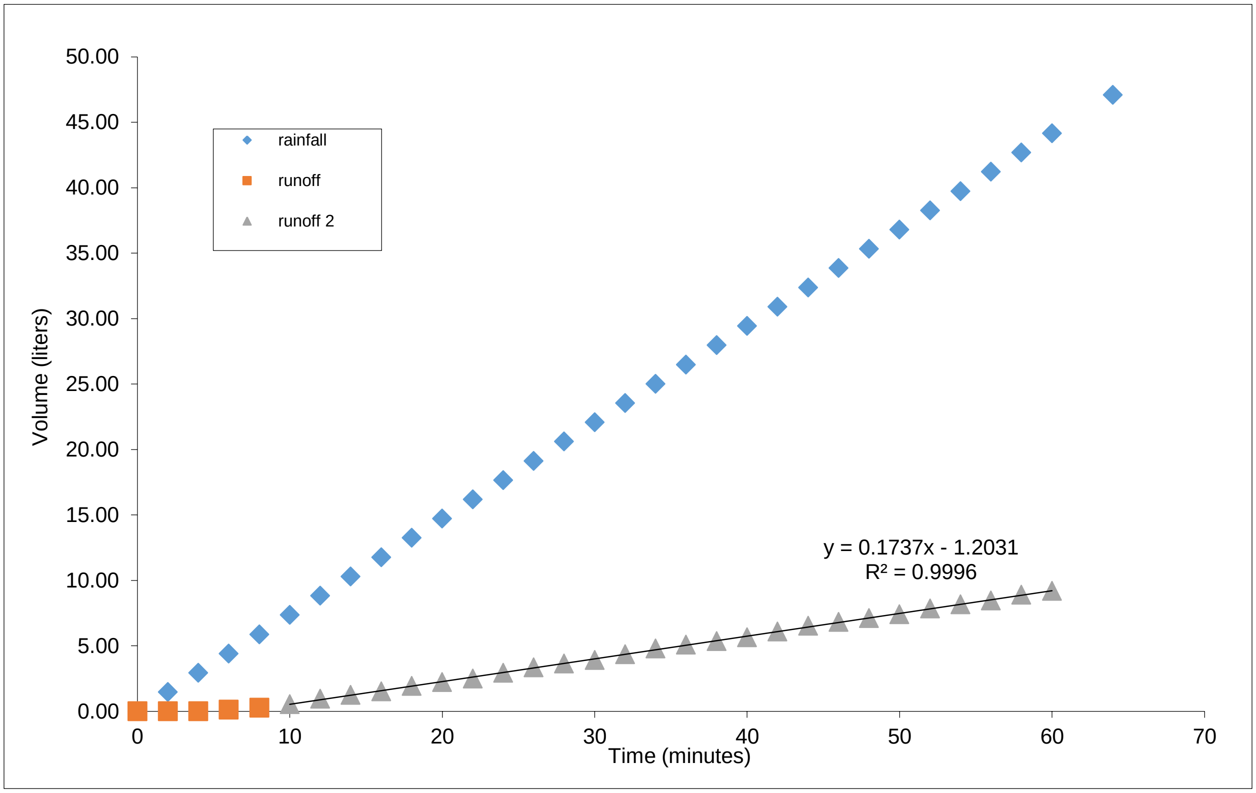
Calibration:

Time on	6
Time off	4
Volume 1	368 mL/30s

Slope corrected rainfall rate: **1.92 in/hr**
0.74 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.00	
2	0	1.47	0.00	Start pressure 14 6on 4 off
4	0	2.94	0.00	
6	0.1	4.42	0.14	
8	0.2	5.89	0.28	
10	0.4	7.36	0.55	
12	0.7	8.83	0.97	
14	0.9	10.30	1.25	
16	1.1	11.78	1.53	
18	1.4	13.25	1.95	
20	1.6	14.72	2.23	
22	1.8	16.19	2.51	
24	2.1	17.66	2.93	
26	2.4	19.14	3.36	
28	2.6	20.61	3.65	
30	2.8	22.08	3.93	
32	3.1	23.55	4.36	
34	3.4	25.02	4.79	
36	3.6	26.50	5.08	
38	3.8	27.97	5.37	
40	4	29.44	5.66	
42	4.3	30.91	6.10	
44	4.6	32.38	6.54	
46	4.8	33.86	6.83	
48	5	35.33	7.13	

50	5.2	36.80	7.42	
52	5.5	38.27	7.87	
54	5.7	39.74	8.16	
56	5.9	41.22	8.46	
58	6.2	42.69	8.91	
60	6.4	44.16	9.21	
64	6.5	47.10	9.36	turned off, reduced to small dripping



Total Rain:	47.10 L	2.05 in
Total Runoff:	9.36 L	0.41 in
Runoff Ratio:	**0.1987**	

Rainfall Rate:	0.736 L/min	1.92 in/hr
Runoff Rate:	0.170 L/min	0.44 in/hr
Infiltration Rate:	0.566 L/min	**1.48 in/hr**

Results: No results recorded in field book.

Site 7

Date and time: 10/09/2010 @ 16:00
Slope %: 48
Area m^2: 0.902
Location: South Fork Little Creek approximately 150 ft. uphill from first landing in the redwoods. Site was altered by slash thrown onto soil.
Vegetation: Redwood, Tan oak, Douglas-fir. Moderate burn intensity; scorch heights 3-10 ft. locally with 30 ft. plus within 50 ft.
Soils: Mudstone colluvium parent material. Duff layer high in pine needles 8% clay at surface. 6 inches down 19% clay.

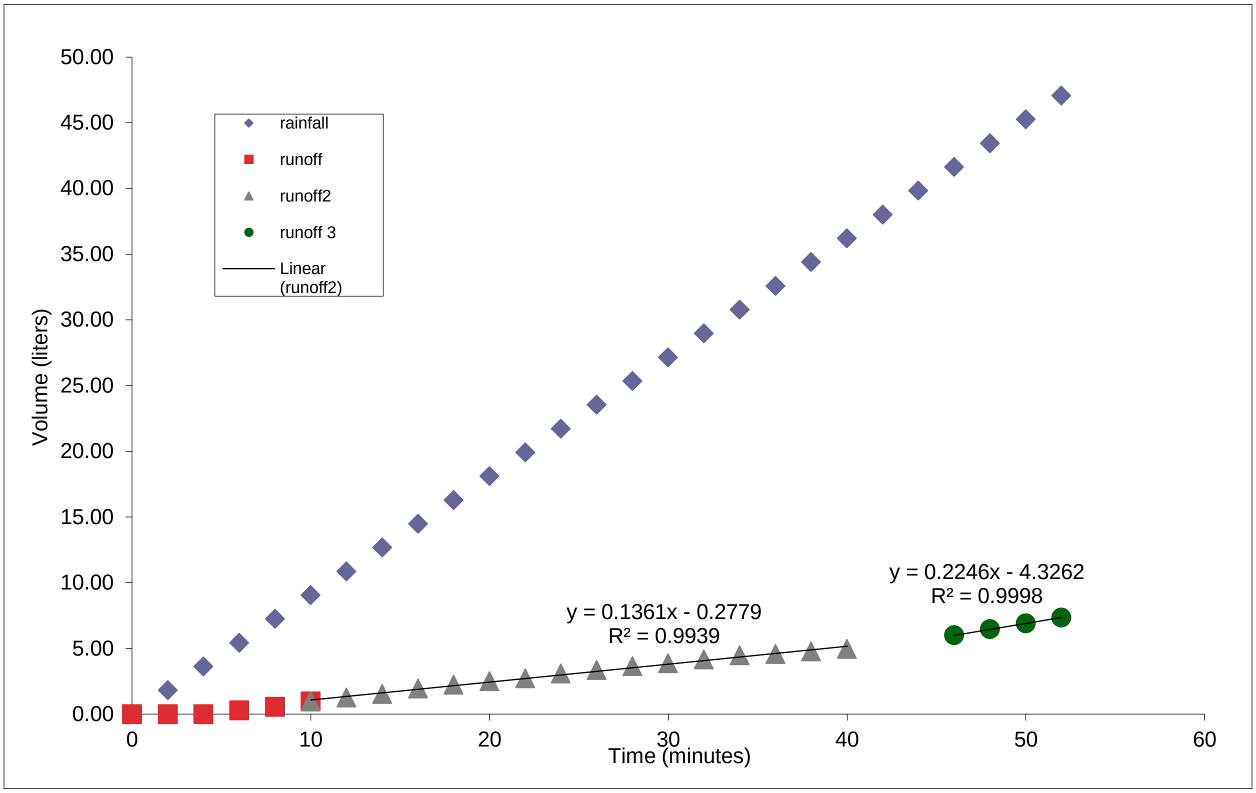
Calibration:

Time on	0.6	0.9
Time off	0.4	0.1
Volume 1	485 mL/30s	594 mL/30s
Volume 2	440 mL/30s	510 mL/30s
Volume 3	430 mL/30s	510 mL/30s
Volume 4	455 mL/30s	566 mL/30s
Volume 5		580 mL/30s

Slope corrected rainfall rate:	**2.37 in/hr**	**2.89 in/hr**
	0.91 L/min	1.10 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.00	
2	0	1.81	0.00	
4	0	3.62	0.00	
6	0.2	5.43	0.28	
8	0.4	7.24	0.55	
10	0.7	9.05	0.97	
12	0.9	10.86	1.25	
14	1.1	12.67	1.53	
16	1.4	14.48	1.95	
18	1.6	16.29	2.23	
20	1.8	18.10	2.51	
22	1.95	19.91	2.72	
24	2.2	21.72	3.08	
26	2.4	23.53	3.36	
28	2.6	25.34	3.65	
30	2.75	27.15	3.86	
32	2.95	28.96	4.15	
34	3.17	30.77	4.46	
36	3.25	32.58	4.58	
38	3.38	34.39	4.77	

40	3.52	36.20	4.97	41:30 stopped and switched to 9 on 1 off
42	3.65	38.01	5.16	
44	3.88	39.82	5.49	
46	4.23	41.63	6.00	
48	4.55	43.44	6.47	
50	4.85	45.25	6.91	
52	5.15	47.06	7.35	



Total Rain:	47.06 L	2.06 in
Total Runoff:	7.35 L	0.32 in
Runoff Ratio:	**0.1562**	

Rainfall Rate:	0.905 L/min	2.37 in/hr
Runoff Rate:	0.136 L/min	0.36 in/hr
Infiltration Rate:	0.769 L/min	**2.01 in/hr**

Rainfall Rate:	1.10 L/min	2.89 in/hr
Runoff Rate:	0.22 L/min	0.59 in/hr
Infiltration Rate:	0.88 L/min	**2.30 in/hr**

Results: Water mainly stays in the top 3cm of soil, however water did infiltrate deeper in many spots. Extremely slow runoff signifies likely not impacted by fire.

Site 8

Date and time: 09/10/2010 @ 10:30
Slope %: 47
Area m²: 0.905
Location: Lockheed above Boyer Creek.
Vegetation: Knobcone pine and manzanita.
Soils: Very rocky and soils are mudstone derived. Soil profile is A/Cr-very shallow soils.

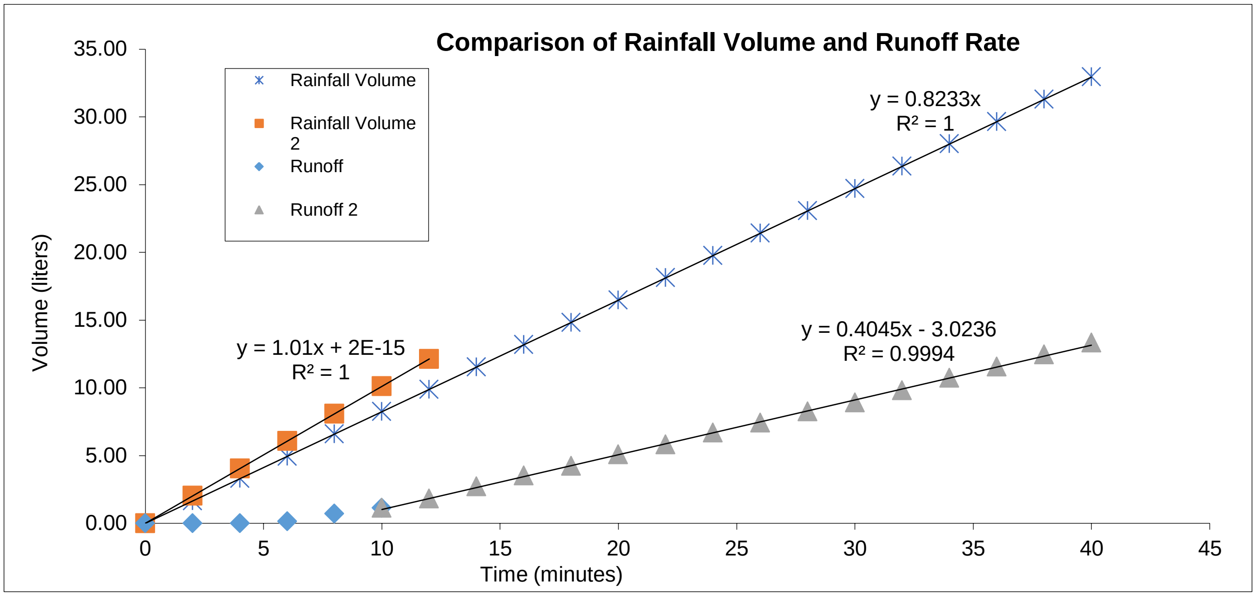
Calibration:

Time on	0.6	
Time off	0.4	
Volume 1	380 mL/30s	500 mL/30s
Volume 2	430 mL/30s	510 mL/30s
Volume 3	445 mL/30s	505 mL/30s
Volume 4	400 mL/30s	
Volume 5	405 mL/30s	

Slope corrected rainfall	**2.15 in/hr**	**2.64 in/hr**	**rate:**
	0.82 L/min	1.01 L/min	

time (min)	**Bucket Water Depth (in)**	**Rainfall Volume (L)**	**Runoff Volume (L)**	**Notes**
0	0	0.00	0.00	Start
2	0	1.65	0.00	
4	0	3.29	0.00	
6	0.1	4.94	0.14	
8	0.5	6.59	0.69	
10	0.82	8.23	1.14	
12	1.3	9.88	1.81	
14	1.94	11.53	2.71	
16	2.5	13.17	3.50	
18	3	14.82	4.22	
20	3.6	16.47	5.08	
22	4.1	18.11	5.81	
24	4.7	19.76	6.69	
26	5.2	21.41	7.42	
28	5.75	23.05	8.24	
30	6.2	24.70	8.91	
32	6.8	26.35	9.81	
34	7.4	27.99	10.72	
36	7.95	29.64	11.56	
38	8.53	31.29	12.45	
40	9.1	32.93	13.33	
0	0	0	0.00	

2	0.25	2.02	0.34	
4	0.6	4.04	0.83	
6	1.9	6.06	2.65	
8	2.7	8.08	3.79	
10	3.25	10.1	4.58	
12	3.7	12.12	5.23	



Total Rain:	32.93 L	1.43 in
Total Runoff:	13.33 L	0.58 in
Runoff Ratio:	**0.4049**	

Rainfall Rate:	0.823 L/min	2.15 in/hr
Runoff Rate:	0.405 L/min	1.06 in/hr
Infiltration Rate:	0.419 L/min	**1.09 in/hr**

Results: After both trials only the top 1.0 cm of soil was wet. No evidence was found of water escaping through macropores.

Site 9

Date and time: 10/09/2010
Slope %: 60
Area m^2: 0.857
Location: Lockheed ridge on top of Mill Creek and Boyer Creek watersheds on Boyer Creek side. Unburned control site. Near rectangular fenced area.
Vegetation: Manzanita, Knobcone pine, Doug-fir, oak, (chaparral)
Soils: mudstone/sandstone, possibly at contact of two parent materials. Sandy loam soil.

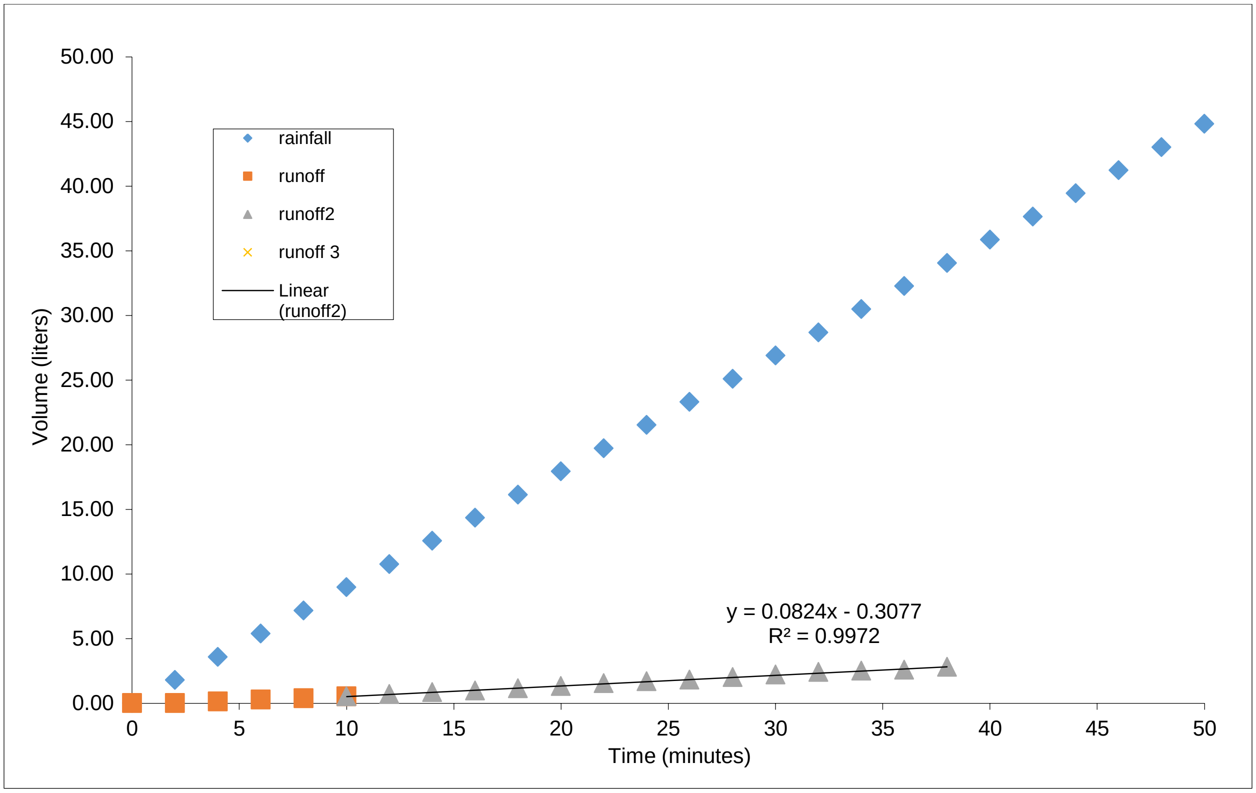
Calibration:

Time on	0.8
Time off	0.2
Volume 1	440 mL/30s
Volume 2	470 mL/30s
Volume 3	460 mL/30s
Volume 4	445 mL/30s
Volume 5	425 mL/30s
Volume 6	448 mL/30s

Slope corrected rainfall rate: **2.47 in/hr** 0.90 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0	0.00	0.00	
2	0	1.79	0.00	
4	0.1	3.58	0.14	
6	0.2	5.38	0.28	
8	0.28	7.17	0.39	
10	0.38	8.96	0.52	
12	0.5	10.75	0.69	
14	0.61	12.54	0.84	
16	0.7	14.34	0.97	
18	0.82	16.13	1.14	
20	0.95	17.92	1.32	
22	1.11	19.71	1.54	
24	1.22	21.50	1.69	
26	1.31	23.30	1.82	
28	1.45	25.09	2.02	
30	1.58	26.88	2.20	
32	1.73	28.67	2.41	
34	1.79	30.46	2.50	
36	1.85	32.26	2.58	
38	2	34.05	2.79	

40	2.1	35.84	2.93	
42	2.23	37.63	3.12	
44	2.39	39.42	3.35	
46	2.52	41.22	3.53	
48	2.68	43.01	3.76	
50	2.81	44.80	3.95	



Total Rain:	44.80 L	2.06 in
Total Runoff:	3.95 L	0.18 in
Runoff Ratio:	**0.0881**	

Rainfall Rate:	0.896 L/min	2.47 in/hr
Runoff Rate:	0.082 L/min	0.23 in/hr
Infiltration Rate:	0.814 L/min	**2.24 in/hr**

Results: The water stayed almost entirely in the top centimeter of soil. The material was very organic with a high occurrence of rootballs and mycorrhizal visible to naked eye. The oil becomes highly rocky at a depth of 4 in. All moisture found remained in duff layer. Some saturated spots got to about 3 in of moisture depth.

Site 10

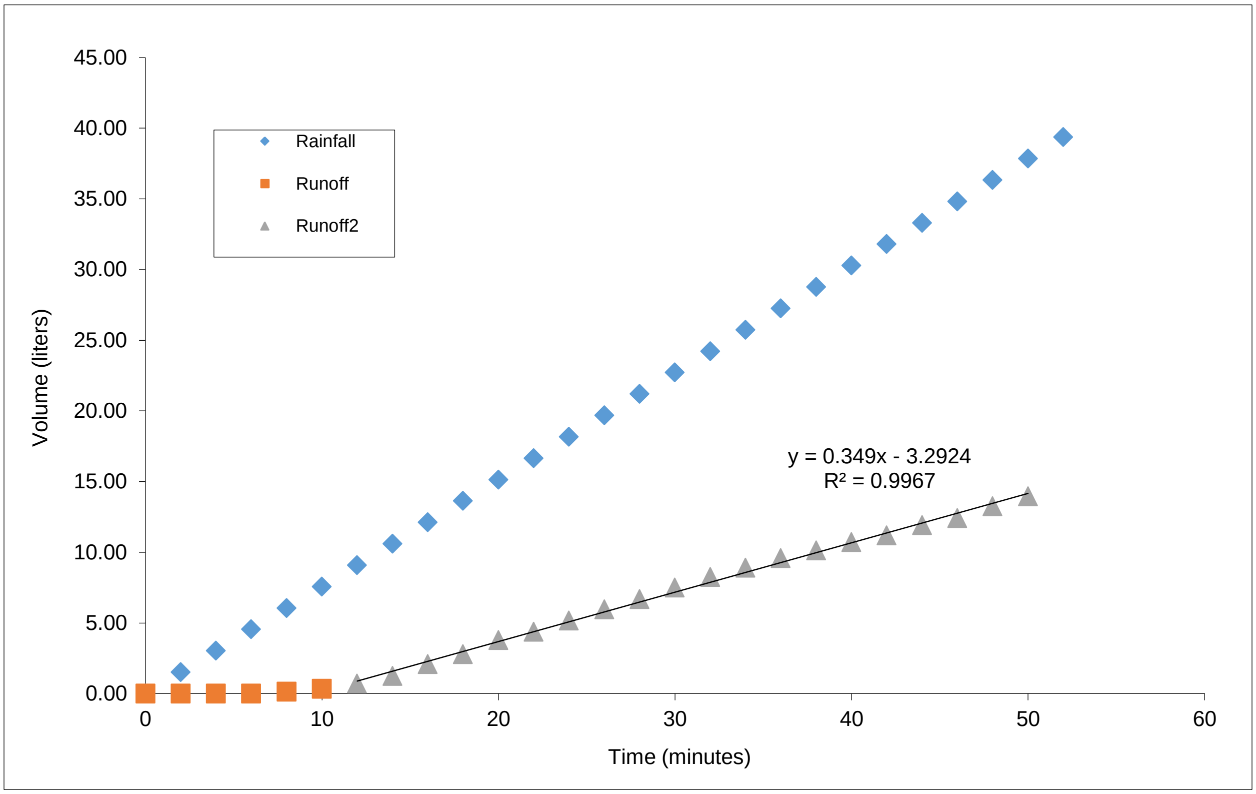
Date and time: 9/13/2010 @ 14:01
Slope %: 45
Area m^2: 0.912
Location: Mill Creek and Upper Scotts ridge on Mill Creek side. Lockheed or State Parks property. High burn intensity
Vegetation: Chaparral: Knobcone pine, manzanita, scrub oak.
Soils: shallow, mudstone, very little leaf litter, majority of surface is rock fragment.

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	430 mL/30s
Volume 2	430 mL/30s
Volume 3	385 mL/30s
Volume 4	430 mL/30s

Slope corrected rainfall	**1.96 in/hr**	**3.32 in/hr**	**rate:**
	0.76 L/min	1.28 L/min	

time (min)	**Bucket Water Depth (in)**	**Rainfall Volume (L)**	**Runoff Volume (L)**	**Notes**
0	0	0.00	0.00	start 6on/4off
2	0	1.51	0.00	
4	0	3.03	0.00	
6	0	4.54	0.00	
8	0.1	6.06	0.14	
10	0.25	7.57	0.34	
12	0.5	9.08	0.69	
14	0.9	10.60	1.25	
16	1.5	12.11	2.09	
18	2	13.62	2.79	
20	2.7	15.14	3.79	
22	3.1	16.65	4.36	
24	3.65	18.17	5.16	
26	4.2	19.68	5.95	
28	4.7	21.19	6.69	
30	5.25	22.71	7.50	runoff rate 185ml/30s
32	5.75	24.22	8.24	
34	6.2	25.73	8.91	
36	6.65	27.25	9.59	
38	7	28.76	10.11	
40	7.4	30.28	10.72	
42	7.7	31.79	11.18	
44	8.18	33.30	11.91	

46	8.5	34.82	12.41	
48	9.05	36.33	13.26	
50	9.5	37.84	13.96	turned off
52	9.7	39.36	14.27	
54				
56	0	42.39	0.00	9 on 1 off
58	0.7	43.90	0.97	
60	1.65	45.41	2.30	
62	2.7	46.93	3.79	
64	3.65	48.44	5.16	
66	4.65	49.96	6.61	
68	5.3	51.47	7.57	



Total Rain:	51.47 L	2.22 in
Total Runoff:	14.27 L	0.62 in
Runoff Ratio:	**0.2773**	

Rainfall Rate:	0.760 L/min	1.96 in/hr
Runoff Rate:	0.349 L/min	0.82 in/hr
Infiltration Rate:	0.411 L/min	**1.14 in/hr**

Results: Top inch of soil very wet. No signs of surface erosion (rills, pedestals, etc.). Some evidence of deeper wetting from macropores but no more than 2in in depth. Most runoff from surface and top inch. Some leakage at attachment board.

Site 11

Date and time: 9/13/2010 @ 10:45
Slope %: 40
Area m^2: 0.928
Location: Mill Creek and Upper Scotts Creek ridge on Scotts side. Lockheed property. Control site - unburned.
Vegetation: Chaparral: knobcone pine, manzanita, oak.
Soils: Mudstone, silty clay loam. Initially slightly moist.

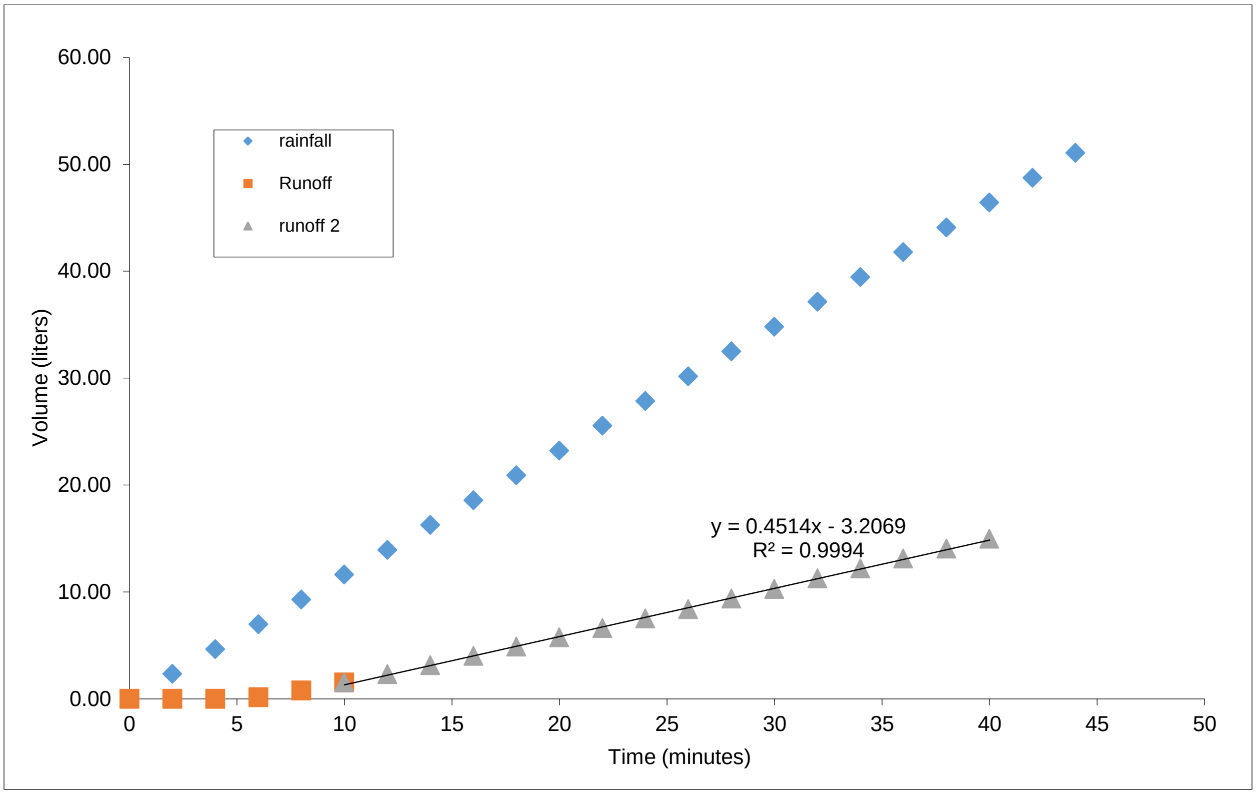
Calibration:

Time on	6	8
Time off	4	2
Volume 1	425 mL/30s	570 mL/30s
Volume 2	420 mL/30s	600 mL/30s
Volume 3	415 mL/30s	570 mL/30s

Slope corrected rainfall	**2.14 in/hr**	**2.95 in/hr**	**rate:**
	0.84 L/min	1.16 L/min	

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	start @ 1:05 6on 4 off
2	0.00	2.32	0.00	
4	0.00	4.64	0.00	4:30 runoff starts
6	0.10	6.96	0.14	
8	0.55	9.28	0.76	
10	1.10	11.60	1.53	
12	1.65	13.92	2.30	
14	2.25	16.24	3.15	runoff rate 220ml/30s
16	2.85	18.56	4.00	
18	3.45	20.88	4.87	
20	4.05	23.20	5.74	
22	4.65	25.52	6.61	
24	5.25	27.84	7.50	
26	5.85	30.16	8.39	
28	6.5	32.48	9.36	
30	7.1	34.80	10.27	
32	7.75	37.12	11.26	
34	8.35	39.44	12.18	
36	8.95	41.76	13.10	
38	9.55	44.08	14.04	
40	10.15	46.40	14.98	turned off
42	10.5	48.72	15.53	
44	10.75	51.04	15.93	

48	0	55.68	0.00	8on 2off=3.0 in/hr
50	0	58.00	0.00	
52	0.7	60.32	0.97	
54	1.4	62.64	1.95	
56	2.25	64.96	3.15	
58	3.1	67.28	4.36	
60	3.9	69.60	5.52	
62	4.75	71.92	6.76	
64	5.55	74.24	7.94	
66	6.4	76.56	9.21	
68	7.2	78.88	10.42	
70	7.9	81.20	11.48	turned off
72	8.3	83.52	12.10	
74	8.45	85.84	12.33	



Total Rain:	85.84 L	3.64 in
Total Runoff:	15.93 L	0.68 in
Runoff Ratio:	**0.1855**	

Rainfall Rate:	0.840 L/min	2.95 in/hr
Runoff Rate:	0.451 L/min	1.15 in/hr
Infiltration Rate:	0.389 L/min	**1.80 in/hr**

Results: Top inch of soil wet, below 1 in very dry. Large rock fragments in soil, platey, some areas most under 1in but no more than 2in in depth. Lots of surface runoff observed, but not rills or pedestals.

Site 12

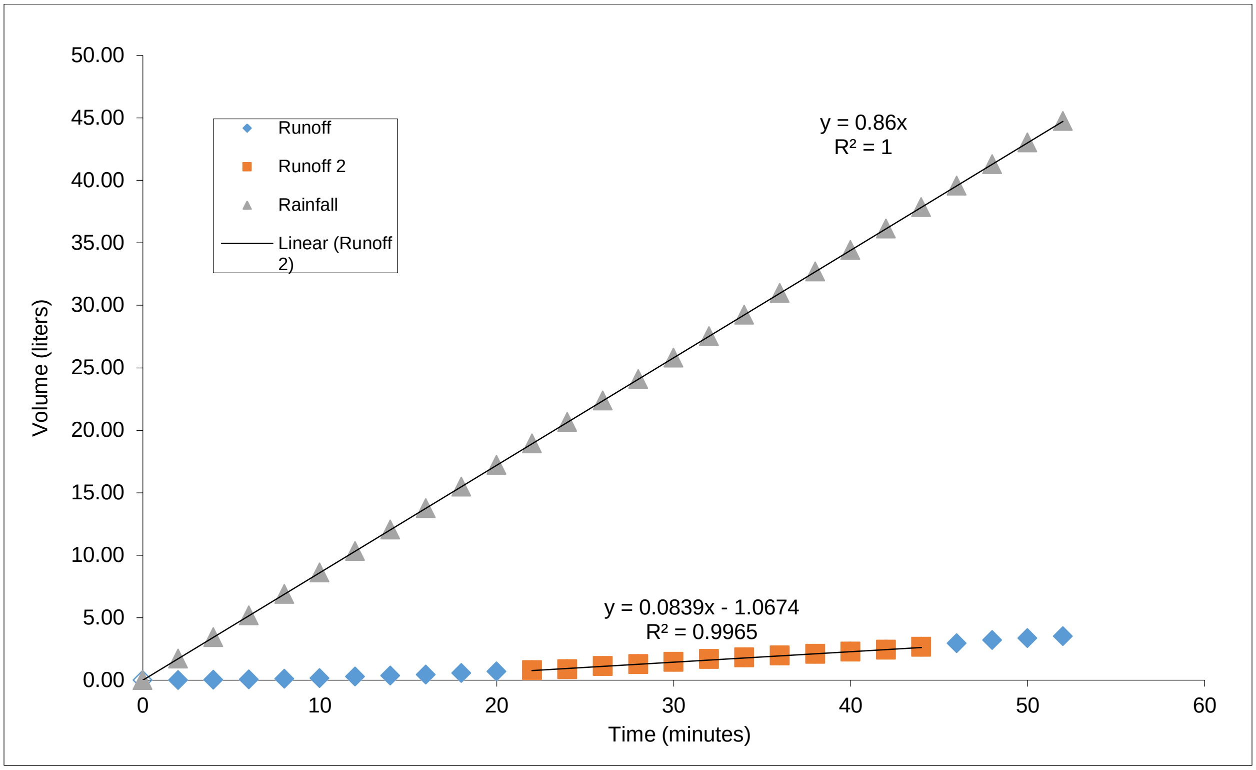
Date and time: 09/14/2010
Slope %: 38
Area m^2: 0.935
Location: Upper Boyer Creek, unburned
Vegetation: Tan Oak and madrone dominated leaf litter, redwood also nearby.
Soils: Granitic parent material 8% caly high silt content. 3cm duff layer, variable sub-angular blocky and massive.

Calibration:	
Time on	0.6
Time off	0.3
Volume 1	425 mL/30s
Volume 2	435 mL/30s
Volume 3	430 mL/30s

Slope corrected rainfall **2.17 in/hr** **rate:**
0.86 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	.3 off .6 on
2	0.00	1.72	0.00	
4	0.02	3.44	0.03	
6	0.04	5.16	0.06	
8	0.08	6.88	0.11	
10	0.10	8.60	0.14	
12	0.21	10.32	0.29	
14	0.25	12.04	0.34	
16	0.32	13.76	0.44	
18	0.40	15.48	0.55	
20	0.50	17.20	0.69	
22	0.58	18.92	0.80	
24	0.63	20.64	0.87	
26	0.81	22.36	1.12	
28	0.93	24.08	1.29	
30	1.05	25.80	1.46	
32	1.21	27.52	1.68	
34	1.3	29.24	1.81	
36	1.41	30.96	1.96	
38	1.5	32.68	2.09	
40	1.63	34.40	2.27	
42	1.74	36.12	2.43	Jack removed 0.3475 const in col G from here down
44	1.9	37.84	2.65	
46	2.1	39.56	2.93	

48	2.29	41.28	3.20	
50	2.4	43.00	3.36	turned off
52	2.5	44.72	3.50	



Total Rain:	44.72 L	1.88 in
Total Runoff:	3.50 L	0.15 in
Runoff Ratio:	**0.0783**	

Rainfall Rate:	0.860 L/min	2.17 in/hr
Runoff Rate:	0.084 L/min	0.21 in/hr
Infiltration Rate:	0.776 L/min	**1.96 in/hr**

Results: Water infiltrated in most places to about 6in of depth. Runoff extremely slow.

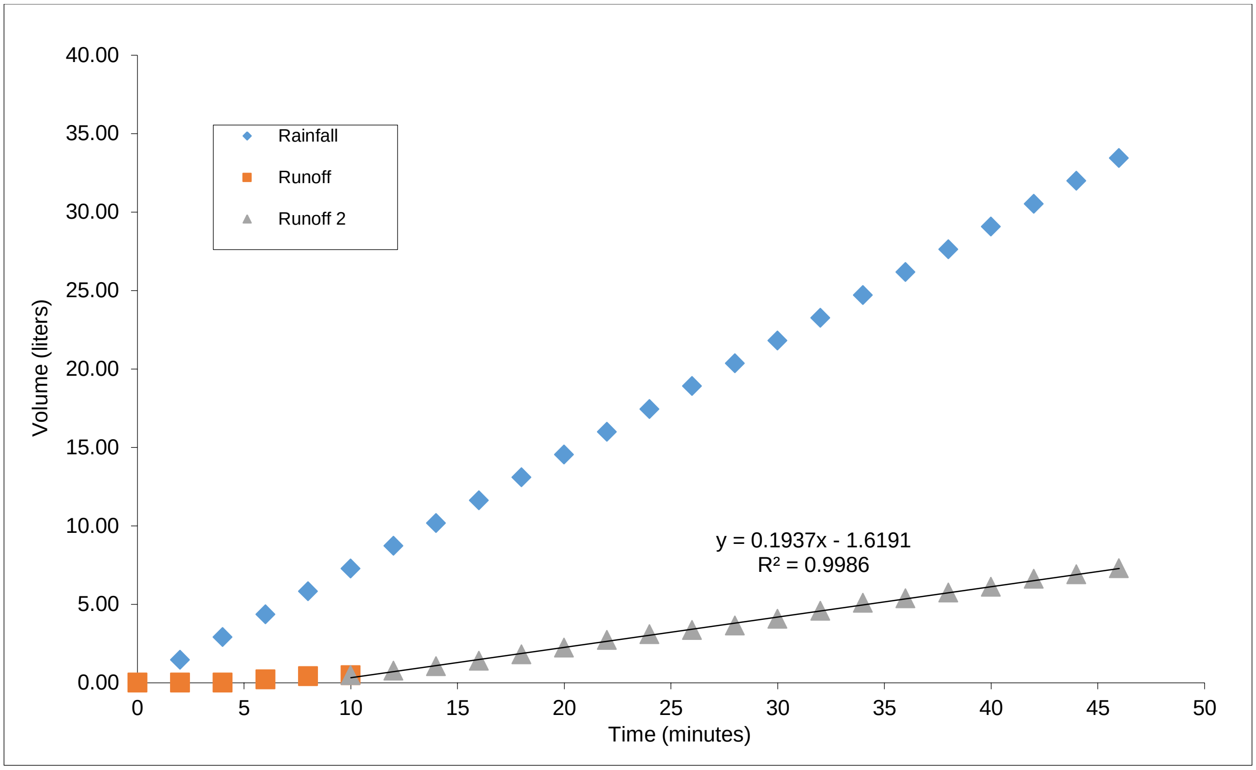
Site 13

Date and time: 9/15/2010
Slope %: 65
Area m²: 0.838
Location: South fork ridge on Lions Flat Road. 100 feet from property line.
Vegetation: Tan oak, Doug Fir, Scrub Oak
Soils: Mudstone parent material 8%clay high silt content. Very ashy in this area. Soil was likely burnt at very hot temp. Very rocky mudstone colluvium mixed in with duff layer.

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	365 mL/30s
Volume 2	365 mL/30s
Volume 3	360 mL/30s

Slope corrected rainfall rate: **2.05 in/hr**
0.73 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.45	0.00	
4	0.00	2.91	0.00	
6	0.15	4.36	0.21	
8	0.30	5.81	0.41	
10	0.35	7.27	0.48	
12	0.55	8.72	0.76	
14	0.75	10.17	1.04	
16	1.00	11.63	1.39	
18	1.30	13.08	1.81	
20	1.60	14.53	2.23	
22	1.95	15.99	2.72	
24	2.20	17.44	3.08	
26	2.40	18.89	3.36	
28	2.6	20.35	3.65	
30	2.9	21.80	4.07	
32	3.25	23.25	4.58	
34	3.6	24.71	5.08	
36	3.8	26.16	5.37	
38	4.05	27.61	5.74	
40	4.3	29.07	6.10	
42	4.65	30.52	6.61	
44	4.85	31.97	6.91	
46	5.11	33.43	7.29	



Total Rain:	33.43 L	1.57 in
Total Runoff:	7.29 L	0.34 in
Runoff Ratio:	**0.2181**	

Rainfall Rate:	0.727 L/min	2.05 in/hr
Runoff Rate:	0.194 L/min	0.55 in/hr
Infiltration Rate:	0.533 L/min	**1.50 in/hr**

Results: Water stayed mainly in the top 1.5cm of soil. The top layer was very high in organic matter and contained a lot of pine needles. The soil is very ashy beneath the top two centimeters. In some places this ash absorbed a large amount of water. Other places remained dry.

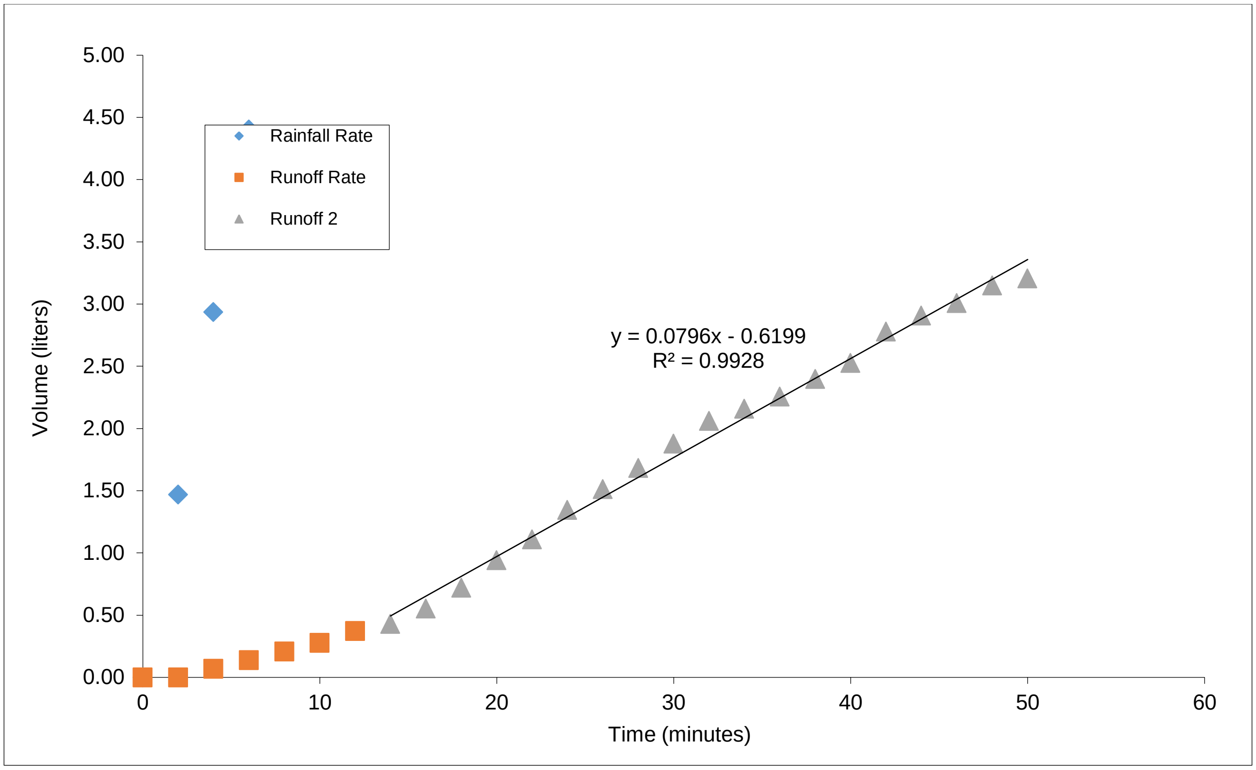
Site 14

Date: 9/8/2010
Slope %: 72
Area m²: 0.812
Location: Hillslope erosion site.
Vegetation: Redwood, Douglas fir, bay laurel.
Soils: Mudstone derived soils.

Calibration:	
Time on	0.7
Time off	0.3
Volume 1	410 mL/30s
Volume 2	350 mL/30s
Volume 3	390 mL/30s
Volume 4	360 mL/30s
Volume 5	335 mL/30s

Slope corrected rainfall rate: **2.13 in/hr**
0.73 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.47	0.00	
4	0.05	2.93	0.07	
6	0.10	4.40	0.14	
8	0.15	5.87	0.21	
10	0.20	7.33	0.28	
12	0.27	8.80	0.37	
14	0.31	10.27	0.43	
16	0.40	11.73	0.55	
18	0.52	13.20	0.72	
20	0.68	14.67	0.94	
22	0.80	16.13	1.11	
24	0.97	17.60	1.34	
26	1.09	19.07	1.51	
28	1.21	20.53	1.68	
30	1.35	22.00	1.88	
32	1.48	23.47	2.06	
34	1.55	24.93	2.16	
36	1.62	26.40	2.26	
38	1.72	27.87	2.40	
40	1.81	29.33	2.52	
42	1.99	30.80	2.78	
44	2.08	32.27	2.91	
46	2.15	33.73	3.01	
48	2.25	35.20	3.15	
50	2.29	36.67	3.20	



Total Rain:	36.67 L	1.78 in
Total Runoff:	3.20 L	0.16 in
Runoff Ratio:	**0.0874**	

Rainfall Rate:	0.733 L/min	2.13 in/hr
Runoff Rate:	0.080 L/min	0.23 in/hr
Infiltration Rate:	0.654 L/min	**1.90 in/hr**

Results: No results documented in the field notebook.

Site 15

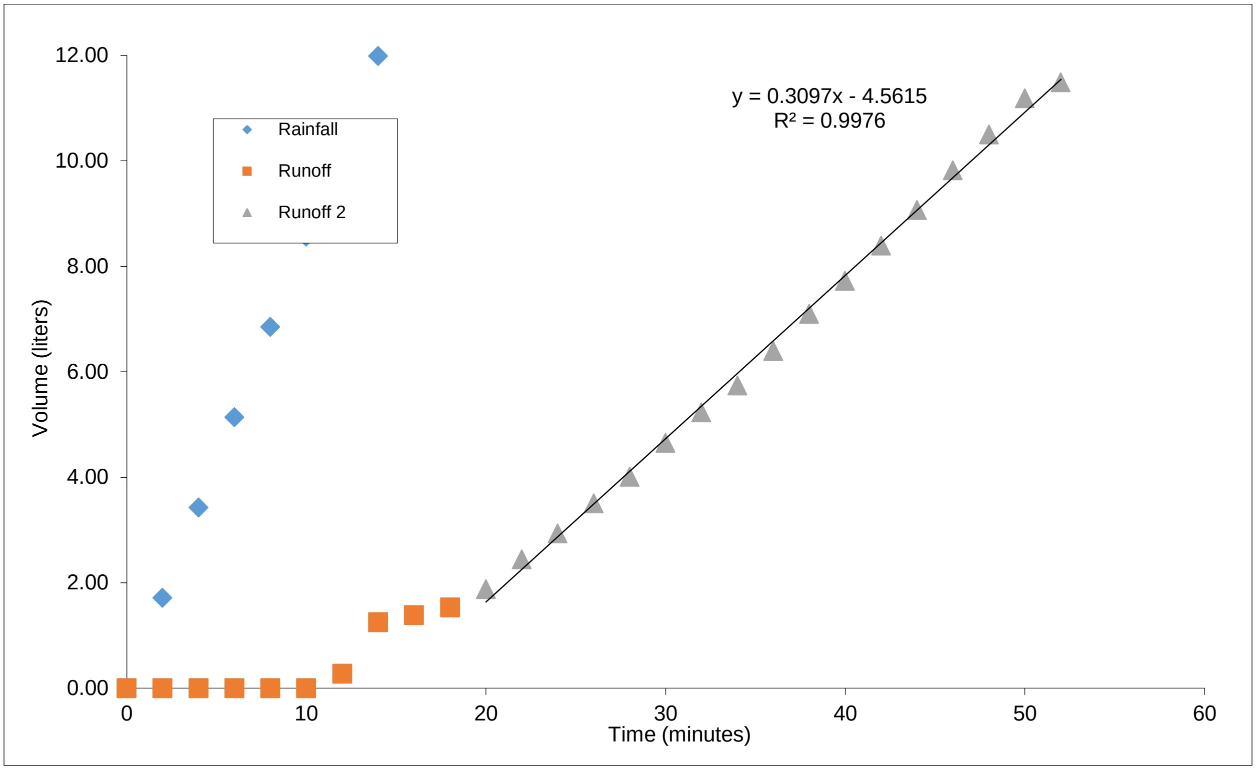
Date: 9/14/2010
Slope %: 38
Area m^2: 0.935
Location: Mill/Boyer Creek Ridgeline. Very high burn severity site.
Vegetation: Knobcone pine, manzanita on ground along w/ deerweed
Soils: Mudstone derived soils.

Calibration:	
Time on	7
Time off	3
Volume 1	405 mL/30s
Volume 2	445 mL/30s
Volume 3	430 mL/30s
Volume 4	450 mL/30s
Volume 5	410 mL/30s

Slope corrected rainfall **2.16 in/hr** **rate:**
0.86 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.71	0.00	
4	0.00	3.42	0.00	
6	0.00	5.14	0.00	
8	0.00	6.85	0.00	
10	0.00	8.56	0.00	
12	0.20	10.27	0.28	
14	0.90	11.98	1.25	
16	1.00	13.70	1.39	
18	1.10	15.41	1.53	
20	1.35	17.12	1.88	
22	1.75	18.83	2.44	
24	2.10	20.54	2.93	
26	2.50	22.26	3.50	
28	2.85	23.97	4.00	
30	3.3	25.68	4.65	
32	3.7	27.39	5.23	
34	4.05	29.10	5.74	
36	4.5	30.82	6.39	
38	4.98	32.53	7.10	
40	5.4	34.24	7.72	
42	5.85	35.95	8.39	
44	6.3	37.66	9.06	
46	6.8	39.38	9.81	
48	7.25	41.09	10.49	
50	7.7	42.80	11.18	

52	7.9	44.51	11.48	



Total Rain:	44.51 L	1.87 in
Total Runoff:	11.48 L	0.48 in
Runoff Ratio:	**0.2580**	

Rainfall Rate:	0.856 L/min	2.16 in/hr
Runoff Rate:	0.310 L/min	0.78 in/hr
Infiltration Rate:	0.546 L/min	**1.38 in/hr**

Results: Very rocky mudstone dominated soil. The water mainly stayed within the top 1cm of soil, however there were macropores wetting approximately 10% of the plot to about 5cm of depth.

2011

<u>Site 2</u>

Date and time: 07/13/2011 @13:52
Slope %: 60
Area m²: 0.857
Location: Upper Swanton Road, non-burned area. Semi-clear and windy weather. East/Southeast aspect.
Vegetation: Redwood understory, no vegetation on plot, 2-3 inches of duff.
Soils: Soils not described in the field book.

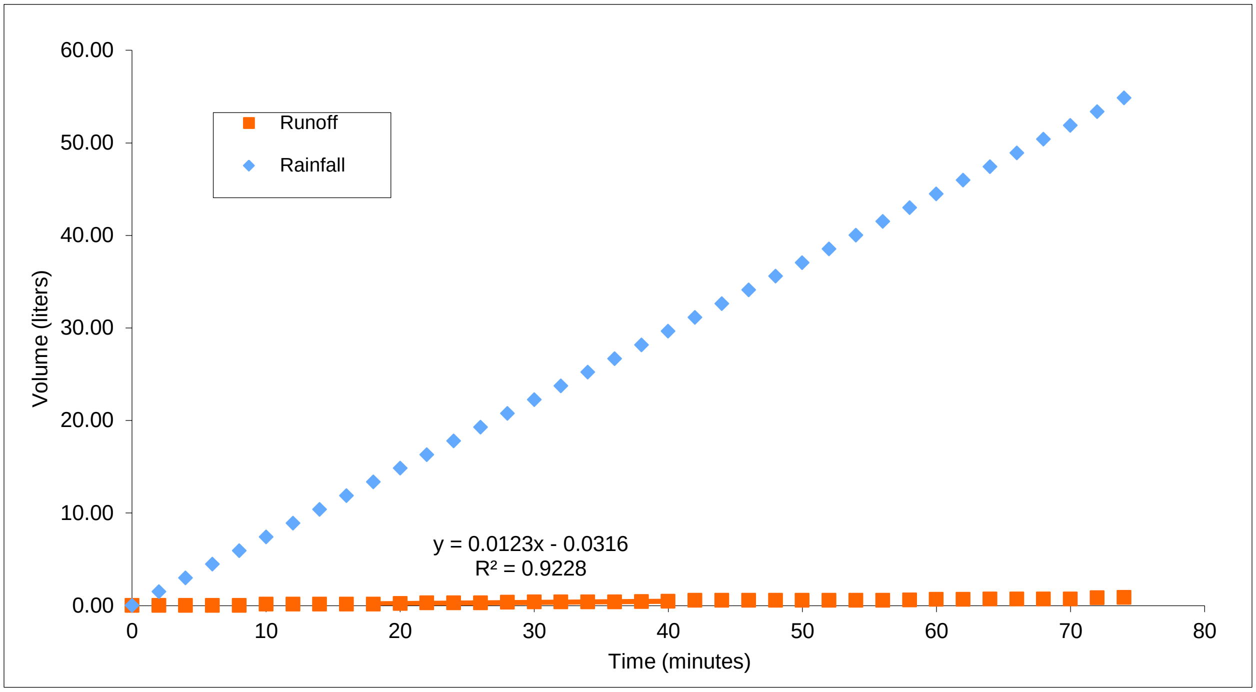
Calibration:

Time on	
Time off	
Volume 1	350 mL/30s
Volume 2	363 mL/30s
Volume 3	375 mL/30s
Volume 4	390 mL/30s
Volume 5	375 mL/30s
Volume 6	370 mL/30s

Slope corrected rainfall rate: **2.04 in/hr**
0.74 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.48	0.00	
4	0.00	2.96	0.00	
6	0.00	4.45	0.00	Slow drips begin
8	0.00	5.93	0.00	
10	0.10	7.41	0.14	
12	0.10	8.89	0.14	
14	0.10	10.37	0.14	
16	0.10	11.86	0.14	
18	0.10	13.34	0.14	
20	0.15	14.82	0.21	
22	0.20	16.30	0.28	
24	0.20	17.78	0.28	
26	0.20	19.27	0.28	
28	0.24	20.75	0.33	
30	0.27	22.23	0.37	
32	0.27	23.71	0.37	
34	0.28	25.19	0.39	
36	0.28	26.68	0.39	
38	0.3	28.16	0.41	

40	0.33	29.64	0.46	
42	0.4	31.12	0.55	
44	0.4	32.60	0.55	
46	0.4	34.09	0.55	
48	0.4	35.57	0.55	
50	0.4	37.05	0.55	
52	0.4	38.53	0.55	
54	0.41	40.01	0.57	
56	0.41	41.50	0.57	
58	0.43	42.98	0.59	
60	0.48	44.46	0.66	
62	0.48	45.94	0.66	
64	0.49	47.42	0.68	
66	0.49	48.91	0.68	
68	0.5	50.39	0.69	Stopped simulation
70	0.5	51.87	0.69	
72	0.6	53.35	0.83	
74	0.62	54.83	0.86	



Total Rain:	54.834	2.518
Total Runoff:	0.857	0.039
Runoff Ratio:		**0.016**

Rainfall Rate:	0.741	2.041
Runoff Rate:	0.012	0.034
Infiltration Rate:	0.729	**2.007**

Results: Not much runoff due to the duff. Slow, steady drip throughout most of the simulation. 1 mL of runoff occurred after the simulation.

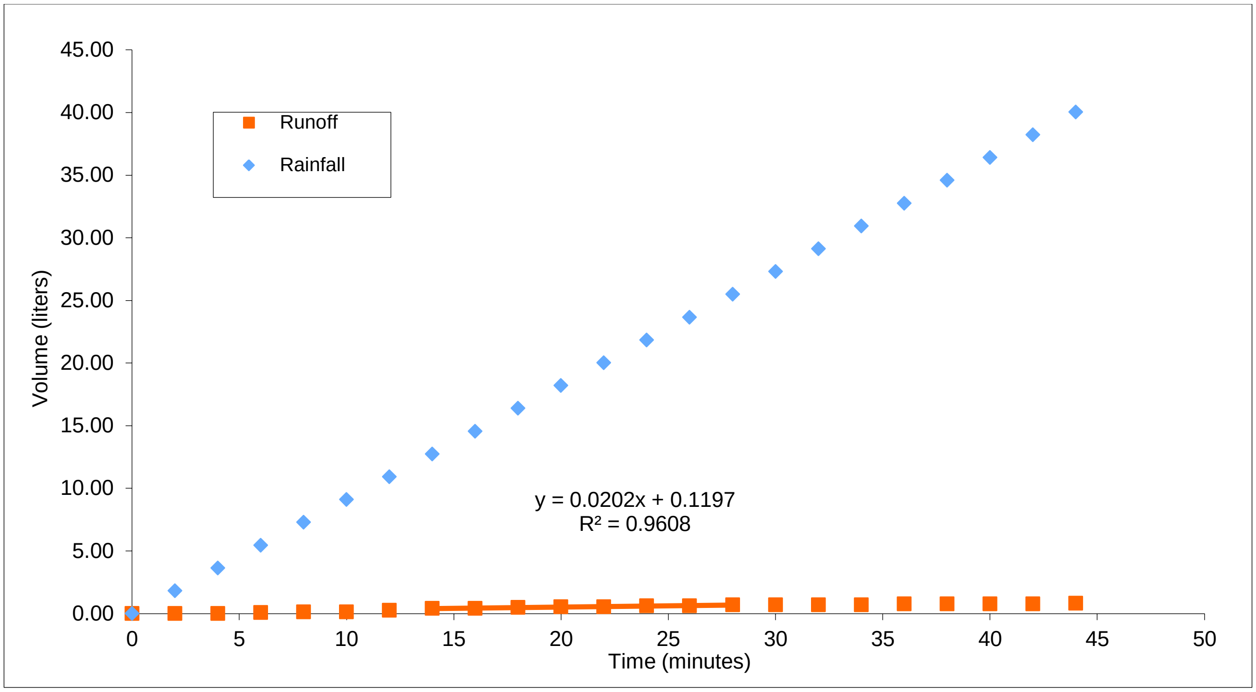
Site 4

Date and time: 07/06/2011 @ 15:21
Slope %: 65
Area m^2: 0.838
Location: L.C. Control. Weather is sunny and there is a slight breeze present. Southeast aspect.
Vegetation: No vegetation was recorded in the field book.
Soils: Soil characteristics not recorded in the field book.

Calibration:	
Time on	
Time off	
Volume 1	455 mL/30s

Slope corrected rainfall rate: **2.56 in/hr**
0.91 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.82	0.00	
4	0.00	3.64	0.00	
6	0.05	5.46	0.07	
8	0.10	7.28	0.14	
10	0.10	9.10	0.14	
12	0.18	10.92	0.25	
14	0.30	12.74	0.41	
16	0.30	14.56	0.41	
18	0.35	16.38	0.48	
20	0.40	18.20	0.55	
22	0.40	20.02	0.55	
24	0.45	21.84	0.62	
26	0.45	23.66	0.62	
28	0.5	25.48	0.69	
30	0.5	27.30	0.69	
32	0.5	29.12	0.69	
34	0.5	30.94	0.69	
36	0.55	32.76	0.76	
38	0.55	34.58	0.76	
40	0.55	36.40	0.76	
42	0.55	38.22	0.76	Stopped
44	0.6	40.04	0.83	



Total Rain:	40.04 L	1.88 in
Total Runoff:	0.83 L	0.04 in
Runoff Ratio:	**0.0207**	

Rainfall Rate:	0.910 L/min	2.56 in/hr
Runoff Rate:	0.020 L/min	0.06 in/hr
Infiltration Rate:	0.890 L/min	**2.51 in/hr**

Results: Some technical difficulties arose between 0-6 minutes. Forgot to cover the back with plastic.

Site 5

Date and time: 07/06/2011 @ 11:45
Slope %: 47
Area m^2: 0.905
Location: Cabins, there was a yellow jackets nest so moved 50 yards up the road. Sunny and slight breeze present.
Vegetation: No vegetation recorded in field book.
Soils: No soil characteristics recorded in field book.

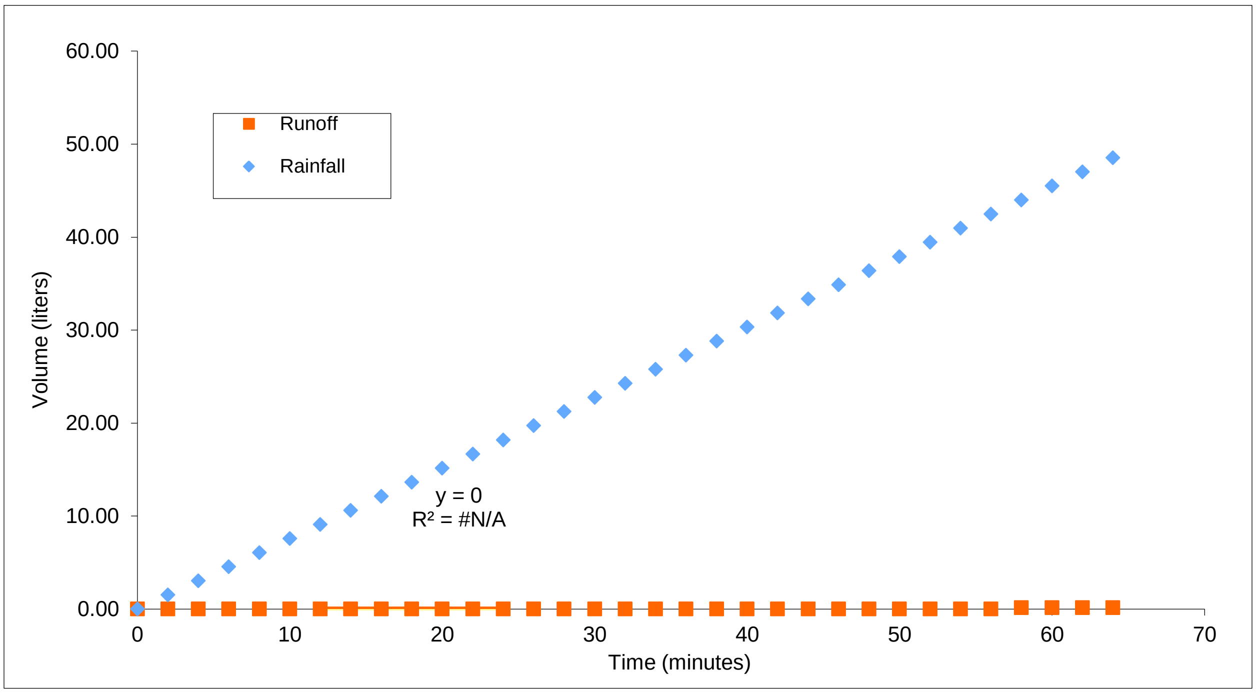
Calibration:

Time on	0.6
Time off	0.4
Volume 1	345 mL/30s
Volume 2	400 mL/30s
Volume 3	385 mL/30s
Volume 4	360 mL/30s
Volume 5	390 mL/30s
Volume 6	395 mL/30s

Slope corrected rainfall rate: **1.98 in/hr**
0.76 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.52	0.00	dripping slowly
4	0.00	3.03	0.00	
6	0.00	4.55	0.00	
8	0.00	6.07	0.00	Drips slowed down
10	0.00	7.58	0.00	
12	0.00	9.10	0.00	
14	0.00	10.62	0.00	Drips about every 1 Minute
16	0.00	12.13	0.00	
18	0.00	13.65	0.00	
20	0.00	15.17	0.00	
22	0.00	16.68	0.00	
24	0.00	18.20	0.00	
26	0.00	19.72	0.00	
28	0.00	21.23	0.00	
30	0.00	22.75	0.00	
32	0.00	24.27	0.00	
34	0.00	25.78	0.00	
36	0.00	27.30	0.00	
38	0.00	28.82	0.00	No drips
40	0.00	30.33	0.00	

42	0.00	31.85	0.00	Jack removed 0.3475 const from col G from here down
44	0.00	33.37	0.00	
46	0.00	34.88	0.00	
48	0.00	36.40	0.00	
50	0.00	37.92	0.00	
52	0.00	39.43	0.00	
54	0.00	40.95	0.00	
56	0.00	42.47	0.00	Steady dripping begins
58	0.10	43.98	0.14	
60	0.10	45.50	0.14	Stopped
62	0.10	47.02	0.14	
64	0.10	48.53	0.14	Dripping stopped



Total Rain:	48.53 L	2.11 in
Total Runoff:	0.14 L	0.01 in
Runoff Ratio:	**0.0028**	

Rainfall Rate:	0.758 L/min	1.98 in/hr
Runoff Rate:	0.000 L/min	0.00 in/hr
Infiltration Rate:	0.758 L/min	**1.98 in/hr**

Results: Little to no runoff. Duff and soil seem to be infiltrating all rainfall.

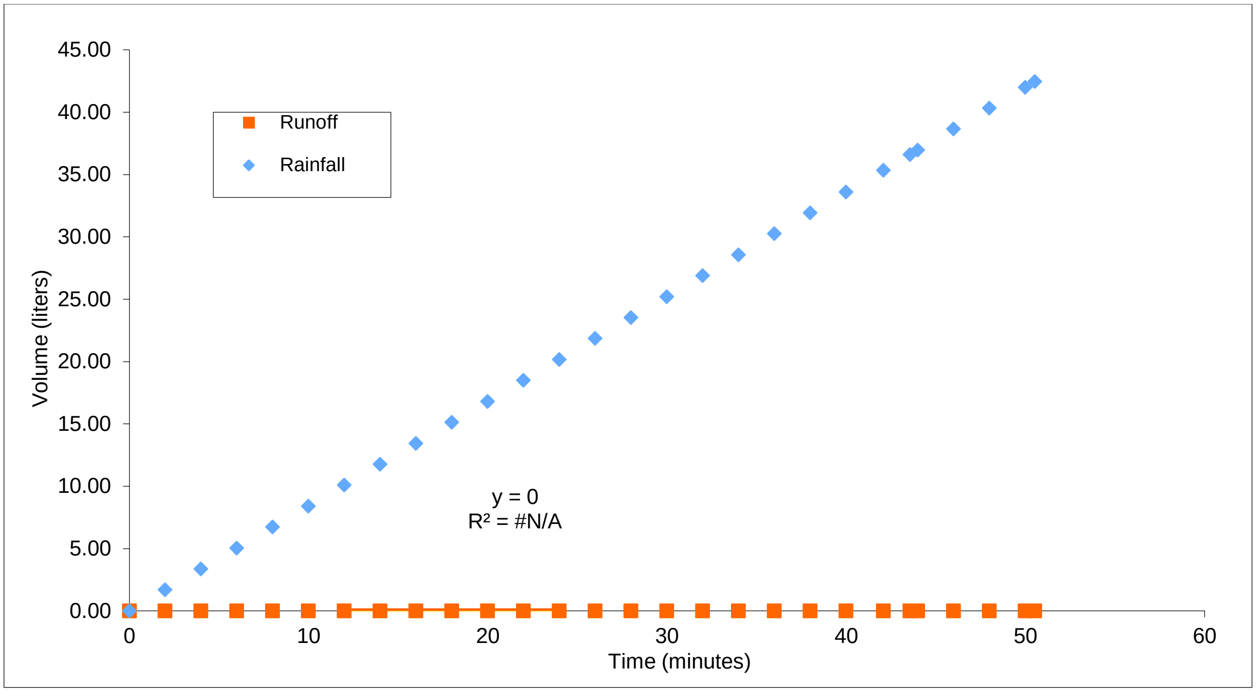
Site 6

Date and time: 7/5/2011 @ 15:00
Slope %: 40
Area m^2: 0.928
Location: Upper North Fork of the Little Creek Watershed.
Vegetation: tanoak, ferns, Doug firs, and forested slope. Slope is burned. Redwood sorrel inside plot and there is a thick duff and leaf litter layer
Soils: Soil is moist, granite parent material.

Calibration:	
Time on	
Time off	
Volume 1	420 mL/30s

Slope corrected rainfall rate: **2.14 in/hr**
0.84 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.68	0.00	
4	0.00	3.36	0.00	
6	0.00	5.04	0.00	
8	0.00	6.72	0.00	
10	0.00	8.40	0.00	
12	0.00	10.08	0.00	
14	0.00	11.76	0.00	
16	0.00	13.44	0.00	
18	0.00	15.12	0.00	
20	0.00	16.80	0.00	
22	0.00	18.48	0.00	
24	0.00	20.16	0.00	
26	0.00	21.84	0.00	
28	0.00	23.52	0.00	
30	0.00	25.20	0.00	
32	0.00	26.88	0.00	
34	0.00	28.56	0.00	
36	0.00	30.24	0.00	
38	0.00	31.92	0.00	
40	0.00	33.60	0.00	
42.08	0.00	35.35	0.00	Stopped to remove duff
43.56	0.00	36.59	0.00	Started up again
44	0.00	36.96	0.00	
46	0.00	38.64	0.00	
48	0.00	40.32	0.00	
50	0.00	42.00	0.00	
50.53	0.00	42.45	0.00	Stopped



Total Rain:	42.45 L	1.80 in
Total Runoff:	0.00 L	0.00 in
Runoff Ratio:	**0.0000**	

Rainfall Rate:	0.840 L/min	2.14 in/hr
Runoff Rate:	0.000 L/min	0.00 in/hr
Infiltration Rate:	0.840 L/min	**2.14 in/hr**

Results: Little runoff with and without leaf litter. Duff and soil seem to be infiltrating all rainfall.

Site 7

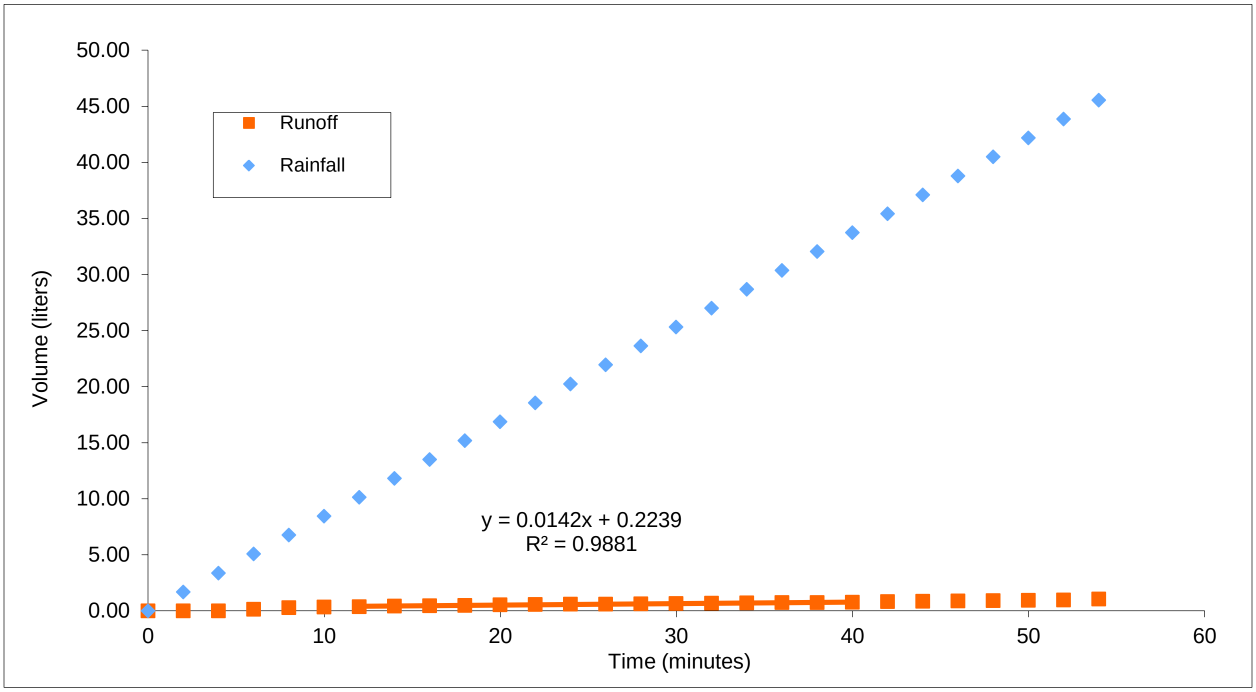
Date and time: 07/11/2011 @ 15:03
Slope %: 47
Area m^2: 0.905
Location: South fork on Cemex/Swanton boundary.
Vegetation: RW Chapparal, Tanoak, ferns and fir. Ground cover 95% mostly leaves
Soils: Mudstone parent material, thick duff layer, macropores visible, moderately deep soils, topsoil moist, 15% clay, mostly silt.

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	420 mL/30s
Volume 2	430 mL/30s
Volume 3	415 mL/30s

Slope corrected rainfall rate: **2.20 in/hr**
0.84 L/min

time (min)	**Bucket Water Depth (in)**	**Rainfall Volume (L)**	**Runoff Volume (L)**	**Notes**
0	0.00	0.00	0.00	
2	0.00	1.69	0.00	
4	0.00	3.37	0.00	
6	0.10	5.06	0.14	
8	0.20	6.75	0.28	
10	0.25	8.43	0.34	
12	0.27	10.12	0.37	
14	0.30	11.81	0.41	
16	0.32	13.49	0.44	
18	0.35	15.18	0.48	
20	0.38	16.87	0.52	
22	0.40	18.55	0.55	
24	0.42	20.24	0.58	
26	0.43	21.93	0.59	
28	0.44	23.61	0.61	
30	0.48	25.30	0.66	
32	0.5	26.99	0.69	
34	0.52	28.67	0.72	
36	0.53	30.36	0.73	
38	0.54	32.05	0.75	
40	0.56	33.73	0.77	
42	0.6	35.42	0.83	Jack removed 0.3475 const from col G from here down
44	0.62	37.11	0.86	
46	0.64	38.79	0.89	
48	0.65	40.48	0.90	

50	0.68	42.17	0.94	
52	0.7	43.85	0.97	
54	0.75	45.54	1.04	



Total Rain:	45.54 L	1.98 in
Total Runoff:	1.04 L	0.05 in
Runoff Ratio:	**0.0228**	

Rainfall Rate:	0.843 L/min	2.20 in/hr
Runoff Rate:	0.014 L/min	0.04 in/hr
Infiltration Rate:	0.829 L/min	**2.16 in/hr**

Results: Slow runoff rate due to ground cover being very steady. Most of the leaves were oak which took the initial impact of the rainfall and let the water percolate slowly through the soil.

Site 8

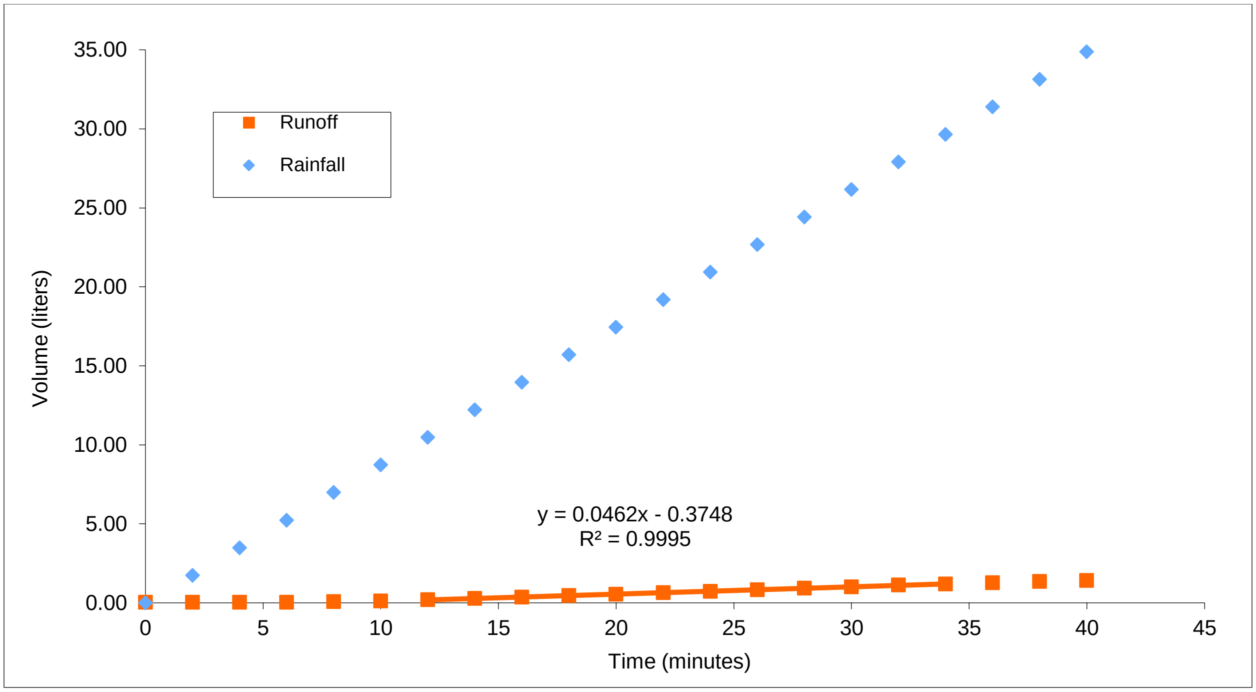
Date and time: 9/08/2011 @ 11:00
Slope %: 49
Area $\boldsymbol{m^2}$***:*** 1.00
Location: Boyer Creek burned. Sunny, warm, slight breeze and no clouds.
Vegetation: Knobcone pine, dead knobcone, manzanita, no duff layer.
Soils: Mudstone rocks at surface. No duff layer .Hydrophobic layer. No overstory cover and 30% understory cover.

Calibration:

Time on	0.6
Time off	0.4
Volume 1	410 mL/30s
Volume 2	425 mL/30s
Volume 3	435 mL/30s
Volume 4	450 mL/30s
Volume 5	460 mL/30s

Slope corrected rainfall rate: **2.06 in/hr**
0.87 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.02	0.00	0.03	
2	0.02	1.74	0.03	
4	0.02	3.49	0.03	
6	0.03	5.23	0.03	
8	0.05	6.98	0.07	
10	0.08	8.72	0.11	
12	0.14	10.46	0.19	
14	0.20	12.21	0.28	
16	0.27	13.95	0.37	
18	0.33	15.70	0.46	
20	0.39	17.44	0.54	
22	0.46	19.18	0.64	
24	0.53	20.93	0.73	
26	0.60	22.67	0.83	
28	0.665	24.42	0.92	
30	0.725	26.16	1.00	
32	0.81	27.90	1.12	
34	0.86	29.65	1.19	
36	0.92	31.39	1.28	
38	0.97	33.14	1.34	
40	1.02	34.88	1.41	



Total Rain:	34.88 L	1.37 in
Total Runoff:	1.41 L	0.06 in
Runoff Ratio:	**0.0406**	

Rainfall Rate:	0.872 L/min	2.06 in/hr
Runoff Rate:	0.046 L/min	0.11 in/hr
Infiltration Rate:	0.826 L/min	**1.95 in/hr**

Results: No results recorded in the field book.

Site 9

Date and time: 9/7/2011 @ 14:23
Slope %: 65
Area m^2: 0.838
Location: Mill Creek ridge Unburned. Sunny, warm weather with some wind occasionally.
Vegetation: Lots of dead/dry materials. Manzanita, knobcone pine, possibly some interior live oak (or oak), madrone, doug fir. About 30% overstory canopy and about 55% understory.
Soils: 1-2 inch duff layer; rocks on the surface (mudstone) and a hydrophobic layer present.

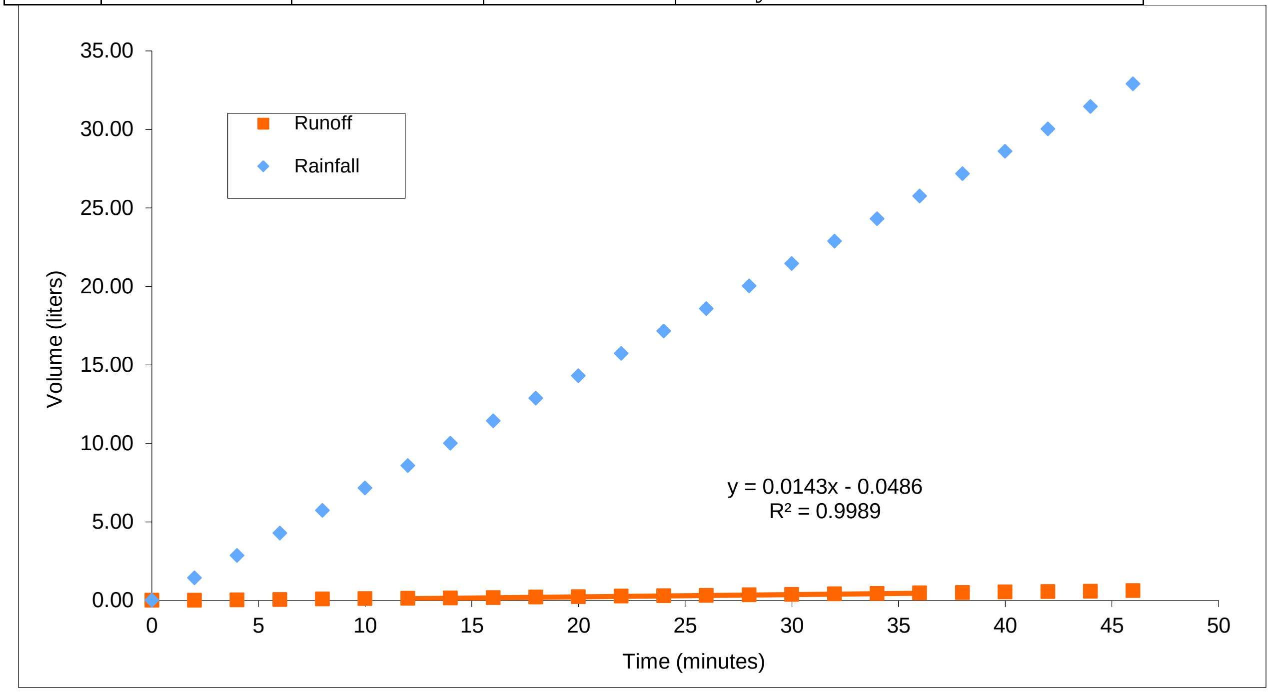
Calibration:

Time on	0.6
Time off	0.4
Volume 1	355 mL/30s
Volume 2	365 mL/30s
Volume 3	370 mL/30s
Volume 4	350 mL/30s
Volume 5	360 mL/30s
Volume 6	345 mL/30s

Slope corrected rainfall rate: **2.01 in/hr**
0.72 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.43	0.00	2:51 first drop
4	0.02	2.86	0.03	Steady stream
6	0.04	4.29	0.05	
8	0.06	5.72	0.08	
10	0.08	7.15	0.11	
12	0.10	8.58	0.13	
14	0.11	10.01	0.14	
16	0.13	11.44	0.18	
18	0.15	12.87	0.21	
20	0.17	14.30	0.24	
22	0.20	15.73	0.27	
24	0.22	17.16	0.30	
26	0.23	18.59	0.32	
28	0.258	20.02	0.36	
30	0.275	21.45	0.38	
32	0.3	22.88	0.41	
34	0.317	24.31	0.44	
36	0.338	25.74	0.47	
38	0.36	27.17	0.50	
40	0.381	28.60	0.53	
42	0.4	30.03	0.55	
44	0.42	31.46	0.58	

46	0.44	32.89	0.61	Steady stream till end of simulation



Total Rain:	32.89 L	1.54 in
Total Runoff:	0.61 L	0.03 in
Runoff Ratio:	**0.0185**	

Rainfall Rate:	0.715 L/min	2.01 in/hr
Runoff Rate:	0.014 L/min	0.04 in/hr
Infiltration Rate:	0.701 L/min	**1.97 in/hr**

Resutls: No results recorded in field book.

Site 10

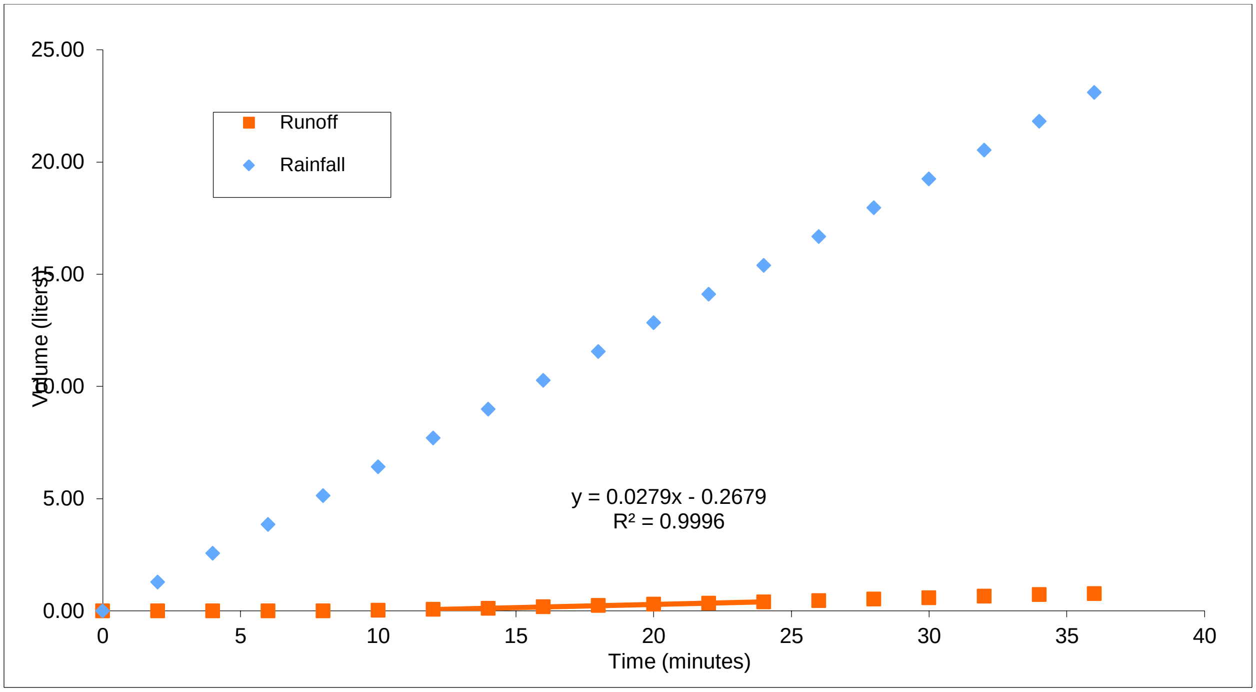
Date and time: 9/6/2011 @ 14:00
Slope %: 27
Area m^2: 0.965
Location: Lockheed ridge (aka LeHi) Southeast facing slope
Vegetation: scrub oak, knobcone pine, manzanita. Lots of dead knobcone.
Soils: Mudstone parent materials, shallow, lots of rocks on surface. 5% duff cover and 30% vegetative cover.

Calibration:

Time on	0.6
Time off	0.4
Volume 1	300 mL/30s
Volume 2	305 mL/30s
Volume 3	325 mL/30s
Volume 4	340 mL/30s
Volume 5	340 mL/30s
Volume 6	315 mL/30s

Slope corrected rainfall rate: **1.57 in/hr**
0.64 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.28	0.00	
4	0.00	2.57	0.00	
6	0.00	3.85	0.00	6:47 starts of dribble
8	0.00	5.13	0.00	
10	0.02	6.42	0.03	
12	0.05	7.70	0.07	
14	0.09	8.98	0.12	
16	0.13	10.27	0.18	
18	0.17	11.55	0.23	
20	0.21	12.83	0.29	
22	0.25	14.12	0.34	
24	0.29	15.40	0.40	
26	0.33	16.68	0.46	
28	0.38	17.97	0.52	
30	0.42	19.25	0.58	
32	0.47	20.53	0.65	
34	0.52	21.82	0.72	
36	0.56	23.10	0.77	



Total Rain:	23.10 L	0.94 in
Total Runoff:	0.77 L	0.03 in
Runoff Ratio:	**0.0335**	

Rainfall Rate:	0.642 L/min	1.57 in/hr
Runoff Rate:	0.028 L/min	0.07 in/hr
Infiltration Rate:	0.614 L/min	**1.50 in/hr**

Results: No results recorded in field book.

Site 11

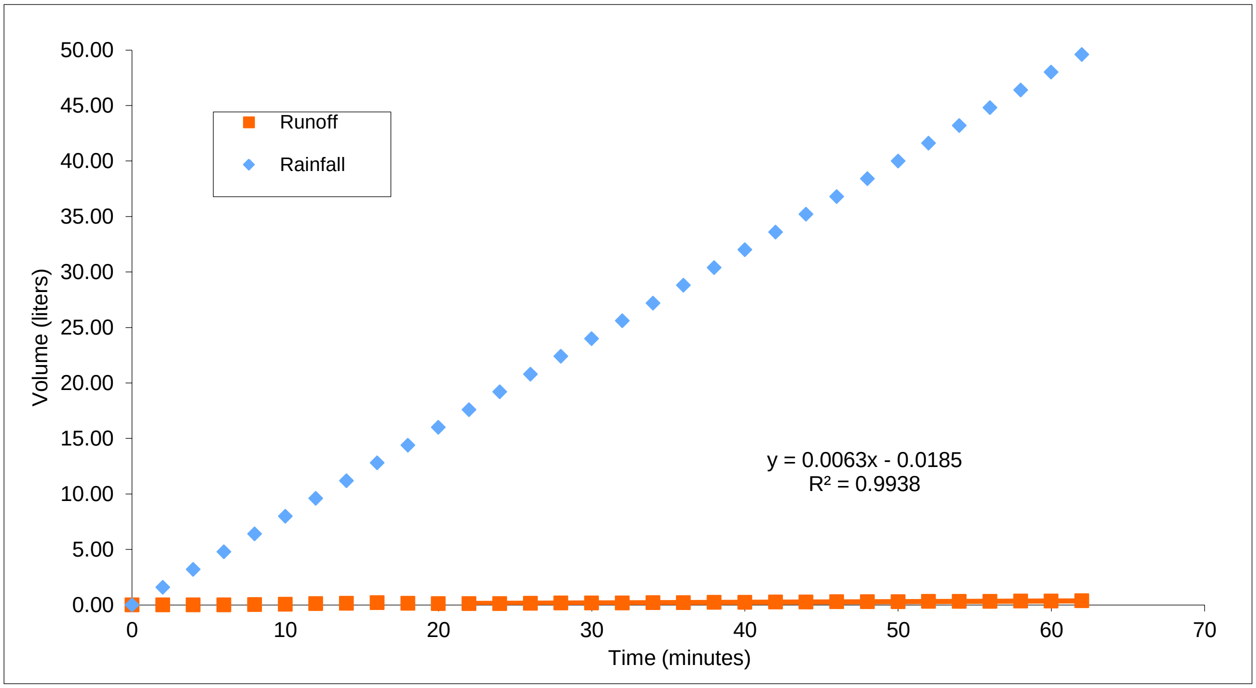
Date and time: 9/6/2011 @ 12:00
Slope %: 17
Area m^2***:*** 0.986
Location: Lockheed Ridge (LeHi) aka Scotts/Mill unburned/control. Northwest facing slopes.
Vegetation: Knobcone pine, manzanita, oak, about 50% surface cover.
Soils: Mudstone with 2-3 inch duff layer. Shallow soil with mudstone beneath.

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	425 mL/30s
Volume 2	410 mL/30s
Volume 3	380 mL/30s
Volume 4	385 mL/30s

Slope corrected rainfall rate: **1.92 in/hr**
0.80 L/min

time (min)	**Bucket Water Depth (in)**	**Rainfall Volume (L)**	**Runoff Volume (L)**	**Notes**
0	0.00	0.00	0.00	Bucket not level from 0 to 20 minutes
2	0.00	1.60	0.00	
4	0.00	3.20	0.00	
6	0.00	4.80	0.00	runoff begins at 6:44
8	0.03	6.40	0.04	
10	0.05	8.00	0.07	
12	0.08	9.60	0.11	
14	0.10	11.20	0.14	
16	0.15	12.80	0.21	
18	0.10	14.40	0.14	
20	0.09	16.00	0.12	
22	0.09	17.60	0.12	Leveled bucket from here to end of simulation
24	0.10	19.20	0.13	
26	0.10	20.80	0.14	
28	0.12	22.40	0.17	
30	0.125	24.00	0.17	
32	0.13	25.60	0.18	
34	0.145	27.20	0.20	
36	0.15	28.80	0.21	
38	0.16	30.40	0.22	
40	0.17	32.00	0.23	
42	0.185	33.60	0.26	
44	0.193	35.20	0.27	
46	0.21	36.80	0.29	
48	0.215	38.40	0.30	

50	0.219	40.00	0.30	
52	0.225	41.60	0.31	
54	0.232	43.20	0.32	
56	0.24	44.80	0.33	
58	0.249	46.40	0.34	
60	0.26	48.00	0.36	
62	0.268	49.60	0.37	



Total Rain:	49.60 L	1.98 in
Total Runoff:	0.37 L	0.01 in
Runoff Ratio:	**0.0075**	

Rainfall Rate:	0.800 L/min	1.92 in/hr
Runoff Rate:	0.006 L/min	0.02 in/hr
Infiltration Rate:	0.794 L/min	**1.90 in/hr**

Results: No results recorded in the field book.

Site 12

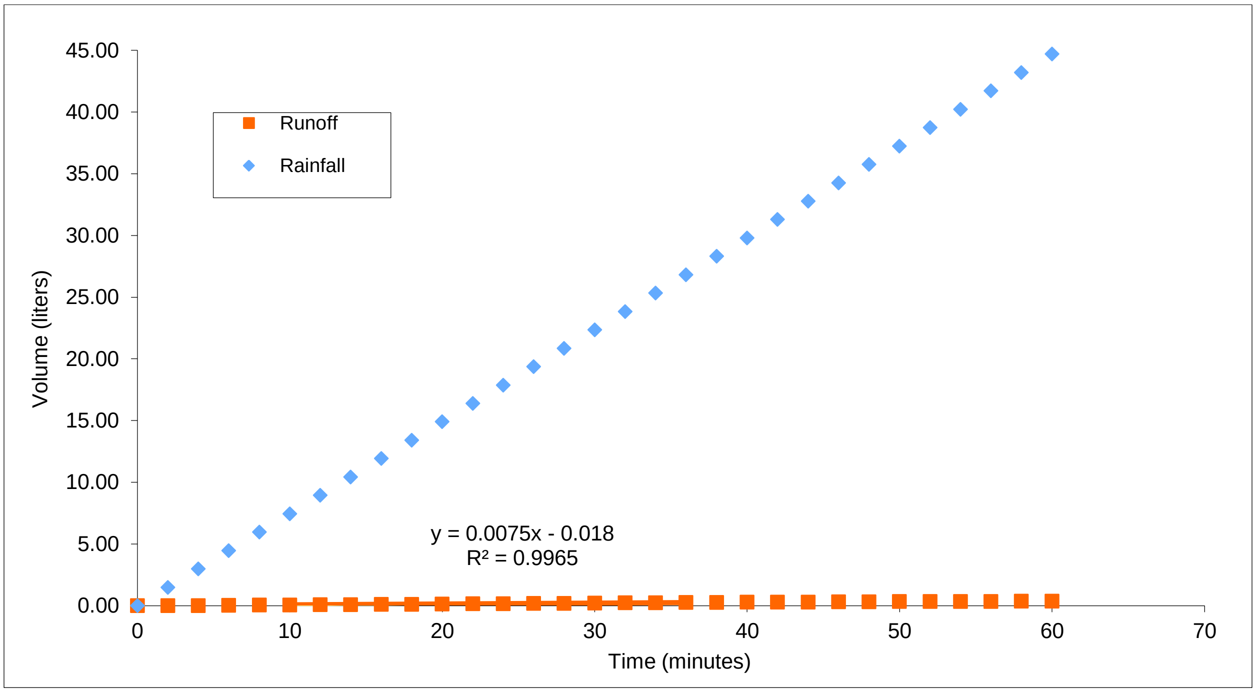
Date and time: 9/7/2011 @ 11:30
Slope %: 46
Area m^2: 0.908
Location: Boyer Creek Control Lockheed Property Unburned. Aspect is South facing slope. Sunny, warm, slight to no breeze.
Vegetation: Madrone, Tanoak, redwood
Soils: 3-4 inch duff layer (Tanoak and Madrone), perhaps a sandy clay loam. 95% cover from duff and 90% canopy cover. NO hydrophobicity

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	370 mL/30s
Volume 2	350 mL/30s
Volume 3	390 mL/30s
Volume 4	380 mL/30s

Slope corrected rainfall rate: **1.94 in/hr**
0.75 L/min

time (min)	**Bucket Water Depth (in)**	**Rainfall Volume (L)**	**Runoff Volume (L)**	**Notes**
0	0.00	0.00	0.00	
2	0.00	1.49	0.00	Drips begin at 3:30
4	0.01	2.98	0.01	
6	0.02	4.47	0.03	
8	0.03	5.96	0.04	
10	0.05	7.45	0.06	
12	0.05	8.94	0.07	
14	0.06	10.43	0.08	
16	0.07	11.92	0.10	
18	0.08	13.41	0.11	
20	0.10	14.90	0.13	
22	0.11	16.39	0.15	
24	0.12	17.88	0.17	
26	0.13	19.37	0.18	
28	0.14	20.86	0.19	
30	0.15	22.35	0.21	
32	0.162	23.84	0.22	
34	0.17	25.33	0.23	
36	0.18	26.82	0.25	
38	0.195	28.31	0.27	
40	0.2	29.80	0.28	
42	0.21	31.29	0.29	

44	0.215	32.78	0.30	
46	0.22	34.27	0.30	
48	0.23	35.76	0.32	Slow drip from here onward
50	0.24	37.25	0.33	slow drips about 3 per second
52	0.244	38.74	0.34	
54	0.248	40.23	0.34	
56	0.251	41.72	0.35	
58	0.259	43.21	0.36	
60	0.261	44.70	0.36	



Total Rain:	44.70 L	1.94 in
Total Runoff:	0.36 L	0.02 in
Runoff Ratio:	**0.0081**	

Rainfall Rate:	0.745 L/min	1.94 in/hr
Runoff Rate:	0.008 L/min	0.02 in/hr
Infiltration Rate:	0.738 L/min	**1.92 in/hr**

Results: No results recorded in the field book.

Site 13

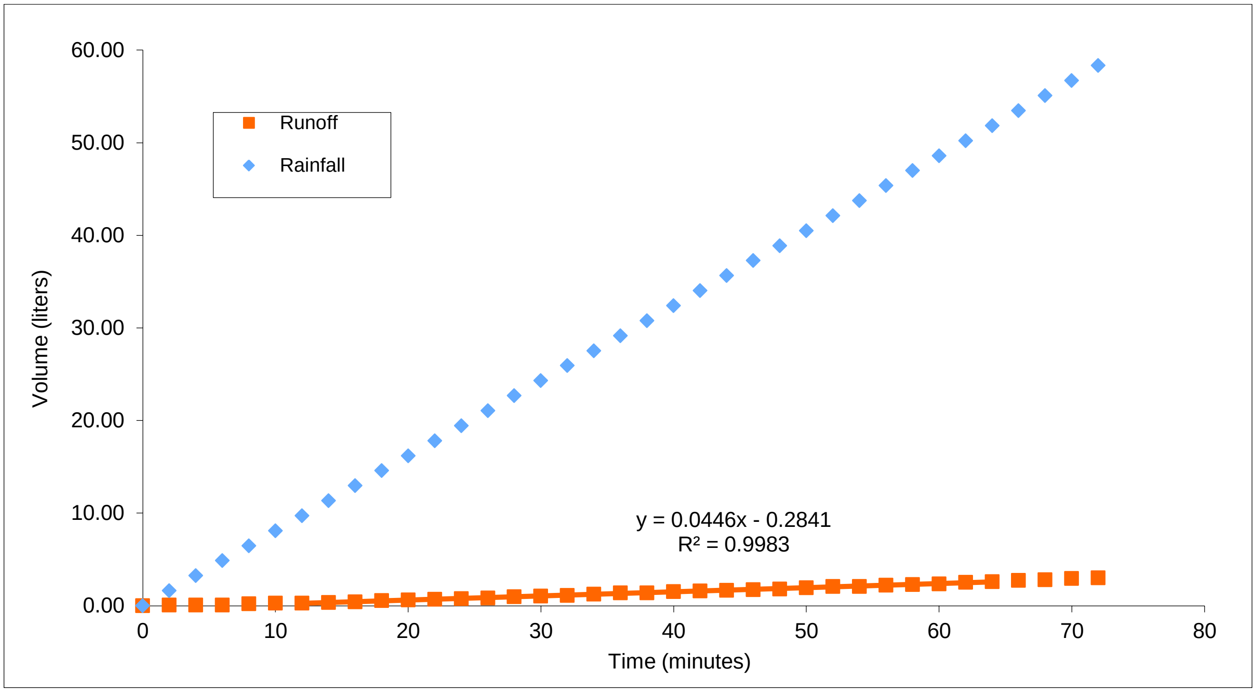
Date: 7/7/2011
Slope %: 60
Area m²: 0.857
Location: Lions flat ridgeline (South fork ridge)
Vegetation: Thick vetch, burnt redwood and fir.
Soils: Nothing recorded in field book.

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	405 mL/30s

Slope corrected rainfall rate: **2.23 in/hr**
0.81 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.05	1.62	0.07	
4	0.05	3.24	0.07	
6	0.05	4.86	0.07	drips started at 5:30 (likely from vegetation)
8	0.15	6.48	0.21	
10	0.20	8.10	0.28	
12	0.20	9.72	0.28	
14	0.25	11.34	0.34	
16	0.30	12.96	0.41	
18	0.40	14.58	0.55	
20	0.45	16.20	0.62	
22	0.50	17.82	0.69	
24	0.55	19.44	0.76	
26	0.60	21.06	0.83	
28	0.7	22.68	0.97	
30	0.75	24.30	1.04	
32	0.8	25.92	1.11	
34	0.9	27.54	1.25	
36	1	29.16	1.39	
38	1	30.78	1.39	
40	1.1	32.40	1.53	
42	1.15	34.02	1.60	
44	1.2	35.64	1.67	
46	1.25	37.26	1.74	
48	1.3	38.88	1.81	
50	1.4	40.50	1.95	
52	1.5	42.12	2.09	

54	1.5	43.74	2.09	
56	1.6	45.36	2.23	
58	1.65	46.98	2.30	
60	1.7	48.60	2.37	
62	1.8	50.22	2.51	
64	1.85	51.84	2.58	
66	1.95	53.46	2.72	
68	2	55.08	2.79	
70	2.1	56.70	2.93	
72	2.15	58.32	3.01	turned off



Total Rain:	58.32 L	2.68 in
Total Runoff:	3.01 L	0.14 in
Runoff Ratio:	**0.0515**	

Rainfall Rate:	0.810 L/min	2.23 in/hr
Runoff Rate:	0.045 L/min	0.12 in/hr
Infiltration Rate:	0.765 L/min	**2.11 in/hr**

Results: No results recorded in field book.

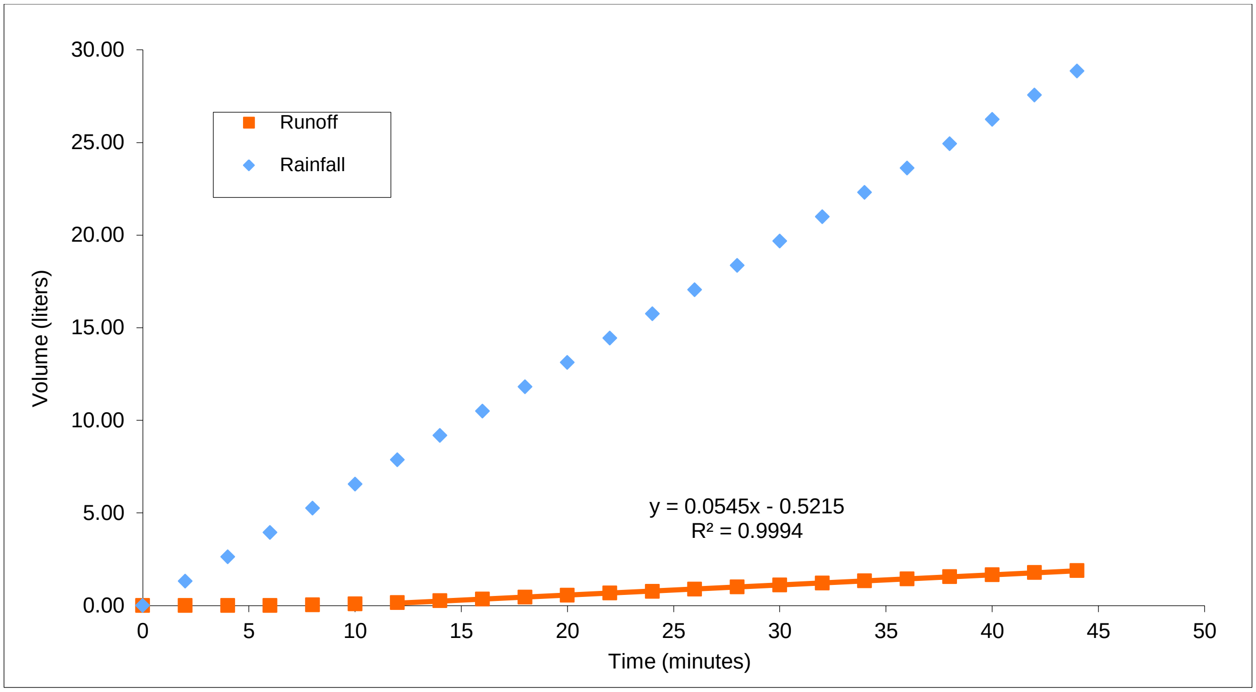
Site 15

Date and time: 9/8/2011
Slope %: 36
Area m^2: 0.941
Location: Mill creek Ridge burned. North Facing slope. Sunny warm, wind gusts, occassionally 10mph.
Vegetation: Manzanita, knobcone sprouts, dead knobcone, lupine, scruboak. No overstory, 20% understory cover.
Soils: Bare rock surface (mudstone) no duff layer, hydrophobic layer

Calibration:	
Time on	
Time off	
Volume 1	310 mL/30s
Volume 2	330 mL/30s
Volume 3	340 mL/30s
Volume 4	325 mL/30s
Volume 5	335 mL/30s

Slope corrected rainfall rate: **1.65 in/hr**
0.66 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.31	0.00	
4	0.00	2.62	0.00	
6	0.00	3.94	0.00	
8	0.03	5.25	0.03	
10	0.06	6.56	0.08	
12	0.12	7.87	0.16	
14	0.19	9.18	0.26	
16	0.26	10.50	0.35	
18	0.32	11.81	0.44	
20	0.40	13.12	0.55	
22	0.49	14.43	0.68	
24	0.55	15.74	0.76	
26	0.64	17.06	0.89	
28	0.72	18.37	1.00	
30	0.8	19.68	1.11	
32	0.88	20.99	1.22	
34	0.96	22.30	1.33	
36	1.04	23.62	1.44	
38	1.12	24.93	1.55	
40	1.195	26.24	1.66	
42	1.28	27.55	1.78	
44	1.35	28.86	1.88	



Total Rain:	28.86 L	1.21 in
Total Runoff:	1.88 L	0.08 in
Runoff Ratio:	**0.0650**	

Rainfall Rate:	0.656 L/min	1.65 in/hr
Runoff Rate:	0.051 L/min	0.13 in/hr
Infiltration Rate:	0.605 L/min	**1.52 in/hr**

Results: No results recorded in field book.

2012

<u>Site 2</u>

Date and time: 8/22/2012 @ 10:31
Slope %: 60
Area m²: 0.857
Location: Upper Swanton Road, non-burned area. Weather: nice day, warm and sunny Aspect: East/Southeast
Vegetation: Redwood dominant with very thick redwood needle duff layer about 3-5 inches thick.
Soils: Soils under thick duff layer were well developed; not too rocky.

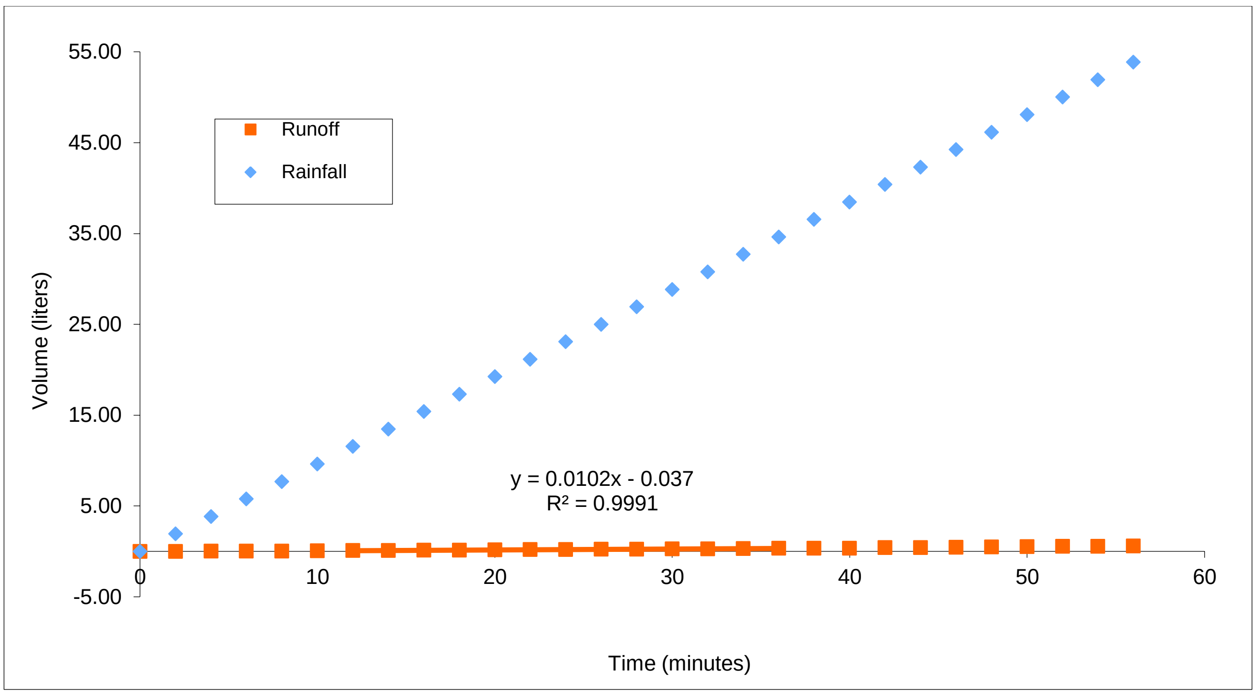
Calibration:

Time on	0.6
Time off	0.4
Volume 1	455 mL/30s
Volume 2	460 mL/30s
Volume 3	495 mL/30s
Volume 4	480 mL/30s
Volume 5	500 mL/30s
Volume 6	495 mL/30s

Slope corrected rainfall rate: **2.65 in/hr**
0.96 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.92	0.00	Started dripping @3:00
4	0.01	3.85	0.01	Steady flow @4:00
6	0.02	5.77	0.03	
8	0.03	7.69	0.04	
10	0.05	9.62	0.07	
12	0.06	11.54	0.08	
14	0.08	13.46	0.11	
16	0.09	15.39	0.12	
18	0.11	17.31	0.14	
20	0.12	19.23	0.17	
22	0.14	21.16	0.19	
24	0.15	23.08	0.21	
26	0.17	25.00	0.23	
28	0.18	26.93	0.25	
30	0.195	28.85	0.27	
32	0.21	30.77	0.29	
34	0.22	32.70	0.30	

36	0.24	34.62	0.33	
38	0.25	36.54	0.34	
40	0.24	38.47	0.33	
42	0.29	40.39	0.40	
44	0.305	42.31	0.42	
46	0.315	44.24	0.43	
48	0.34	46.16	0.47	Sprayer stopped oscillating@ 48:00
50	0.375	48.08	0.52	Water started up again 13 minutes later and depth of bucket was at 0.36 depth
52	0.39	50.01	0.54	
54	0.41	51.93	0.57	
56	0.42	53.85	0.58	



Total Rain:	53.85 L	2.47 in
Total Runoff:	0.58 L	0.03 in
Runoff Ratio:	**0.0108**	

Rainfall Rate:	0.962 L/min	2.65 in/hr
Runoff Rate:	0.010 L/min	0.03 in/hr
Infiltration Rate:	0.951 L/min	**2.62 in/hr**

Results: A lot of the moisture was held in the duff layer. There was uneven moisture dispersal vertivally throughout the plot. One spot in the middle of the plot was vertically moist about 0.5-1 foot depth. There were pockets of wetness but most of the moisture was held in the 2-3 inch duff layer. Back of plot (upslope side) was not moist because of slope.

Site 4

Date and time: 8/13/2012 @ 11:26
Slope %: 70
Area m^2: 0.819
Location: L.C. unburned. Sunny with a slight breeze.
Vegetation: Aspect is southeast. Thick layer of duff (about 4 inches depth and greater in sone areas of plot). Redwood sorel, ferns, california bay and big leaf maple present near plot.
Soils: Santa Cruz mudstone over granite; high amount of cobble and gravels).

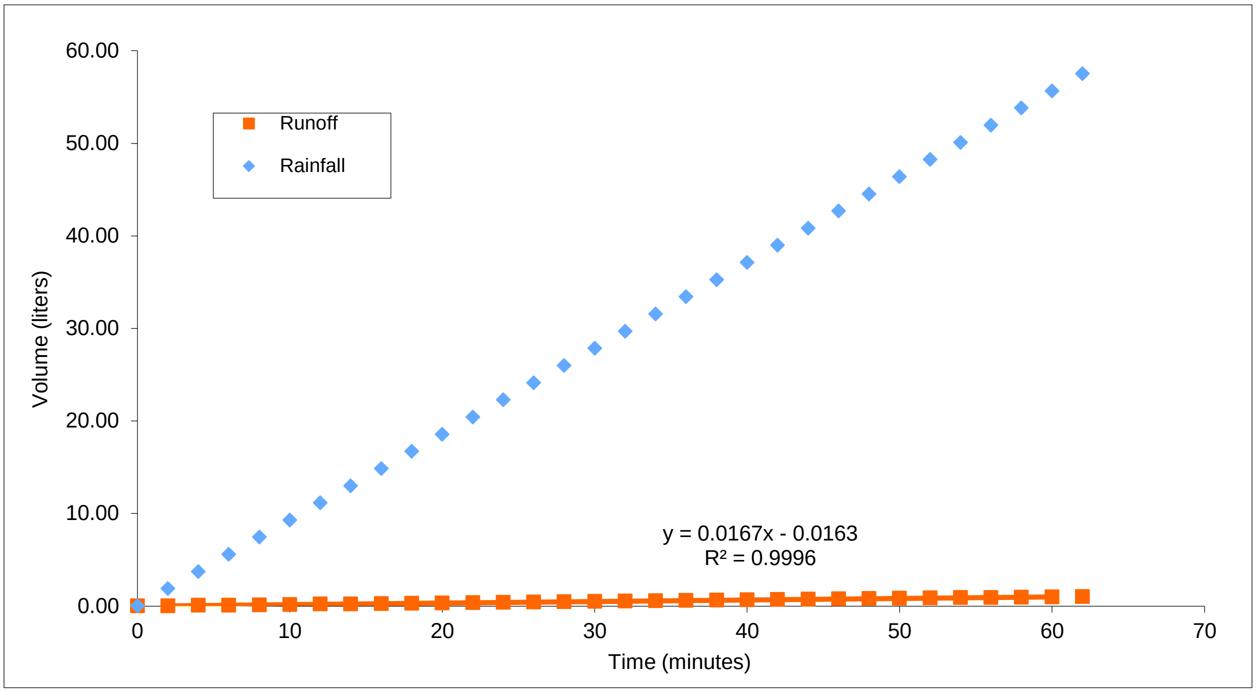
Calibration:

Time on	0.6
Time off	0.4
Volume 1	445 mL/30s
Volume 2	460 mL/30s
Volume 3	480 mL/30s
Volume 4	470 mL/30s

Slope corrected rainfall rate: **2.67 in/hr**
0.93 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.01	1.86	0.01	Start of runoff at 1 minute 24 seconds
4	0.04	3.71	0.06	Consistent runoff
6	0.06	5.57	0.08	
8	0.08	7.42	0.11	
10	0.11	9.28	0.15	
12	0.14	11.13	0.19	
14	0.16	12.99	0.22	
16	0.18	14.84	0.25	
18	0.20	16.70	0.28	
20	0.23	18.55	0.32	
22	0.26	20.41	0.35	
24	0.28	22.26	0.39	
26	0.30	24.12	0.41	
28	0.32	25.97	0.44	
30	0.36	27.83	0.50	
32	0.37	29.68	0.51	
34	0.4	31.54	0.55	
36	0.42	33.39	0.58	
38	0.44	35.25	0.61	
40	0.47	37.10	0.65	
42	0.49	38.96	0.68	
44	0.52	40.81	0.72	

46	0.55	42.67	0.76	
48	0.57	44.52	0.79	
50	0.59	46.38	0.82	
52	0.62	48.23	0.86	
54	0.64	50.09	0.89	
56	0.66	51.94	0.91	
58	0.68	53.80	0.94	
60	0.71	55.65	0.98	Stopped simulator at 12:26
62	0.72	57.51	1.00	



Total Rain:	57.51 L	2.76 in
Total Runoff:	1.00 L	0.05 in
Runoff Ratio:	**0.0173**	

Rainfall Rate:	0.928 L/min	2.67 in/hr
Runoff Rate:	0.017 L/min	0.05 in/hr
Infiltration Rate:	0.911 L/min	**2.63 in/hr**

Results: Thick layer of duff about 4 inches in some areas. Only the top 1 cm of duff was wet. Nothing under 1 cm had water percolate through it-completely dry. Also, due to slope, back portion of plot (uphill side) was not moist.

Site 5

Date and time: 7/26/2012 @! 11:45
Slope %: 63
Area $\boldsymbol{m^2}$***:*** 1.00
Location: Cabins. Some fog, no wind.
Vegetation: southeast aspect. Thick ground cover, poison oak, blackberry, ceanothus. Doug fir and Ca Bay present in the area.
Soils: Santa Cruz mudstone over granite.

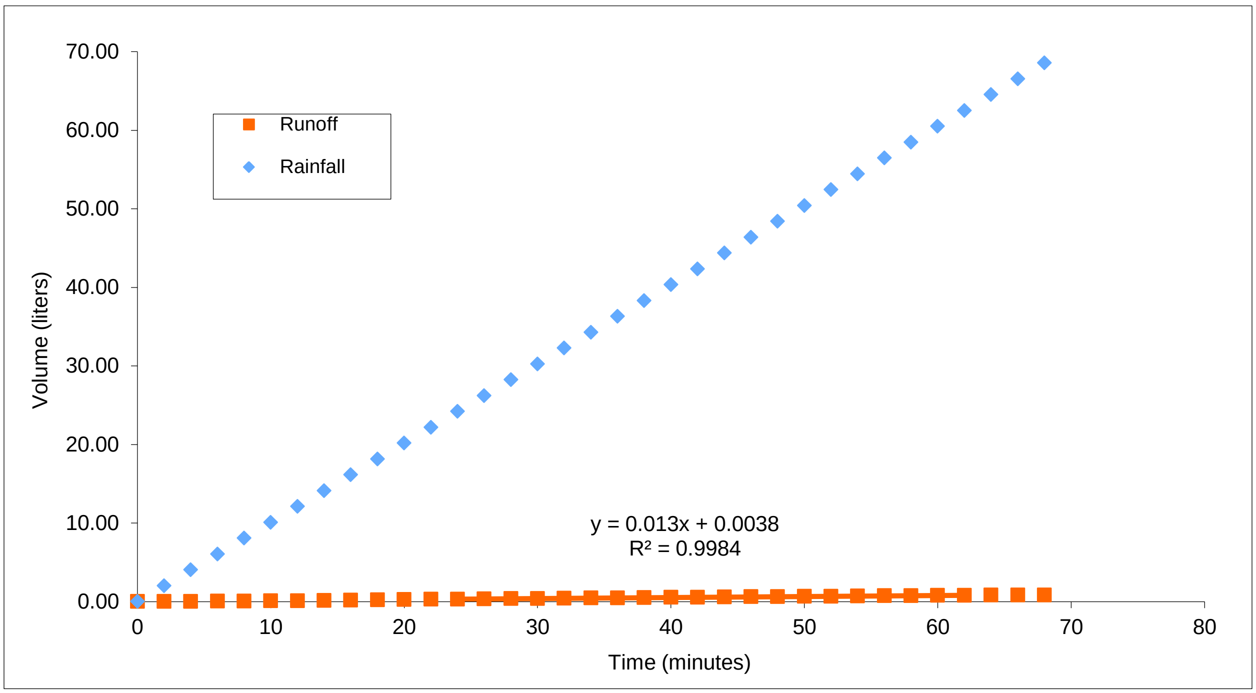
Calibration:

Time on	0.6	
Time off	0.4	
Volume 1	450 mL/30s	490 mL/30s
Volume 2	500 mL/30s	525 mL/30s

Slope corrected rainfall rate:	**2.38 in/hr**	**2.40 in/hr**
	1.01 L/min	1.02 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	2.02	0.00	Flow begins at 2min 30 seconds
4	0.02	4.03	0.03	
6	0.03	6.05	0.04	
8	0.05	8.07	0.07	
10	0.06	10.08	0.08	
12	0.08	12.10	0.11	
14	0.11	14.12	0.15	
16	0.13	16.13	0.18	
18	0.16	18.15	0.22	
20	0.18	20.17	0.25	
22	0.21	22.18	0.29	
24	0.23	24.20	0.32	
26	0.24	26.22	0.33	
28	0.27	28.23	0.37	
30	0.28	30.25	0.39	
32	0.30	32.27	0.41	
34	0.33	34.28	0.46	
36	0.34	36.30	0.47	
38	0.36	38.32	0.50	
40	0.38	40.33	0.52	
42	0.40	42.35	0.55	
44	0.42	44.37	0.58	
46	0.44	46.38	0.61	

48	0.46	48.40	0.64	
50	0.48	50.42	0.66	
52	0.49	52.43	0.68	
54	0.51	54.45	0.70	
56	0.53	56.47	0.73	
58	0.55	58.48	0.76	
60	0.56	60.50	0.77	
62	0.58	62.52	0.80	stopped simulator
64	0.59	64.53	0.82	
66	0.59	66.55	0.82	dripping slightly
68	0.6	68.57	0.83	



Total Rain:	68.57 L	2.70 in
Total Runoff:	0.83 L	0.03 in
Runoff Ratio:	**0.0121**	

Rainfall Rate:	1.008 L/min	2.40 in/hr
Runoff Rate:	0.013 L/min	0.03 in/hr
Infiltration Rate:	0.995 L/min	**2.37 in/hr**

Results: Runoff was mostly steady, but slowed down at times. Water appears to have fully saturated the layer of organic debris but did not significantly infiltrate the underlying soil. Completely dry about 1 inch beneath the surface. Some areas have higher infiltration where macropores are prevalent. At 1 inch depth, drop test performed and water only beaded for 3 seconds.

Site 6

Date and time: 7/25/2012 @ 15:00
Slope %: 52
Area m^2: 0.887
Location: UNF Little Creek watershed.
Vegetation: 100% Cover-duff between 1 and 2 inches, redwood sorel, tanoak leaves. Northwest facing slope. Tanoak and redwood present.
Soils: Granite soil parent material.

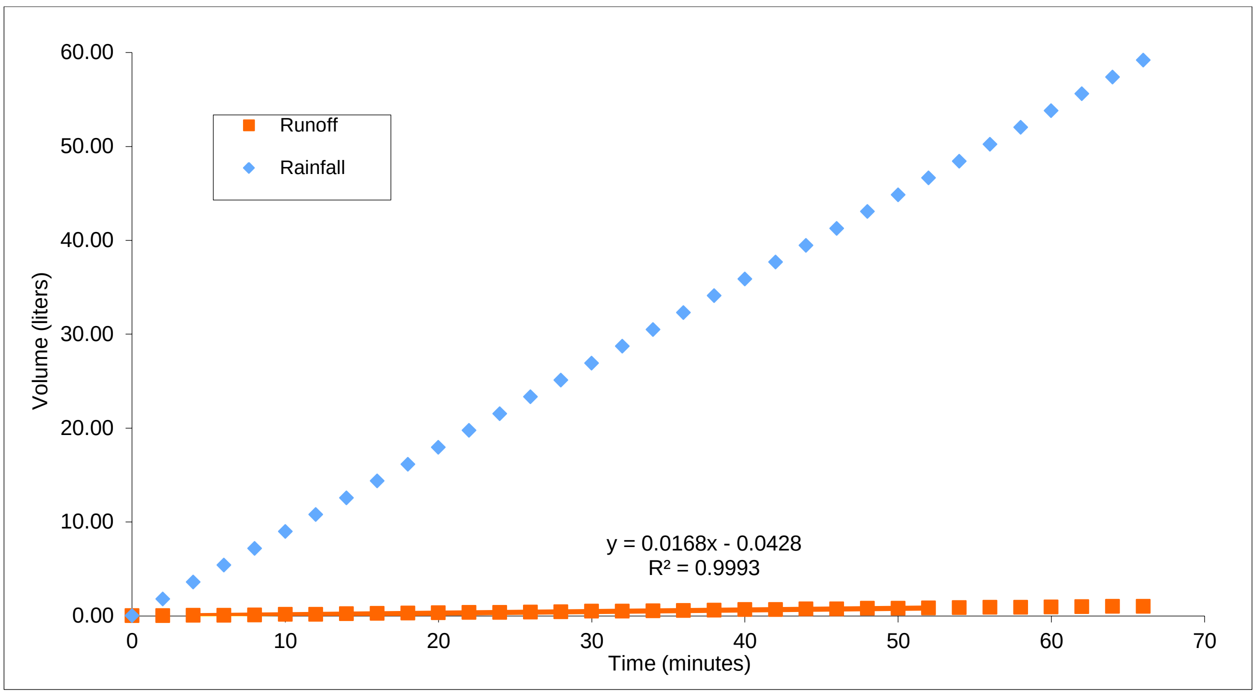
Calibration:

Time on	0.6
Time off	0.4
Volume 1	440 mL/30s
Volume 2	435 mL/30s
Volume 3	445 mL/30s
Volume 4	450 mL/30s
Volume 5	465 mL/30s
Volume 6	455 mL/30s

Slope corrected rainfall rate: **2.39 in/hr**
0.90 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.79	0.00	at 3:40 water starts to flow
4	0.02	3.59	0.03	
6	0.04	5.38	0.06	
8	0.06	7.17	0.08	
10	0.09	8.97	0.12	
12	0.11	10.76	0.15	
14	0.14	12.55	0.19	
16	0.17	14.35	0.23	
18	0.19	16.14	0.26	
20	0.22	17.93	0.30	
22	0.25	19.73	0.34	We notice wood is not over trough entirely; water drops hitting trough directly
24	0.26	21.52	0.36	At 22 min we cover trough with plywood
26	0.28	23.31	0.39	at 24 min, looks like runoff slowed with adjustment of plywood
28	0.31	25.11	0.43	
30	0.34	26.90	0.47	
32	0.36	28.69	0.50	
34	0.38	30.49	0.52	

36	0.41	32.28	0.57	
38	0.43	34.07	0.59	
40	0.46	35.87	0.64	
42	0.48	37.66	0.66	
44	0.51	39.45	0.70	
46	0.53	41.25	0.73	
48	0.56	43.04	0.77	
50	0.57	44.83	0.79	
52	0.60	46.63	0.83	
54	0.62	48.42	0.86	
56	0.64	50.21	0.89	
58	0.655	52.01	0.91	
60	0.675	53.80	0.93	stopped simulator at 1:03:20
62	0.7	55.59	0.97	
64	0.71	57.39	0.98	
66	0.72	59.18	1.00	



Total Rain:	59.18 L	2.63 in
Total Runoff:	1.00 L	0.04 in
Runoff Ratio:	**0.0168**	

Rainfall Rate:	0.897 L/min	2.39 in/hr
Runoff Rate:	0.017 L/min	0.04 in/hr
Infiltration Rate:	0.880 L/min	2.34 in/hr

Results: Plot was uniformly wetted but not saturated, soil was moist under duff layer.

Site 7

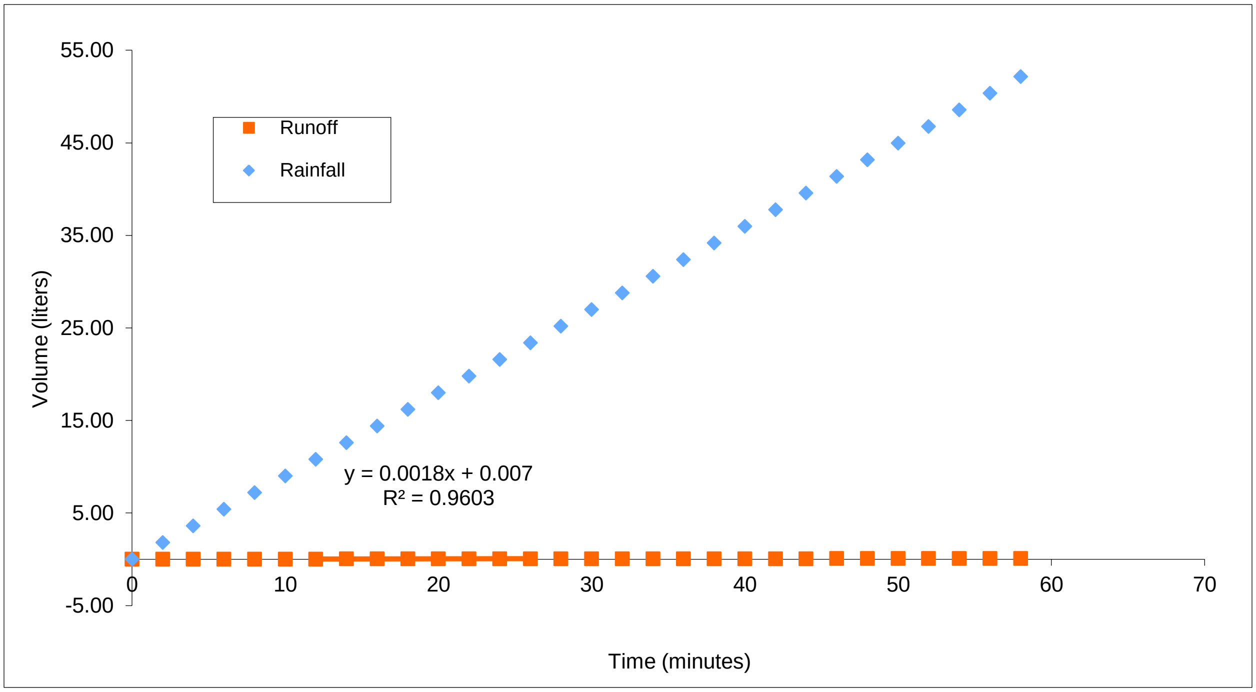
Date and time: 8/14/2012 @ 12:36
Slope %: 46
Area m^2: 0.908
Location: South fork on Cemex property/Swanton boundary.
Vegetation: Northwest aspect. Redwood and tanoak, some Doug fir. Ground cover consists of sedge nettle, fern, iris and blackberry. There is some slash present from the logging in 2011.
Soils: Infiltration was about 7 inches deep in most areas of plot that had a duff layer of 1 inch. Where duff was 2 inches and greater, there was very little infiltration that occurred.

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	450 mL/30s
Volume 2	450 mL/30s
Volume 3	449 mL/30s

Slope corrected rainfall rate: **2.34 in/hr**
0.90 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.80	0.00	2:30 start of drips
4	0.00	3.60	0.00	
6	0.00	5.40	0.00	
8	0.00	7.19	0.00	
10	0.01	8.99	0.01	still dripping, not consistent flow
12	0.02	10.79	0.03	
14	0.03	12.59	0.03	
16	0.03	14.39	0.03	
18	0.03	16.19	0.04	
20	0.03	17.99	0.04	
22	0.04	19.79	0.05	
24	0.04	21.58	0.05	
26	0.04	23.38	0.06	
28	0.04	25.18	0.06	
30	0.04	26.98	0.06	still dripping, not consistent flow
32	0.04	28.78	0.06	
34	0.04	30.58	0.06	
36	0.04	32.38	0.06	
38	0.04	34.17	0.06	
40	0.04	35.97	0.06	
42	0.045	37.77	0.06	
44	0.045	39.57	0.06	

46	0.05	41.37	0.07	
48	0.05	43.17	0.07	
50	0.05	44.97	0.07	
52	0.05	46.77	0.07	
54	0.05	48.56	0.07	
56	0.05	50.36	0.07	Stopped simulation at 57:13
58	0.05	52.16	0.07	



Total Rain:	52.16 L	2.26 in
Total Runoff:	0.07 L	0.00 in
Runoff Ratio:	**0.0013**	

Rainfall Rate:	0.899 L/min	2.34 in/hr
Runoff Rate:	0.002 L/min	0.00 in/hr
Infiltration Rate:	0.898 L/min	**2.33 in/hr**

Results: Infiltration was about 7 inches deep in most areas of plot that had a duff layer of 1 inch. Where duff was 2 inches and greater, there was very little infiltration that occurred.

Site 8

Date and time: 8/29/2012 @ 13:00
Slope %: 49
Area m^2: 1.00
Location: Boyer Creek burned. Slight wind and sunny, HOT day.
Vegetation: manzanita, small oak bushes, dead deerweed, knobcone sprouts, chamise, bush poppy.
Soils: Soil is somewhat rock and soil is granular and gravelly. There is a charred organic black layer under rocks on surface.

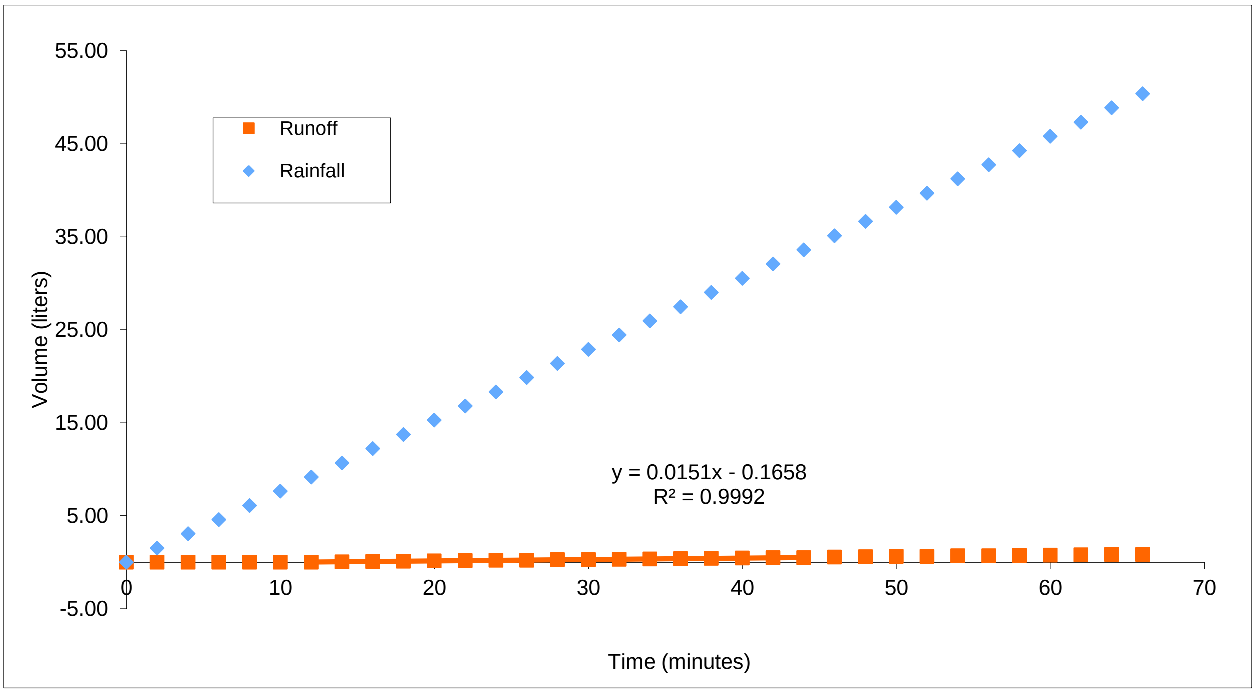
Calibration:

Time on	0.6
Time off	0.4
Volume 1	410 mL/30s
Volume 2	410 mL/30s
Volume 3	360 mL/30s
Volume 4	355 mL/30s
Volume 5	395 mL/30s
Volume 6	360 mL/30s

Slope corrected rainfall rate: **1.80 in/hr**
0.76 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	Wind is slight but present
2	0.00	1.53	0.00	
4	0.00	3.05	0.00	
6	0.00	4.58	0.00	Breeze is somewhat consistent
8	0.00	6.11	0.00	Water starts to drip and steady flow
10	0.01	7.63	0.01	
12	0.02	9.16	0.02	
14	0.03	10.69	0.04	
16	0.05	12.21	0.07	
18	0.08	13.74	0.11	
20	0.11	15.27	0.14	wind picks up
22	0.12	16.79	0.17	
24	0.14	18.32	0.19	
26	0.16	19.85	0.22	
28	0.19	21.37	0.26	
30	0.205	22.90	0.28	
32	0.23	24.43	0.32	
34	0.25	25.95	0.34	
36	0.275	27.48	0.38	

38	0.295	29.01	0.41	
40	0.32	30.53	0.44	
42	0.34	32.06	0.47	Jack removed constant 0.3475 from col G starting here
44	0.36	33.59	0.50	
46	0.39	35.11	0.54	
48	0.415	36.64	0.57	
50	0.44	38.17	0.61	
52	0.46	39.69	0.64	Still breezy
54	0.49	41.22	0.68	
56	0.51	42.75	0.70	
58	0.53	44.27	0.73	
60	0.55	45.80	0.76	
62	0.575	47.33	0.79	
64	0.6	48.85	0.83	Turned off simulator at 64:00
66	0.61	50.38	0.84	Runoff stopped at 65:30



Total Rain:	50.38 L	1.98 in
Total Runoff:	0.84 L	0.03 in
Runoff Ratio:	**0.0167**	

Rainfall Rate:	0.763 L/min	1.82 in/hr
Runoff Rate:	0.015 L/min	0.04 in/hr
Infiltration Rate:	0.748 L/min	**1.78 in/hr**

Results: Topsoil was thin about 0.5-1 inch deep and is composed of charred organics.

Site 9

Date and time: 9/5/2012 @ 12:39
Slope %: 65
Area m^2: 0.838
Location: Mill Creek ridge-unburned. Weather: slight wind/breeze. It did start to sprinkle a little when conducting simulation-nothing substantial.
Vegetation: Oak brush, manzanita, doug fir, madrone and knobcone. Plot has madrone leaves, manzanita leaves and needles, small twigs and doug fir cones.
Soils: 2-3 inch duff layer; rocks on the surface (mudstone)

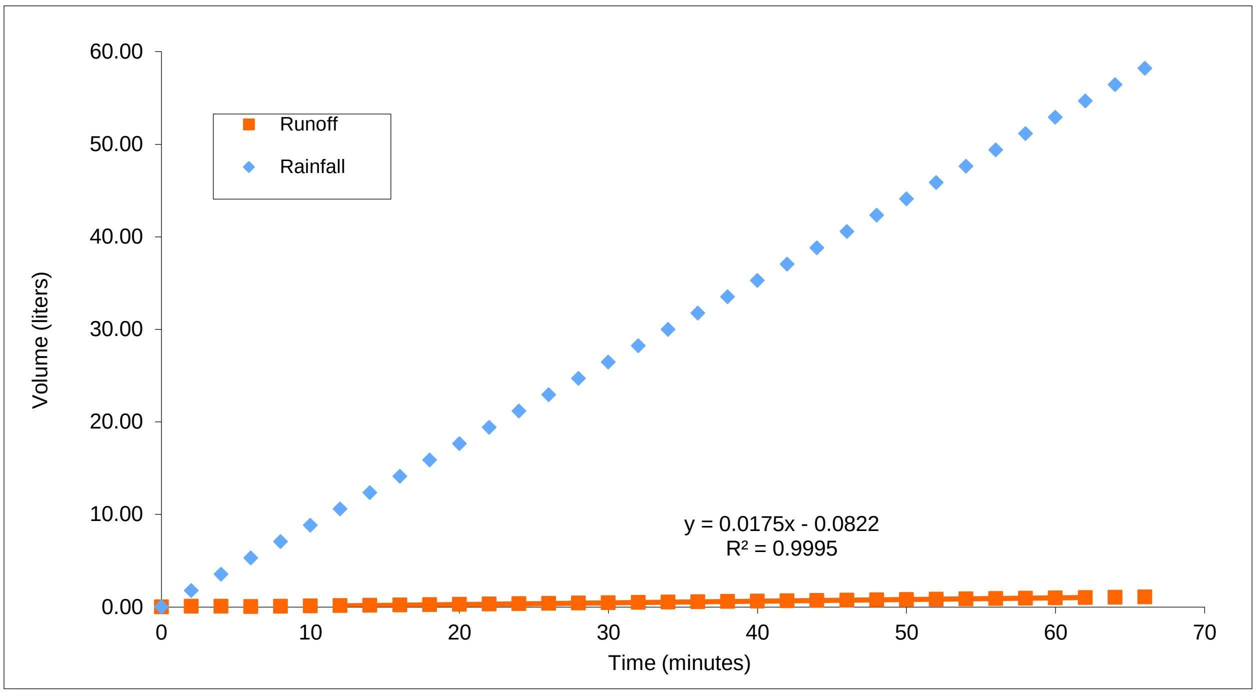
Calibration:

Time on	0.6
Time off	0.4
Volume 1	425 mL/30s
Volume 2	410 mL/30s
Volume 3	430 mL/30s
Volume 4	455 mL/30s
Volume 5	470 mL/30s
Volume 6	455 mL/30s

Slope corrected rainfall rate: **2.48 in/hr**
0.88 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.01	0.00	0.01	
2	0.04	1.76	0.06	2:51 first drop
4	0.05	3.53	0.07	Steady stream
6	0.04	5.29	0.05	
8	0.06	7.05	0.08	
10	0.08	8.82	0.11	
12	0.10	10.58	0.14	
14	0.12	12.34	0.17	
16	0.15	14.11	0.21	
18	0.17	15.87	0.23	
20	0.19	17.63	0.26	
22	0.22	19.40	0.30	
24	0.25	21.16	0.34	
26	0.27	22.92	0.37	at 26:29 stopped simulation because there was a rock in the nozzle
28	0.295	24.69	0.41	Resumed simulation at depth .295 depth.
30	0.32	26.45	0.44	
32	0.34	28.21	0.47	
34	0.37	29.98	0.51	

36	0.39	31.74	0.54	
38	0.43	33.50	0.59	
40	0.45	35.27	0.62	
42	0.47	37.03	0.65	Jack removed constant 0.3475 from col G starting here
44	0.5	38.79	0.69	
46	0.525	40.56	0.73	
48	0.55	42.32	0.76	
50	0.57	44.08	0.79	
52	0.595	45.85	0.82	
54	0.625	47.61	0.86	
56	0.65	49.37	0.90	
58	0.68	51.14	0.94	
60	0.71	52.90	0.98	
62	0.725	54.66	1.00	Stopped simulation at 1:02:45
64	0.76	56.43	1.05	
66	0.775	58.19	1.07	



Total Rain:	58.19 L	2.73 in
Total Runoff:	1.07 L	0.05 in
Runoff Ratio:	**0.0184**	

Rainfall Rate:	0.882 L/min	2.48 in/hr
Runoff Rate:	0.018 L/min	0.05 in/hr
Infiltration Rate:	0.864 L/min	**2.43 in/hr**

Results: Upper most organic layer (2-3 inches) was very intact and held most of the water; this layer was moist. Under about 3 inches of the organic matter, the material was more of a fine organic matter and it was dry. The top 2 inches of plot on uphill side were dry because of the slope (water did not get sprinkled on that portion of the plot). Bottom of the plot had the deepest penetration of moisture.

Site 10

Date and time: 8/27/2012 @ 12:00
Slope %: 36
Area m²: 0.941
Location: Scotts/Mill burned; Mild breeze
Vegetation: scrub oak, knobcone pine, manzanita. Lots of dead knobcone, deer weed
Soils: Mudstone parent materials, shallow, lots of rocks on surface.

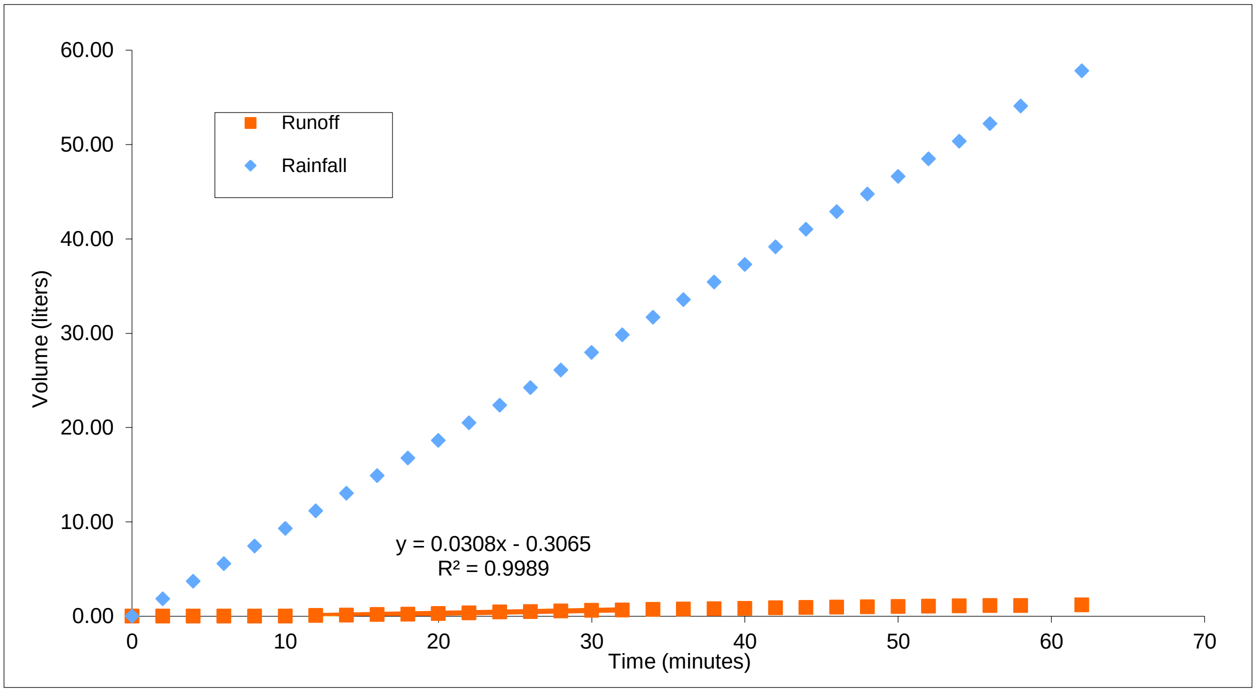
Calibration:

Time on	0.7
Time off	0.3
Volume 1	450 mL/30s
Volume 2	465 mL/30s
Volume 3	470 mL/30s
Volume 4	480 mL/30s

Slope corrected rainfall rate: **2.34 in/hr**
0.93 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.87	0.00	
4	0.00	3.73	0.00	
6	0.00	5.60	0.00	
8	0.00	7.46	0.00	
10	0.01	9.33	0.01	@ 9:22 drips start
12	0.05	11.19	0.07	@9:38 steady flow
14	0.09	13.06	0.12	
16	0.14	14.92	0.19	
18	0.17	16.79	0.23	
20	0.22	18.65	0.30	
22	0.27	20.52	0.37	
24	0.32	22.38	0.44	
26	0.36	24.25	0.50	
28	0.4	26.11	0.55	
30	0.45	27.98	0.62	
32	0.49	29.84	0.68	
34	0.52	31.71	0.72	
36	0.55	33.57	0.76	
38	0.58	35.44	0.80	
40	0.61	37.30	0.84	
42	0.64	39.17	0.89	
44	0.67	41.03	0.93	
46	0.7	42.90	0.97	

48	0.72	44.76	1.00	
50	0.75	46.63	1.04	
52	0.78	48.49	1.08	
54	0.8	50.36	1.11	
56	0.81	52.22	1.12	
58	0.83	54.09	1.15	
62	0.88	57.82	1.22	



Total Rain:	57.82 L	2.42 in
Total Runoff:	1.22 L	0.05 in
Runoff Ratio:	**0.0211**	

Rainfall Rate:	0.933 L/min	2.34 in/hr
Runoff Rate:	0.031 L/min	0.08 in/hr
Infiltration Rate:	0.902 L/min	**2.26 in/hr**

Results: 1-2 cm of infiltration, below that there is a hydrophobic layer.

Site 11

Date and time: 8/23/2012 @ 13:00
Slope %: 30
Area m^2: 0.958
Location: Scotts/Mill Control/unburned. Northwest facing slopes.
Vegetation: Mosses present.
Soils: Mudstone derived; plot contains mudstone shards.

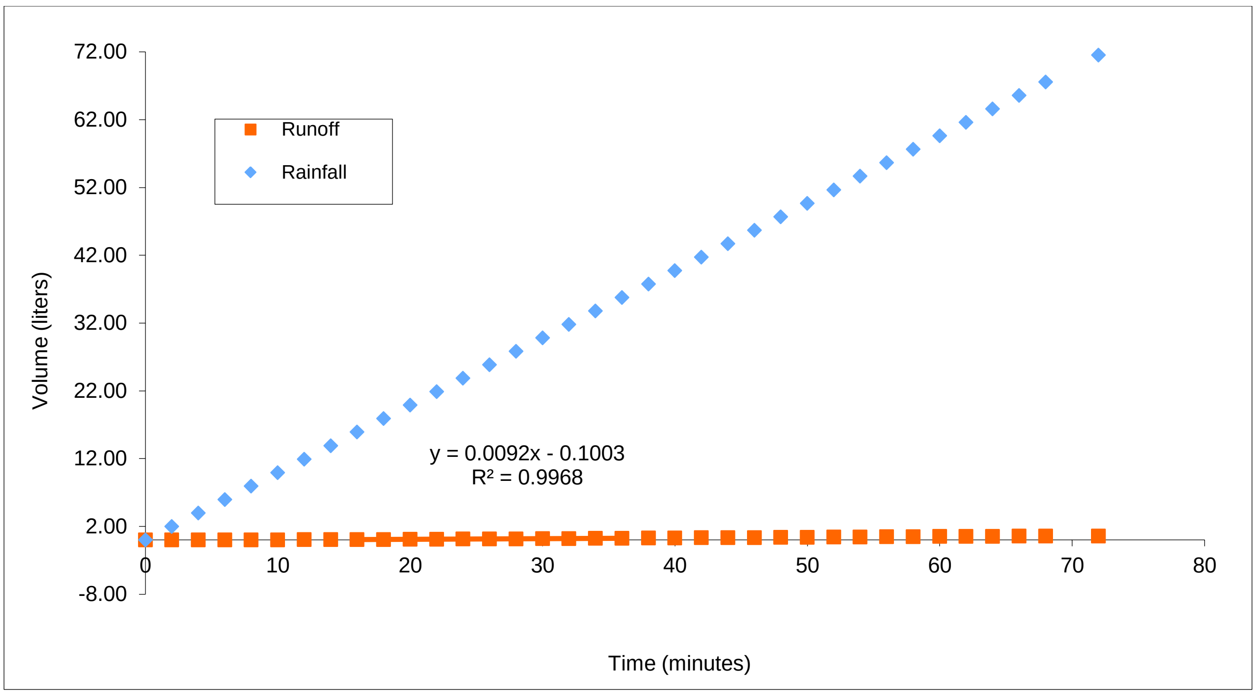
Calibration:

Time on	0.6
Time off	0.4
Volume 1	470 mL/30s
Volume 2	470 mL/30s
Volume 3	470 mL/30s
Volume 4	530 mL/30s
Volume 5	520 mL/30s
Volume 6	520 mL/30s

Slope corrected rainfall rate: **2.45 in/hr**
0.99 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.99	0.00	
4	0.00	3.97	0.00	
6	0.00	5.96	0.00	
8	0.00	7.95	0.00	
10	0.01	9.93	0.01	drips start at 9:38
12	0.02	11.92	0.03	
14	0.03	13.91	0.03	Steady stream at 15:40
16	0.04	15.89	0.05	
18	0.05	17.88	0.06	
20	0.06	19.87	0.08	
22	0.08	21.85	0.10	
24	0.09	23.84	0.12	
26	0.10	25.83	0.14	
28	0.11	27.81	0.15	
30	0.13	29.80	0.18	
32	0.14	31.79	0.19	
34	0.15	33.77	0.21	
36	0.17	35.76	0.23	
38	0.195	37.75	0.27	
40	0.21	39.73	0.29	

42	0.22	41.72	0.30	
44	0.24	43.71	0.33	
46	0.25	45.69	0.34	
48	0.27	47.68	0.37	
50	0.28	49.67	0.39	
52	0.3	51.65	0.41	
54	0.31	53.64	0.43	
56	0.325	55.63	0.45	
58	0.34	57.61	0.47	
60	0.355	59.60	0.49	
62	0.37	61.59	0.51	
64	0.38	63.57	0.52	
66	0.4	65.56	0.55	
68	0.41	67.55	0.57	simulator turned off
72	0.42	71.52	0.58	



Total Rain:	71.52 L	2.94 in
Total Runoff:	0.58 L	0.02 in
Runoff Ratio:	0.0081	

Rainfall Rate:	0.993 L/min	2.45 in/hr
Runoff Rate:	0.009 L/min	0.02 in/hr
Infiltration Rate:	0.984 L/min	**2.43 in/hr**

Results: There was some leakage due to a gap between trough and soil. The top layer of soil about 1 inch was moist. Below one inch was not moist.

Site 12

Date and time: 2/5/2013 @ 13:03
Slope %: 46%
Area m^2: 1.0
Location: Upper Boyer Non-burned
Vegetation: Tanoak dominant and some madrone redwood, and fir. Understroy has small tanoaks. Very thick duff layer composed of tanoak leaves and madrone leaves.
Soils: soils are thick and deep, they contain some moisture because it has rained this season. Moisture content is unknown.

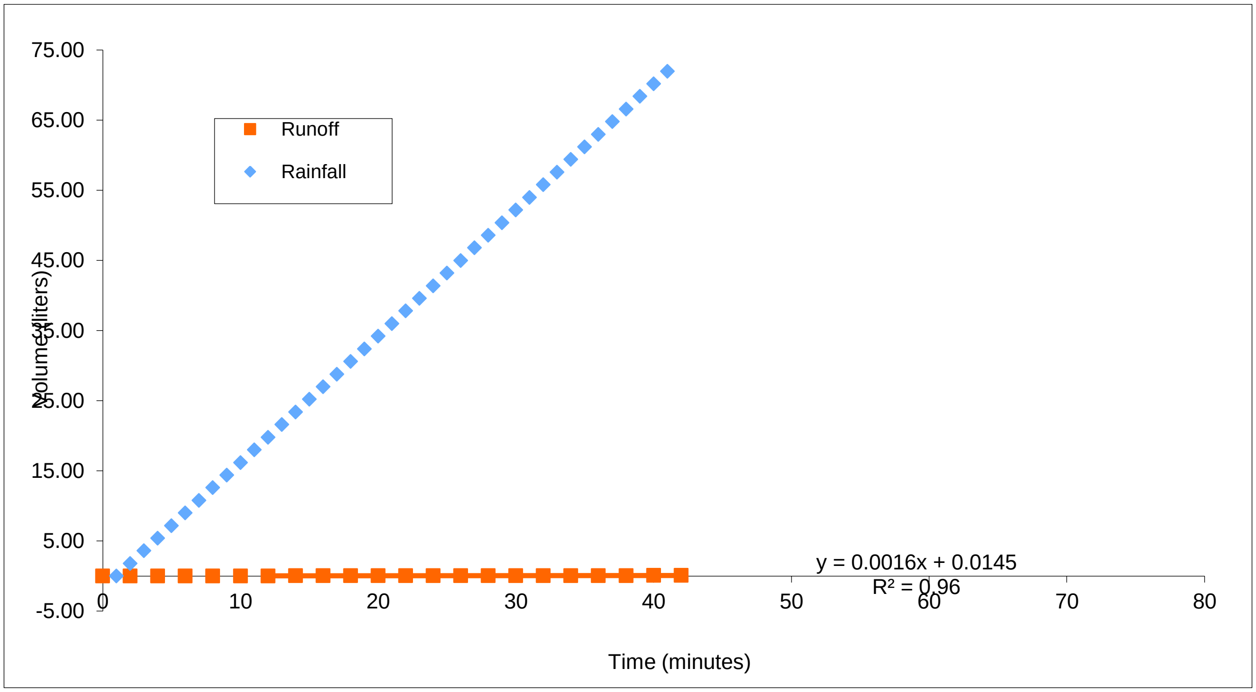
Calibration:

Time on	0.6
Time off	0.4
Volume 1	440 mL/30s
Volume 2	460 mL/30s
Volume 3	450 mL/30s
Volume 4	450 mL/30s

Slope corrected rainfall **2.13 in/hr** **rate:**
0.90 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.000	0.00	0.00	
2	0.000	1.80	0.00	Drips start @ 3:23
4	0.000	3.60	0.00	
6	0.005	5.40	0.01	
8	0.015	7.20	0.02	
10	0.025	9.00	0.03	Still Dripping
12	0.025	10.80	0.03	
14	0.030	12.60	0.04	
16	0.030	14.40	0.04	
18	0.030	16.20	0.04	
20	0.035	18.00	0.05	
22	0.035	19.80	0.05	
24	0.035	21.60	0.05	
26	0.040	23.40	0.06	
28	0.040	25.20	0.06	
30	0.050	27.00	0.07	Small Breeze
32	0.050	28.80	0.07	Still Dripping
34	0.050	30.60	0.07	
36	0.050	32.40	0.07	
38	0.055	34.20	0.08	
40	0.060	36.00	0.08	
42	0.060	37.80	0.08	Still Dripping

44	0.060	39.60	0.08	
46	0.060	41.40	0.08	A little breezy
48	0.070	43.20	0.10	
50	0.070	45.00	0.10	
52	0.070	46.80	0.10	
54	0.070	48.60	0.10	Still Dripping
56	0.080	50.40	0.11	
58	0.080	52.20	0.11	
60	0.080	54.00	0.11	
62	0.085	55.80	0.12	
64	0.090	57.60	0.12	
66	0.090	59.40	0.12	
68	0.09	61.20	0.12	
70	0.09	63.00	0.12	
72	0.095	64.80	0.13	
74	0.1	66.60	0.14	Still Dripping
76	0.1	68.40	0.14	
78	0.1	70.20	0.14	Water turned off at 78 minutes
80	0.1	72.00	0.14	Final Depth of bucket



Total Rain:	72.00 L	2.83 in
Total Runoff:	0.14 L	0.01 in
Runoff Ratio:	**0.0019**	

Rainfall Rate:	0.900 L/min	2.13 in/hr
Runoff Rate:	0.002 L/min	0.00 in/hr

Infiltration Rate: 0.898 L/min **2.12 in/hr**

Results: About 2 inches of coarse organic material (mostly leaves). Below this is more broken down organic matter (leaves). Both these layers are saturated from the simulation. Below these two layers you get to soil that is granular and also moist-not sure if moisture content is attributed to simulation or natural rainfall. Runoff dripped throughout the simulation, there was never a consistent stream of runoff into the bucket.

Site 13

Date and time: 8/20/2012 @ 11:09
Slope %: 50
Area m^2: 0.894
Location: Lions Flat (South fork ridge)
Vegetation: Northwest aspect. Redwood sprouts, ceanothus, salmon berry, tanoak sprouts, dead standing tanoak and redwoods. In the plot there are a lot of tanoak leaves. There is a bee plant stems, redwood needles and doug fir cones. Duff depth ranged from 0.5 inch to 1.5 inches
Soils: Nothing recorded in field book.

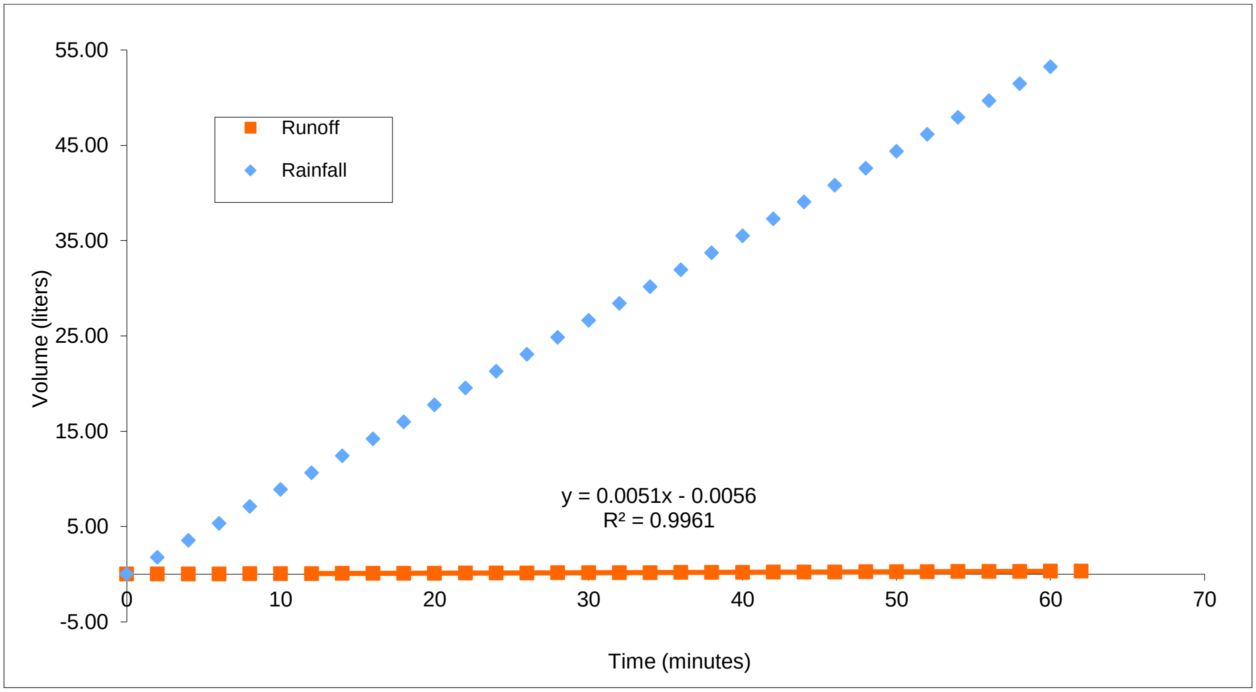
Calibration:

Time on	0.6
Time off	0.4
Volume 1	425 mL/30s
Volume 2	450 mL/30s
Volume 3	450 mL/30s
Volume 4	450 mL/30s

Slope corrected rainfall rate: **2.34 in/hr**
0.89 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.78	0.00	
4	0.00	3.55	0.00	Started dripping
6	0.02	5.33	0.03	Steady flow
8	0.03	7.10	0.04	
10	0.04	8.88	0.06	
12	0.04	10.65	0.06	
14	0.05	12.43	0.07	
16	0.06	14.20	0.08	
18	0.07	15.98	0.09	
20	0.07	17.75	0.10	
22	0.08	19.53	0.11	
24	0.09	21.30	0.12	
26	0.09	23.08	0.12	
28	0.1	24.85	0.14	
30	0.1	26.63	0.14	
32	0.11	28.40	0.15	
34	0.12	30.18	0.17	
36	0.13	31.95	0.18	
38	0.135	33.73	0.19	
40	0.14	35.50	0.19	
42	0.15	37.28	0.21	

44	0.16	39.05	0.22	
46	0.165	40.83	0.23	Stopped simulation briefly to fix pump
48	0.18	42.60	0.25	
50	0.19	44.38	0.26	Steady stream started again
52	0.19	46.15	0.26	
54	0.195	47.93	0.27	
56	0.2	49.70	0.28	
58	0.21	51.48	0.29	
60	0.22	53.25	0.30	Stopped simulation
62	0.22	55.03	0.30	



Total Rain:	55.03 L	2.42 in
Total Runoff:	0.30 L	0.01 in
Runoff Ratio:	**0.0055**	

Rainfall Rate:	0.888 L/min	2.34 in/hr
Runoff Rate:	0.005 L/min	0.01 in/hr
Infiltration Rate:	0.882 L/min	**2.33 in/hr**

Results: Uneven distribution of vertical moisture. Greater vertical moisture depth closer to the trough/bottom portion of plot. Moisture depth decreased as you move upslope in plot. Very back of plot was barely moist. Where duff was thicker, there was less penetration of water vertically.

Site 14

Date and time: 8/16/2012 @ 10:40
Slope %: 70
Area m^2: 0.819
Location: Hillslope. Weather-slight breeze. SIDE NOTE: A simulation was performed here the day before on 08-15-2012 for about 36 minutes until the pump stopped working. Therefore the plot was moist when conducting the simulation today.
Vegetation: Site is overgrown with ceanothus, eldererry, sticky monkey flower, poison oak, and blackberry. A lot of stems in the plot because we cut the leaves off of the plants. There is about 100% duff cover throughout entire plot. Northwest aspect.
Soils: Mudstone parent material, (soil was Initiall dry before first simulation) shallow, rocky soils with shallow duff layer 0.5-1 inch.

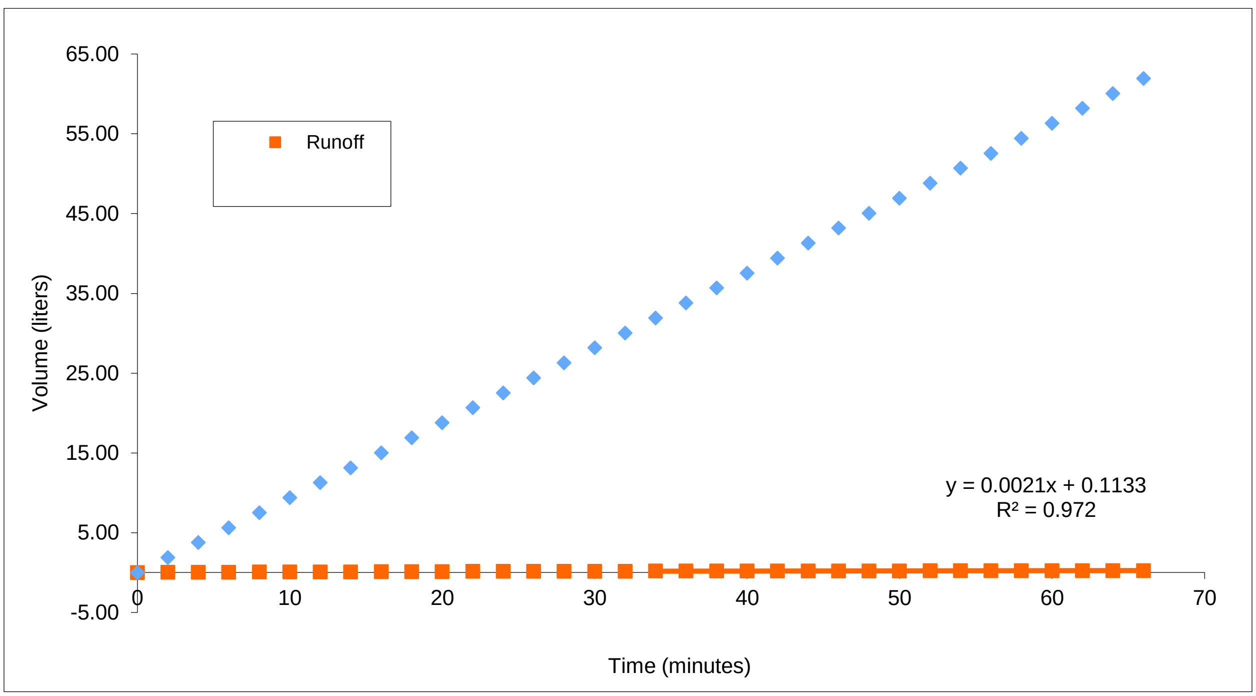
Calibration:

Time on	0.6
Time off	0.4
Volume 1	454 mL/30s
Volume 2	459 mL/30s
Volume 3	503 mL/30s
Volume 4	500 mL/30s
Volume 5	450 mL/30s
Volume 6	450 mL/30s

Slope corrected rainfall rate: **2.71 in/hr**
0.94 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	@ 42 seconds dripping occurs
2	0.02	1.88	0.03	
4	0.02	3.75	0.03	
6	0.03	5.63	0.04	
8	0.04	7.51	0.06	
10	0.04	9.39	0.06	Steady flow at 11:30
12	0.05	11.26	0.07	
14	0.06	13.14	0.08	
16	0.07	15.02	0.10	
18	0.08	16.90	0.11	Notice minor leakage over trough which is contributing to runoff. Fixed leakage and runoff went back to dripping.
20	0.09	18.77	0.12	
22	0.10	20.65	0.14	
24	0.10	22.53	0.14	Runoff still dripping since fixed leak
26	0.11	24.41	0.15	
28	0.12	26.28	0.17	Wind picks up a little

30	0.12	28.16	0.17	
32	0.125	30.04	0.17	
34	0.13	31.91	0.18	
36	0.14	33.79	0.19	Still dripping, no steady flow since fixing the leak
38	0.14	35.67	0.19	
40	0.14	37.55	0.19	
42	0.15	39.42	0.21	
44	0.15	41.30	0.21	
46	0.15	43.18	0.21	
48	0.15	45.06	0.21	
50	0.155	46.93	0.21	
52	0.16	48.81	0.22	
54	0.16	50.69	0.22	Still dripping
56	0.165	52.57	0.23	
58	0.17	54.44	0.23	
60	0.175	56.32	0.24	
62	0.175	58.20	0.24	
64	0.18	60.07	0.25	
66	0.18	61.95	0.25	End of simulation, water still dripping, no steady flow.



Total Rain:	61.95 L	2.98 in
Total Runoff:	0.25 L	0.01 in
Runoff Ratio:	**0.0040**	

Rainfall Rate:	0.939 L/min	2.71 in/hr
Runoff Rate:	0.002 L/min	0.01 in/hr
Infiltration Rate:	0.937 L/min	**2.70 in/hr**

Results: Lowed half of plot had evenly distributed moisture about 1 foot vertically. As you move upslope towards back of plot, depth of vertical moisture decreased until you reach back boarder where plot was slightly moist.

2013

<u>Site 2</u>

Date and time: 7/23/2013 @ 13:30
Slope %: 60
Area m^2: 0.857
Location: Upper Swanton Road, non-burned area. Nice weather, Aspect is southeast facing.
Vegetation: Redwood dominant. Duff is very thick and is composed of mostly redwood and some tanoak. There are ferns present in the area and solomans seal.
Soils: Deep, rich soil beneath thick, redwood duff layer.

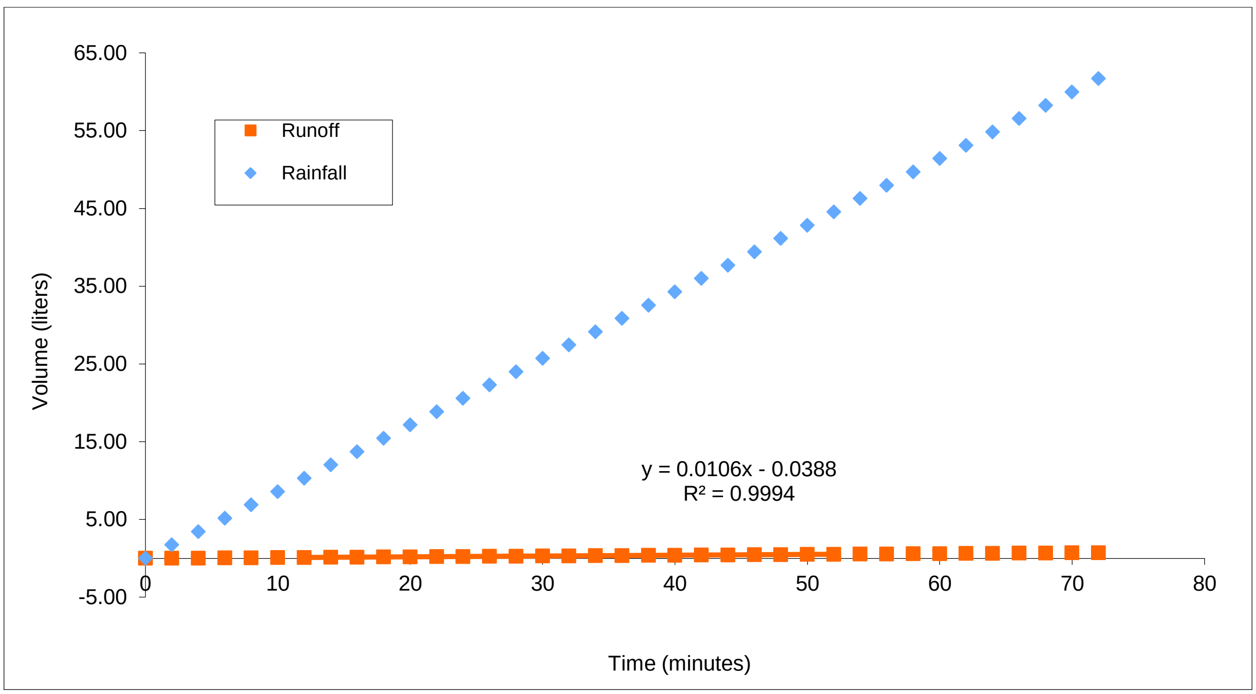
Calibration:

Time on	0.6
Time off	0.4
Volume 1	427 mL/30s
Volume 2	445 mL/30s
Volume 3	420 mL/30s
Volume 4	420 mL/30s
Volume 5	430 mL/30s

Slope corrected rainfall rate: **2.36 in/hr**
0.86 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.71	0.00	Drips begin at 2:23
4	0.02	3.43	0.02	Flow starts at 2:50
6	0.03	5.14	0.04	
8	0.04	6.85	0.06	
10	0.06	8.57	0.08	
12	0.06	10.28	0.08	
14	0.08	12.00	0.11	
16	0.10	13.71	0.13	
18	0.11	15.42	0.15	
20	0.13	17.14	0.17	
22	0.14	18.85	0.19	
24	0.16	20.56	0.22	
26	0.17	22.28	0.23	
28	0.19	23.99	0.26	
30	0.2	25.70	0.28	
32	0.215	27.42	0.30	
34	0.23	29.13	0.32	
36	0.25	30.84	0.34	
38	0.26	32.56	0.36	

40	0.28	34.27	0.39	
42	0.29	35.99	0.40	
44	0.31	37.70	0.43	
46	0.32	39.41	0.44	
48	0.34	41.13	0.47	
50	0.355	42.84	0.49	
52	0.37	44.55	0.51	
54	0.38	46.27	0.52	
56	0.4	47.98	0.55	
58	0.42	49.69	0.58	
60	0.43	51.41	0.59	
62	0.44	53.12	0.61	
64	0.46	54.84	0.64	
66	0.47	56.55	0.65	
68	0.485	58.26	0.67	
70	0.5	59.98	0.69	Turned off simulator
72	0.515	61.69	0.71	final depth



Total Rain:	61.690	2.832
Total Runoff:	0.712	0.033
Runoff Ratio:		**0.0115**

Rainfall Rate:	0.857	2.36 in/hr
Runoff Rate:	0.011	0.03 in/hr
Infiltration Rate:	0.846	**2.33 in/hr**

Results: Duff layer is moist in upper portion 1.0-1.5" and below that duff is dry. There are macropores within the duff and soil so water was able to infiltrate. Below duff, soil is wetted in some areas of plot to a depth of about 2". Soil throughout plot is not equally wetted but did have some infiltration of water through soil.

Site 5

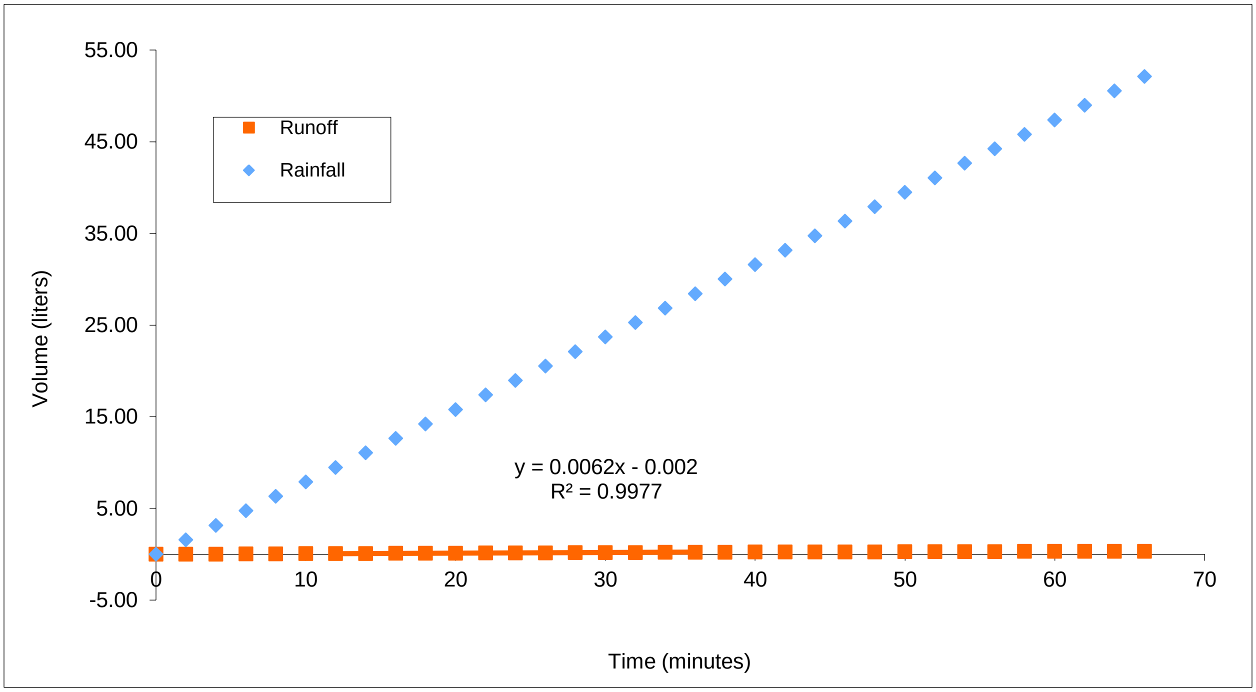
Date and time: 8/2/2013 @ 10:12
Slope %: 56
Area m^2: 0.873
Location: Cabins.
Vegetation: There is blackberry and sedge nettle. Also some poison oak. Lots of twigs and blackberry vines in plot. Duff is not thick, just the blackberry vines are.
Soils: Duff is around .5-1 cm which is composed of some redwood needles and some sandstone rocks. There is soil beneath duff with lots of mica.

Calibration:	
Time on	0.6
Time off	1.4
Volume 1	390 mL/30s
Volume 2	410 mL/30s
Volume 3	380 mL/30s
Volume 4	380 mL/30s
Volume 5	415 mL/30s

Slope corrected rainfall rate: **2.14 in/hr**
0.79 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.58	0.00	drops at 2:23
4	0.01	3.16	0.01	Steady flow at 4:19
6	0.03	4.74	0.04	
8	0.04	6.32	0.06	
10	0.05	7.90	0.07	
12	0.05	9.48	0.07	
14	0.06	11.06	0.08	
16	0.07	12.64	0.10	
18	0.08	14.22	0.11	
20	0.09	15.80	0.12	
22	0.10	17.38	0.14	
24	0.11	18.96	0.14	
26	0.12	20.54	0.16	
28	0.13	22.12	0.17	
30	0.13	23.70	0.18	
32	0.14	25.28	0.19	
34	0.15	26.86	0.21	
36	0.16	28.44	0.22	
38	0.16	30.02	0.22	
40	0.17	31.60	0.23	
42	0.18	33.18	0.25	Jack removed constant 0.3475 from col G starting here
44	0.18	34.76	0.25	
46	0.19	36.34	0.26	

48	0.19	37.92	0.26	
50	0.20	39.50	0.28	
52	0.20	41.08	0.28	
54	0.21	42.66	0.29	
56	0.21	44.24	0.29	
58	0.22	45.82	0.30	
60	0.23	47.40	0.31	
62	0.23	48.98	0.32	
64	0.23	50.56	0.32	Stopped simulation
66	0.24	52.14	0.33	Final Depth



Total Rain:	52.14 L	2.35 in
Total Runoff:	0.33 L	0.01 in
Runoff Ratio:	**0.0063**	

Rainfall Rate:	0.790 L/min	2.14 in/hr
Runoff Rate:	0.006 L/min	0.02 in/hr
Infiltration Rate:	0.784 L/min	**2.12 in/hr**

Results: Patchy infiltration throughout plot, some dry pockets but mostly wet. Infiltration is about 1 foot deep.

Site 6

Date and time: 7/31/2013 @ 12:50
Slope %: 50
Area m^2: 0.894
Location: Upper North Fork of Little Creek.
Vegetation: Sorel and star flower. Duff is composed of redwood and tanoak leaves, some twigs present. Duff depth ranges from 0.5 inches to 1 inch.
Soils: Soil is beneath duff layer, looks like thick rich soil.

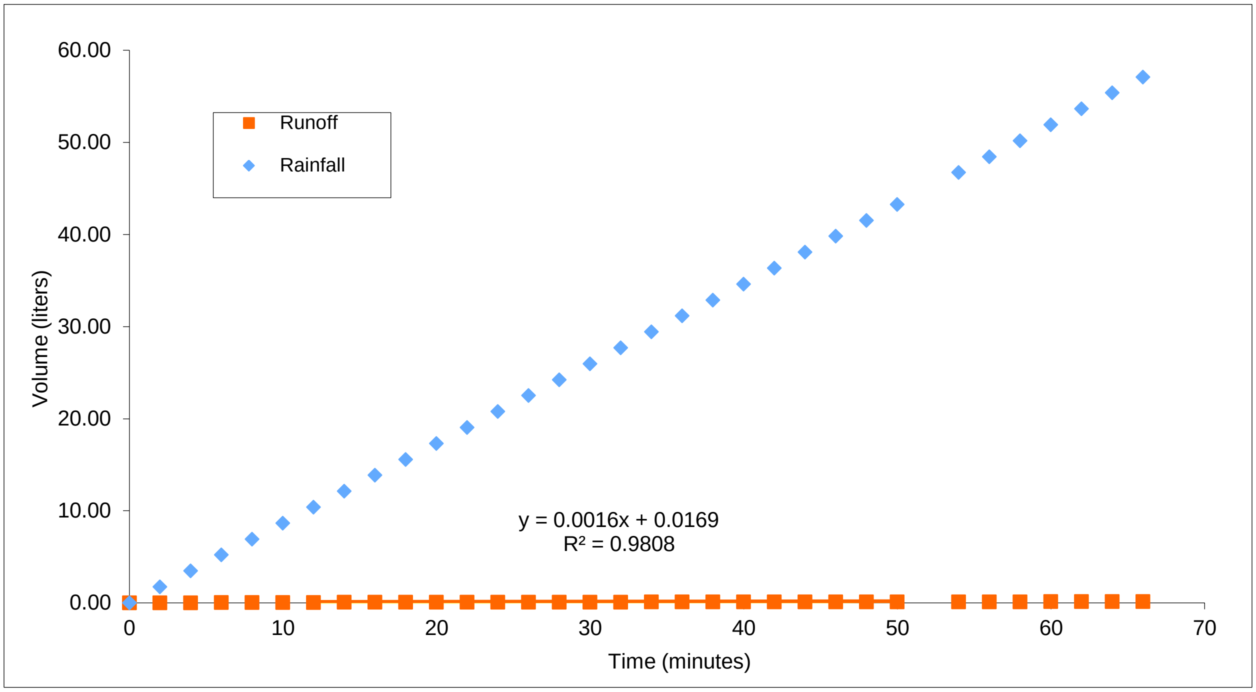
Calibration:

Time on	0.6
Time off	0.4
Volume 1	415 mL/30s
Volume 2	430 mL/30s
Volume 3	445 mL/30s
Volume 4	440 mL/30s
Volume 5	425 mL/30s
Volume 6	440 mL/30s

Slope corrected rainfall rate: **2.28 in/hr**
0.87 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.73	0.00	
4	0.00	3.46	0.00	drips at 4:13
6	0.010	5.19	0.01	
8	0.015	6.92	0.02	
10	0.020	8.65	0.03	
12	0.025	10.38	0.03	
14	0.030	12.11	0.04	
16	0.030	13.84	0.04	
18	0.030	15.57	0.04	
20	0.035	17.30	0.05	
22	0.040	19.03	0.06	
24	0.040	20.76	0.06	
26	0.045	22.49	0.06	
28	0.050	24.22	0.07	
30	0.050	25.95	0.07	
32	0.050	27.68	0.07	
34	0.055	29.41	0.08	
36	0.055	31.14	0.08	
38	0.060	32.87	0.08	

40	0.060	34.60	0.08	
42	0.060	36.33	0.08	
44	0.065	38.06	0.09	
46	0.065	39.79	0.09	
48	0.070	41.52	0.10	
50	0.070	43.25	0.10	
54	0.075	46.71	0.10	missed reading at 52
56	0.075	48.44	0.10	
58	0.075	50.17	0.10	
60	0.080	51.90	0.11	
62	0.080	53.63	0.11	
64	0.090	55.36	0.12	Simulation stopped
66	0.090	57.09	0.12	



Total Rain:	57.09 L	2.51 in
Total Runoff:	0.12 L	0.01 in
Runoff Ratio:	**0.0022**	

Rainfall Rate:	0.865 L/min	2.28 in/hr
Runoff Rate:	0.002 L/min	0.00 in/hr
Infiltration Rate:	0.863 L/min	**2.28 in/hr**

Results: Plot has a lot of infiltration that is deep (greater than 2 feet). Infiltration on downhill side of plot has greater infiltration and infiltration depth decreases slightly uphill. Plot seems to be uniformly wetted.

Site 7

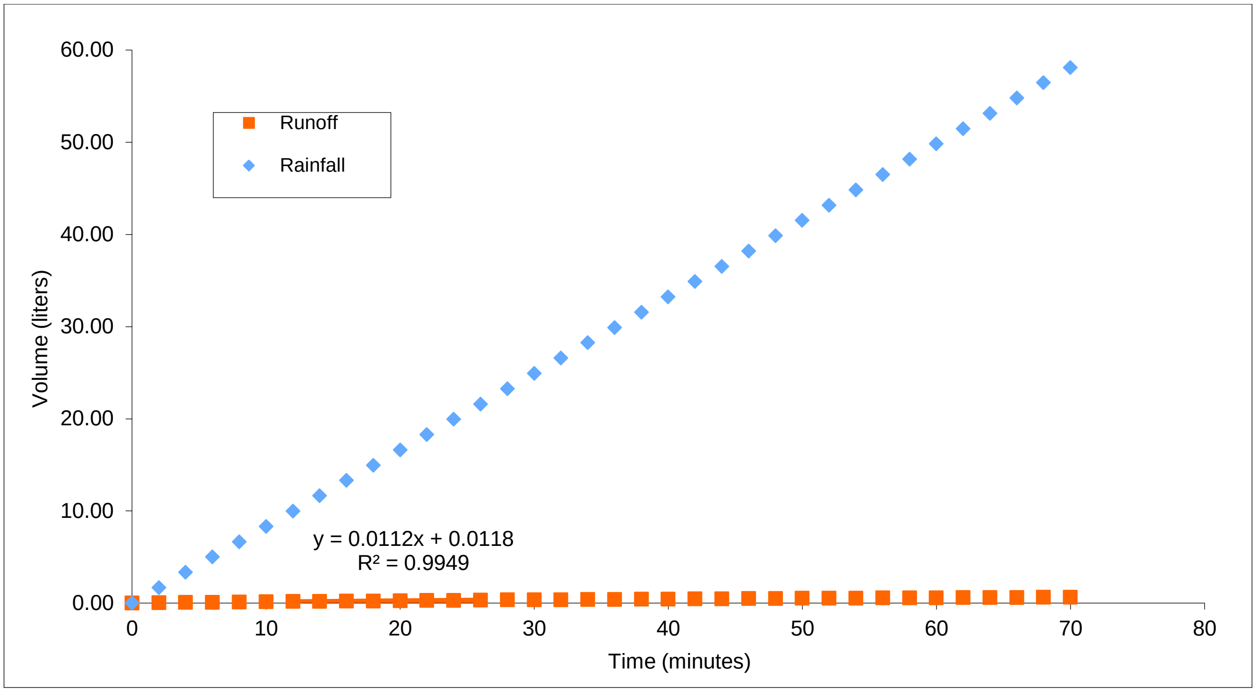
Date and time: 7/25/2013 @ 12:20
Slope %: 45
Area m^2: 0.912
Location: South fork on Cemex/Swanton boundary.
Vegetation: Redwood and tanoak. Duff is thick composed of redwood and tanoak litter. Blackberry, fern, and wild iris present in area. Duff ranges from 1-2" thickness. Below duff is decomposed duff and below that is soil. Soil has mycelium in it.
Soils: No soils recorded in field book.

Calibration:	
Time on	0.6
Time off	0.4
Volume 1	415 mL/30s
Volume 2	405 mL/30s
Volume 3	410 mL/30s
Volume 4	425 mL/30s
Volume 5	420 mL/30s

Slope corrected rainfall rate: **2.15 in/hr**
0.83 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.01	1.66	0.01	Drips start and flow seconds after at 1:36
4	0.03	3.32	0.04	
6	0.05	4.98	0.07	
8	0.07	6.64	0.10	
10	0.09	8.30	0.12	
12	0.11	9.96	0.15	
14	0.12	11.62	0.17	
16	0.14	13.28	0.19	
18	0.15	14.94	0.21	
20	0.17	16.60	0.23	
22	0.19	18.26	0.26	
24	0.21	19.92	0.28	
26	0.22	21.58	0.30	
28	0.245	23.24	0.34	
30	0.25	24.90	0.34	
32	0.25	26.56	0.34	
34	0.27	28.22	0.37	
36	0.275	29.88	0.38	
38	0.29	31.54	0.40	

40	0.3	33.20	0.41	
42	0.31	34.86	0.43	
44	0.325	36.52	0.45	
46	0.34	38.18	0.47	
48	0.35	39.84	0.48	
50	0.36	41.50	0.50	
52	0.37	43.16	0.51	
54	0.38	44.82	0.52	
56	0.39	46.48	0.54	
58	0.4	48.14	0.55	
60	0.405	49.80	0.56	
62	0.415	51.46	0.57	
64	0.425	53.12	0.59	
66	0.43	54.78	0.59	
68	0.44	56.44	0.61	Simulation stopped
70	0.445	58.10	0.61	Final Depth



Total Rain:	58.10 L	2.51 in
Total Runoff:	0.61 L	0.03 in
Runoff Ratio:	**0.0106**	

Rainfall Rate:	0.830 L/min	2.15 in/hr
Runoff Rate:	0.011 L/min	0.03 in/hr
Infiltration Rate:	0.819 L/min	**2.12 in/hr**

Results: Water infiltrated through duff and soil. Water infiltrated soil greater than 8 inches in some areas of plot. Large pockets of wetness throughout the plot. Some areas below duff was dry and could be attributed to mycorrhizal fungi.

Site 8

Date and time: 7/16/2013 @ 13:00
Slope %: 50
Area m^2***:*** 1.0
Location: Boyer Creek burned. Sunny weather and on a southeast facing slope.
Vegetation: Knobcone pine, dead knobcone, manzanita, some deerweed-Those seedlings and deerweed were removed.
Soils: No continuous duff layer present, mostly rock fragments. Some are charred but mostly larger coarse fragments. Thickness of this rock layer ranges from 0.25" to about 1".

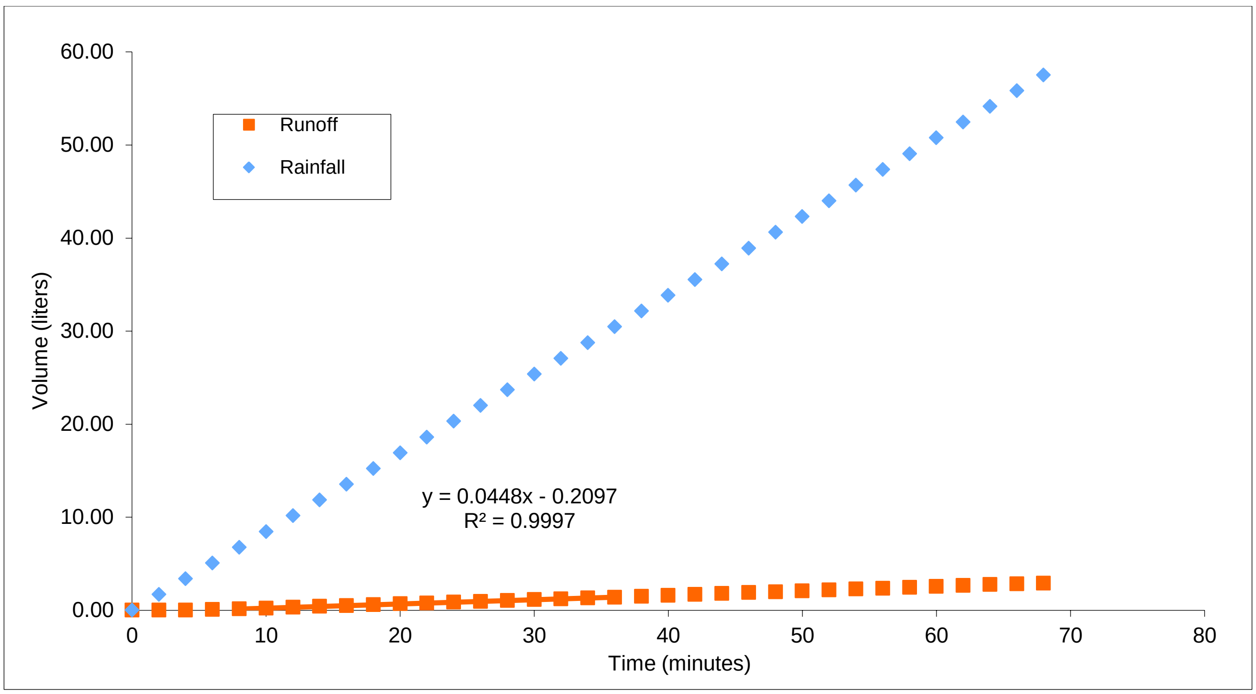
Calibration:

Time on	0.6
Time off	0.4
Volume 1	420 mL/30s
Volume 2	445 mL/30s
Volume 3	405 mL/30s
Volume 4	425 mL/30s
Volume 5	420 mL/30s

Slope corrected rainfall rate: **2.00 in/hr**
0.85 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.69	0.00	
4	0.01	3.38	0.01	
6	0.06	5.08	0.08	
8	0.11	6.77	0.15	
10	0.17	8.46	0.23	
12	0.23	10.15	0.32	
14	0.30	11.84	0.41	
16	0.37	13.54	0.51	
18	0.43	15.23	0.59	
20	0.50	16.92	0.69	
22	0.56	18.61	0.77	
24	0.63	20.30	0.87	
26	0.69	22.00	0.95	
28	0.76	23.69	1.05	
30	0.82	25.38	1.14	
32	0.88	27.07	1.22	
34	0.95	28.76	1.32	
36	1	30.46	1.39	Dumped bucket
38	1.08	32.15	1.50	

40	1.15	33.84	1.60	
42	1.22	35.53	1.69	
44	1.29	37.22	1.79	
46	1.36	38.92	1.89	
48	1.43	40.61	1.99	
50	1.5	42.30	2.09	
52	1.57	43.99	2.19	
54	1.64	45.68	2.28	
56	1.7	47.38	2.37	
58	1.77	49.07	2.47	
60	1.83	50.76	2.55	
62	1.9	52.45	2.65	
64	1.97	54.14	2.75	
66	2.02	55.84	2.82	
68	2.08	57.53	2.91	Final depth is 1.08



Total Rain:	57.53 L	2.26 in
Total Runoff:	2.91 L	0.11 in
Runoff Ratio:	**0.0505**	

Rainfall Rate:	0.846 L/min	2.00 in/hr
Runoff Rate:	0.045 L/min	0.11 in/hr
Infiltration Rate:	0.801 L/min	**1.89 in/hr**

Results: Infiltration is only in topmost layer of rock and charcoaled soil/material. Below the rock is ashy layer about 0.5" to1" with smaller rock fragments. Below ash/soil is larger rock.

There was a very high runoff rate, we had to empty the bucket midway through. Ash layer is hydrophobic and water does not infiltrate below rock/surface layer.

Site 9

Date and time: 7/3/2013 @ 14:40
Slope %: 62
Area m^2: 0.850
Location: Mill Creek ridgeline unburned. Sunny, warm weather with some wind gusts.
Vegetation: Thick duff layer composed of manzanita, knobcone, chamise. Duff is 2-3" thick, below is decomposed duff and some mycorrhizal fungi. Below is soil and Mycorrhizal fungi.
Soils: Granite parent material.

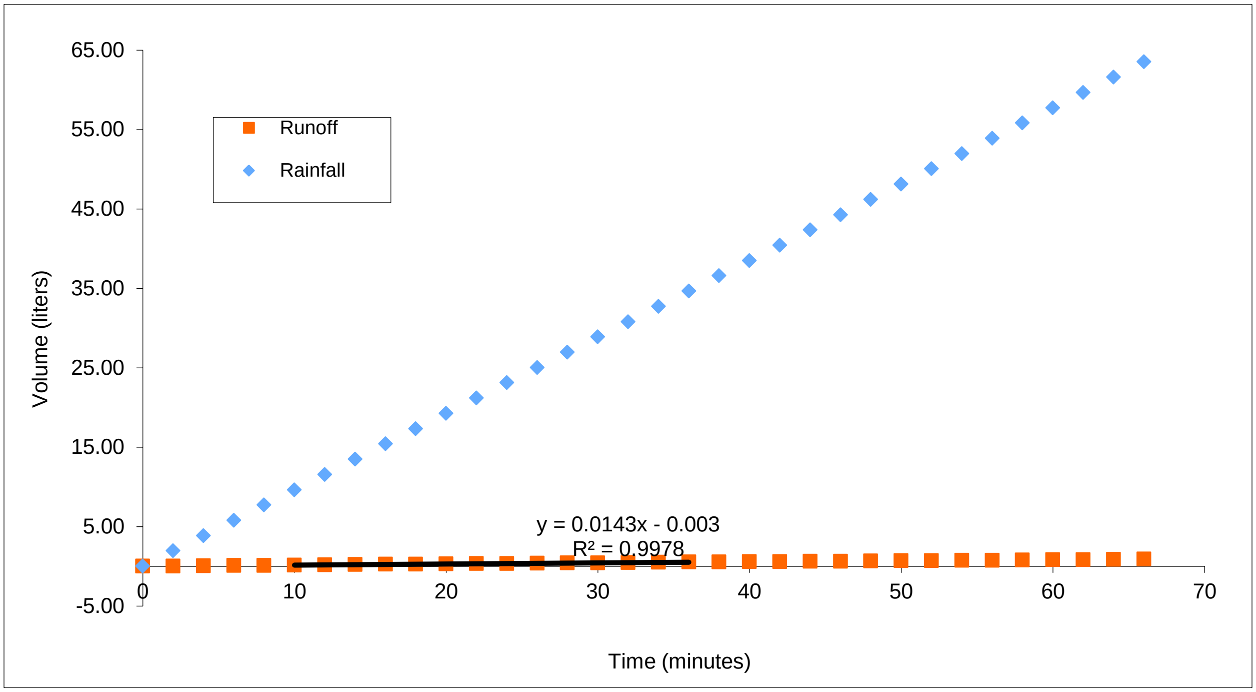
Calibration:

Time on	0.6
Time off	0.4
Volume 1	475 mL/30s
Volume 2	485 mL/30s
Volume 3	480 mL/30s
Volume 4	485 mL/30s

Slope corrected rainfall rate: **2.68 in/hr**
0.96 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.93	0.00	2:16 first drip
4	0.03	3.85	0.04	2:58 steady stream
6	0.05	5.78	0.07	
8	0.08	7.70	0.10	
10	0.10	9.63	0.14	
12	0.12	11.55	0.17	
14	0.14	13.48	0.20	
16	0.17	15.40	0.23	
18	0.18	17.33	0.25	
20	0.21	19.25	0.29	
22	0.23	21.18	0.32	
24	0.25	23.10	0.34	
26	0.27	25.03	0.37	
28	0.295	26.95	0.41	
30	0.3	28.88	0.41	
32	0.33	30.80	0.46	
34	0.35	32.73	0.48	
36	0.37	34.65	0.51	
38	0.38	36.58	0.52	
40	0.4	38.50	0.55	
42	0.42	40.43	0.58	
44	0.44	42.35	0.61	

46	0.45	44.28	0.62	
48	0.47	46.20	0.65	
50	0.49	48.13	0.68	
52	0.51	50.05	0.70	
54	0.53	51.98	0.73	
56	0.54	53.90	0.75	
58	0.56	55.83	0.77	
60	0.58	57.75	0.80	
62	0.6	59.68	0.83	
64	0.62	61.60	0.86	64:00 simulator turned off
66	0.64	63.53	0.89	Final Depth @0.64 inch.



Total Rain:	63.53 L	2.94 in
Total Runoff:	0.89 L	0.04 in
Runoff Ratio:	0.0139	

Rainfall Rate:	0.963 L/min	2.68 in/hr
Runoff Rate:	0.014 L/min	0.04 in/hr
Infiltration Rate:	0.948 L/min	**2.64 in/hr**

Results: Only the top 2-3" Duff layer was moist. Below that, the decomposed layer was not saturated. The soil underneath all of this was not moist and had a lot of mycorrhizal fungi woven throughout.

Site 10

Date and time: 7/11/2013
Slope %: 36
Area m^2: 0.941
Location: Lockheed ridge (aka LeHi); Southeast facing slope.
Vegetation: Deer weed, a couple pine needles.
Soils: No duff layer present, there are shards of small rock-Mudstone. Some pieces are charred and black. Below rocks there is an ash layer-so I think. Some black charcoal present. Below the 1 cm ash is hydrophobic layer.

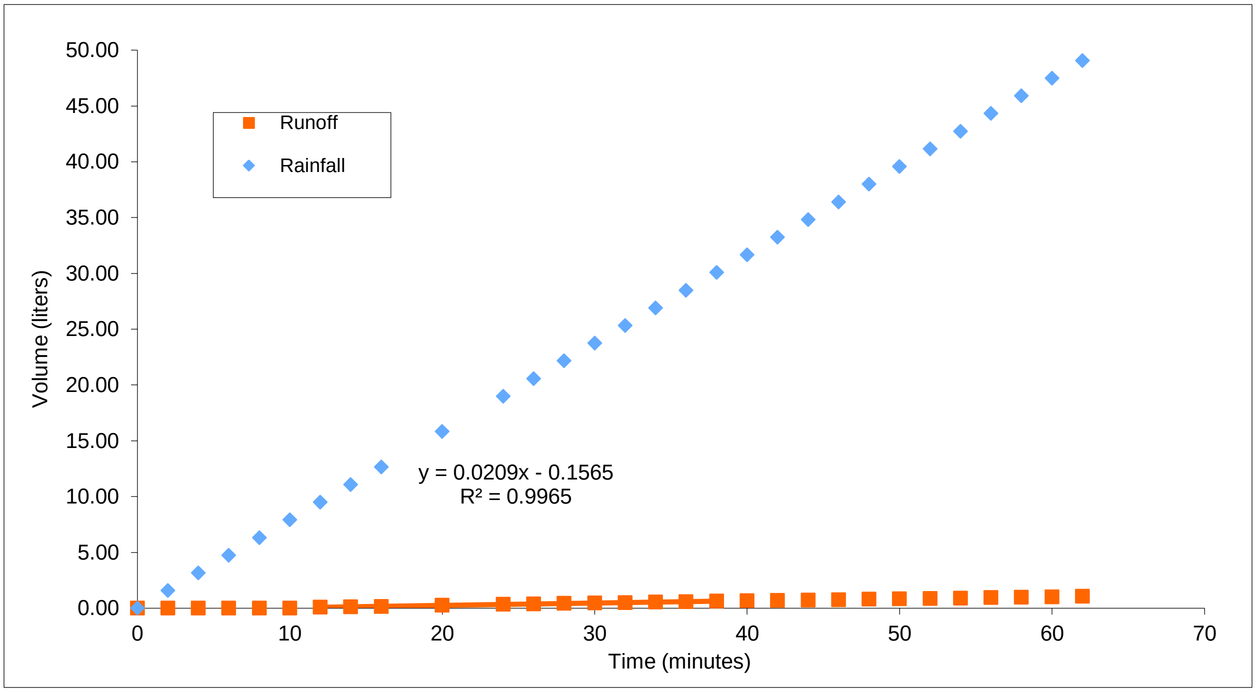
Calibration:

Time on	0.6
Time off	0.4
Volume 1	425 mL/30s
Volume 2	400 mL/30s
Volume 3	380 mL/30s
Volume 4	370 mL/30s
Volume 5	395 mL/30s
Volume 6	405 mL/30s

Slope corrected rainfall rate: **1.99 in/hr**
0.79 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.58	0.00	
4	0.00	3.17	0.00	
6	0.00	4.75	0.00	6:46 start of drops
8	0.01	6.33	0.01	Steady flow before 8 minutes
10		7.92		Stopped simulation at 10:20
12	0.08	9.50	0.11	started it up again
14	0.09	11.08	0.12	
16	0.12	12.67	0.17	
20	0.19	15.83	0.26	issues with simulator at 18 min(volume 14.25)
24	0.25	19.00	0.34	missed reading at 22 (volume 17.42)
26	0.28	20.58	0.39	
28	0.33	22.17	0.46	
30	0.34	23.75	0.47	
32	0.37	25.33	0.51	
34	0.4	26.92	0.55	
36	0.43	28.50	0.59	
38	0.46	30.08	0.64	
40	0.48	31.67	0.66	

42	0.51	33.25	0.70	
44	0.53	34.83	0.73	
46	0.55	36.42	0.76	
48	0.58	38.00	0.80	
50	0.61	39.58	0.84	
52	0.63	41.17	0.87	
54	0.66	42.75	0.91	
56	0.69	44.33	0.95	
58	0.72	45.92	1.00	
60	0.74	47.50	1.02	
62	0.77	49.08	1.07	Simulator stopped at 60 min and final depth is 0.77



Total Rain:	49.08 L	2.05 in
Total Runoff:	1.07 L	0.04 in
Runoff Ratio:	**0.0217**	

Rainfall Rate:	0.792 L/min	1.99 in/hr
Runoff Rate:	0.021 L/min	0.05 in/hr
Infiltration Rate:	0.771 L/min	**1.94 in/hr**

Results: Water stayed within the top 1 cm of soil-below soil at 1 cm it is hydrophobic. Water did not infiltrate below 1cm.

Site 11

Date and time: 7/22/2013 @ 12:34
Slope %: 36
Area m^2: 0.941
Location: Lockheed ridge (LeHi) on Lockheed Martin Property Ridgetop. Northwest facing slopes
Vegetation: Site has leather oak, maybe scrub oak? Some knobcone pine needles and some madrone litter. Some lichen and cones present in the plot. Duff layer is about 0.5-1.5" thick.
Soils: Soil was below the duff layer. Some rocks present in soil.

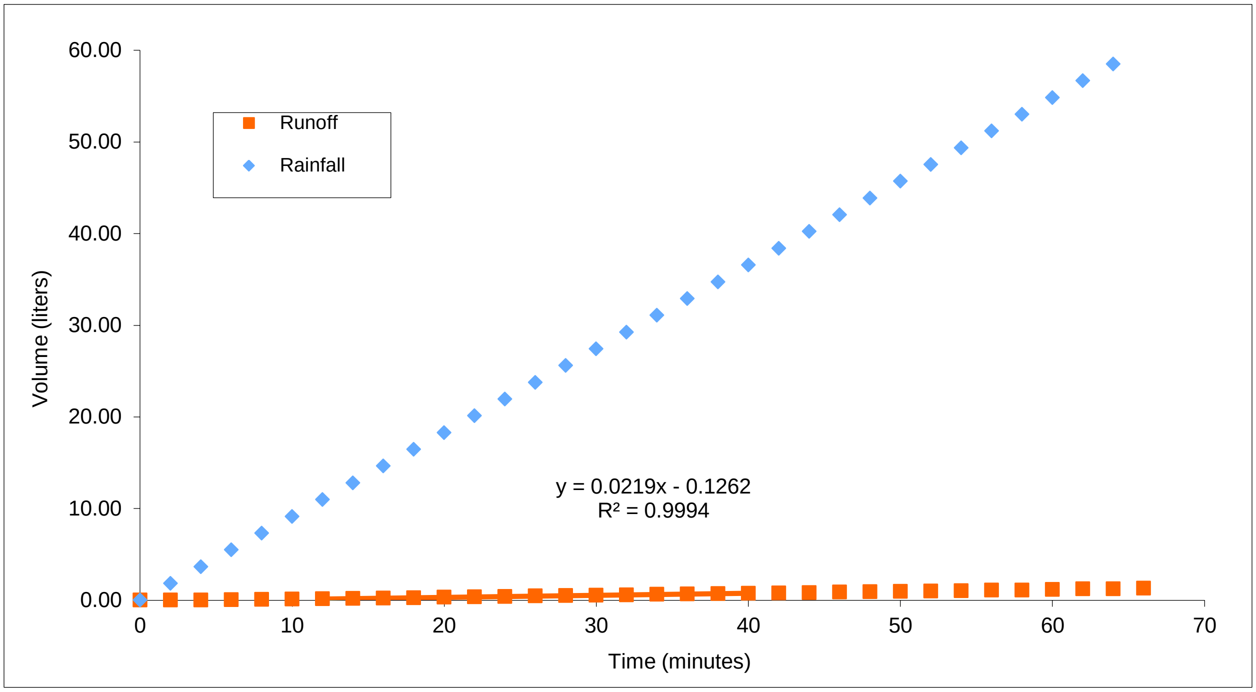
Calibration:

Time on	0.6
Time off	0.4
Volume 1	445 mL/30s
Volume 2	465 mL/30s
Volume 3	480 mL/30s
Volume 4	450 mL/30s
Volume 5	445 mL/30s

Slope corrected rainfall rate: **2.29 in/hr**
0.91 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.83	0.00	Drops start at 3:45
4	0.00	3.66	0.00	constant flow at 5:25
6	0.03	5.48	0.04	
8	0.05	7.31	0.07	
10	0.08	9.14	0.10	
12	0.10	10.97	0.14	
14	0.13	12.80	0.18	
16	0.16	14.62	0.22	
18	0.19	16.45	0.26	
20	0.23	18.28	0.32	
22	0.26	20.11	0.36	
24	0.29	21.94	0.40	
26	0.33	23.76	0.46	
28	0.35	25.59	0.48	
30	0.385	27.42	0.53	
32	0.42	29.25	0.58	
34	0.45	31.08	0.62	
36	0.48	32.90	0.66	
38	0.51	34.73	0.70	
40	0.54	36.56	0.75	

42	0.57	38.39	0.79	
44	0.6	40.22	0.83	
46	0.63	42.04	0.87	
48	0.66	43.87	0.91	
50	0.69	45.70	0.95	
52	0.72	47.53	1.00	
54	0.75	49.36	1.04	
56	0.78	51.18	1.08	
58	0.8	53.01	1.11	
60	0.84	54.84	1.16	
62	0.88	56.67	1.22	
64	0.9	58.50	1.25	turned off simulator
66	0.93	60.32	1.29	end depth



Total Rain:	60.32 L	2.52 in
Total Runoff:	1.29 L	0.05 in
Runoff Ratio:	**0.0214**	

Rainfall Rate:	0.914 L/min	2.29 in/hr
Runoff Rate:	0.022 L/min	0.05 in/hr
Infiltration Rate:	0.892 L/min	**2.24 in/hr**

Results: Duff retained moisture. Soil below duff remained dry. Was is hydrophobic but not as strongly hydrophobic as other sites previously tested with hydrophobicity.

Site 12

Date and time: 7/9/2013 @ 10:46
Slope %: 45
Area m²: 0.912
Location: Boyer Creek control.
Vegetation: Madrone, tanoak, and redwood.
Soils: Tanoak is dominant duff litter, some twigs and some redwood needles. Duff is about 1-2" and below duff is decomposed duff layer with mycorrhizal fungi and below that is soil.

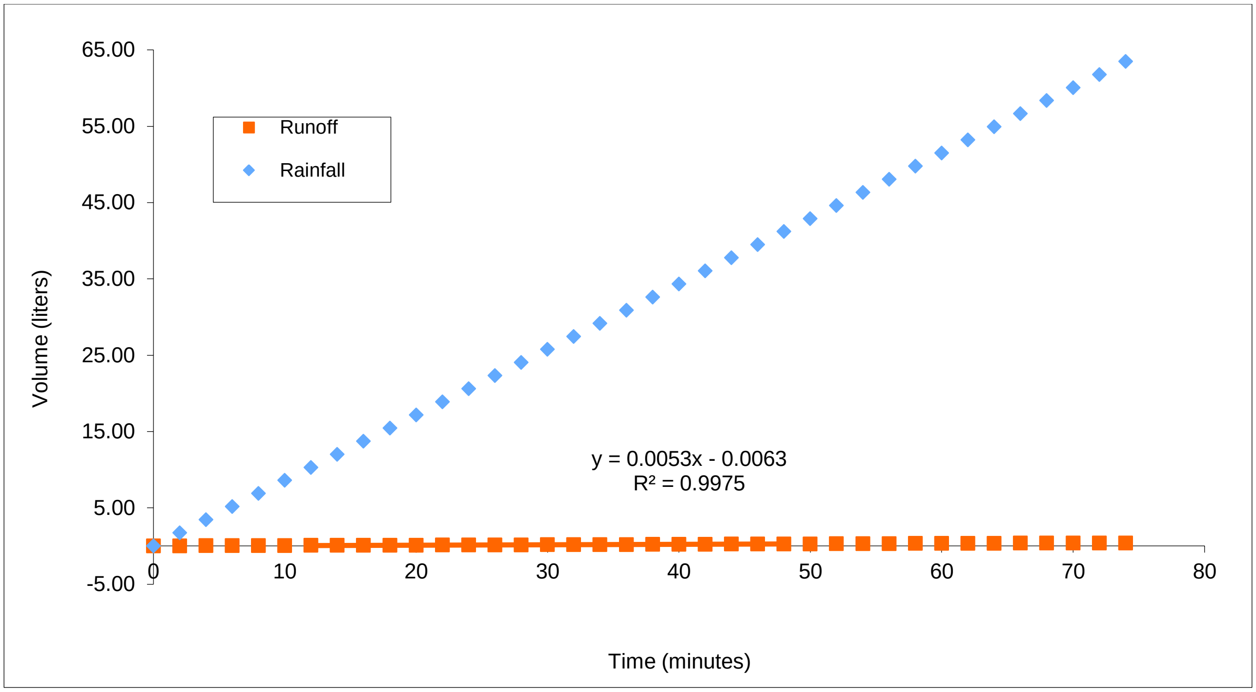
Calibration:

Time on	0.6
Time off	0.4
Volume 1	420 mL/30s
Volume 2	435 mL/30s
Volume 3	445 mL/30s
Volume 4	415 mL/30s
Volume 5	430 mL/30s

Slope corrected rainfall rate: **2.22 in/hr**
0.86 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.72	0.00	2:52 drips start and quickly after light constant flow
4	0.02	3.43	0.03	
6	0.04	5.15	0.05	
8	0.04	6.86	0.06	
10	0.04	8.58	0.06	
12	0.05	10.30	0.06	
14	0.05	12.01	0.07	
16	0.06	13.73	0.08	
18	0.07	15.44	0.09	
20	0.07	17.16	0.10	
22	0.08	18.88	0.11	
24	0.09	20.59	0.12	
26	0.10	22.31	0.13	
28	0.1	24.02	0.14	
30	0.11	25.74	0.15	
32	0.12	27.46	0.17	
34	0.13	29.17	0.18	
36	0.135	30.89	0.19	
38	0.14	32.60	0.19	
40	0.15	34.32	0.21	
42	0.16	36.04	0.22	
44	0.17	37.75	0.23	

46	0.175	39.47	0.24	
48	0.18	41.18	0.25	
50	0.19	42.90	0.26	
52	0.2	44.62	0.28	
54	0.21	46.33	0.29	
56	0.22	48.05	0.30	
58	0.23	49.76	0.32	
60	0.235	51.48	0.32	
62	0.24	53.20	0.33	
64	0.25	54.91	0.34	
66	0.26	56.63	0.36	
68	0.265	58.34	0.37	
70	0.27	60.06	0.37	
72	0.28	61.78	0.39	Turned off simulator
74	0.285	63.49	0.39	Final Depth



Total Rain:	63.49 L	2.74 in
Total Runoff:	0.39 L	0.02 in
Runoff Ratio:	**0.0062**	

Rainfall Rate:	0.858 L/min	2.22 in/hr
Runoff Rate:	0.005 L/min	0.01 in/hr
Infiltration Rate:	0.853 L/min	**2.21 in/hr**

Results: Infiltration in upper duff and decomposed duff and some infiltration in macropores. However, soil is mostly dry.

Site 12

Date and time: 7/9/2013 @ 14:17
Slope %: 43
Area m^2: 0.919
Location: Boyer Creek Control Lockheed Property Unburned. Aspect is South facing slope. This is the second simulation for this site this year. This was done to get more data for unburned sites.
Vegetation: Madrone, tanoak, redwood.
Soils: Duff is 1-2"thick, mostly tanoak litter. Below the decomposed duff is 0.5-1" thick and contains mycorrhizal fungi. Also in this decomposed layer there are lots of insects and holes.

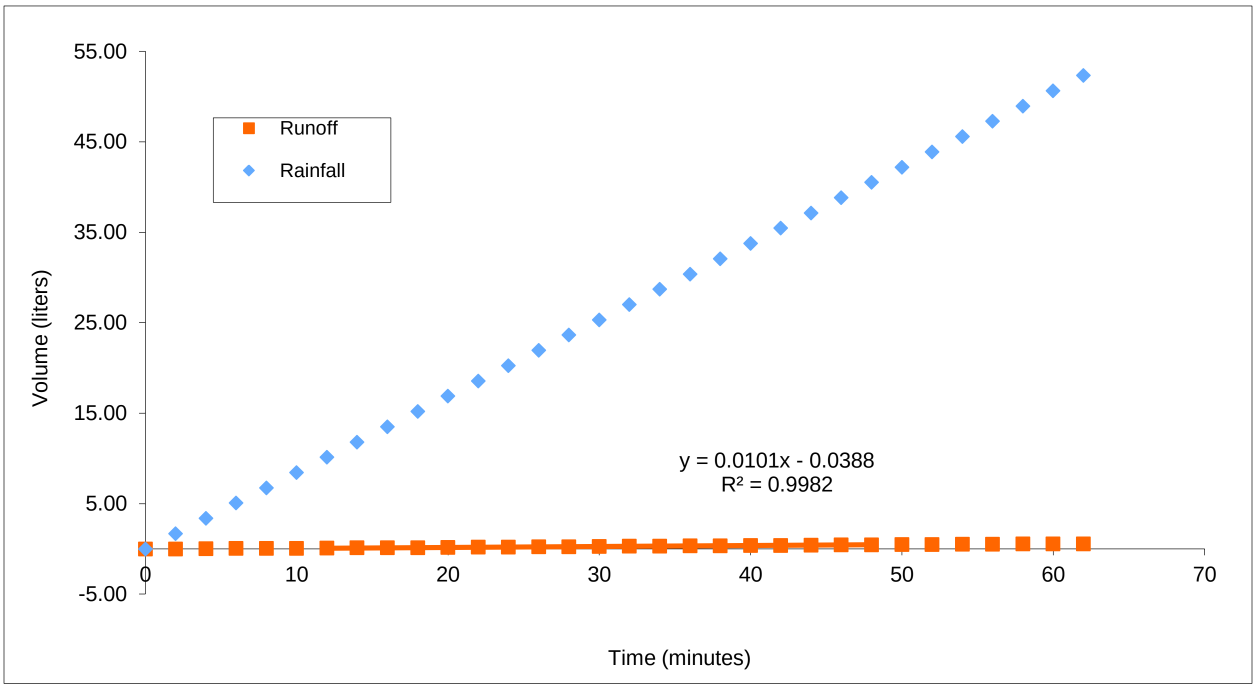
Calibration:

Time on	0.6
Time off	0.4
Volume 1	425 mL/30s
Volume 2	385 mL/30s
Volume 3	430 mL/30s
Volume 4	430 mL/30s
Volume 5	440 mL/30s

Slope corrected rainfall rate: **2.17 in/hr**
0.84 L/min

time (min)	Bucket Water Depth (in)	Rainfall Volume (L)	Runoff Volume (L)	Notes
0	0.00	0.00	0.00	
2	0.00	1.69	0.00	2:00 drips, 2:20 faster drips
4	0.01	3.38	0.01	3:00 consistent low flow.
6	0.03	5.06	0.04	
8	0.04	6.75	0.06	
10	0.05	8.44	0.07	
12	0.06	10.13	0.08	
14	0.08	11.82	0.11	
16	0.09	13.50	0.12	
18	0.10	15.19	0.14	
20	0.12	16.88	0.17	
22	0.13	18.57	0.18	
24	0.14	20.26	0.19	
26	0.16	21.94	0.22	
28	0.18	23.63	0.25	
30	0.19	25.32	0.26	
32	0.21	27.01	0.29	
34	0.22	28.70	0.30	
36	0.24	30.38	0.33	

38	0.25	32.07	0.34	
40	0.27	33.76	0.37	
42	0.28	35.45	0.39	
44	0.29	37.14	0.40	
46	0.31	38.82	0.43	
48	0.32	40.51	0.44	
50	0.34	42.20	0.47	
52	0.36	43.89	0.50	
54	0.37	45.58	0.51	
56	0.38	47.26	0.52	
58	0.4	48.95	0.55	
60	0.41	50.64	0.57	
62	0.405	52.33	0.56	Turned off simulator @ 60:00



Total Rain:	52.33 L	2.24 in
Total Runoff:	0.57 L	0.02 in
Runoff Ratio:	**0.0108**	

Rainfall Rate:	0.844 L/min	2.17 in/hr
Runoff Rate:	0.010 L/min	0.03 in/hr
Infiltration Rate:	0.834 L/min	**2.14 in/hr**

Results: Similar findings as previous site 12. The duff layer is moist but below the mineral surface is dry. Some macropores may have infiltrated some water but moist soil not seen often. Duff retains water very well.

Site 15

Date and time: 7/17/2013 @ 10:42
Slope %: 35
Area m^2: 0.944
Location: Mill Creek ridge burned.
Vegetation: Plot has some knobcone seedlings and deer weed. They were cut out and trimmed up.
Soils: Shards/pieces of rocks cover surface. Some charred mudstone, mostly fragments and not very large rocks. Below rock surface is charred duff and soil, and more rock. Below this is ash I think. There are also a lot of roots present in soil. Not large roots but small to fine sized.

Calibration:

Time on	0.6
Time off	0.4
Volume 1	415 mL/30s
Volume 2	435 mL/30s
Volume 3	450 mL/30s
Volume 4	460 mL/30s
Volume 5	450 mL/30s
Volume 6	460 mL/30s

Slope corrected rainfall rate:
2.23 in/hr
0.89 L/min

Total Rain:	71.20 L	2.97 in
Total Runoff:	2.55 L	0.11 in
Runoff Ratio:	**0.0358**	

Rainfall Rate:	0.890 L/min	2.23 in/hr
Runoff Rate:	0.035 L/min	0.09 in/hr
Infiltration Rate:	0.855 L/min	**2.14 in/hr**

***Results*:** Some infiltration in upper layers (rock down to soil and black charred soil/material). Beneath these layers what looks to be grey ash and it is not wet. It is hydrophobic. Also, we had to empty bucket midway through because of the high runoff rate. Uneven depths of infiltration. 0.5cm to 3 and 4 cm. Sometimes infiltration was greater and that was dependent on the depth of soil and charred organic matter present.

Appendix G. Mini-disk Infiltrometer Field Data

Year	Date	Day Number from 1/1/2009	Site Number	Transect Distance	Burn Severity	Simplified Burn Severity	Site and Burn Severity	Aspect	Slope Position	Depth (cm)	Vol 1 (ml)	Vol 2 (ml)	Vol 3 (ml)	Mean Vol (ml)	Mean Vol Zeroes =0.10	Water Repel Category
year	date	daynum08	sitenum	dist	burn.sev	burn.sev2	site	aspect	slope.pos	depth	vol1	vol2	vol3	meanvol	meanvol2	repel
2009	12/2/2009	335	1	20	H	Hot	1H	SE	L	1	0	18	2	6.67	6.67	Weak
2009	12/2/2009	335	1	20	H	Hot	1H	SE	L	3	0.3	11	9	6.77	6.77	Weak
2009	12/2/2009	335	1	40	H	Hot	1H	SE	L	1	0	0	1	0.33	0.33	Strong
2009	12/2/2009	335	1	40	H	Hot	1H	SE	L	3	2.5	1	1	1.5	1.5	Strong
2009	12/2/2009	335	1	60	H	Hot	1H	SE	L	1	0.5	0	0	0.17	0.17	Strong
2009	12/2/2009	335	1	60	H	Hot	1H	SE	L	3	0	0	0.8	0.27	0.27	Strong
2009	12/2/2009	335	1	80	H	Hot	1H	SE	L	1	1	0	0	0.33	0.33	Strong
2009	12/2/2009	335	1	80	H	Hot	1H	SE	L	3	0	0.5	0	0.17	0.17	Strong
2009	12/2/2009	335	1	100	H	Hot	1H	SE	L	1	2	1	1	1.33	1.33	Strong
2009	12/2/2009	335	1	100	H	Hot	1H	SE	L	3	2	2	1.5	1.83	1.83	Strong
2009	12/2/2009	335	2	20	M	Hot	2M	SE	L	1	1	1	25	9	9	None
2009	12/2/2009	335	2	20	M	Hot	2M	SE	L	3	1	0	0	0.33	0.33	Strong
2009	12/2/2009	335	2	40	M	Hot	2M	SE	L	1	38	48	22	36	36	None
2009	12/2/2009	335	2	40	M	Hot	2M	SE	L	3	0	2	1	1	1	Strong
2009	12/2/2009	335	2	60	M	Hot	2M	SE	L	1	0	0	1	0.33	0.33	Strong
2009	12/2/2009	335	2	60	M	Hot	2M	SE	L	3	0	1	1	0.67	0.67	Strong
2009	12/2/2009	335	2	80	M	Hot	2M	SE	L	1	8	0	0.5	2.83	2.83	Strong
2009	12/2/2009	335	2	80	M	Hot	2M	SE	L	3	0	0	0	0	0.1	Strong
2009	12/2/2009	335	2	100	M	Hot	2M	SE	L	1	0	12	0	4	4	Weak
2009	12/2/2009	335	2	100	M	Hot	2M	SE	L	3	1	0	2	1	1	Strong
2009	12/2/2009	335	3	20	M	Hot	3M	NW	L	1	4	3	2.5	3.17	3.17	Weak
2009	12/2/2009	335	3	20	M	Hot	3M	NW	L	3	4	4.5	4	4.17	4.17	Weak
2009	12/2/2009	335	3	40	M	Hot	3M	NW	L	1	2.5	2	3	2.5	2.5	Strong
2009	12/2/2009	335	3	40	M	Hot	3M	NW	L	3	4	2	1	2.33	2.33	Strong
2009	12/2/2009	335	3	60	M	Hot	3M	NW	L	1	2	3	1	2	2	Strong
2009	12/2/2009	335	3	60	M	Hot	3M	NW	L	3	3	1	1	1.67	1.67	Strong
2009	12/2/2009	335	3	80	M	Hot	3M	NW	L	1	3.5	1	3	2.5	2.5	Strong
2009	12/2/2009	335	3	80	M	Hot	3M	NW	L	3	3	4	3.5	3.5	3.5	Weak

2009	12/2/2009	335	3	100	M	Hot	3M	NW	L	1	1	1.5	2.5	1.67	1.67	Strong
2009	12/2/2009	335	3	100	M	Hot	3M	NW	L	3	2	3	1	2	2	Strong
2009	12/3/2009	336	4	20	H	Hot	4H	N	U	1	1.5	0	0	0.5	0.5	Strong
2009	12/3/2009	336	4	20	H	Hot	4H	N	U	3	4	6	5	5	5	Weak
2009	12/3/2009	336	4	40	H	Hot	4H	N	U	1	2.5	1	2	1.83	1.83	Strong
2009	12/3/2009	336	4	40	H	Hot	4H	N	U	3	4	5	5	4.67	4.67	Weak
2009	12/3/2009	336	4	60	H	Hot	4H	N	U	1	0.5	1	4	1.83	1.83	Strong
2009	12/3/2009	336	4	60	H	Hot	4H	N	U	3	1	0.5	1	0.83	0.83	Strong
2009	12/3/2009	336	4	80	H	Hot	4H	N	U	1	5	2	6	4.33	4.33	Weak
2009	12/3/2009	336	4	80	H	Hot	4H	N	U	3	7	5	5	5.67	5.67	Weak
2009	12/3/2009	336	4	100	H	Hot	4H	N	U	1	3.5	2	1.5	2.33	2.33	Strong
2009	12/3/2009	336	4	100	H	Hot	4H	N	U	3	1.5	1	1.5	1.33	1.33	Strong
2009	12/3/2009	336	5	20	M	Hot	5M	W	L	1	2	2.5	1	1.83	1.83	Strong
2009	12/3/2009	336	5	20	M	Hot	5M	W	L	3	4	5.5	7	5.5	5.5	Weak
2009	12/3/2009	336	5	40	M	Hot	5M	W	L	1	4	3	3	3.33	3.33	Weak
2009	12/3/2009	336	5	40	M	Hot	5M	W	L	3	3	6	4.5	4.5	4.5	Weak
2009	12/3/2009	336	5	60	M	Hot	5M	W	L	1	0.5	1	1	0.83	0.83	Strong
2009	12/3/2009	336	5	60	M	Hot	5M	W	L	3	5	3	4	4	4	Weak
2009	12/3/2009	336	5	80	M	Hot	5M	W	L	1	3	4	5	4	4	Weak
2009	12/3/2009	336	5	80	M	Hot	5M	W	L	3	6	7	14	9	9	None
2009	12/3/2009	336	5	100	M	Hot	5M	W	L	1	1	2	1.5	1.5	1.5	Strong
2009	12/3/2009	336	5	100	M	Hot	5M	W	L	3	4	5	5	4.67	4.67	Weak
2009	12/3/2009	336	6	20	H	Hot	6H	N	U	1	0.5	0	0	0.17	0.17	Strong
2009	12/3/2009	336	6	20	H	Hot	6H	N	U	3	0	0	0	0	0.1	Strong
2009	12/3/2009	336	6	40	H	Hot	6H	N	U	1	0.5	2	0	0.83	0.83	Strong
2009	12/3/2009	336	6	40	H	Hot	6H	N	U	3	1	0.5	0.5	0.67	0.67	Strong
2009	12/3/2009	336	6	60	H	Hot	6H	N	U	1	0	1.5	2.5	1.33	1.33	Strong
2009	12/3/2009	336	6	60	H	Hot	6H	N	U	3	1	0.5	0.5	0.67	0.67	Strong
2009	12/3/2009	336	6	80	H	Hot	6H	N	U	1	0	5.5	0.5	2	2	Strong
2009	12/3/2009	336	6	80	H	Hot	6H	N	U	3	0.5	0.5	0	0.33	0.33	Strong
2009	12/3/2009	336	6	100	H	Hot	6H	N	U	1	6	0.5	0	2.17	2.17	Strong
2009	12/3/2009	336	6	100	H	Hot	6H	N	U	3	3	0.5	0.5	1.33	1.33	Strong
2009	12/3/2009	336	7	20	H	Hot	7H	N	U	1	2.5	1	1	1.5	1.5	Strong
2009	12/3/2009	336	7	20	H	Hot	7H	N	U	3	4.5	4	5	4.5	4.5	Weak
2009	12/3/2009	336	7	40	H	Hot	7H	N	U	1	7.5	1	3	3.83	3.83	Weak

2009	12/3/2009	336	7	40	H	Hot	7H	N	U	3	1.5	1	2	1.5	1.5	Strong
2009	12/3/2009	336	7	60	H	Hot	7H	N	U	1	1	0	0.5	0.5	0.5	Strong
2009	12/3/2009	336	7	60	H	Hot	7H	N	U	3	1	0.5	1	0.83	0.83	Strong
2009	12/3/2009	336	7	80	H	Hot	7H	N	U	1	0	0	1	0.33	0.33	Strong
2009	12/3/2009	336	7	80	H	Hot	7H	N	U	3	1	1	0.5	0.83	0.83	Strong
2009	12/3/2009	336	7	100	H	Hot	7H	N	U	1	4	0.5	17	7.17	7.17	Weak
2009	12/3/2009	336	7	100	H	Hot	7H	N	U	3	0	0	1	0.33	0.33	Strong
2009	12/4/2009	337	8	20	H	Hot	8H	SE	U	1	0	0.5	0	0.17	0.17	Strong
2009	12/4/2009	337	8	20	H	Hot	8H	SE	U	3	1	2	1.5	1.5	1.5	Strong
2009	12/4/2009	337	8	40	H	Hot	8H	SE	U	1	1	1	1	1	1	Strong
2009	12/4/2009	337	8	40	H	Hot	8H	SE	U	3	0.5	0	0	0.17	0.17	Strong
2009	12/4/2009	337	8	60	H	Hot	8H	SE	U	1	0	0.5	0.5	0.33	0.33	Strong
2009	12/4/2009	337	8	60	H	Hot	8H	SE	U	3	1.5	0	1	0.83	0.83	Strong
2009	12/4/2009	337	8	80	H	Hot	8H	SE	U	1	0.5	0.5	1	0.67	0.67	Strong
2009	12/4/2009	337	8	80	H	Hot	8H	SE	U	3	1	0	1	0.67	0.67	Strong
2009	12/4/2009	337	8	100	H	Hot	8H	SE	U	1	0.5	0	1	0.5	0.5	Strong
2009	12/4/2009	337	8	100	H	Hot	8H	SE	U	3	0.5	0	0.5	0.33	0.33	Strong
2009	12/4/2009	337	9	20	M	Hot	9M	SE	L	1	0	3	1.5	1.5	1.5	Strong
2009	12/4/2009	337	9	20	M	Hot	9M	SE	L	3	0	2	0.5	0.83	0.83	Strong
2009	12/4/2009	337	9	40	M	Hot	9M	SE	L	1	0	0	0	0	0.1	Strong
2009	12/4/2009	337	9	40	M	Hot	9M	SE	L	3	0.5	0.5	2	1	1	Strong
2009	12/4/2009	337	9	60	M	Hot	9M	SE	L	1	1	2	2	1.67	1.67	Strong
2009	12/4/2009	337	9	60	M	Hot	9M	SE	L	3	2	2	2	2	2	Strong
2009	12/4/2009	337	9	80	M	Hot	9M	SE	L	1	0.5	0.5	1	0.67	0.67	Strong
2009	12/4/2009	337	9	80	M	Hot	9M	SE	L	3	0	2	0.5	0.83	0.83	Strong
2009	12/4/2009	337	9	100	M	Hot	9M	SE	L	1	3	3	2	2.67	2.67	Strong
2009	12/4/2009	337	9	100	M	Hot	9M	SE	L	3	1	1.5	1.5	1.33	1.33	Strong
2009	12/5/2009	338	10	20	H	Hot	10H	S	U	1	0.5	0.5	2	1	1	Strong
2009	12/5/2009	338	10	20	H	Hot	10H	S	U	3	2	1	1	1.33	1.33	Strong
2009	12/5/2009	338	10	40	H	Hot	10H	S	U	1	1.5	0	0	0.5	0.5	Strong
2009	12/5/2009	338	10	40	H	Hot	10H	S	U	3	1	1	0.5	0.83	0.83	Strong
2009	12/5/2009	338	10	60	H	Hot	10H	S	U	1	0.5	0	1	0.5	0.5	Strong
2009	12/5/2009	338	10	60	H	Hot	10H	S	U	3	1	0	0	0.33	0.33	Strong
2009	12/5/2009	338	10	80	H	Hot	10H	S	U	1	0	0	0.5	0.17	0.17	Strong
2009	12/5/2009	338	10	80	H	Hot	10H	S	U	3	0	0	1	0.33	0.33	Strong

2009	12/5/2009	338	10	100	H	Hot	10H	S	U	1	0	0	0	0	0.1	Strong
2009	12/5/2009	338	10	100	H	Hot	10H	S	U	3	3	1	1	1.67	1.67	Strong
2009	12/5/2009	338	11	20	M	Hot	11M	NW	U	1	1	3	3	2.33	2.33	Strong
2009	12/5/2009	338	11	20	M	Hot	11M	NW	U	3	0	1	3.5	1.5	1.5	Strong
2009	12/5/2009	338	11	40	M	Hot	11M	NW	U	1	3.5	4	3.5	3.67	3.67	Weak
2009	12/5/2009	338	11	40	M	Hot	11M	NW	U	3	4.5	6.5	7	6	6	Weak
2009	12/5/2009	338	11	60	M	Hot	11M	NW	U	1	5	4	3	4	4	Weak
2009	12/5/2009	338	11	60	M	Hot	11M	NW	U	3	3.5	3	3.5	3.33	3.33	Weak
2009	12/5/2009	338	11	80	M	Hot	11M	NW	U	1	3	2	3	2.67	2.67	Strong
2009	12/5/2009	338	11	80	M	Hot	11M	NW	U	3	2.5	4	4	3.5	3.5	Weak
2009	12/5/2009	338	11	100	M	Hot	11M	NW	U	1	3	4.5	4	3.83	3.83	Weak
2009	12/5/2009	338	11	100	M	Hot	11M	NW	U	3	2	1	3	2	2	Strong
2009	12/9/2009	342	12	20	H	Hot	12H	S	U	1	0.5	0.5	0.5	0.5	0.5	Strong
2009	12/9/2009	342	12	20	H	Hot	12H	S	U	3	0.5	0	0	0.17	0.17	Strong
2009	12/9/2009	342	12	20	H	Hot	12H	S	U	10.16	1	NA	NA	1	1	Strong
2009	12/9/2009	342	12	40	H	Hot	12H	S	U	1	0	0.5	0	0.17	0.17	Strong
2009	12/9/2009	342	12	40	H	Hot	12H	S	U	3	0	NA	NA	0	0.1	Strong
2009	12/9/2009	342	12	40	H	Hot	12H	S	U	7.62	0.5	NA	NA	0.5	0.5	Strong
2009	12/9/2009	342	12	40	H	Hot	12H	S	U	12.7	2	NA	NA	2	2	Strong
2009	12/9/2009	342	12	60	H	Hot	12H	S	U	1	0.5	0.5	0	0.33	0.33	Strong
2009	12/9/2009	342	12	60	H	Hot	12H	S	U	3	1	1	1	1	1	Strong
2009	12/9/2009	342	12	60	H	Hot	12H	S	U	7.62	0.5	NA	NA	0.5	0.5	Strong
2009	12/9/2009	342	12	60	H	Hot	12H	S	U	12.7	1	NA	NA	1	1	Strong
2009	12/9/2009	342	12	80	H	Hot	12H	S	U	1	0.5	0	0	0.17	0.17	Strong
2009	12/9/2009	342	12	80	H	Hot	12H	S	U	3	0	0	0.5	0.17	0.17	Strong
2009	12/9/2009	342	12	80	H	Hot	12H	S	U	6.35	1	NA	NA	1	1	Strong
2009	12/9/2009	342	12	80	H	Hot	12H	S	U	10.16	1.5	NA	NA	1.5	1.5	Strong
2009	12/9/2009	342	12	100	H	Hot	12H	S	U	1	0	0.5	0.5	0.33	0.33	Strong
2009	12/9/2009	342	12	100	H	Hot	12H	S	U	3	0	0	0	0	0.1	Strong
2009	12/9/2009	342	12	100	H	Hot	12H	S	U	7.62	1.5	NA	NA	1.5	1.5	Strong
2009	12/9/2009	342	12	100	H	Hot	12H	S	U	12.7	2.5	NA	NA	2.5	2.5	Strong
2009	12/9/2009	342	12	100	H	Hot	12H	S	U	22.86	3	NA	NA	3	3	Strong
2009	12/10/2009	343	13	20	M	Hot	13M	S	L	1	4	3	4.5	3.83	3.83	Weak
2009	12/10/2009	343	13	20	M	Hot	13M	S	L	3	1	5.5	3	3.17	3.17	Weak
2009	12/10/2009	343	13	40	M	Hot	13M	S	L	1	0	0.5	0.5	0.33	0.33	Strong

2009	12/10/2009	343	13	40	M	Hot	13M	S	L	3	0	0	0	0	0.1	Strong
2009	12/10/2009	343	13	40	M	Hot	13M	S	L	10.16	6.5	NA	NA	6.5	6.5	Weak
2009	12/10/2009	343	13	60	M	Hot	13M	S	L	1	1.5	1	2	1.5	1.5	Strong
2009	12/10/2009	343	13	60	M	Hot	13M	S	L	3	3	3	2	2.67	2.67	Strong
2009	12/10/2009	343	13	80	M	Hot	13M	S	L	1	0	1.5	0.5	0.67	0.67	Strong
2009	12/10/2009	343	13	80	M	Hot	13M	S	L	3	1.5	0.5	1	1	1	Strong
2009	12/10/2009	343	13	80	M	Hot	13M	S	L	5.08	3	NA	NA	3	3	Strong
2009	12/10/2009	343	13	80	M	Hot	13M	S	L	7.62	5	NA	NA	5	5	Weak
2009	12/10/2009	343	13	100	M	Hot	13M	S	L	1	2.5	4	1	2.5	2.5	Strong
2009	12/10/2009	343	13	100	M	Hot	13M	S	L	3	0.5	0.5	2	1	1	Strong
2009	12/10/2009	343	14	20	N	Cool	14N	S	L	1	0	0	0	0	0.1	Strong
2009	12/10/2009	343	14	20	N	Cool	14N	S	L	3	0	0	0	0	0.1	Strong
2009	12/10/2009	343	14	40	N	Cool	14N	S	L	1	3	1.5	5	3.17	3.17	Weak
2009	12/10/2009	343	14	40	N	Cool	14N	S	L	3	2.5	4.5	4.5	3.83	3.83	Weak
2009	12/10/2009	343	14	60	N	Cool	14N	S	L	1	2.5	2	6	3.5	3.5	Weak
2009	12/10/2009	343	14	60	N	Cool	14N	S	L	3	2.5	2	2	2.17	2.17	Strong
2009	12/10/2009	343	14	80	N	Cool	14N	S	L	1	3	2	0.5	1.83	1.83	Strong
2009	12/10/2009	343	14	80	N	Cool	14N	S	L	3	2	2	4	2.67	2.67	Strong
2009	12/10/2009	343	14	100	N	Cool	14N	S	L	1	2	1	4	2.33	2.33	Strong
2009	12/10/2009	343	14	100	N	Cool	14N	S	L	3	1	1	1	1	1	Strong
2009	12/15/2009	348	15	20	H	Hot	15H	SE	U	1	1	0	1	0.67	0.67	Strong
2009	12/15/2009	348	15	20	H	Hot	15H	SE	U	3	2	2	7	3.67	3.67	Weak
2009	12/15/2009	348	15	40	H	Hot	15H	SE	U	1	1	2	2	1.67	1.67	Strong
2009	12/15/2009	348	15	40	H	Hot	15H	SE	U	3	1	2	1	1.33	1.33	Strong
2009	12/15/2009	348	15	60	H	Hot	15H	SE	U	1	2	1	0	1	1	Strong
2009	12/15/2009	348	15	60	H	Hot	15H	SE	U	3	2	2	3	2.33	2.33	Strong
2009	12/15/2009	348	15	80	H	Hot	15H	SE	U	1	0	0	6	2	2	Strong
2009	12/15/2009	348	15	80	H	Hot	15H	SE	U	3	1	0	0	0.33	0.33	Strong
2009	12/15/2009	348	15	100	H	Hot	15H	SE	U	1	5	0	0	1.67	1.67	Strong
2009	12/15/2009	348	15	100	H	Hot	15H	SE	U	3	0	1	0	0.33	0.33	Strong
2009	12/15/2009	348	16	20	MH	Hot	16MH	SE	M	1	0	0	6	2	2	Strong
2009	12/15/2009	348	16	20	MH	Hot	16MH	SE	M	3	2	4	1	2.33	2.33	Strong
2009	12/15/2009	348	16	40	MH	Hot	16MH	SE	M	1	1	1	3	1.67	1.67	Strong
2009	12/15/2009	348	16	40	MH	Hot	16MH	SE	M	3	1	3	10	4.67	4.67	Weak
2009	12/15/2009	348	16	60	MH	Hot	16MH	SE	M	1	0	4	10	4.67	4.67	Weak

2009	12/15/2009	348	16	60	MH	Hot	16MH	SE	M	3	3	9	9	7	7	Weak
2009	12/15/2009	348	16	80	MH	Hot	16MH	SE	M	1	1	0	0	0.33	0.33	Strong
2009	12/15/2009	348	16	80	MH	Hot	16MH	SE	M	3	0	0	1	0.33	0.33	Strong
2009	12/15/2009	348	16	100	MH	Hot	16MH	SE	M	1	0	2	0	0.67	0.67	Strong
2009	12/15/2009	348	16	100	MH	Hot	16MH	SE	M	3	0	0	0	0	0.1	Strong
2009	12/15/2009	348	17	20	MH	Hot	17MH	SE	ML	1	1	1	0	0.67	0.67	Strong
2009	12/15/2009	348	17	20	MH	Hot	17MH	SE	ML	3	1	0	1	0.67	0.67	Strong
2009	12/15/2009	348	17	40	MH	Hot	17MH	SE	ML	1	0	0	0	0	0.1	Strong
2009	12/15/2009	348	17	40	MH	Hot	17MH	SE	ML	3	0	0	0	0	0.1	Strong
2009	12/15/2009	348	17	60	MH	Hot	17MH	SE	ML	1	0	0	1	0.33	0.33	Strong
2009	12/15/2009	348	17	60	MH	Hot	17MH	SE	ML	3	0	0	0	0	0.1	Strong
2009	12/15/2009	348	17	80	MH	Hot	17MH	SE	ML	1	4	10	0	4.67	4.67	Weak
2009	12/15/2009	348	17	80	MH	Hot	17MH	SE	ML	3	0	0	0	0	0.1	Strong
2009	12/15/2009	348	17	100	MH	Hot	17MH	SE	ML	1	1	0	0	0.33	0.33	Strong
2009	12/15/2009	348	17	100	MH	Hot	17MH	SE	ML	3	0	1	0	0.33	0.33	Strong
2009	12/15/2009	348	18	20	H	Hot	18H	SE	U	1	2	1	1	1.33	1.33	Strong
2009	12/15/2009	348	18	20	H	Hot	18H	SE	U	3	2	1	6.5	3.17	3.17	Weak
2009	12/15/2009	348	18	40	H	Hot	18H	SE	U	1	0	1	0	0.33	0.33	Strong
2009	12/15/2009	348	18	40	H	Hot	18H	SE	U	3	2	1	0	1	1	Strong
2009	12/15/2009	348	18	60	H	Hot	18H	SE	U	1	0	1	4	1.67	1.67	Strong
2009	12/15/2009	348	18	60	H	Hot	18H	SE	U	3	3	4.5	3.5	3.67	3.67	Weak
2009	12/15/2009	348	18	80	H	Hot	18H	SE	U	1	2.5	0	0	0.83	0.83	Strong
2009	12/15/2009	348	18	80	H	Hot	18H	SE	U	3	2	1	0	1	1	Strong
2009	12/15/2009	348	18	100	H	Hot	18H	SE	U	1	5	1	1	2.33	2.33	Strong
2009	12/15/2009	348	18	100	H	Hot	18H	SE	U	3	1	1	1	1	1	Strong
2009	12/15/2009	348	19	20	M	Hot	19M	SE	L	1	7	12	6	8.33	8.33	None
2009	12/15/2009	348	19	20	M	Hot	19M	SE	L	3	1	0	1	0.67	0.67	Strong
2009	12/15/2009	348	19	40	M	Hot	19M	SE	L	1	1	0	1	0.67	0.67	Strong
2009	12/15/2009	348	19	40	M	Hot	19M	SE	L	3	8	0	28	12	12	None
2009	12/15/2009	348	19	60	M	Hot	19M	SE	L	1	2	1	1	1.33	1.33	Strong
2009	12/15/2009	348	19	60	M	Hot	19M	SE	L	3	1	15	15	10.33	10.33	None
2009	12/15/2009	348	19	80	M	Hot	19M	SE	L	1	2	0	2	1.33	1.33	Strong
2009	12/15/2009	348	19	80	M	Hot	19M	SE	L	3	1	13	1	5	5	Weak
2009	12/15/2009	348	19	100	M	Hot	19M	SE	L	1	3	0	5	2.67	2.67	Strong
2009	12/15/2009	348	19	100	M	Hot	19M	SE	L	3	13	9	20	14	14	None

2009	12/16/2009	349	20	20	H	Hot	20H	NW	U	1	0	0	0	0	0.1	Strong
2009	12/16/2009	349	20	20	H	Hot	20H	NW	U	3	1	0	0	0.33	0.33	Strong
2009	12/16/2009	349	20	40	H	Hot	20H	NW	U	1	0	0	0	0	0.1	Strong
2009	12/16/2009	349	20	40	H	Hot	20H	NW	U	3	0	0	0	0	0.1	Strong
2009	12/16/2009	349	20	60	H	Hot	20H	NW	U	1	1	0	0	0.33	0.33	Strong
2009	12/16/2009	349	20	60	H	Hot	20H	NW	U	3	0	0	0	0	0.1	Strong
2009	12/16/2009	349	20	80	H	Hot	20H	NW	U	1	13	0	0	4.33	4.33	Weak
2009	12/16/2009	349	20	80	H	Hot	20H	NW	U	3	0	0	0	0	0.1	Strong
2009	12/16/2009	349	20	100	H	Hot	20H	NW	U	1	0	0	0	0	0.1	Strong
2009	12/16/2009	349	20	100	H	Hot	20H	NW	U	3	0	1	0	0.33	0.33	Strong
2009	12/16/2009	349	21	20	ML	Cool	21ML	N	L	1	2	4	5	3.67	3.67	Weak
2009	12/16/2009	349	21	20	ML	Cool	21ML	N	L	3	0	8	5	4.33	4.33	Weak
2009	12/16/2009	349	21	40	ML	Cool	21ML	N	L	1	4	19	5	9.33	9.33	None
2009	12/16/2009	349	21	40	ML	Cool	21ML	N	L	3	4	4	4	4	4	Weak
2009	12/16/2009	349	21	60	ML	Cool	21ML	N	L	1	11	5	5	7	7	Weak
2009	12/16/2009	349	21	60	ML	Cool	21ML	N	L	3	6.5	5.5	9	7	7	Weak
2009	12/16/2009	349	21	80	ML	Cool	21ML	N	L	1	15	1	2	6	6	Weak
2009	12/16/2009	349	21	80	ML	Cool	21ML	N	L	3	1	1	4	2	2	Strong
2009	12/16/2009	349	21	100	ML	Cool	21ML	N	L	1	13	3	4	6.67	6.67	Weak
2009	12/16/2009	349	21	100	ML	Cool	21ML	N	L	3	7	3	3	4.33	4.33	Weak
2009	12/16/2009	349	22	20	MH	Hot	22MH	N	U	1	1	7	1	3	3	Strong
2009	12/16/2009	349	22	20	MH	Hot	22MH	N	U	3	0	0	0	0	0.1	Strong
2009	12/16/2009	349	22	40	MH	Hot	22MH	N	U	1	1	0	0	0.33	0.33	Strong
2009	12/16/2009	349	22	40	MH	Hot	22MH	N	U	3	0	0	1	0.33	0.33	Strong
2009	12/16/2009	349	22	60	MH	Hot	22MH	N	U	1	0	0	0	0	0.1	Strong
2009	12/16/2009	349	22	60	MH	Hot	22MH	N	U	3	0	0	0	0	0.1	Strong
2009	12/16/2009	349	22	80	MH	Hot	22MH	N	U	1	11	2	1	4.67	4.67	Weak
2009	12/16/2009	349	22	80	MH	Hot	22MH	N	U	3	1	1	1	1	1	Strong
2009	12/16/2009	349	22	100	MH	Hot	22MH	N	U	1	0	0	0	0	0.1	Strong
2009	12/16/2009	349	22	100	MH	Hot	22MH	N	U	3	0	0	0	0	0.1	Strong
2009	12/18/2009	351	23	20	H	Hot	23H	N	U	1	8	2	4	4.67	4.67	Weak
2009	12/18/2009	351	23	20	H	Hot	23H	N	U	3	3	2	3	2.67	2.67	Strong
2009	12/18/2009	351	23	40	H	Hot	23H	N	U	1	3	6	3	4	4	Weak
2009	12/18/2009	351	23	40	H	Hot	23H	N	U	3	3	2	2	2.33	2.33	Strong
2009	12/18/2009	351	23	60	H	Hot	23H	N	U	1	3	3	7	4.33	4.33	Weak

2009	12/18/2009	351	23	60	H	Hot	23H	N	U	3	2	2	3	2.33	2.33	Strong
2009	12/18/2009	351	23	80	H	Hot	23H	N	U	1	3	2.5	2	2.5	2.5	Strong
2009	12/18/2009	351	23	80	H	Hot	23H	N	U	3	4	2.5	2	2.83	2.83	Strong
2009	12/18/2009	351	23	100	H	Hot	23H	N	U	1	2	2	2	2	2	Strong
2009	12/18/2009	351	23	100	H	Hot	23H	N	U	3	3	3	4	3.33	3.33	Weak
2010	10/14/2010	651	1	20	H	Hot	1H	SE	L	1	0	0	0	0	0.1	Strong
2010	10/14/2010	651	1	20	H	Hot	1H	SE	L	3	0	0	0	0	0.1	Strong
2010	10/14/2010	651	1	40	H	Hot	1H	SE	L	1	1	1	4	2	2	Strong
2010	10/14/2010	651	1	40	H	Hot	1H	SE	L	3	0	2	1	1	1	Strong
2010	10/14/2010	651	1	60	H	Hot	1H	SE	L	1	0	0	0.5	0.17	0.17	Strong
2010	10/14/2010	651	1	60	H	Hot	1H	SE	L	3	0	0	0	0	0.1	Strong
2010	10/14/2010	651	1	80	H	Hot	1H	SE	L	1	2	1	0.5	1.17	1.17	Strong
2010	10/14/2010	651	1	80	H	Hot	1H	SE	L	3	1	2	0.5	1.17	1.17	Strong
2010	10/14/2010	651	1	100	H	Hot	1H	SE	L	1	0.5	1	1	0.83	0.83	Strong
2010	10/14/2010	651	1	100	H	Hot	1H	SE	L	3	1	1	1	1	1	Strong
2010	10/16/2010	653	2	20	M	Hot	2M	SE	L	1	1.5	7	4	4.17	4.17	Weak
2010	10/16/2010	653	2	20	M	Hot	2M	SE	L	3	1	1	6	2.67	2.67	Strong
2010	10/16/2010	653	2	40	M	Hot	2M	SE	L	1	1	2	1	1.33	1.33	Strong
2010	10/16/2010	653	2	40	M	Hot	2M	SE	L	3	1	2	2	1.67	1.67	Strong
2010	10/16/2010	653	2	60	M	Hot	2M	SE	L	1	2	1	6	3	3	Strong
2010	10/16/2010	653	2	60	M	Hot	2M	SE	L	3	1	3	1	1.67	1.67	Strong
2010	10/16/2010	653	2	80	M	Hot	2M	SE	L	1	0.5	1	0	0.5	0.5	Strong
2010	10/16/2010	653	2	80	M	Hot	2M	SE	L	3	1	0	1	0.67	0.67	Strong
2010	10/16/2010	653	2	100	M	Hot	2M	SE	L	1	2	1	2	1.67	1.67	Strong
2010	10/16/2010	653	2	100	M	Hot	2M	SE	L	3	0	1	0	0.33	0.33	Strong
2010	10/9/2010	646	3	20	M	Hot	3M	NW	L	1	2	5	8	5	5	Weak
2010	10/9/2010	646	3	20	M	Hot	3M	NW	L	3	11	6	8	8.33	8.33	None
2010	10/9/2010	646	3	40	M	Hot	3M	NW	L	1	3	2	1	2	2	Strong
2010	10/9/2010	646	3	40	M	Hot	3M	NW	L	3	7	7	4	6	6	Weak
2010	10/9/2010	646	3	60	M	Hot	3M	NW	L	1	2	3	1.5	2.17	2.17	Strong
2010	10/9/2010	646	3	60	M	Hot	3M	NW	L	3	5	10	6	7	7	Weak
2010	10/9/2010	646	3	80	M	Hot	3M	NW	L	1	5	1	1.5	2.5	2.5	Strong
2010	10/9/2010	646	3	80	M	Hot	3M	NW	L	3	4	6	6	5.33	5.33	Weak
2010	10/9/2010	646	3	100	M	Hot	3M	NW	L	1	7.5	6	9	7.5	7.5	Weak
2010	10/9/2010	646	3	100	M	Hot	3M	NW	L	3	10	6	5.5	7.17	7.17	Weak

2010	10/16/2010	653	4	20	H	Hot	4H	N	U	1	3	2	3	2.67	2.67	Strong
2010	10/16/2010	653	4	20	H	Hot	4H	N	U	3	10	12	7	9.67	9.67	None
2010	10/16/2010	653	4	40	H	Hot	4H	N	U	1	12	9	11	10.67	10.67	None
2010	10/16/2010	653	4	40	H	Hot	4H	N	U	3	12	8	9	9.67	9.67	None
2010	10/16/2010	653	4	60	H	Hot	4H	N	U	1	11	10	9	10	10	None
2010	10/16/2010	653	4	60	H	Hot	4H	N	U	3	22	9	14	15	15	None
2010	10/16/2010	653	4	80	H	Hot	4H	N	U	1	8	12	15	11.67	11.67	None
2010	10/16/2010	653	4	80	H	Hot	4H	N	U	3	6	8	6	6.67	6.67	Weak
2010	10/16/2010	653	4	100	H	Hot	4H	N	U	1	7	7	9	7.67	7.67	Weak
2010	10/16/2010	653	4	100	H	Hot	4H	N	U	3	5.5	4	4	4.5	4.5	Weak
2010	10/16/2010	653	5	20	M	Hot	5M	W	L	1	6	7	3	5.33	5.33	Weak
2010	10/16/2010	653	5	20	M	Hot	5M	W	L	3	13	20	12	15	15	None
2010	10/16/2010	653	5	40	M	Hot	5M	W	L	1	15	22	18	18.33	18.33	None
2010	10/16/2010	653	5	40	M	Hot	5M	W	L	3	5.5	9	5	6.5	6.5	Weak
2010	10/16/2010	653	5	60	M	Hot	5M	W	L	1	1	1	5	2.33	2.33	Strong
2010	10/16/2010	653	5	60	M	Hot	5M	W	L	3	0	2	1	1	1	Strong
2010	10/16/2010	653	5	80	M	Hot	5M	W	L	1	7.5	4	7.5	6.33	6.33	Weak
2010	10/16/2010	653	5	80	M	Hot	5M	W	L	3	5	8	6	6.33	6.33	Weak
2010	10/9/2010	646	7	20	H	Hot	7H	N	U	1	5	6	6	5.67	5.67	Weak
2010	10/9/2010	646	7	20	H	Hot	7H	N	U	3	5	2	1	2.67	2.67	Strong
2010	10/9/2010	646	7	40	H	Hot	7H	N	U	1	11	4	11	8.67	8.67	None
2010	10/9/2010	646	7	40	H	Hot	7H	N	U	3	16.5	5	9	10.17	10.17	None
2010	10/9/2010	646	7	60	H	Hot	7H	N	U	1	2	0	2	1.33	1.33	Strong
2010	10/9/2010	646	7	60	H	Hot	7H	N	U	3	0	3	0	1	1	Strong
2010	10/9/2010	646	7	80	H	Hot	7H	N	U	1	4	2	2	2.67	2.67	Strong
2010	10/9/2010	646	7	80	H	Hot	7H	N	U	3	2	2	5	3	3	Strong
2010	10/9/2010	646	7	100	H	Hot	7H	N	U	1	1	3	3	2.33	2.33	Strong
2010	10/9/2010	646	7	100	H	Hot	7H	N	U	3	4.5	2	0	2.17	2.17	Strong
2010	10/8/2010	645	8	20	H	Hot	8H	SE	U	1	0	1	0	0.33	0.33	Strong
2010	10/8/2010	645	8	20	H	Hot	8H	SE	U	3	1	1	1	1	1	Strong
2010	10/8/2010	645	8	40	H	Hot	8H	SE	U	1	12	2	19	11	11	None
2010	10/8/2010	645	8	40	H	Hot	8H	SE	U	3	2	4	6	4	4	Weak
2010	10/8/2010	645	8	60	H	Hot	8H	SE	U	1	6	55	15	25.33	25.33	None
2010	10/8/2010	645	8	60	H	Hot	8H	SE	U	3	28	1	1	10	10	None
2010	10/8/2010	645	8	80	H	Hot	8H	SE	U	1	6	20	5	10.33	10.33	None

2010	10/8/2010	645	8	80	H	Hot	8H	SE	U	3	10	5	7	7.33	7.33	Weak
2010	10/8/2010	645	8	100	H	Hot	8H	SE	U	1	0	0	1	0.33	0.33	Strong
2010	10/8/2010	645	8	100	H	Hot	8H	SE	U	3	2	0	2	1.33	1.33	Strong
2010	10/8/2010	645	9	20	M	Hot	9M	SE	L	1	8	9	6	7.67	7.67	Weak
2010	10/8/2010	645	9	20	M	Hot	9M	SE	L	3	6	10	9	8.33	8.33	None
2010	10/8/2010	645	9	40	M	Hot	9M	SE	L	1	3	2	10	5	5	Weak
2010	10/8/2010	645	9	40	M	Hot	9M	SE	L	3	0	2	3	1.67	1.67	Strong
2010	10/8/2010	645	9	60	M	Hot	9M	SE	L	1	9	4	8	7	7	Weak
2010	10/8/2010	645	9	60	M	Hot	9M	SE	L	3	8	2	2	4	4	Weak
2010	10/8/2010	645	9	80	M	Hot	9M	SE	L	1	4	5	4	4.33	4.33	Weak
2010	10/8/2010	645	9	80	M	Hot	9M	SE	L	3	12	7	13	10.67	10.67	None
2010	10/8/2010	645	9	100	M	Hot	9M	SE	L	1	1	7	2	3.33	3.33	Weak
2010	10/8/2010	645	9	100	M	Hot	9M	SE	L	3	1	1	1	1	1	Strong
2010	10/9/2010	646	10	20	H	Hot	10H	S	U	1	1	1	1	1	1	Strong
2010	10/9/2010	646	10	20	H	Hot	10H	S	U	3	1	1	1	1	1	Strong
2010	10/9/2010	646	10	40	H	Hot	10H	S	U	1	5	2	18	8.33	8.33	None
2010	10/9/2010	646	10	40	H	Hot	10H	S	U	3	9	14	8	10.33	10.33	None
2010	10/9/2010	646	10	60	H	Hot	10H	S	U	1	2.5	1	2	1.83	1.83	Strong
2010	10/9/2010	646	10	60	H	Hot	10H	S	U	3	2.5	2	2	2.17	2.17	Strong
2010	10/9/2010	646	10	80	H	Hot	10H	S	U	1	1	0	5	2	2	Strong
2010	10/9/2010	646	10	80	H	Hot	10H	S	U	3	1	1	0	0.67	0.67	Strong
2010	10/9/2010	646	10	100	H	Hot	10H	S	U	1	0.5	1	5	2.17	2.17	Strong
2010	10/9/2010	646	10	100	H	Hot	10H	S	U	3	1	0	0	0.33	0.33	Strong
2010	10/9/2010	646	11	20	M	Hot	11M	NW	U	1	0	2	1	1	1	Strong
2010	10/9/2010	646	11	20	M	Hot	11M	NW	U	3	1.5	2	0.5	1.33	1.33	Strong
2010	10/9/2010	646	11	40	M	Hot	11M	NW	U	1	36	26	14	25.33	25.33	None
2010	10/9/2010	646	11	40	M	Hot	11M	NW	U	3	10.5	3	0	4.5	4.5	Weak
2010	10/9/2010	646	11	60	M	Hot	11M	NW	U	1	2	3	6	3.67	3.67	Weak
2010	10/9/2010	646	11	60	M	Hot	11M	NW	U	3	2	8	1	3.67	3.67	Weak
2010	10/9/2010	646	11	80	M	Hot	11M	NW	U	1	0	1	5	2	2	Strong
2010	10/9/2010	646	11	80	M	Hot	11M	NW	U	3	2	7	4	4.33	4.33	Weak
2010	10/16/2010	653	12	20	H	Hot	12H	S	U	1	4	4	6	4.67	4.67	Weak
2010	10/16/2010	653	12	20	H	Hot	12H	S	U	3	8	4	7	6.33	6.33	Weak
2010	10/16/2010	653	12	40	H	Hot	12H	S	U	1	1	7	0.5	2.83	2.83	Strong
2010	10/16/2010	653	12	40	H	Hot	12H	S	U	3	1	1	0.5	0.83	0.83	Strong

2010	10/16/2010	653	12	60	H	Hot	12H	S	U	1	7	2	1	3.33	3.33	Weak
2010	10/16/2010	653	12	60	H	Hot	12H	S	U	3	0.5	0	1	0.5	0.5	Strong
2010	10/16/2010	653	12	80	H	Hot	12H	S	U	1	2.5	2	0.5	1.67	1.67	Strong
2010	10/16/2010	653	12	80	H	Hot	12H	S	U	3	1	1	1	1	1	Strong
2010	10/16/2010	653	12	100	H	Hot	12H	S	U	1	1.5	1	4	2.17	2.17	Strong
2010	10/16/2010	653	12	100	H	Hot	12H	S	U	3	0	0	3	1	1	Strong
2010	10/22/2010	659	14	20	N	Cool	14N	S	L	1	1	1	1	1	1	Strong
2010	10/22/2010	659	14	20	N	Cool	14N	S	L	3	7	3	15	8.33	8.33	None
2010	10/22/2010	659	14	40	N	Cool	14N	S	L	1	0.5	0	3	1.17	1.17	Strong
2010	10/22/2010	659	14	40	N	Cool	14N	S	L	3	2	6	4	4	4	Weak
2010	10/22/2010	659	14	60	N	Cool	14N	S	L	1	3	3	5	3.67	3.67	Weak
2010	10/22/2010	659	14	60	N	Cool	14N	S	L	3	4	8	4	5.33	5.33	Weak
2010	10/22/2010	659	14	80	N	Cool	14N	S	L	1	2	1	1	1.33	1.33	Strong
2010	10/22/2010	659	14	80	N	Cool	14N	S	L	3	2	2	1	1.67	1.67	Strong
2010	10/22/2010	659	14	100	N	Cool	14N	S	L	1	1	1	6	2.67	2.67	Strong
2010	10/22/2010	659	14	100	N	Cool	14N	S	L	3	1	2	1	1.33	1.33	Strong
2010	10/15/2010	652	18	20	H	Hot	18H	SE	U	1	15.5	13	12	13.5	13.5	None
2010	10/15/2010	652	18	20	H	Hot	18H	SE	U	3	28	16	14	19.33	19.33	None
2010	10/15/2010	652	18	40	H	Hot	18H	SE	U	1	3	3	6	4	4	Weak
2010	10/15/2010	652	18	40	H	Hot	18H	SE	U	3	2	1	3	2	2	Strong
2010	10/15/2010	652	18	60	H	Hot	18H	SE	U	1	14	21	24	19.67	19.67	None
2010	10/15/2010	652	18	60	H	Hot	18H	SE	U	3	8	8	15	10.33	10.33	None
2010	10/15/2010	652	18	80	H	Hot	18H	SE	U	1	15	19	3	12.33	12.33	None
2010	10/15/2010	652	18	80	H	Hot	18H	SE	U	3	9	20	19	16	16	None
2010	10/15/2010	652	18	100	H	Hot	18H	SE	U	1	23	7	9	13	13	None
2010	10/15/2010	652	18	100	H	Hot	18H	SE	U	3	3	3	9	5	5	Weak
2010	10/9/2010	646	19	20	M	Hot	19M	SE	L	1	3	13	5	7	7	Weak
2010	10/9/2010	646	19	20	M	Hot	19M	SE	L	3	2	2	7	3.67	3.67	Weak
2010	10/9/2010	646	19	40	M	Hot	19M	SE	L	1	15	6	16	12.33	12.33	None
2010	10/9/2010	646	19	40	M	Hot	19M	SE	L	3	3	3	3	3	3	Strong
2010	10/9/2010	646	19	60	M	Hot	19M	SE	L	1	2	1	1	1.33	1.33	Strong
2010	10/9/2010	646	19	60	M	Hot	19M	SE	L	3	3	1	2	2	2	Strong
2010	10/9/2010	646	19	80	M	Hot	19M	SE	L	1	7	3	3	4.33	4.33	Weak
2010	10/9/2010	646	19	80	M	Hot	19M	SE	L	3	2	0	3	1.67	1.67	Strong
2010	10/9/2010	646	19	100	M	Hot	19M	SE	L	1	1.5	1	6	2.83	2.83	Strong

2010	10/9/2010	646	19	100	M	Hot	19M	SE	L	3	2.5	1	6	3.17	3.17	Weak
2010	10/17/2010	654	20	20	H	Hot	20H	NW	U	1	1	0	1	0.67	0.67	Strong
2010	10/17/2010	654	20	20	H	Hot	20H	NW	U	3	2	1	3	2	2	Strong
2010	10/17/2010	654	20	40	H	Hot	20H	NW	U	1	3.5	10	7.5	7	7	Weak
2010	10/17/2010	654	20	40	H	Hot	20H	NW	U	3	4	4	1	3	3	Strong
2010	10/17/2010	654	20	60	H	Hot	20H	NW	U	1	1.5	2	6	3.17	3.17	Weak
2010	10/17/2010	654	20	60	H	Hot	20H	NW	U	3	2	2	3	2.33	2.33	Strong
2010	10/17/2010	654	20	80	H	Hot	20H	NW	U	1	2	1	2	1.67	1.67	Strong
2010	10/17/2010	654	20	80	H	Hot	20H	NW	U	3	0	1	0	0.33	0.33	Strong
2010	10/17/2010	654	20	100	H	Hot	20H	NW	U	1	2	3	3	2.67	2.67	Strong
2010	10/17/2010	654	20	100	H	Hot	20H	NW	U	3	5	15	8	9.33	9.33	None
2010	10/22/2010	659	21	20	ML	Cool	21ML	N	L	1	0	2	1	1	1	Strong
2010	10/22/2010	659	21	20	ML	Cool	21ML	N	L	3	4	4	6	4.67	4.67	Weak
2010	10/22/2010	659	21	40	ML	Cool	21ML	N	L	1	3	9	8	6.67	6.67	Weak
2010	10/22/2010	659	21	40	ML	Cool	21ML	N	L	3	7	5	5	5.67	5.67	Weak
2010	10/22/2010	659	21	60	ML	Cool	21ML	N	L	1	2	6	2	3.33	3.33	Weak
2010	10/22/2010	659	21	60	ML	Cool	21ML	N	L	3	5	2	4	3.67	3.67	Weak
2010	10/22/2010	659	21	80	ML	Cool	21ML	N	L	1	17	8	3	9.33	9.33	None
2010	10/22/2010	659	21	80	ML	Cool	21ML	N	L	3	19	8	5	10.67	10.67	None
2010	10/22/2010	659	21	100	ML	Cool	21ML	N	L	1	5	0	1	2	2	Strong
2010	10/22/2010	659	21	100	ML	Cool	21ML	N	L	3	3	2	5	3.33	3.33	Weak
2010	10/22/2010	659	22	20	MH	Hot	22MH	N	U	1	11	3	2	5.33	5.33	Weak
2010	10/22/2010	659	22	20	MH	Hot	22MH	N	U	3	8	2	2	4	4	Weak
2010	10/22/2010	659	22	40	MH	Hot	22MH	N	U	1	5	1	1	2.33	2.33	Strong
2010	10/22/2010	659	22	40	MH	Hot	22MH	N	U	3	2	0	1	1	1	Strong
2010	10/22/2010	659	22	60	MH	Hot	22MH	N	U	1	3	6	2	3.67	3.67	Weak
2010	10/22/2010	659	22	60	MH	Hot	22MH	N	U	3	9	3	4	5.33	5.33	Weak
2010	10/22/2010	659	22	80	MH	Hot	22MH	N	U	1	2	3	3	2.67	2.67	Strong
2010	10/22/2010	659	22	80	MH	Hot	22MH	N	U	3	5	6	2	4.33	4.33	Weak
2010	10/22/2010	659	22	100	MH	Hot	22MH	N	U	1	0	1	1	0.67	0.67	Strong
2010	10/22/2010	659	22	100	MH	Hot	22MH	N	U	3	4	2	1	2.33	2.33	Strong
2010	10/16/2010	653	23	20	H	Hot	23H	N	U	1	2	8	6	5.33	5.33	Weak
2010	10/16/2010	653	23	20	H	Hot	23H	N	U	3	4.5	3	4	3.83	3.83	Weak
2010	10/16/2010	653	23	40	H	Hot	23H	N	U	1	4	3	3	3.33	3.33	Weak
2010	10/16/2010	653	23	40	H	Hot	23H	N	U	3	4	4	11	6.33	6.33	Weak

2010	10/16/2010	653	23	60	H	Hot	23H	N	U	1	8	8	10	8.67	8.67	None
2010	10/16/2010	653	23	60	H	Hot	23H	N	U	3	2	6	7	5	5	Weak
2010	10/16/2010	653	23	80	H	Hot	23H	N	U	1	4	7	9	6.67	6.67	Weak
2010	10/16/2010	653	23	80	H	Hot	23H	N	U	3	8	6	10	8	8	None
2010	10/16/2010	653	23	100	H	Hot	23H	N	U	1	11	12	12	11.67	11.67	None
2010	10/16/2010	653	23	100	H	Hot	23H	N	U	3	14	10	15	13	13	None
2011	8/30/2011	971	1	20	H	Hot	1H	SE	L	1	19	23	9	17	17	None
2011	8/30/2011	971	1	20	H	Hot	1H	SE	L	3	1	1	1	1	1	Strong
2011	8/30/2011	971	1	40	H	Hot	1H	SE	L	1	2	11	2	5	5	Weak
2011	8/30/2011	971	1	40	H	Hot	1H	SE	L	3	1	1	0.5	0.83	0.83	Strong
2011	8/30/2011	971	1	60	H	Hot	1H	SE	L	1	1	8	5	4.67	4.67	Weak
2011	8/30/2011	971	1	60	H	Hot	1H	SE	L	3	7	4	3	4.67	4.67	Weak
2011	8/30/2011	971	1	80	H	Hot	1H	SE	L	1	26	13	1	13.33	13.33	None
2011	8/30/2011	971	1	80	H	Hot	1H	SE	L	3	1	0	1	0.67	0.67	Strong
2011	8/30/2011	971	1	100	H	Hot	1H	SE	L	1	1	0	1	0.67	0.67	Strong
2011	8/30/2011	971	1	100	H	Hot	1H	SE	L	3	1	2	1	1.33	1.33	Strong
2011	8/29/2011	970	2	0	M	Hot	2M	SE	L	1	19	18	14	17	17	None
2011	8/29/2011	970	2	0	M	Hot	2M	SE	L	3	9	10	5	8	8	None
2011	8/29/2011	970	2	20	M	Hot	2M	SE	L	1	5	8	5	6	6	Weak
2011	8/29/2011	970	2	20	M	Hot	2M	SE	L	3	4	1	1	2	2	Strong
2011	8/29/2011	970	2	40	M	Hot	2M	SE	L	1	4	2	2	2.67	2.67	Strong
2011	8/29/2011	970	2	40	M	Hot	2M	SE	L	3	5	2	5	4	4	Weak
2011	8/29/2011	970	2	60	M	Hot	2M	SE	L	1	4	11	NA	7.5	7.5	Weak
2011	8/29/2011	970	2	60	M	Hot	2M	SE	L	3	1	4	1.5	2.17	2.17	Strong
2011	8/29/2011	970	2	80	M	Hot	2M	SE	L	1	17	13	13	14.33	14.33	None
2011	8/29/2011	970	2	80	M	Hot	2M	SE	L	3	1	0	1	0.67	0.67	Strong
2011	8/29/2011	970	2	100	M	Hot	2M	SE	L	1	19	7	6	10.67	10.67	None
2011	8/29/2011	970	2	100	M	Hot	2M	SE	L	3	0	0	1	0.33	0.33	Strong
2011	8/29/2011	970	3	0	M	Hot	3M	NW	L	1	6	4	2	4	4	Weak
2011	8/29/2011	970	3	0	M	Hot	3M	NW	L	3	4	5	2.5	3.83	3.83	Weak
2011	8/29/2011	970	3	20	M	Hot	3M	NW	L	1	1	2	2	1.67	1.67	Strong
2011	8/29/2011	970	3	20	M	Hot	3M	NW	L	3	4	3	4	3.67	3.67	Weak
2011	8/29/2011	970	3	40	M	Hot	3M	NW	L	1	4	3	3	3.33	3.33	Weak
2011	8/29/2011	970	3	40	M	Hot	3M	NW	L	3	2	2	2	2	2	Strong
2011	8/29/2011	970	3	60	M	Hot	3M	NW	L	1	4	2	4	3.33	3.33	Weak

2011	8/29/2011	970	3	60	M	Hot	3M	NW	L	3	4.5	5	3	4.17	4.17	Weak
2011	8/29/2011	970	3	80	M	Hot	3M	NW	L	1	10	9	9	9.33	9.33	None
2011	8/29/2011	970	3	80	M	Hot	3M	NW	L	3	2	1	3	2	2	Strong
2011	8/29/2011	970	3	100	M	Hot	3M	NW	L	1	5	4	4	4.33	4.33	Weak
2011	8/29/2011	970	3	100	M	Hot	3M	NW	L	3	2	2	2	2	2	Strong
2011	7/6/2011	916	4	20	H	Hot	4H	N	U	1	2	4	5	3.67	3.67	Weak
2011	7/6/2011	916	4	20	H	Hot	4H	N	U	3	2	1	1	1.33	1.33	Strong
2011	7/6/2011	916	4	40	H	Hot	4H	N	U	1	8	10	9	9	9	None
2011	7/6/2011	916	4	40	H	Hot	4H	N	U	3	3.5	3	4	3.5	3.5	Weak
2011	7/6/2011	916	4	60	H	Hot	4H	N	U	1	6	3	7	5.33	5.33	Weak
2011	7/6/2011	916	4	60	H	Hot	4H	N	U	3	2.5	2	5	3.17	3.17	Weak
2011	7/6/2011	916	4	80	H	Hot	4H	N	U	1	5	3	3	3.67	3.67	Weak
2011	7/6/2011	916	4	80	H	Hot	4H	N	U	3	3	1	2	2	2	Strong
2011	7/6/2011	916	4	100	H	Hot	4H	N	U	1	3	4	2	3	3	Strong
2011	7/6/2011	916	4	100	H	Hot	4H	N	U	3	3	3.5	3	3.17	3.17	Weak
2011	7/7/2011	917	6	0	H	Hot	6H	N	U	1	3	3	2.5	2.83	2.83	Strong
2011	7/7/2011	917	6	0	H	Hot	6H	N	U	3	1	2	4	2.33	2.33	Strong
2011	7/7/2011	917	6	20	H	Hot	6H	N	U	1	4	5	5	4.67	4.67	Weak
2011	7/7/2011	917	6	20	H	Hot	6H	N	U	3	3	3	6	4	4	Weak
2011	7/7/2011	917	6	40	H	Hot	6H	N	U	1	3	3	2	2.67	2.67	Strong
2011	7/7/2011	917	6	40	H	Hot	6H	N	U	3	4	6	5	5	5	Weak
2011	7/7/2011	917	6	60	H	Hot	6H	N	U	1	1	3	2.5	2.17	2.17	Strong
2011	7/7/2011	917	6	60	H	Hot	6H	N	U	3	3	3	6	4	4	Weak
2011	7/7/2011	917	6	80	H	Hot	6H	N	U	1	5	4	2	3.67	3.67	Weak
2011	7/7/2011	917	6	80	H	Hot	6H	N	U	3	6	8	4	6	6	Weak
2011	7/7/2011	917	6	100	H	Hot	6H	N	U	1	8	8	3	6.33	6.33	Weak
2011	7/7/2011	917	6	100	H	Hot	6H	N	U	3	2	2	3	2.33	2.33	Strong
2011	7/7/2011	917	7	0	H	Hot	7H	N	U	1	3	4	7	4.67	4.67	Weak
2011	7/7/2011	917	7	0	H	Hot	7H	N	U	3	3	2	2	2.33	2.33	Strong
2011	7/7/2011	917	7	20	H	Hot	7H	N	U	1	1	0.5	0.5	0.67	0.67	Strong
2011	7/7/2011	917	7	20	H	Hot	7H	N	U	3	2	2	2	2	2	Strong
2011	7/7/2011	917	7	40	H	Hot	7H	N	U	1	3	2	3	2.67	2.67	Strong
2011	7/7/2011	917	7	40	H	Hot	7H	N	U	3	6	1	2	3	3	Strong
2011	7/7/2011	917	7	60	H	Hot	7H	N	U	1	3	5	4	4	4	Weak
2011	7/7/2011	917	7	60	H	Hot	7H	N	U	3	4	6	2	4	4	Weak

2011	7/7/2011	917	7	80	H	Hot	7H	N	U	1	1	1	4.5	2.17	2.17	Strong
2011	7/7/2011	917	7	80	H	Hot	7H	N	U	3	2	1	2	1.67	1.67	Strong
2011	7/7/2011	917	7	100	H	Hot	7H	N	U	1	2	3	1	2	2	Strong
2011	7/7/2011	917	7	100	H	Hot	7H	N	U	3	3	5	2	3.33	3.33	Weak
2011	7/6/2011	916	8	20	H	Hot	8H	SE	U	1	1	2	1	1.33	1.33	Strong
2011	7/6/2011	916	8	20	H	Hot	8H	SE	U	3	0.5	1	1	0.83	0.83	Strong
2011	7/6/2011	916	8	40	H	Hot	8H	SE	U	1	0.5	1	0.5	0.67	0.67	Strong
2011	7/6/2011	916	8	40	H	Hot	8H	SE	U	3	0	0	1	0.33	0.33	Strong
2011	7/6/2011	916	8	60	H	Hot	8H	SE	U	1	0	1	2	1	1	Strong
2011	7/6/2011	916	8	60	H	Hot	8H	SE	U	3	1.5	3.5	4	3	3	Strong
2011	7/6/2011	916	8	80	H	Hot	8H	SE	U	1	5	5	13	7.67	7.67	Weak
2011	7/6/2011	916	8	80	H	Hot	8H	SE	U	3	12	2.5	8	7.5	7.5	Weak
2011	7/6/2011	916	8	100	H	Hot	8H	SE	U	1	1	2	4	2.33	2.33	Strong
2011	7/6/2011	916	8	100	H	Hot	8H	SE	U	3	3	1	1	1.67	1.67	Strong
2011	8/29/2011	970	9	0	M	Hot	9M	SE	L	1	4	2	1	2.33	2.33	Strong
2011	8/29/2011	970	9	0	M	Hot	9M	SE	L	3	1	1	4	2	2	Strong
2011	8/29/2011	970	9	20	M	Hot	9M	SE	L	1	3	2.5	10.5	5.33	5.33	Weak
2011	8/29/2011	970	9	20	M	Hot	9M	SE	L	3	14	4	11	9.67	9.67	None
2011	8/29/2011	970	9	40	M	Hot	9M	SE	L	1	4	4	8	5.33	5.33	Weak
2011	8/29/2011	970	9	40	M	Hot	9M	SE	L	3	3	3	3	3	3	Strong
2011	8/29/2011	970	9	60	M	Hot	9M	SE	L	1	4	4	5	4.33	4.33	Weak
2011	8/29/2011	970	9	60	M	Hot	9M	SE	L	3	3	1	0.5	1.5	1.5	Strong
2011	8/29/2011	970	9	80	M	Hot	9M	SE	L	1	4	4	4	4	4	Weak
2011	8/29/2011	970	9	80	M	Hot	9M	SE	L	3	1	4	1	2	2	Strong
2011	8/29/2011	970	9	100	M	Hot	9M	SE	L	1	20	35	42	32.33	32.33	None
2011	8/29/2011	970	9	100	M	Hot	9M	SE	L	3	4	11	7	7.33	7.33	Weak
2011	11/3/2011	1036	12	20	H	Hot	12H	S	U	1	4.5	8	10	7.5	7.5	Weak
2011	11/3/2011	1036	12	20	H	Hot	12H	S	U	3	1	1	1	1	1	Strong
2011	11/3/2011	1036	12	40	H	Hot	12H	S	U	1	6.5	7	1.5	5	5	Weak
2011	11/3/2011	1036	12	40	H	Hot	12H	S	U	3	1	0	0.5	0.5	0.5	Strong
2011	11/3/2011	1036	12	60	H	Hot	12H	S	U	1	4.5	7.5	3.5	5.17	5.17	Weak
2011	11/3/2011	1036	12	60	H	Hot	12H	S	U	3	0	1	2	1	1	Strong
2011	11/3/2011	1036	12	80	H	Hot	12H	S	U	1	14.5	17	15	15.5	15.5	None
2011	11/3/2011	1036	12	80	H	Hot	12H	S	U	3	5	3	2	3.33	3.33	Weak
2011	11/3/2011	1036	12	100	H	Hot	12H	S	U	1	8.5	12	19.5	13.33	13.33	None

2011	11/3/2011	1036	12	100	H	Hot	12H	S	U	3	0.5	0	0.5	0.33	0.33	Strong
2011	8/29/2011	970	13	0	M	Hot	13M	S	L	1	2	11	5	6	6	Weak
2011	8/29/2011	970	13	0	M	Hot	13M	S	L	3	2	2	1	1.67	1.67	Strong
2011	8/29/2011	970	13	20	M	Hot	13M	S	L	1	16	3	6	8.33	8.33	None
2011	8/29/2011	970	13	20	M	Hot	13M	S	L	3	3	3	4	3.33	3.33	Weak
2011	8/29/2011	970	13	40	M	Hot	13M	S	L	1	4	11	19	11.33	11.33	None
2011	8/29/2011	970	13	40	M	Hot	13M	S	L	3	5	2	3	3.33	3.33	Weak
2011	8/29/2011	970	13	60	M	Hot	13M	S	L	1	16	9	6	10.33	10.33	None
2011	8/29/2011	970	13	60	M	Hot	13M	S	L	3	6	10	11	9	9	None
2011	8/29/2011	970	13	80	M	Hot	13M	S	L	1	1	8	3	4	4	Weak
2011	8/29/2011	970	13	80	M	Hot	13M	S	L	3	2	3	5	3.33	3.33	Weak
2011	8/29/2011	970	13	100	M	Hot	13M	S	L	1	11	1	6	6	6	Weak
2011	8/29/2011	970	13	100	M	Hot	13M	S	L	3	8	5	6	6.33	6.33	Weak
2011	8/30/2011	971	14	20	N	Cool	14N	S	L	1	0	1	0.5	0.5	0.5	Strong
2011	8/30/2011	971	14	20	N	Cool	14N	S	L	3	0	1	1	0.67	0.67	Strong
2011	8/30/2011	971	14	40	N	Cool	14N	S	L	1	2	2	3	2.33	2.33	Strong
2011	8/30/2011	971	14	40	N	Cool	14N	S	L	3	0	1	2	1	1	Strong
2011	8/30/2011	971	14	60	N	Cool	14N	S	L	1	0.5	0.5	0	0.33	0.33	Strong
2011	8/30/2011	971	14	60	N	Cool	14N	S	L	3	2	2	2	2	2	Strong
2011	8/30/2011	971	14	80	N	Cool	14N	S	L	1	1	0	1	0.67	0.67	Strong
2011	8/30/2011	971	14	80	N	Cool	14N	S	L	3	2	2	1	1.67	1.67	Strong
2011	8/30/2011	971	14	100	N	Cool	14N	S	L	1	0	0	1	0.33	0.33	Strong
2011	8/30/2011	971	14	100	N	Cool	14N	S	L	3	2	2	3	2.33	2.33	Strong
2011	10/20/2011	1022	18	0	H	Hot	18H	SE	U	1	11	6.5	11	9.5	9.5	None
2011	10/20/2011	1022	18	0	H	Hot	18H	SE	U	3	5	2	3	3.33	3.33	Weak
2011	10/20/2011	1022	18	20	H	Hot	18H	SE	U	1	3	2	3.5	2.83	2.83	Strong
2011	10/20/2011	1022	18	20	H	Hot	18H	SE	U	3	3	6	5.5	4.83	4.83	Weak
2011	10/20/2011	1022	18	40	H	Hot	18H	SE	U	1	1	2.5	1	1.5	1.5	Strong
2011	10/20/2011	1022	18	40	H	Hot	18H	SE	U	3	4	2	3.5	3.17	3.17	Weak
2011	10/20/2011	1022	18	60	H	Hot	18H	SE	U	1	3	3	3	3	3	Strong
2011	10/20/2011	1022	18	60	H	Hot	18H	SE	U	3	2	6	11	6.33	6.33	Weak
2011	10/20/2011	1022	18	80	H	Hot	18H	SE	U	1	5.5	8.5	6	6.67	6.67	Weak
2011	10/20/2011	1022	18	80	H	Hot	18H	SE	U	3	6	11	2.5	6.5	6.5	Weak
2011	9/15/2011	987	20	20	H	Hot	20H	NW	U	1	4	2	NA	3	3	Strong
2011	9/15/2011	987	20	20	H	Hot	20H	NW	U	3	6	4	NA	5	5	Weak

2011	9/15/2011	987	20	40	H	Hot	20H	NW	U	1	0	0	NA	0	0.1	Strong
2011	9/15/2011	987	20	40	H	Hot	20H	NW	U	3	0	0	NA	0	0.1	Strong
2011	9/15/2011	987	20	60	H	Hot	20H	NW	U	1	2	0	NA	1	1	Strong
2011	9/15/2011	987	20	60	H	Hot	20H	NW	U	3	0	0	NA	0	0.1	Strong
2011	9/15/2011	987	20	80	H	Hot	20H	NW	U	1	2	3	NA	2.5	2.5	Strong
2011	9/15/2011	987	20	80	H	Hot	20H	NW	U	3	2	2	NA	2	2	Strong
2011	9/15/2011	987	20	100	H	Hot	20H	NW	U	1	1	1	NA	1	1	Strong
2011	9/15/2011	987	20	100	H	Hot	20H	NW	U	3	9	2	NA	5.5	5.5	Weak
2011	8/30/2011	971	21	20	ML	Cool	21ML	N	L	1	7.5	3.5	9	6.67	6.67	Weak
2011	8/30/2011	971	21	20	ML	Cool	21ML	N	L	3	12	1	0.5	4.5	4.5	Weak
2011	8/30/2011	971	21	40	ML	Cool	21ML	N	L	1	6	6	5	5.67	5.67	Weak
2011	8/30/2011	971	21	40	ML	Cool	21ML	N	L	3	10.5	6.5	2	6.33	6.33	Weak
2011	8/30/2011	971	21	60	ML	Cool	21ML	N	L	1	19	9	8	12	12	None
2011	8/30/2011	971	21	60	ML	Cool	21ML	N	L	3	14	5	2	7	7	Weak
2011	8/30/2011	971	21	80	ML	Cool	21ML	N	L	1	3	3	5	3.67	3.67	Weak
2011	8/30/2011	971	21	80	ML	Cool	21ML	N	L	3	0.5	0.5	2	1	1	Strong
2011	8/30/2011	971	21	100	ML	Cool	21ML	N	L	1	5	6	5	5.33	5.33	Weak
2011	8/30/2011	971	21	100	ML	Cool	21ML	N	L	3	8	12	7.5	9.17	9.17	None
2011	8/30/2011	971	22	20	MH	Hot	22MH	N	U	1	5	7	5	5.67	5.67	Weak
2011	8/30/2011	971	22	20	MH	Hot	22MH	N	U	3	3	5	5	4.33	4.33	Weak
2011	8/30/2011	971	22	40	MH	Hot	22MH	N	U	1	4	3	5	4	4	Weak
2011	8/30/2011	971	22	40	MH	Hot	22MH	N	U	3	2	3	3	2.67	2.67	Strong
2011	8/30/2011	971	22	60	MH	Hot	22MH	N	U	1	24	18	8	16.67	16.67	None
2011	8/30/2011	971	22	60	MH	Hot	22MH	N	U	3	15	2	9	8.67	8.67	None
2011	8/30/2011	971	22	80	MH	Hot	22MH	N	U	1	15	12	12	13	13	None
2011	8/30/2011	971	22	80	MH	Hot	22MH	N	U	3	7	4	4	5	5	Weak
2011	8/30/2011	971	22	100	MH	Hot	22MH	N	U	1	15	20	20	18.33	18.33	None
2011	8/30/2011	971	22	100	MH	Hot	22MH	N	U	3	2	2	4	2.67	2.67	Strong
2012	7/30/2012	1306	1	0	H	Hot	1H	SE	L	1	7	6	10	7.67	7.67	Weak
2012	7/30/2012	1306	1	0	H	Hot	1H	SE	L	3	5	6	4	5	5	Weak
2012	7/30/2012	1306	1	20	H	Hot	1H	SE	L	1	22	11	26	19.67	19.67	None
2012	7/30/2012	1306	1	20	H	Hot	1H	SE	L	3	7	7	8	7.33	7.33	Weak
2012	7/30/2012	1306	1	40	H	Hot	1H	SE	L	1	22	15	14	17	17	None
2012	7/30/2012	1306	1	40	H	Hot	1H	SE	L	3	11	10	11	10.67	10.67	None
2012	7/30/2012	1306	1	60	H	Hot	1H	SE	L	1	4	5	7	5.33	5.33	Weak

2012	7/30/2012	1306	1	60	H	Hot	1H	SE	L	3	3	5	6	4.67	4.67	Weak
2012	7/30/2012	1306	1	80	H	Hot	1H	SE	L	1	11	15	3	9.67	9.67	None
2012	7/30/2012	1306	1	80	H	Hot	1H	SE	L	3	8	11	16	11.67	11.67	None
2012	7/30/2012	1306	1	100	H	Hot	1H	SE	L	1	11	24	11	15.33	15.33	None
2012	7/30/2012	1306	1	100	H	Hot	1H	SE	L	3	6	12	4	7.33	7.33	Weak
2012	7/31/2012	1307	2	0	M	Hot	2M	SE	L	1	9	9	8	8.67	8.67	None
2012	7/31/2012	1307	2	0	M	Hot	2M	SE	L	3	3	8	13	8	8	None
2012	7/31/2012	1307	2	20	M	Hot	2M	SE	L	1	0.5	3.5	2	2	2	Strong
2012	7/31/2012	1307	2	20	M	Hot	2M	SE	L	3	3	8	7	6	6	Weak
2012	7/31/2012	1307	2	40	M	Hot	2M	SE	L	1	5	5	3	4.33	4.33	Weak
2012	7/31/2012	1307	2	40	M	Hot	2M	SE	L	3	8	8	8	8	8	None
2012	7/31/2012	1307	2	60	M	Hot	2M	SE	L	1	3	5	1	3	3	Strong
2012	7/31/2012	1307	2	60	M	Hot	2M	SE	L	3	1	1	2	1.33	1.33	Strong
2012	7/31/2012	1307	2	80	M	Hot	2M	SE	L	1	8	2	5	5	5	Weak
2012	7/31/2012	1307	2	80	M	Hot	2M	SE	L	3	3	2	NA	2.5	2.5	Strong
2012	7/31/2012	1307	2	100	M	Hot	2M	SE	L	1	10	8	6	8	8	None
2012	7/31/2012	1307	2	100	M	Hot	2M	SE	L	3	3	5	3	3.67	3.67	Weak
2012	7/31/2012	1307	3	0	M	Hot	3M	NW	L	1	4	8	3	5	5	Weak
2012	7/31/2012	1307	3	0	M	Hot	3M	NW	L	3	4	2	5	3.67	3.67	Weak
2012	7/31/2012	1307	3	20	M	Hot	3M	NW	L	1	6	9	11	8.67	8.67	None
2012	7/31/2012	1307	3	20	M	Hot	3M	NW	L	3	12	12	11	11.67	11.67	None
2012	7/31/2012	1307	3	40	M	Hot	3M	NW	L	1	19	8	15	14	14	None
2012	7/31/2012	1307	3	40	M	Hot	3M	NW	L	3	4	8	7	6.33	6.33	Weak
2012	7/31/2012	1307	3	60	M	Hot	3M	NW	L	1	16	16	16	16	16	None
2012	7/31/2012	1307	3	60	M	Hot	3M	NW	L	3	13	20	20	17.67	17.67	None
2012	7/31/2012	1307	3	80	M	Hot	3M	NW	L	1	25	8	12	15	15	None
2012	7/31/2012	1307	3	80	M	Hot	3M	NW	L	3	2	20	15	12.33	12.33	None
2012	7/31/2012	1307	3	100	M	Hot	3M	NW	L	1	13	10	8	10.33	10.33	None
2012	7/31/2012	1307	3	100	M	Hot	3M	NW	L	3	8	6	10	8	8	None
2012	8/8/2012	1315	4	0	H	Hot	4H	N	U	1	24	27	26	25.67	25.67	None
2012	8/8/2012	1315	4	0	H	Hot	4H	N	U	3	10	17	28	18.33	18.33	None
2012	8/8/2012	1315	4	20	H	Hot	4H	N	U	1	3	4	6	4.33	4.33	Weak
2012	8/8/2012	1315	4	20	H	Hot	4H	N	U	3	4	3	2	3	3	Strong
2012	8/8/2012	1315	4	40	H	Hot	4H	N	U	1	23	19	21	21	21	None
2012	8/8/2012	1315	4	40	H	Hot	4H	N	U	3	15	11	7	11	11	None

2012	8/8/2012	1315	4	80	H	Hot	4H	N	U	1	2	3	2	2.33	2.33	Strong
2012	8/8/2012	1315	4	80	H	Hot	4H	N	U	3	5	2	2	3	3	Strong
2012	8/8/2012	1315	4	100	H	Hot	4H	N	U	1	4	1	2	2.33	2.33	Strong
2012	8/8/2012	1315	4	100	H	Hot	4H	N	U	3	1	2	3	2	2	Strong
2012	8/7/2012	1314	5	0	M	Hot	5M	W	L	1	6	4	7	5.67	5.67	Weak
2012	8/7/2012	1314	5	0	M	Hot	5M	W	L	3	6	5	5	5.33	5.33	Weak
2012	8/7/2012	1314	5	20	M	Hot	5M	W	L	1	8	8	5	7	7	Weak
2012	8/7/2012	1314	5	20	M	Hot	5M	W	L	3	12	7	12	10.33	10.33	None
2012	8/7/2012	1314	5	40	M	Hot	5M	W	L	1	0	0	2	0.67	0.67	Strong
2012	8/7/2012	1314	5	40	M	Hot	5M	W	L	3	0	2	0	0.67	0.67	Strong
2012	8/7/2012	1314	5	60	M	Hot	5M	W	L	1	6	4	5	5	5	Weak
2012	8/7/2012	1314	5	60	M	Hot	5M	W	L	3	9	8	11	9.33	9.33	None
2012	8/7/2012	1314	5	80	M	Hot	5M	W	L	1	12	12	9	11	11	None
2012	8/7/2012	1314	5	80	M	Hot	5M	W	L	3	14	8	24	15.33	15.33	None
2012	8/7/2012	1314	5	100	M	Hot	5M	W	L	1	1	2	0	1	1	Strong
2012	8/7/2012	1314	5	100	M	Hot	5M	W	L	3	5	9	10	8	8	None
2012	8/7/2012	1314	6	0	H	Hot	6H	N	U	1	11	9	4	8	8	None
2012	8/7/2012	1314	6	0	H	Hot	6H	N	U	3	12	16	8	12	12	None
2012	8/7/2012	1314	6	20	H	Hot	6H	N	U	1	4	20	7	10.33	10.33	None
2012	8/7/2012	1314	6	20	H	Hot	6H	N	U	3	4	2	13	6.33	6.33	Weak
2012	8/7/2012	1314	6	40	H	Hot	6H	N	U	1	10	19	20	16.33	16.33	None
2012	8/7/2012	1314	6	40	H	Hot	6H	N	U	3	5	31	10	15.33	15.33	None
2012	8/7/2012	1314	6	60	H	Hot	6H	N	U	1	10	5	11	8.67	8.67	None
2012	8/7/2012	1314	6	60	H	Hot	6H	N	U	3	18	6	14	12.67	12.67	None
2012	8/7/2012	1314	6	80	H	Hot	6H	N	U	1	4	6	6	5.33	5.33	Weak
2012	8/7/2012	1314	6	80	H	Hot	6H	N	U	3	51	48	7	35.33	35.33	None
2012	8/7/2012	1314	6	100	H	Hot	6H	N	U	1	4	5	7	5.33	5.33	Weak
2012	8/7/2012	1314	6	100	H	Hot	6H	N	U	3	1	4	5	3.33	3.33	Weak
2012	8/2/2012	1309	7	0	H	Hot	7H	N	U	1	3	6	10	6.33	6.33	Weak
2012	8/2/2012	1309	7	0	H	Hot	7H	N	U	3	5	3	9	5.67	5.67	Weak
2012	8/2/2012	1309	7	20	H	Hot	7H	N	U	1	5	17	10	10.67	10.67	None
2012	8/2/2012	1309	7	20	H	Hot	7H	N	U	3	5	9	5	6.33	6.33	Weak
2012	8/2/2012	1309	7	40	H	Hot	7H	N	U	1	2.5	3	5	3.5	3.5	Weak
2012	8/2/2012	1309	7	40	H	Hot	7H	N	U	3	5	11	10	8.67	8.67	None
2012	8/2/2012	1309	7	60	H	Hot	7H	N	U	1	6	8	4	6	6	Weak

2012	8/2/2012	1309	7	60	H	Hot	7H	N	U	3	3	4	3	3.33	3.33	Weak
2012	8/2/2012	1309	7	80	H	Hot	7H	N	U	1	10	6	4	6.67	6.67	Weak
2012	8/2/2012	1309	7	80	H	Hot	7H	N	U	3	0	1	1	0.67	0.67	Strong
2012	8/2/2012	1309	7	100	H	Hot	7H	N	U	1	13	14	13	13.33	13.33	None
2012	8/2/2012	1309	7	100	H	Hot	7H	N	U	3	1	2	2	1.67	1.67	Strong
2012	8/1/2012	1308	8	0	H	Hot	8H	SE	U	1	2	3	2	2.33	2.33	Strong
2012	8/1/2012	1308	8	0	H	Hot	8H	SE	U	3	1	1	4	2	2	Strong
2012	8/1/2012	1308	8	20	H	Hot	8H	SE	U	1	9	5	2	5.33	5.33	Weak
2012	8/1/2012	1308	8	20	H	Hot	8H	SE	U	3	7	4	4	5	5	Weak
2012	8/1/2012	1308	8	40	H	Hot	8H	SE	U	1	7	5	13	8.33	8.33	None
2012	8/1/2012	1308	8	40	H	Hot	8H	SE	U	3	5	8	9	7.33	7.33	Weak
2012	8/1/2012	1308	8	60	H	Hot	8H	SE	U	1	7	8	19	11.33	11.33	None
2012	8/1/2012	1308	8	60	H	Hot	8H	SE	U	3	4	0.5	2	2.17	2.17	Strong
2012	8/1/2012	1308	8	80	H	Hot	8H	SE	U	1	15	11	18	14.67	14.67	None
2012	8/1/2012	1308	8	80	H	Hot	8H	SE	U	3	20	7	18	15	15	None
2012	8/1/2012	1308	8	100	H	Hot	8H	SE	U	1	7	6	4	5.67	5.67	Weak
2012	8/1/2012	1308	8	100	H	Hot	8H	SE	U	3	1	2	3	2	2	Strong
2012	7/25/2012	1301	9	0	M	Hot	9M	SE	L	1	6	2	1	3	3	Strong
2012	7/25/2012	1301	9	0	M	Hot	9M	SE	L	3	3	2	3	2.67	2.67	Strong
2012	7/25/2012	1301	9	20	M	Hot	9M	SE	L	1	5	3	3	3.67	3.67	Weak
2012	7/25/2012	1301	9	20	M	Hot	9M	SE	L	3	8	11	17	12	12	None
2012	7/25/2012	1301	9	40	M	Hot	9M	SE	L	1	24	14	35	24.33	24.33	None
2012	7/25/2012	1301	9	40	M	Hot	9M	SE	L	3	6	31	29	22	22	None
2012	7/25/2012	1301	9	60	M	Hot	9M	SE	L	1	5	7	6	6	6	Weak
2012	7/25/2012	1301	9	60	M	Hot	9M	SE	L	3	23	14	13	16.67	16.67	None
2012	7/25/2012	1301	9	80	M	Hot	9M	SE	L	1	4	3	2	3	3	Strong
2012	7/25/2012	1301	9	80	M	Hot	9M	SE	L	3	1	0.5	0.5	0.67	0.67	Strong
2012	7/25/2012	1301	9	100	M	Hot	9M	SE	L	1	3	4	7	4.67	4.67	Weak
2012	7/25/2012	1301	9	100	M	Hot	9M	SE	L	3	6	2	2	3.33	3.33	Weak
2012	8/2/2012	1309	10	0	H	Hot	10H	S	U	1	3	18	24	15	15	None
2012	8/2/2012	1309	10	0	H	Hot	10H	S	U	3	16	12	11	13	13	None
2012	8/2/2012	1309	10	20	H	Hot	10H	S	U	1	24	25	24	24.33	24.33	None
2012	8/2/2012	1309	10	20	H	Hot	10H	S	U	3	3	6	37	15.33	15.33	None
2012	8/2/2012	1309	10	40	H	Hot	10H	S	U	1	14	6	5	8.33	8.33	None
2012	8/2/2012	1309	10	40	H	Hot	10H	S	U	3	1	0	18	6.33	6.33	Weak

2012	8/2/2012	1309	10	60	H	Hot	10H	S	U	1	29	24	18	23.67	23.67	None
2012	8/2/2012	1309	10	60	H	Hot	10H	S	U	3	17	2	17	12	12	None
2012	8/2/2012	1309	10	80	H	Hot	10H	S	U	1	23	21	21	21.67	21.67	None
2012	8/2/2012	1309	10	80	H	Hot	10H	S	U	3	1	1	22	8	8	None
2012	8/2/2012	1309	10	100	H	Hot	10H	S	U	1	8	14	8	10	10	None
2012	8/2/2012	1309	10	100	H	Hot	10H	S	U	3	0	4	1	1.67	1.67	Strong
2012	8/9/2012	1316	11	0	M	Hot	11M	NW	U	1	4	1	1	2	2	Strong
2012	8/9/2012	1316	11	0	M	Hot	11M	NW	U	3	2	0	1	1	1	Strong
2012	8/9/2012	1316	11	20	M	Hot	11M	NW	U	1	2	2	1	1.67	1.67	Strong
2012	8/9/2012	1316	11	20	M	Hot	11M	NW	U	3	13	8	5	8.67	8.67	None
2012	8/9/2012	1316	11	40	M	Hot	11M	NW	U	1	20	7	17	14.67	14.67	None
2012	8/9/2012	1316	11	40	M	Hot	11M	NW	U	3	6	4	7	5.67	5.67	Weak
2012	8/9/2012	1316	11	60	M	Hot	11M	NW	U	1	0	0	6	2	2	Strong
2012	8/9/2012	1316	11	60	M	Hot	11M	NW	U	3	20	12	11	14.33	14.33	None
2012	8/9/2012	1316	11	80	M	Hot	11M	NW	U	1	3	3	3	3	3	Strong
2012	8/9/2012	1316	11	80	M	Hot	11M	NW	U	3	8	5	11	8	8	None
2012	8/9/2012	1316	11	100	M	Hot	11M	NW	U	1	15	14	11	13.33	13.33	None
2012	8/9/2012	1316	11	100	M	Hot	11M	NW	U	3	9	9	10	9.33	9.33	None
2012	8/6/2012	1313	12	0	H	Hot	12H	S	U	1	36	23	28	29	29	None
2012	8/6/2012	1313	12	0	H	Hot	12H	S	U	3	14	5	21	13.33	13.33	None
2012	8/6/2012	1313	12	20	H	Hot	12H	S	U	1	26	6	10	14	14	None
2012	8/6/2012	1313	12	20	H	Hot	12H	S	U	3	1	2	5	2.67	2.67	Strong
2012	8/6/2012	1313	12	40	H	Hot	12H	S	U	1	9	14	8	10.33	10.33	None
2012	8/6/2012	1313	12	40	H	Hot	12H	S	U	3	7	3	6	5.33	5.33	Weak
2012	8/6/2012	1313	12	60	H	Hot	12H	S	U	1	7	4	36	15.67	15.67	None
2012	8/6/2012	1313	12	60	H	Hot	12H	S	U	3	4	10	0	4.67	4.67	Weak
2012	8/6/2012	1313	12	80	H	Hot	12H	S	U	1	21	9	17	15.67	15.67	None
2012	8/6/2012	1313	12	80	H	Hot	12H	S	U	3	2	2	4	2.67	2.67	Strong
2012	8/6/2012	1313	12	100	H	Hot	12H	S	U	1	7	13	5	8.33	8.33	None
2012	8/6/2012	1313	12	100	H	Hot	12H	S	U	3	6	9	10	8.33	8.33	None
2012	7/31/2012	1307	13	0	M	Hot	13M	S	L	1	8	25	27	20	20	None
2012	7/31/2012	1307	13	0	M	Hot	13M	S	L	3	7	15	11	11	11	None
2012	7/31/2012	1307	13	20	M	Hot	13M	S	L	1	12	7	20	13	13	None
2012	7/31/2012	1307	13	20	M	Hot	13M	S	L	3	20	23	23	22	22	None
2012	7/31/2012	1307	13	40	M	Hot	13M	S	L	1	24	49	10	27.67	27.67	None

2012	7/31/2012	1307	13	40	M	Hot	13M	S	L	3	50	4	8	20.67	20.67	None
2012	7/31/2012	1307	13	60	M	Hot	13M	S	L	1	5	9	17	10.33	10.33	None
2012	7/31/2012	1307	13	60	M	Hot	13M	S	L	3	16	13	15	14.67	14.67	None
2012	7/31/2012	1307	13	80	M	Hot	13M	S	L	1	4	14	8	8.67	8.67	None
2012	7/31/2012	1307	13	80	M	Hot	13M	S	L	3	8	8	6	7.33	7.33	Weak
2012	7/31/2012	1307	13	100	M	Hot	13M	S	L	1	8	7	10	8.33	8.33	None
2012	7/31/2012	1307	13	100	M	Hot	13M	S	L	3	9	13	18	13.33	13.33	None
2012	7/30/2012	1306	14	20	N	Cool	14N	S	L	1	40	15	7	20.67	20.67	None
2012	7/30/2012	1306	14	20	N	Cool	14N	S	L	3	6	5	12	7.67	7.67	Weak
2012	7/30/2012	1306	14	40	N	Cool	14N	S	L	1	1	4	NA	2.5	2.5	Strong
2012	7/30/2012	1306	14	40	N	Cool	14N	S	L	3	4	9	3	5.33	5.33	Weak
2012	7/30/2012	1306	14	60	N	Cool	14N	S	L	1	2	4	2	2.67	2.67	Strong
2012	7/30/2012	1306	14	60	N	Cool	14N	S	L	3	6	4	5	5	5	Weak
2012	7/30/2012	1306	14	80	N	Cool	14N	S	L	1	23	16	15	18	18	None
2012	7/30/2012	1306	14	80	N	Cool	14N	S	L	3	14	9	8	10.33	10.33	None
2012	8/1/2012	1308	15	0	H	Hot	15H	SE	U	1	5	5	3	4.33	4.33	Weak
2012	8/1/2012	1308	15	0	H	Hot	15H	SE	U	3	3	3	5	3.67	3.67	Weak
2012	8/1/2012	1308	15	20	H	Hot	15H	SE	U	1	3	8	10	7	7	Weak
2012	8/1/2012	1308	15	20	H	Hot	15H	SE	U	3	8	3	11	7.33	7.33	Weak
2012	8/1/2012	1308	15	40	H	Hot	15H	SE	U	1	2	2	4	2.67	2.67	Strong
2012	8/1/2012	1308	15	40	H	Hot	15H	SE	U	3	8	1	2	3.67	3.67	Weak
2012	8/1/2012	1308	15	60	H	Hot	15H	SE	U	1	2	2	1	1.67	1.67	Strong
2012	8/1/2012	1308	15	60	H	Hot	15H	SE	U	3	3	2	3	2.67	2.67	Strong
2012	8/1/2012	1308	15	80	H	Hot	15H	SE	U	1	10	9	19	12.67	12.67	None
2012	8/1/2012	1308	15	80	H	Hot	15H	SE	U	3	2	5	3	3.33	3.33	Weak
2012	8/1/2012	1308	15	100	H	Hot	15H	SE	U	1	2	9	11	7.33	7.33	Weak
2012	8/1/2012	1308	15	100	H	Hot	15H	SE	U	3	8	2	5	5	5	Weak
2012	8/13/2012	1320	20	0	H	Hot	20H	NW	U	1	0	1	0	0.33	0.33	Strong
2012	8/13/2012	1320	20	0	H	Hot	20H	NW	U	3	0	1	0	0.33	0.33	Strong
2012	8/13/2012	1320	20	20	H	Hot	20H	NW	U	1	0.5	0	0.5	0.33	0.33	Strong
2012	8/13/2012	1320	20	20	H	Hot	20H	NW	U	3	2	1	3	2	2	Strong
2012	8/13/2012	1320	20	40	H	Hot	20H	NW	U	1	1	0	0	0.33	0.33	Strong
2012	8/13/2012	1320	20	40	H	Hot	20H	NW	U	3	0	0	0	0	0.1	Strong
2012	8/13/2012	1320	20	60	H	Hot	20H	NW	U	1	3	5	3	3.67	3.67	Weak
2012	8/13/2012	1320	20	60	H	Hot	20H	NW	U	3	8	4	7	6.33	6.33	Weak

2012	8/13/2012	1320	20	80	H	Hot	20H	NW	U	1	5	2	1	2.67	2.67	Strong
2012	8/13/2012	1320	20	80	H	Hot	20H	NW	U	3	5	2	20	9	9	None
2012	8/13/2012	1320	20	100	H	Hot	20H	NW	U	1	12	2	8	7.33	7.33	Weak
2012	8/13/2012	1320	20	100	H	Hot	20H	NW	U	3	3	6	7	5.33	5.33	Weak
2012	8/9/2012	1316	21	0	ML	Cool	21ML	N	L	1	19	7	7	11	11	None
2012	8/9/2012	1316	21	0	ML	Cool	21ML	N	L	3	2	3	9	4.67	4.67	Weak
2012	8/9/2012	1316	21	20	ML	Cool	21ML	N	L	1	11	20	12	14.33	14.33	None
2012	8/9/2012	1316	21	20	ML	Cool	21ML	N	L	3	8	8	8	8	8	None
2012	8/9/2012	1316	21	40	ML	Cool	21ML	N	L	1	2	0	2	1.33	1.33	Strong
2012	8/9/2012	1316	21	40	ML	Cool	21ML	N	L	3	3	2	6	3.67	3.67	Weak
2012	8/9/2012	1316	21	60	ML	Cool	21ML	N	L	1	9	17	11	12.33	12.33	None
2012	8/9/2012	1316	21	60	ML	Cool	21ML	N	L	3	3	7	12	7.33	7.33	Weak
2012	8/9/2012	1316	21	80	ML	Cool	21ML	N	L	1	14	7	13	11.33	11.33	None
2012	8/9/2012	1316	21	80	ML	Cool	21ML	N	L	3	14	17	18	16.33	16.33	None
2012	8/9/2012	1316	21	100	ML	Cool	21ML	N	L	1	36	34	50	40	40	None
2012	8/9/2012	1316	21	100	ML	Cool	21ML	N	L	3	23	30	18	23.67	23.67	None
2012	8/13/2012	1320	22	0	MH	Hot	22MH	N	U	1	11	7	6	8	8	None
2012	8/13/2012	1320	22	0	MH	Hot	22MH	N	U	3	8	3	9	6.67	6.67	Weak
2012	8/13/2012	1320	22	20	MH	Hot	22MH	N	U	1	1	8	5	4.67	4.67	Weak
2012	8/13/2012	1320	22	20	MH	Hot	22MH	N	U	3	10	7	5	7.33	7.33	Weak
2012	8/13/2012	1320	22	40	MH	Hot	22MH	N	U	1	5	7	4	5.33	5.33	Weak
2012	8/13/2012	1320	22	40	MH	Hot	22MH	N	U	3	3	4	8	5	5	Weak
2012	8/13/2012	1320	22	60	MH	Hot	22MH	N	U	1	10	19	12	13.67	13.67	None
2012	8/13/2012	1320	22	60	MH	Hot	22MH	N	U	3	7	9	6	7.33	7.33	Weak
2012	8/13/2012	1320	22	80	MH	Hot	22MH	N	U	1	14	11	14	13	13	None
2012	8/13/2012	1320	22	80	MH	Hot	22MH	N	U	3	13	10	10	11	11	None
2012	8/13/2012	1320	22	100	MH	Hot	22MH	N	U	1	6	7	4	5.67	5.67	Weak
2012	8/13/2012	1320	22	100	MH	Hot	22MH	N	U	3	5	4	6	5	5	Weak
2012	8/8/2012	1315	23	0	H	Hot	23H	N	U	1	3	2	2	2.33	2.33	Strong
2012	8/8/2012	1315	23	0	H	Hot	23H	N	U	3	1	1	1	1	1	Strong
2012	8/8/2012	1315	23	20	H	Hot	23H	N	U	1	11	9	7	9	9	None
2012	8/8/2012	1315	23	20	H	Hot	23H	N	U	3	7	6	9	7.33	7.33	Weak
2012	8/8/2012	1315	23	40	H	Hot	23H	N	U	1	10	12	3	8.33	8.33	None
2012	8/8/2012	1315	23	40	H	Hot	23H	N	U	3	14	12	11	12.33	12.33	None
2012	8/8/2012	1315	23	60	H	Hot	23H	N	U	1	1	1	1	1	1	Strong

2012	8/8/2012	1315	23	60	H	Hot	23H	N	U	3	1	56	1	19.33	19.33	None
2012	8/8/2012	1315	23	80	H	Hot	23H	N	U	1	1	9	2	4	4	Weak
2012	8/8/2012	1315	23	80	H	Hot	23H	N	U	3	13	7	5	8.33	8.33	None
2012	8/8/2012	1315	23	100	H	Hot	23H	N	U	1	7	7	7	7	7	Weak
2012	8/8/2012	1315	23	100	H	Hot	23H	N	U	3	7	4	22	11	11	None
2013	7/17/2013	1658	1	0	H	Hot	1H	SE	L	1	0	3	1	1.33	1.33	Strong
2013	7/17/2013	1658	1	0	H	Hot	1H	SE	L	3	3	2	1	2	2	Strong
2013	7/17/2013	1658	1	20	H	Hot	1H	SE	L	1	16	11	2	9.67	9.67	None
2013	7/17/2013	1658	1	20	H	Hot	1H	SE	L	3	1	2	1	1.33	1.33	Strong
2013	7/17/2013	1658	1	40	H	Hot	1H	SE	L	1	1	5	7	4.33	4.33	Weak
2013	7/17/2013	1658	1	40	H	Hot	1H	SE	L	3	15	19	13	15.67	15.67	None
2013	7/17/2013	1658	1	60	H	Hot	1H	SE	L	1	8	4	2	4.67	4.67	Weak
2013	7/17/2013	1658	1	60	H	Hot	1H	SE	L	3	4	2	7	4.33	4.33	Weak
2013	7/17/2013	1658	1	80	H	Hot	1H	SE	L	1	8	6	8	7.33	7.33	Weak
2013	7/17/2013	1658	1	80	H	Hot	1H	SE	L	3	2	3	1	2	2	Strong
2013	7/17/2013	1658	1	100	H	Hot	1H	SE	L	1	10	20	16	15.33	15.33	None
2013	7/17/2013	1658	1	100	H	Hot	1H	SE	L	3	16	7	1	8	8	None
2013	7/8/2013	1649	3	0	M	Hot	3M	NW	L	1	3	3	3	3	3	Strong
2013	7/8/2013	1649	3	0	M	Hot	3M	NW	L	3	3	3	3	3	3	Strong
2013	7/8/2013	1649	3	20	M	Hot	3M	NW	L	1	9	3	3	5	5	Weak
2013	7/8/2013	1649	3	20	M	Hot	3M	NW	L	3	7	9	12	9.33	9.33	None
2013	7/8/2013	1649	3	40	M	Hot	3M	NW	L	1	4	3	4	3.67	3.67	Weak
2013	7/8/2013	1649	3	40	M	Hot	3M	NW	L	3	5	6	4	5	5	Weak
2013	7/8/2013	1649	3	60	M	Hot	3M	NW	L	1	10	6	11	9	9	None
2013	7/8/2013	1649	3	60	M	Hot	3M	NW	L	3	5	7	7	6.33	6.33	Weak
2013	7/8/2013	1649	3	80	M	Hot	3M	NW	L	1	1	3	3	2.33	2.33	Strong
2013	7/8/2013	1649	3	80	M	Hot	3M	NW	L	3	6	4	5	5	5	Weak
2013	7/8/2013	1649	3	100	M	Hot	3M	NW	L	1	2	1	5	2.67	2.67	Strong
2013	7/8/2013	1649	3	100	M	Hot	3M	NW	L	3	7	6	4	5.67	5.67	Weak
2013	7/18/2013	1659	5	0	M	Hot	5M	W	L	1	0	0	0	0	0.1	Strong
2013	7/18/2013	1659	5	0	M	Hot	5M	W	L	3	1	1	1	1	1	Strong
2013	7/18/2013	1659	5	20	M	Hot	5M	W	L	1	2	2	5	3	3	Strong
2013	7/18/2013	1659	5	20	M	Hot	5M	W	L	3	3	4	1	2.67	2.67	Strong
2013	7/18/2013	1659	5	40	M	Hot	5M	W	L	1	2	9	6	5.67	5.67	Weak
2013	7/18/2013	1659	5	40	M	Hot	5M	W	L	3	7	4	1	4	4	Weak

2013	7/18/2013	1659	5	60	M	Hot	5M	W	L	1	1	0	6	2.33	2.33	Strong
2013	7/18/2013	1659	5	60	M	Hot	5M	W	L	3	3	3	6	4	4	Weak
2013	7/18/2013	1659	5	80	M	Hot	5M	W	L	1	1	0	1	0.67	0.67	Strong
2013	7/18/2013	1659	5	80	M	Hot	5M	W	L	3	6	6	3	5	5	Weak
2013	7/18/2013	1659	5	100	M	Hot	5M	W	L	1	1	1	2	1.33	1.33	Strong
2013	7/18/2013	1659	5	100	M	Hot	5M	W	L	3	4	11	3	6	6	Weak
2013	7/9/2013	1650	9	0	M	Hot	9M	SE	L	1	5	9	13	9	9	None
2013	7/9/2013	1650	9	0	M	Hot	9M	SE	L	3	9	9	15	11	11	None
2013	7/9/2013	1650	9	20	M	Hot	9M	SE	L	1	5	15	11	10.33	10.33	None
2013	7/9/2013	1650	9	20	M	Hot	9M	SE	L	3	7	16	15	12.67	12.67	None
2013	7/9/2013	1650	9	40	M	Hot	9M	SE	L	1	5	4	6	5	5	Weak
2013	7/9/2013	1650	9	40	M	Hot	9M	SE	L	3	3	3	5	3.67	3.67	Weak
2013	7/9/2013	1650	9	60	M	Hot	9M	SE	L	1	1	0	7	2.67	2.67	Strong
2013	7/9/2013	1650	9	60	M	Hot	9M	SE	L	3	3	2	4	3	3	Strong
2013	7/9/2013	1650	9	80	M	Hot	9M	SE	L	1	1.5	1.5	2	1.67	1.67	Strong
2013	7/9/2013	1650	9	80	M	Hot	9M	SE	L	3	6	9	9	8	8	None
2013	7/9/2013	1650	9	100	M	Hot	9M	SE	L	1	1.5	1	2	1.5	1.5	Strong
2013	7/9/2013	1650	9	100	M	Hot	9M	SE	L	3	1	0.5	2.5	1.33	1.33	Strong
2013	7/16/2013	1657	10	0	H	Hot	10H	S	U	1	2	8	2	4	4	Weak
2013	7/16/2013	1657	10	0	H	Hot	10H	S	U	3	3	7	3	4.33	4.33	Weak
2013	7/16/2013	1657	10	20	H	Hot	10H	S	U	1	38	27	30	31.67	31.67	None
2013	7/16/2013	1657	10	20	H	Hot	10H	S	U	3	12	15	17	14.67	14.67	None
2013	7/16/2013	1657	10	40	H	Hot	10H	S	U	1	18	21	25	21.33	21.33	None
2013	7/16/2013	1657	10	40	H	Hot	10H	S	U	3	28	22	7	19	19	None
2013	7/16/2013	1657	10	60	H	Hot	10H	S	U	1	34	16	14	21.33	21.33	None
2013	7/16/2013	1657	10	60	H	Hot	10H	S	U	3	20	8	0	9.33	9.33	None
2013	7/16/2013	1657	10	80	H	Hot	10H	S	U	1	24	10	2	12	12	None
2013	7/16/2013	1657	10	80	H	Hot	10H	S	U	3	2	4	4	3.33	3.33	Weak
2013	7/16/2013	1657	10	100	H	Hot	10H	S	U	1	9	11	21	13.67	13.67	None
2013	7/16/2013	1657	10	100	H	Hot	10H	S	U	3	14	1	1	5.33	5.33	Weak
2013	7/17/2013	1658	11	0	M	Hot	11M	NW	U	1	3	3	3	3	3	Strong
2013	7/17/2013	1658	11	0	M	Hot	11M	NW	U	3	2	3	3	2.67	2.67	Strong
2013	7/17/2013	1658	11	20	M	Hot	11M	NW	U	1	0	1	3	1.33	1.33	Strong
2013	7/17/2013	1658	11	20	M	Hot	11M	NW	U	3	2	11	0	4.33	4.33	Weak
2013	7/17/2013	1658	11	40	M	Hot	11M	NW	U	1	6	5	5	5.33	5.33	Weak

2013	7/17/2013	1658	11	40	M	Hot	11M	NW	U	3	4	3	0	2.33	2.33	Strong
2013	7/17/2013	1658	11	60	M	Hot	11M	NW	U	1	5	6	4	5	5	Weak
2013	7/17/2013	1658	11	60	M	Hot	11M	NW	U	3	3	3	2	2.67	2.67	Strong
2013	7/17/2013	1658	11	80	M	Hot	11M	NW	U	1	10	12	10	10.67	10.67	None
2013	7/17/2013	1658	11	80	M	Hot	11M	NW	U	3	4	4	6	4.67	4.67	Weak
2013	7/17/2013	1658	11	100	M	Hot	11M	NW	U	1	4	4	6	4.67	4.67	Weak
2013	7/17/2013	1658	11	100	M	Hot	11M	NW	U	3	6	5	3	4.67	4.67	Weak
2013	7/9/2013	1650	15	0	H	Hot	15H	SE	U	1	1	5	1	2.33	2.33	Strong
2013	7/9/2013	1650	15	0	H	Hot	15H	SE	U	3	1	0	0	0.33	0.33	Strong
2013	7/9/2013	1650	15	20	H	Hot	15H	SE	U	1	5	4	6	5	5	Weak
2013	7/9/2013	1650	15	20	H	Hot	15H	SE	U	3	9	3	13	8.33	8.33	None
2013	7/9/2013	1650	15	40	H	Hot	15H	SE	U	1	1	1	4	2	2	Strong
2013	7/9/2013	1650	15	40	H	Hot	15H	SE	U	3	2	1	1	1.33	1.33	Strong
2013	7/9/2013	1650	15	60	H	Hot	15H	SE	U	1	3	7	7	5.67	5.67	Weak
2013	7/9/2013	1650	15	60	H	Hot	15H	SE	U	3	1	4	4	3	3	Strong
2013	7/9/2013	1650	15	80	H	Hot	15H	SE	U	1	9	16	15	13.33	13.33	None
2013	7/9/2013	1650	15	80	H	Hot	15H	SE	U	3	4	3	2	3	3	Strong
2013	7/9/2013	1650	15	100	H	Hot	15H	SE	U	1	1	2	1	1.33	1.33	Strong
2013	7/9/2013	1650	15	100	H	Hot	15H	SE	U	3	12	12	13	12.33	12.33	None
2013	7/18/2013	1659	20	0	H	Hot	20H	NW	U	1	0	16	12	9.33	9.33	None
2013	7/18/2013	1659	20	0	H	Hot	20H	NW	U	3	2	2	2	2	2	Strong
2013	7/18/2013	1659	20	20	H	Hot	20H	NW	U	1	9	17	1	9	9	None
2013	7/18/2013	1659	20	20	H	Hot	20H	NW	U	3	2	1	4	2.33	2.33	Strong
2013	7/18/2013	1659	20	40	H	Hot	20H	NW	U	1	1	2	3	2	2	Strong
2013	7/18/2013	1659	20	40	H	Hot	20H	NW	U	3	3	2	1	2	2	Strong
2013	7/18/2013	1659	20	60	H	Hot	20H	NW	U	1	39	18	4	20.33	20.33	None
2013	7/18/2013	1659	20	60	H	Hot	20H	NW	U	3	13	4	4	7	7	Weak
2013	7/18/2013	1659	20	80	H	Hot	20H	NW	U	1	2	5	1	2.67	2.67	Strong
2013	7/18/2013	1659	20	80	H	Hot	20H	NW	U	3	3	3	1	2.33	2.33	Strong
2013	7/18/2013	1659	20	100	H	Hot	20H	NW	U	1	13	4	4	7	7	Weak
2013	7/18/2013	1659	20	100	H	Hot	20H	NW	U	3	21	4	2	9	9	None
2013	7/16/2013	1657	21	0	ML	Cool	21ML	N	L	1	12	3	5	6.67	6.67	Weak
2013	7/16/2013	1657	21	0	ML	Cool	21ML	N	L	3	2	12	18	10.67	10.67	None
2013	7/16/2013	1657	21	20	ML	Cool	21ML	N	L	1	3	0	14	5.67	5.67	Weak
2013	7/16/2013	1657	21	20	ML	Cool	21ML	N	L	3	7	7	12	8.67	8.67	None

2013	7/16/2013	1657	21	40	ML	Cool	21ML	N	L	1	2	4	3	3	3	Strong
2013	7/16/2013	1657	21	40	ML	Cool	21ML	N	L	3	1	2	4	2.33	2.33	Strong
2013	7/16/2013	1657	21	60	ML	Cool	21ML	N	L	1	1	2	2	1.67	1.67	Strong
2013	7/16/2013	1657	21	60	ML	Cool	21ML	N	L	3	4	4	1	3	3	Strong
2013	7/16/2013	1657	21	80	ML	Cool	21ML	N	L	1	1	1	0	0.67	0.67	Strong
2013	7/16/2013	1657	21	80	ML	Cool	21ML	N	L	3	0	0	1	0.33	0.33	Strong
2013	7/16/2013	1657	21	100	ML	Cool	21ML	N	L	1	10	10	5	8.33	8.33	None
2013	7/16/2013	1657	21	100	ML	Cool	21ML	N	L	3	4	2	1	2.33	2.33	Strong
2013	7/16/2013	1657	22	0	MH	Hot	22MH	N	U	1	9	7	8	8	8	None
2013	7/16/2013	1657	22	0	MH	Hot	22MH	N	U	3	4	3	3	3.33	3.33	Weak
2013	7/16/2013	1657	22	20	MH	Hot	22MH	N	U	1	11	9	6	8.67	8.67	None
2013	7/16/2013	1657	22	20	MH	Hot	22MH	N	U	3	3	8	6	5.67	5.67	Weak
2013	7/16/2013	1657	22	40	MH	Hot	22MH	N	U	1	4	5	5	4.67	4.67	Weak
2013	7/16/2013	1657	22	40	MH	Hot	22MH	N	U	3	4	2	3	3	3	Strong
2013	7/16/2013	1657	22	60	MH	Hot	22MH	N	U	1	2	2	0	1.33	1.33	Strong
2013	7/16/2013	1657	22	60	MH	Hot	22MH	N	U	3	0	2	1	1	1	Strong
2013	7/16/2013	1657	22	80	MH	Hot	22MH	N	U	1	0	1	0	0.33	0.33	Strong
2013	7/16/2013	1657	22	80	MH	Hot	22MH	N	U	3	0	0	1	0.33	0.33	Strong
2013	7/16/2013	1657	22	100	MH	Hot	22MH	N	U	1	3	8	10	7	7	Weak
2013	7/16/2013	1657	22	100	MH	Hot	22MH	N	U	3	3	1	1	1.67	1.67	Strong

Appendix H. Water Drop Penetration Times Field Data

Year	Date	Day number from 1/1/2009	Site Number	Transec Distance	Burn Severity	Simplified Burn Severity	Site and Burn Severity	Aspect	Slope Position	Depth (in.)	Pene-tration Time (secs)	Pen. Time Censored = 400	Pen. Time Zeroes = 0.5
year	date	daynum08	sitenum	dist	burn.sev	burn.sev2	site	aspect	slope.pos	depth	time	time2	time3
2010	10/14/2010	651	1	20	H	Hot	1H	SE	L	1	305	305	305
2010	10/14/2010	651	1	20	H	Hot	1H	SE	L	2	305	305	305
2010	10/14/2010	651	1	20	H	Hot	1H	SE	L	3	20	20	20
2010	10/14/2010	651	1	40	H	Hot	1H	SE	L	1	60	60	60
2010	10/14/2010	651	1	40	H	Hot	1H	SE	L	2	20	20	20
2010	10/14/2010	651	1	40	H	Hot	1H	SE	L	3	10	10	10
2010	10/14/2010	651	1	60	H	Hot	1H	SE	L	1	305	305	305
2010	10/14/2010	651	1	60	H	Hot	1H	SE	L	2	305	305	305
2010	10/14/2010	651	1	60	H	Hot	1H	SE	L	3	305	305	305
2010	10/14/2010	651	1	80	H	Hot	1H	SE	L	1	305	305	305
2010	10/14/2010	651	1	80	H	Hot	1H	SE	L	2	305	305	305
2010	10/14/2010	651	1	80	H	Hot	1H	SE	L	3	305	305	305
2010	10/14/2010	651	1	100	H	Hot	1H	SE	L	1	305	305	305
2010	10/14/2010	651	1	100	H	Hot	1H	SE	L	2	305	305	305
2010	10/14/2010	651	1	100	H	Hot	1H	SE	L	3	305	305	305
2010	10/16/2010	653	2	20	M	Hot	2M	SE	L	1	5	5	5
2010	10/16/2010	653	2	20	M	Hot	2M	SE	L	2	5	5	5
2010	10/16/2010	653	2	20	M	Hot	2M	SE	L	3	30	30	30
2010	10/16/2010	653	2	40	M	Hot	2M	SE	L	1	305	305	305
2010	10/16/2010	653	2	40	M	Hot	2M	SE	L	2	30	30	30
2010	10/16/2010	653	2	40	M	Hot	2M	SE	L	3	120	120	120
2010	10/16/2010	653	2	60	M	Hot	2M	SE	L	1	305	305	305
2010	10/16/2010	653	2	60	M	Hot	2M	SE	L	2	120	120	120
2010	10/16/2010	653	2	60	M	Hot	2M	SE	L	3	5	5	5
2010	10/16/2010	653	2	80	M	Hot	2M	SE	L	1	305	305	305
2010	10/16/2010	653	2	80	M	Hot	2M	SE	L	2	305	305	305
2010	10/16/2010	653	2	80	M	Hot	2M	SE	L	3	240	240	240
2010	10/16/2010	653	2	100	M	Hot	2M	SE	L	1	240	240	240

2010	10/16/2010	653	2	100	M	Hot	2M	SE	L	2	305	305	305
2010	10/16/2010	653	2	100	M	Hot	2M	SE	L	3	305	305	305
2010	10/9/2010	646	3	20	M	Hot	3M	NW	L	1	5	5	5
2010	10/9/2010	646	3	20	M	Hot	3M	NW	L	2	5	5	5
2010	10/9/2010	646	3	20	M	Hot	3M	NW	L	3	5	5	5
2010	10/9/2010	646	3	40	M	Hot	3M	NW	L	1	5	5	5
2010	10/9/2010	646	3	40	M	Hot	3M	NW	L	2	5	5	5
2010	10/9/2010	646	3	40	M	Hot	3M	NW	L	3	5	5	5
2010	10/9/2010	646	3	60	M	Hot	3M	NW	L	1	10	10	10
2010	10/9/2010	646	3	60	M	Hot	3M	NW	L	2	10	10	10
2010	10/9/2010	646	3	60	M	Hot	3M	NW	L	3	10	10	10
2010	10/9/2010	646	3	80	M	Hot	3M	NW	L	1	305	305	305
2010	10/9/2010	646	3	80	M	Hot	3M	NW	L	2	10	10	10
2010	10/9/2010	646	3	80	M	Hot	3M	NW	L	3	10	10	10
2010	10/9/2010	646	3	100	M	Hot	3M	NW	L	1	10	10	10
2010	10/9/2010	646	3	100	M	Hot	3M	NW	L	2	10	10	10
2010	10/9/2010	646	3	100	M	Hot	3M	NW	L	3	20	20	20
2010	10/16/2010	653	4	20	H	Hot	4H	N	U	1	10	10	10
2010	10/16/2010	653	4	20	H	Hot	4H	N	U	2	10	10	10
2010	10/16/2010	653	4	20	H	Hot	4H	N	U	3	10	10	10
2010	10/16/2010	653	4	40	H	Hot	4H	N	U	1	10	10	10
2010	10/16/2010	653	4	40	H	Hot	4H	N	U	2	10	10	10
2010	10/16/2010	653	4	40	H	Hot	4H	N	U	3	10	10	10
2010	10/16/2010	653	4	60	H	Hot	4H	N	U	1	10	10	10
2010	10/16/2010	653	4	60	H	Hot	4H	N	U	2	10	10	10
2010	10/16/2010	653	4	60	H	Hot	4H	N	U	3	10	10	10
2010	10/16/2010	653	4	80	H	Hot	4H	N	U	1	5	5	5
2010	10/16/2010	653	4	80	H	Hot	4H	N	U	2	5	5	5
2010	10/16/2010	653	4	80	H	Hot	4H	N	U	3	5	5	5
2010	10/16/2010	653	4	100	H	Hot	4H	N	U	1	5	5	5
2010	10/16/2010	653	4	100	H	Hot	4H	N	U	2	5	5	5
2010	10/16/2010	653	4	100	H	Hot	4H	N	U	3	5	5	5
2010	10/16/2010	653	5	20	M	Hot	5M	W	L	1	25	25	25
2010	10/16/2010	653	5	20	M	Hot	5M	W	L	2	5	5	5
2010	10/16/2010	653	5	20	M	Hot	5M	W	L	3	5	5	5

2010	10/16/2010	653	5	40	M	Hot	5M	W	L	1	5	5	5
2010	10/16/2010	653	5	40	M	Hot	5M	W	L	2	5	5	5
2010	10/16/2010	653	5	40	M	Hot	5M	W	L	3	5	5	5
2010	10/16/2010	653	5	60	M	Hot	5M	W	L	1	40	40	40
2010	10/16/2010	653	5	60	M	Hot	5M	W	L	2	5	5	5
2010	10/16/2010	653	5	60	M	Hot	5M	W	L	3	5	5	5
2010	10/16/2010	653	5	80	M	Hot	5M	W	L	1	45	45	45
2010	10/16/2010	653	5	80	M	Hot	5M	W	L	2	300	300	300
2010	10/16/2010	653	5	80	M	Hot	5M	W	L	3	300	300	300
2010	10/16/2010	653	5	100	M	Hot	5M	W	L	1	5	5	5
2010	10/16/2010	653	5	100	M	Hot	5M	W	L	2	5	5	5
2010	10/16/2010	653	5	100	M	Hot	5M	W	L	3	10	10	10
2010	10/9/2010	646	7	20	H	Hot	7H	N	U	1	10	10	10
2010	10/9/2010	646	7	20	H	Hot	7H	N	U	2	10	10	10
2010	10/9/2010	646	7	20	H	Hot	7H	N	U	3	10	10	10
2010	10/9/2010	646	7	40	H	Hot	7H	N	U	1	10	10	10
2010	10/9/2010	646	7	40	H	Hot	7H	N	U	2	10	10	10
2010	10/9/2010	646	7	40	H	Hot	7H	N	U	3	10	10	10
2010	10/9/2010	646	7	60	H	Hot	7H	N	U	1	110	110	110
2010	10/9/2010	646	7	60	H	Hot	7H	N	U	2	25	25	25
2010	10/9/2010	646	7	60	H	Hot	7H	N	U	3	125	125	125
2010	10/9/2010	646	7	80	H	Hot	7H	N	U	1	5	5	5
2010	10/9/2010	646	7	80	H	Hot	7H	N	U	2	10	10	10
2010	10/9/2010	646	7	80	H	Hot	7H	N	U	3	10	10	10
2010	10/9/2010	646	7	100	H	Hot	7H	N	U	1	305	305	305
2010	10/9/2010	646	7	100	H	Hot	7H	N	U	2	10	10	10
2010	10/9/2010	646	7	100	H	Hot	7H	N	U	3	10	10	10
2010	10/8/2010	645	8	20	H	Hot	8H	SE	U	1	200	200	200
2010	10/8/2010	645	8	20	H	Hot	8H	SE	U	2	300	300	300
2010	10/8/2010	645	8	20	H	Hot	8H	SE	U	3	30	30	30
2010	10/8/2010	645	8	40	H	Hot	8H	SE	U	1	10	10	10
2010	10/8/2010	645	8	40	H	Hot	8H	SE	U	2	60	60	60
2010	10/8/2010	645	8	40	H	Hot	8H	SE	U	3	300	300	300
2010	10/8/2010	645	8	60	H	Hot	8H	SE	U	1	70	70	70
2010	10/8/2010	645	8	60	H	Hot	8H	SE	U	2	300	300	300

2010	10/8/2010	645	8	60	H	Hot	8H	SE	U	3	300	300	300
2010	10/8/2010	645	8	80	H	Hot	8H	SE	U	1	90	90	90
2010	10/8/2010	645	8	80	H	Hot	8H	SE	U	2	300	300	300
2010	10/8/2010	645	8	80	H	Hot	8H	SE	U	3	30	30	30
2010	10/8/2010	645	8	100	H	Hot	8H	SE	U	1	30	30	30
2010	10/8/2010	645	8	100	H	Hot	8H	SE	U	2	65	65	65
2010	10/8/2010	645	8	100	H	Hot	8H	SE	U	3	90	90	90
2010	10/8/2010	645	9	20	M	Hot	9M	SE	L	1	5	5	5
2010	10/8/2010	645	9	20	M	Hot	9M	SE	L	2	5	5	5
2010	10/8/2010	645	9	20	M	Hot	9M	SE	L	3	5	5	5
2010	10/8/2010	645	9	40	M	Hot	9M	SE	L	1	50	50	50
2010	10/8/2010	645	9	40	M	Hot	9M	SE	L	2	120	120	120
2010	10/8/2010	645	9	40	M	Hot	9M	SE	L	3	130	130	130
2010	10/8/2010	645	9	60	M	Hot	9M	SE	L	1	20	20	20
2010	10/8/2010	645	9	60	M	Hot	9M	SE	L	2	20	20	20
2010	10/8/2010	645	9	60	M	Hot	9M	SE	L	3	30	30	30
2010	10/8/2010	645	9	80	M	Hot	9M	SE	L	1	20	20	20
2010	10/8/2010	645	9	80	M	Hot	9M	SE	L	2	10	10	10
2010	10/8/2010	645	9	80	M	Hot	9M	SE	L	3	30	30	30
2010	10/8/2010	645	9	100	M	Hot	9M	SE	L	1	5	5	5
2010	10/8/2010	645	9	100	M	Hot	9M	SE	L	2	5	5	5
2010	10/8/2010	645	9	100	M	Hot	9M	SE	L	3	5	5	5
2010	10/9/2010	646	10	20	H	Hot	10H	S	U	1	30	30	30
2010	10/9/2010	646	10	20	H	Hot	10H	S	U	2	40	40	40
2010	10/9/2010	646	10	20	H	Hot	10H	S	U	3	40	40	40
2010	10/9/2010	646	10	40	H	Hot	10H	S	U	1	30	30	30
2010	10/9/2010	646	10	40	H	Hot	10H	S	U	2	10	10	10
2010	10/9/2010	646	10	40	H	Hot	10H	S	U	3	10	10	10
2010	10/9/2010	646	10	60	H	Hot	10H	S	U	1	305	305	305
2010	10/9/2010	646	10	60	H	Hot	10H	S	U	2	30	30	30
2010	10/9/2010	646	10	60	H	Hot	10H	S	U	3	30	30	30
2010	10/9/2010	646	10	80	H	Hot	10H	S	U	1	120	120	120
2010	10/9/2010	646	10	80	H	Hot	10H	S	U	2	240	240	240
2010	10/9/2010	646	10	80	H	Hot	10H	S	U	3	300	300	300
2010	10/9/2010	646	10	100	H	Hot	10H	S	U	1	290	290	290

2010	10/9/2010	646	10	100	H	Hot	10H	S	U	2	130	130	130
2010	10/9/2010	646	10	100	H	Hot	10H	S	U	3	290	290	290
2010	10/9/2010	646	11	20	M	Hot	11M	NW	U	1	300	300	300
2010	10/9/2010	646	11	20	M	Hot	11M	NW	U	2	300	300	300
2010	10/9/2010	646	11	20	M	Hot	11M	NW	U	3	225	225	225
2010	10/9/2010	646	11	40	M	Hot	11M	NW	U	1	10	10	10
2010	10/9/2010	646	11	40	M	Hot	11M	NW	U	2	10	10	10
2010	10/9/2010	646	11	40	M	Hot	11M	NW	U	3	10	10	10
2010	10/9/2010	646	11	60	M	Hot	11M	NW	U	1	5	5	5
2010	10/9/2010	646	11	60	M	Hot	11M	NW	U	2	5	5	5
2010	10/9/2010	646	11	60	M	Hot	11M	NW	U	3	5	5	5
2010	10/9/2010	646	11	80	M	Hot	11M	NW	U	1	45	45	45
2010	10/9/2010	646	11	80	M	Hot	11M	NW	U	2	10	10	10
2010	10/9/2010	646	11	80	M	Hot	11M	NW	U	3	10	10	10
2010	10/16/2010	653	12	20	H	Hot	12H	S	U	1	305	305	305
2010	10/16/2010	653	12	20	H	Hot	12H	S	U	2	305	305	305
2010	10/16/2010	653	12	20	H	Hot	12H	S	U	3	305	305	305
2010	10/16/2010	653	12	40	H	Hot	12H	S	U	1	5	5	5
2010	10/16/2010	653	12	40	H	Hot	12H	S	U	2	305	305	305
2010	10/16/2010	653	12	40	H	Hot	12H	S	U	3	305	305	305
2010	10/16/2010	653	12	60	H	Hot	12H	S	U	1	305	305	305
2010	10/16/2010	653	12	60	H	Hot	12H	S	U	2	305	305	305
2010	10/16/2010	653	12	60	H	Hot	12H	S	U	3	130	130	130
2010	10/16/2010	653	12	80	H	Hot	12H	S	U	1	305	305	305
2010	10/16/2010	653	12	80	H	Hot	12H	S	U	2	305	305	305
2010	10/16/2010	653	12	80	H	Hot	12H	S	U	3	305	305	305
2010	10/16/2010	653	12	100	H	Hot	12H	S	U	1	305	305	305
2010	10/16/2010	653	12	100	H	Hot	12H	S	U	2	305	305	305
2010	10/16/2010	653	12	100	H	Hot	12H	S	U	3	50	50	50
2010	10/22/2010	659	14	20	N	Cool	14N	S	L	1	30	30	30
2010	10/22/2010	659	14	20	N	Cool	14N	S	L	2	30	30	30
2010	10/22/2010	659	14	20	N	Cool	14N	S	L	3	30	30	30
2010	10/22/2010	659	14	40	N	Cool	14N	S	L	1	200	200	200
2010	10/22/2010	659	14	40	N	Cool	14N	S	L	2	10	10	10
2010	10/22/2010	659	14	40	N	Cool	14N	S	L	3	5	5	5

2010	10/22/2010	659	14	60	N	Cool	14N	S	L	1	5	5	5
2010	10/22/2010	659	14	60	N	Cool	14N	S	L	2	5	5	5
2010	10/22/2010	659	14	60	N	Cool	14N	S	L	3	5	5	5
2010	10/22/2010	659	14	80	N	Cool	14N	S	L	1	30	30	30
2010	10/22/2010	659	14	80	N	Cool	14N	S	L	2	30	30	30
2010	10/22/2010	659	14	80	N	Cool	14N	S	L	3	30	30	30
2010	10/22/2010	659	14	100	N	Cool	14N	S	L	1	60	60	60
2010	10/22/2010	659	14	100	N	Cool	14N	S	L	2	60	60	60
2010	10/22/2010	659	14	100	N	Cool	14N	S	L	3	60	60	60
2010	10/15/2010	652	18	20	H	Hot	18H	SE	U	1	10	10	10
2010	10/15/2010	652	18	20	H	Hot	18H	SE	U	2	10	10	10
2010	10/15/2010	652	18	20	H	Hot	18H	SE	U	3	10	10	10
2010	10/15/2010	652	18	40	H	Hot	18H	SE	U	1	30	30	30
2010	10/15/2010	652	18	40	H	Hot	18H	SE	U	2	10	10	10
2010	10/15/2010	652	18	40	H	Hot	18H	SE	U	3	10	10	10
2010	10/15/2010	652	18	60	H	Hot	18H	SE	U	1	10	10	10
2010	10/15/2010	652	18	60	H	Hot	18H	SE	U	2	10	10	10
2010	10/15/2010	652	18	60	H	Hot	18H	SE	U	3	10	10	10
2010	10/15/2010	652	18	80	H	Hot	18H	SE	U	1	10	10	10
2010	10/15/2010	652	18	80	H	Hot	18H	SE	U	2	10	10	10
2010	10/15/2010	652	18	80	H	Hot	18H	SE	U	3	10	10	10
2010	10/15/2010	652	18	100	H	Hot	18H	SE	U	1	10	10	10
2010	10/15/2010	652	18	100	H	Hot	18H	SE	U	2	10	10	10
2010	10/15/2010	652	18	100	H	Hot	18H	SE	U	3	10	10	10
2010	10/9/2010	646	19	20	M	Hot	19M	SE	L	1	10	10	10
2010	10/9/2010	646	19	20	M	Hot	19M	SE	L	2	10	10	10
2010	10/9/2010	646	19	20	M	Hot	19M	SE	L	3	10	10	10
2010	10/9/2010	646	19	40	M	Hot	19M	SE	L	1	10	10	10
2010	10/9/2010	646	19	40	M	Hot	19M	SE	L	2	10	10	10
2010	10/9/2010	646	19	40	M	Hot	19M	SE	L	3	10	10	10
2010	10/9/2010	646	19	60	M	Hot	19M	SE	L	1	5	5	5
2010	10/9/2010	646	19	60	M	Hot	19M	SE	L	2	20	20	20
2010	10/9/2010	646	19	60	M	Hot	19M	SE	L	3	10	10	10
2010	10/9/2010	646	19	80	M	Hot	19M	SE	L	1	10	10	10
2010	10/9/2010	646	19	80	M	Hot	19M	SE	L	2	10	10	10

2010	10/9/2010	646	19	80	M	Hot	19M	SE	L	3	10	10	10
2010	10/9/2010	646	19	100	M	Hot	19M	SE	L	1	10	10	10
2010	10/9/2010	646	19	100	M	Hot	19M	SE	L	2	10	10	10
2010	10/9/2010	646	19	100	M	Hot	19M	SE	L	3	10	10	10
2010	10/17/2010	654	20	20	H	Hot	20H	NW	U	1	5	5	5
2010	10/17/2010	654	20	20	H	Hot	20H	NW	U	2	10	10	10
2010	10/17/2010	654	20	20	H	Hot	20H	NW	U	3	10	10	10
2010	10/17/2010	654	20	40	H	Hot	20H	NW	U	1	10	10	10
2010	10/17/2010	654	20	40	H	Hot	20H	NW	U	2	10	10	10
2010	10/17/2010	654	20	40	H	Hot	20H	NW	U	3	10	10	10
2010	10/17/2010	654	20	60	H	Hot	20H	NW	U	1	300	300	300
2010	10/17/2010	654	20	60	H	Hot	20H	NW	U	2	300	300	300
2010	10/17/2010	654	20	60	H	Hot	20H	NW	U	3	300	300	300
2010	10/17/2010	654	20	80	H	Hot	20H	NW	U	1	240	240	240
2010	10/17/2010	654	20	80	H	Hot	20H	NW	U	2	300	300	300
2010	10/17/2010	654	20	80	H	Hot	20H	NW	U	3	300	300	300
2010	10/17/2010	654	20	100	H	Hot	20H	NW	U	1	90	90	90
2010	10/17/2010	654	20	100	H	Hot	20H	NW	U	2	300	300	300
2010	10/17/2010	654	20	100	H	Hot	20H	NW	U	3	30	30	30
2010	10/22/2010	659	21	20	ML	Cool	21ML	N	L	1	200	200	200
2010	10/22/2010	659	21	20	ML	Cool	21ML	N	L	2	60	60	60
2010	10/22/2010	659	21	20	ML	Cool	21ML	N	L	3	5	5	5
2010	10/22/2010	659	21	40	ML	Cool	21ML	N	L	1	10	10	10
2010	10/22/2010	659	21	40	ML	Cool	21ML	N	L	2	10	10	10
2010	10/22/2010	659	21	40	ML	Cool	21ML	N	L	3	10	10	10
2010	10/22/2010	659	21	60	ML	Cool	21ML	N	L	1	30	30	30
2010	10/22/2010	659	21	60	ML	Cool	21ML	N	L	2	30	30	30
2010	10/22/2010	659	21	60	ML	Cool	21ML	N	L	3	30	30	30
2010	10/22/2010	659	21	80	ML	Cool	21ML	N	L	1	90	90	90
2010	10/22/2010	659	21	80	ML	Cool	21ML	N	L	2	90	90	90
2010	10/22/2010	659	21	80	ML	Cool	21ML	N	L	3	30	30	30
2010	10/22/2010	659	22	20	MH	Hot	22MH	N	U	1	60	60	60
2010	10/22/2010	659	22	20	MH	Hot	22MH	N	U	2	30	30	30
2010	10/22/2010	659	22	20	MH	Hot	22MH	N	U	3	30	30	30
2010	10/22/2010	659	22	40	MH	Hot	22MH	N	U	1	125	125	125

2010	10/22/2010	659	22	40	MH	Hot	22MH	N	U	2	125	125	125
2010	10/22/2010	659	22	40	MH	Hot	22MH	N	U	3	125	125	125
2010	10/22/2010	659	22	60	MH	Hot	22MH	N	U	1	30	30	30
2010	10/22/2010	659	22	60	MH	Hot	22MH	N	U	2	30	30	30
2010	10/22/2010	659	22	60	MH	Hot	22MH	N	U	3	30	30	30
2010	10/22/2010	659	22	80	MH	Hot	22MH	N	U	1	30	30	30
2010	10/22/2010	659	22	80	MH	Hot	22MH	N	U	2	10	10	10
2010	10/22/2010	659	22	80	MH	Hot	22MH	N	U	3	20	20	20
2010	10/22/2010	659	22	100	MH	Hot	22MH	N	U	1	305	305	305
2010	10/22/2010	659	22	100	MH	Hot	22MH	N	U	2	305	305	305
2010	10/22/2010	659	22	100	MH	Hot	22MH	N	U	3	305	305	305
2010	10/16/2010	653	23	20	H	Hot	23H	N	U	1	5	5	5
2010	10/16/2010	653	23	20	H	Hot	23H	N	U	2	5	5	5
2010	10/16/2010	653	23	20	H	Hot	23H	N	U	3	5	5	5
2010	10/16/2010	653	23	40	H	Hot	23H	N	U	1	20	20	20
2010	10/16/2010	653	23	40	H	Hot	23H	N	U	2	5	5	5
2010	10/16/2010	653	23	40	H	Hot	23H	N	U	3	5	5	5
2010	10/16/2010	653	23	60	H	Hot	23H	N	U	1	5	5	5
2010	10/16/2010	653	23	60	H	Hot	23H	N	U	2	90	90	90
2010	10/16/2010	653	23	60	H	Hot	23H	N	U	3	10	10	10
2010	10/16/2010	653	23	80	H	Hot	23H	N	U	1	5	5	5
2010	10/16/2010	653	23	80	H	Hot	23H	N	U	2	5	5	5
2010	10/16/2010	653	23	80	H	Hot	23H	N	U	3	10	10	10
2010	10/16/2010	653	23	100	H	Hot	23H	N	U	1	5	5	5
2010	10/16/2010	653	23	100	H	Hot	23H	N	U	2	5	5	5
2010	10/16/2010	653	23	100	H	Hot	23H	N	U	3	5	5	5
2011	8/30/2011	971	1	20	H	Hot	1H	SE	L	0.393701	0	0	0.5
2011	8/30/2011	971	1	20	H	Hot	1H	SE	L	1.181102	30	30	30
2011	8/30/2011	971	1	40	H	Hot	1H	SE	L	0.393701	0	0	0.5
2011	8/30/2011	971	1	40	H	Hot	1H	SE	L	1.181102	30	30	30
2011	8/30/2011	971	1	60	H	Hot	1H	SE	L	0.393701	0	0	0.5
2011	8/30/2011	971	1	60	H	Hot	1H	SE	L	1.181102	2	2	2
2011	8/30/2011	971	1	80	H	Hot	1H	SE	L	0.393701	0	0	0.5
2011	8/30/2011	971	1	80	H	Hot	1H	SE	L	1.181102	1	1	1
2011	8/30/2011	971	1	100	H	Hot	1H	SE	L	0.393701	2	2	2

2011	8/30/2011	971	1	100	H	Hot	1H	SE	L	1.181102	30	30	30
2011	8/29/2011	970	2	0	M	Hot	2M	SE	L	0.393701	0	0	0.5
2011	8/29/2011	970	2	0	M	Hot	2M	SE	L	1.181102	0	0	0.5
2011	8/29/2011	970	2	20	M	Hot	2M	SE	L	0.393701	0	0	0.5
2011	8/29/2011	970	2	20	M	Hot	2M	SE	L	1.181102	0	0	0.5
2011	8/29/2011	970	2	40	M	Hot	2M	SE	L	0.393701	0	0	0.5
2011	8/29/2011	970	2	40	M	Hot	2M	SE	L	1.181102	2	2	2
2011	8/29/2011	970	2	60	M	Hot	2M	SE	L	0.393701	0	0	0.5
2011	8/29/2011	970	2	60	M	Hot	2M	SE	L	0.393701	0	0	0.5
2011	8/29/2011	970	2	80	M	Hot	2M	SE	L	1.181102	0	0	0.5
2011	8/29/2011	970	2	80	M	Hot	2M	SE	L	0.393701	10	10	10
2011	8/29/2011	970	2	100	M	Hot	2M	SE	L	1.181102	0	0	0.5
2011	8/29/2011	970	2	100	M	Hot	2M	SE	L	0.393701	15	15	15
2011	8/29/2011	970	3	0	M	Hot	3M	NW	L	1.181102	1	1	1
2011	8/29/2011	970	3	0	M	Hot	3M	NW	L	0.393701	0	0	0.5
2011	8/29/2011	970	3	20	M	Hot	3M	NW	L	1.181102	1	1	1
2011	8/29/2011	970	3	20	M	Hot	3M	NW	L	0.393701	0	0	0.5
2011	8/29/2011	970	3	40	M	Hot	3M	NW	L	1.181102	1	1	1
2011	8/29/2011	970	3	40	M	Hot	3M	NW	L	0.393701	0	0	0.5
2011	8/29/2011	970	3	60	M	Hot	3M	NW	L	1.181102	0	0	0.5
2011	8/29/2011	970	3	60	M	Hot	3M	NW	L	0.393701	0	0	0.5
2011	8/29/2011	970	3	80	M	Hot	3M	NW	L	1.181102	0	0	0.5
2011	8/29/2011	970	3	80	M	Hot	3M	NW	L	0.393701	0	0	0.5
2011	8/29/2011	970	3	100	M	Hot	3M	NW	L	1.181102	0	0	0.5
2011	8/29/2011	970	3	100	M	Hot	3M	NW	L	0.393701	0	0	0.5
2011	7/6/2011	916	4	20	H	Hot	4H	N	U	0.393701	0	0	0.5
2011	7/6/2011	916	4	20	H	Hot	4H	N	U	1.181102	0	0	0.5
2011	7/6/2011	916	4	40	H	Hot	4H	N	U	0.393701	0	0	0.5
2011	7/6/2011	916	4	40	H	Hot	4H	N	U	1.181102	0	0	0.5
2011	7/6/2011	916	4	60	H	Hot	4H	N	U	0.393701	0	0	0.5
2011	7/6/2011	916	4	60	H	Hot	4H	N	U	1.181102	0	0	0.5
2011	7/6/2011	916	4	80	H	Hot	4H	N	U	0.393701	0	0	0.5
2011	7/6/2011	916	4	80	H	Hot	4H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	6	20	H	Hot	6H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	6	20	H	Hot	6H	N	U	0.393701	0	0	0.5

2011	7/7/2011	917	6	40	H	Hot	6H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	6	40	H	Hot	6H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	6	60	H	Hot	6H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	6	60	H	Hot	6H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	6	80	H	Hot	6H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	6	80	H	Hot	6H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	6	100	H	Hot	6H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	6	100	H	Hot	6H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	7	0	H	Hot	7H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	7	0	H	Hot	7H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	7	20	H	Hot	7H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	7	20	H	Hot	7H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	7	40	H	Hot	7H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	7	40	H	Hot	7H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	7	60	H	Hot	7H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	7	60	H	Hot	7H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	7	80	H	Hot	7H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	7	80	H	Hot	7H	N	U	1.181102	0	0	0.5
2011	7/7/2011	917	7	100	H	Hot	7H	N	U	0.393701	0	0	0.5
2011	7/7/2011	917	7	100	H	Hot	7H	N	U	1.181102	0	0	0.5
2011	7/6/2011	916	8	20	H	Hot	8H	SE	U	0.393701	15	15	15
2011	7/6/2011	916	8	20	H	Hot	8H	SE	U	1.181102	305	305	305
2011	7/6/2011	916	8	40	H	Hot	8H	SE	U	0.393701	160	160	160
2011	7/6/2011	916	8	60	H	Hot	8H	SE	U	0.393701	305	305	305
2011	7/6/2011	916	8	60	H	Hot	8H	SE	U	1.181102	305	305	305
2011	7/6/2011	916	8	80	H	Hot	8H	SE	U	0.393701	225	225	225
2011	7/6/2011	916	8	80	H	Hot	8H	SE	U	0.393701	135	135	135
2011	7/6/2011	916	8	100	H	Hot	8H	SE	U	1.181102	305	305	305
2011	7/6/2011	916	8	100	H	Hot	8H	SE	U	0.393701	305	305	305
2011	8/29/2011	970	9	0	M	Hot	9M	SE	L	1.181102	1	1	1
2011	8/29/2011	970	9	0	M	Hot	9M	SE	L	0.393701	2	2	2
2011	8/29/2011	970	9	20	M	Hot	9M	SE	L	1.181102	1	1	1
2011	8/29/2011	970	9	20	M	Hot	9M	SE	L	0.393701	2	2	2
2011	8/29/2011	970	9	40	M	Hot	9M	SE	L	1.181102	1	1	1
2011	8/29/2011	970	9	40	M	Hot	9M	SE	L	0.393701	2	2	2

2011	8/29/2011	970	9	60	M	Hot	9M	SE	L	1.181102	0	0	0.5
2011	8/29/2011	970	9	60	M	Hot	9M	SE	L	0.393701	1	1	1
2011	8/29/2011	970	9	80	M	Hot	9M	SE	L	1.181102	0	0	0.5
2011	8/29/2011	970	9	80	M	Hot	9M	SE	L	0.393701	0	0	0.5
2011	8/29/2011	970	9	100	M	Hot	9M	SE	L	1.181102	0	0	0.5
2011	8/29/2011	970	9	100	M	Hot	9M	SE	L	0.393701	0	0	0.5
2011	11/3/2011	1036	12	60	H	Hot	12H	S	U	1.181102	4	4	4
2011	11/3/2011	1036	12	60	H	Hot	12H	S	U	0.393701	10	10	10
2011	11/3/2011	1036	12	100	H	Hot	12H	S	U	1.181102	1	1	1
2011	11/3/2011	1036	12	100	H	Hot	12H	S	U	0.393701	45	45	45
2011	8/29/2011	970	13	0	M	Hot	13M	S	L	1.181102	0	0	0.5
2011	8/29/2011	970	13	0	M	Hot	13M	S	L	0.393701	0	0	0.5
2011	8/29/2011	970	13	20	M	Hot	13M	S	L	1.181102	0	0	0.5
2011	8/29/2011	970	13	20	M	Hot	13M	S	L	0.393701	0	0	0.5
2011	8/29/2011	970	13	40	M	Hot	13M	S	L	1.181102	0	0	0.5
2011	8/29/2011	970	13	40	M	Hot	13M	S	L	0.393701	0	0	0.5
2011	8/29/2011	970	13	60	M	Hot	13M	S	L	0.393701	0	0	0.5
2011	8/29/2011	970	13	60	M	Hot	13M	S	L	1.181102	0	0	0.5
2011	8/29/2011	970	13	80	M	Hot	13M	S	L	0.393701	2	2	2
2011	8/29/2011	970	13	80	M	Hot	13M	S	L	1.181102	0	0	0.5
2011	8/29/2011	970	13	100	M	Hot	13M	S	L	0.393701	0	0	0.5
2011	8/29/2011	970	13	100	M	Hot	13M	S	L	1.181102	0	0	0.5
2011	8/30/2011	971	14	20	N	Cool	14N	S	L	0.393701	0	0	0.5
2011	8/30/2011	971	14	20	N	Cool	14N	S	L	1.181102	0	0	0.5
2011	8/30/2011	971	14	40	N	Cool	14N	S	L	0.393701	0	0	0.5
2011	8/30/2011	971	14	40	N	Cool	14N	S	L	1.181102	0	0	0.5
2011	8/30/2011	971	14	60	N	Cool	14N	S	L	0.393701	0	0	0.5
2011	8/30/2011	971	14	60	N	Cool	14N	S	L	1.181102	3	3	3
2011	8/30/2011	971	14	80	N	Cool	14N	S	L	0.393701	0	0	0.5
2011	8/30/2011	971	14	80	N	Cool	14N	S	L	1.181102	0	0	0.5
2011	8/30/2011	971	14	100	N	Cool	14N	S	L	0.393701	0	0	0.5
2011	8/30/2011	971	14	100	N	Cool	14N	S	L	1.181102	3	3	3
2011	10/20/2011	1022	18	0	H	Hot	18H	SE	U	1.181102	3	3	3
2011	9/15/2011	987	20	20	H	Hot	20H	NW	U	1.181102	0	0	0.5
2011	9/15/2011	987	20	40	H	Hot	20H	NW	U	1.181102	305	305	305

2011	9/15/2011	987	20	60	H	Hot	20H	NW	U	0.393701	20	20	20
2011	9/15/2011	987	20	60	H	Hot	20H	NW	U	1.181102	305	305	305
2011	9/15/2011	987	20	80	H	Hot	20H	NW	U	0.393701	0	0	0.5
2011	9/15/2011	987	20	100	H	Hot	20H	NW	U	0.393701	2	2	2
2011	9/15/2011	987	20	100	H	Hot	20H	NW	U	1.181102	0	0	0.5
2011	8/30/2011	971	21	20	ML	Cool	21ML	N	L	0.393701	0	0	0.5
2011	8/30/2011	971	21	20	ML	Cool	21ML	N	L	1.181102	5	5	5
2011	8/30/2011	971	21	40	ML	Cool	21ML	N	L	0.393701	5	5	5
2011	8/30/2011	971	21	60	ML	Cool	21ML	N	L	0.393701	0	0	0.5
2011	8/30/2011	971	21	80	ML	Cool	21ML	N	L	0.393701	1	1	1
2011	8/30/2011	971	21	80	ML	Cool	21ML	N	L	1.181102	7	7	7
2011	8/30/2011	971	21	100	ML	Cool	21ML	N	L	0.393701	2	2	2
2011	8/30/2011	971	21	100	ML	Cool	21ML	N	L	0.393701	0	0	0.5
2011	8/30/2011	971	22	20	MH	Hot	22MH	N	U	1.181102	0	0	0.5
2011	8/30/2011	971	22	20	MH	Hot	22MH	N	U	0.393701	0	0	0.5
2011	8/30/2011	971	22	40	MH	Hot	22MH	N	U	1.181102	0	0	0.5
2011	8/30/2011	971	22	40	MH	Hot	22MH	N	U	0.393701	0	0	0.5
2011	8/30/2011	971	22	60	MH	Hot	22MH	N	U	1.181102	0	0	0.5
2011	8/30/2011	971	22	60	MH	Hot	22MH	N	U	0.393701	0	0	0.5
2011	8/30/2011	971	22	80	MH	Hot	22MH	N	U	1.181102	0	0	0.5
2011	8/30/2011	971	22	80	MH	Hot	22MH	N	U	0.393701	0	0	0.5
2011	8/30/2011	971	22	100	MH	Hot	22MH	N	U	1.181102	0	0	0.5
2011	8/30/2011	971	22	100	MH	Hot	22MH	N	U	0.393701	0	0	0.5
2012	7/30/2012	1306	1	0	H	Hot	1H	SE	L	1	0	0	0.5
2012	7/30/2012	1306	1	0	H	Hot	1H	SE	L	2	1	1	1
2012	7/30/2012	1306	1	0	H	Hot	1H	SE	L	3	0	0	0.5
2012	7/30/2012	1306	1	20	H	Hot	1H	SE	L	1	1	1	1
2012	7/30/2012	1306	1	20	H	Hot	1H	SE	L	2	10	10	10
2012	7/30/2012	1306	1	20	H	Hot	1H	SE	L	3	10	10	10
2012	7/30/2012	1306	1	40	H	Hot	1H	SE	L	1	10	10	10
2012	7/30/2012	1306	1	40	H	Hot	1H	SE	L	2	6	6	6
2012	7/30/2012	1306	1	40	H	Hot	1H	SE	L	3	10	10	10
2012	7/30/2012	1306	1	60	H	Hot	1H	SE	L	1	2	2	2
2012	7/30/2012	1306	1	60	H	Hot	1H	SE	L	2	1	1	1
2012	7/30/2012	1306	1	60	H	Hot	1H	SE	L	3	0	0	0.5

2012	7/30/2012	1306	1	80	H	Hot	1H	SE	L	1	10	10	10
2012	7/30/2012	1306	1	80	H	Hot	1H	SE	L	2	6	6	6
2012	7/30/2012	1306	1	80	H	Hot	1H	SE	L	3	10	10	10
2012	7/30/2012	1306	1	100	H	Hot	1H	SE	L	1	0	0	0.5
2012	7/30/2012	1306	1	100	H	Hot	1H	SE	L	2	0	0	0.5
2012	7/30/2012	1306	1	100	H	Hot	1H	SE	L	3	2	2	2
2012	7/31/2012	1307	2	0	M	Hot	2M	SE	L	1	0	0	0.5
2012	7/31/2012	1307	2	0	M	Hot	2M	SE	L	2	10	10	10
2012	7/31/2012	1307	2	0	M	Hot	2M	SE	L	3	6	6	6
2012	7/31/2012	1307	2	20	M	Hot	2M	SE	L	1	4	4	4
2012	7/31/2012	1307	2	20	M	Hot	2M	SE	L	2	0	0	0.5
2012	7/31/2012	1307	2	20	M	Hot	2M	SE	L	3	0	0	0.5
2012	7/31/2012	1307	2	40	M	Hot	2M	SE	L	1	3	3	3
2012	7/31/2012	1307	2	40	M	Hot	2M	SE	L	2	3	3	3
2012	7/31/2012	1307	2	40	M	Hot	2M	SE	L	3	2	2	2
2012	7/31/2012	1307	2	60	M	Hot	2M	SE	L	1	6	6	6
2012	7/31/2012	1307	2	60	M	Hot	2M	SE	L	2	16	16	16
2012	7/31/2012	1307	2	60	M	Hot	2M	SE	L	3	4	4	4
2012	7/31/2012	1307	2	80	M	Hot	2M	SE	L	1	3	3	3
2012	7/31/2012	1307	2	80	M	Hot	2M	SE	L	2	7	7	7
2012	7/31/2012	1307	2	80	M	Hot	2M	SE	L	3	3	3	3
2012	7/31/2012	1307	2	100	M	Hot	2M	SE	L	1	0	0	0.5
2012	7/31/2012	1307	2	100	M	Hot	2M	SE	L	2	7	7	7
2012	7/31/2012	1307	2	100	M	Hot	2M	SE	L	3	5	5	5
2012	7/31/2012	1307	3	0	M	Hot	3M	NW	L	1	0	0	0.5
2012	7/31/2012	1307	3	0	M	Hot	3M	NW	L	2	0	0	0.5
2012	7/31/2012	1307	3	0	M	Hot	3M	NW	L	3	0	0	0.5
2012	7/31/2012	1307	3	20	M	Hot	3M	NW	L	1	0	0	0.5
2012	7/31/2012	1307	3	20	M	Hot	3M	NW	L	2	0	0	0.5
2012	7/31/2012	1307	3	20	M	Hot	3M	NW	L	3	0	0	0.5
2012	7/31/2012	1307	3	40	M	Hot	3M	NW	L	1	2	2	2
2012	7/31/2012	1307	3	40	M	Hot	3M	NW	L	2	5	5	5
2012	7/31/2012	1307	3	40	M	Hot	3M	NW	L	3	2	2	2
2012	7/31/2012	1307	3	60	M	Hot	3M	NW	L	1	0	0	0.5
2012	7/31/2012	1307	3	60	M	Hot	3M	NW	L	2	0	0	0.5

2012	7/31/2012	1307	3	60	M	Hot	3M	NW	L	3	0	0	0.5
2012	7/31/2012	1307	3	80	M	Hot	3M	NW	L	1	2	2	2
2012	7/31/2012	1307	3	80	M	Hot	3M	NW	L	2	1	1	1
2012	7/31/2012	1307	3	80	M	Hot	3M	NW	L	3	2	2	2
2012	7/31/2012	1307	3	100	M	Hot	3M	NW	L	1	3	3	3
2012	7/31/2012	1307	3	100	M	Hot	3M	NW	L	2	0	0	0.5
2012	7/31/2012	1307	3	100	M	Hot	3M	NW	L	3	0	0	0.5
2012	8/8/2012	1315	4	0	H	Hot	4H	N	U	1	0	0	0.5
2012	8/8/2012	1315	4	0	H	Hot	4H	N	U	2	0	0	0.5
2012	8/8/2012	1315	4	0	H	Hot	4H	N	U	3	0	0	0.5
2012	8/8/2012	1315	4	20	H	Hot	4H	N	U	1	2	2	2
2012	8/8/2012	1315	4	20	H	Hot	4H	N	U	2	2	2	2
2012	8/8/2012	1315	4	20	H	Hot	4H	N	U	3	2	2	2
2012	8/8/2012	1315	4	40	H	Hot	4H	N	U	1	2	2	2
2012	8/8/2012	1315	4	40	H	Hot	4H	N	U	2	3	3	3
2012	8/8/2012	1315	4	40	H	Hot	4H	N	U	3	0	0	0.5
2012	8/8/2012	1315	4	80	H	Hot	4H	N	U	1	0	0	0.5
2012	8/8/2012	1315	4	80	H	Hot	4H	N	U	2	2	2	2
2012	8/8/2012	1315	4	80	H	Hot	4H	N	U	3	3	3	3
2012	8/8/2012	1315	4	100	H	Hot	4H	N	U	1	1	1	1
2012	8/8/2012	1315	4	100	H	Hot	4H	N	U	2	1	1	1
2012	8/8/2012	1315	4	100	H	Hot	4H	N	U	3	1	1	1
2012	8/7/2012	1314	5	0	M	Hot	5M	W	L	1	10	10	10
2012	8/7/2012	1314	5	0	M	Hot	5M	W	L	2	4	4	4
2012	8/7/2012	1314	5	0	M	Hot	5M	W	L	3	14	14	14
2012	8/7/2012	1314	5	20	M	Hot	5M	W	L	1	6	6	6
2012	8/7/2012	1314	5	20	M	Hot	5M	W	L	2	2	2	2
2012	8/7/2012	1314	5	20	M	Hot	5M	W	L	3	0	0	0.5
2012	8/7/2012	1314	5	40	M	Hot	5M	W	L	1	0	0	0.5
2012	8/7/2012	1314	5	40	M	Hot	5M	W	L	2	3	3	3
2012	8/7/2012	1314	5	40	M	Hot	5M	W	L	3	4	4	4
2012	8/7/2012	1314	5	60	M	Hot	5M	W	L	1	11	11	11
2012	8/7/2012	1314	5	60	M	Hot	5M	W	L	2	4	4	4
2012	8/7/2012	1314	5	60	M	Hot	5M	W	L	3	8	8	8
2012	8/7/2012	1314	5	80	M	Hot	5M	W	L	1	8	8	8

2012	8/7/2012	1314	5	80	M	Hot	5M	W	L	2	2	2	2
2012	8/7/2012	1314	5	80	M	Hot	5M	W	L	3	2	2	2
2012	8/7/2012	1314	5	100	M	Hot	5M	W	L	1	1000	400	400
2012	8/7/2012	1314	5	100	M	Hot	5M	W	L	2	5	5	5
2012	8/7/2012	1314	5	100	M	Hot	5M	W	L	3	3	3	3
2012	8/7/2012	1314	6	0	H	Hot	6H	N	U	1	7	7	7
2012	8/7/2012	1314	6	0	H	Hot	6H	N	U	2	0	0	0.5
2012	8/7/2012	1314	6	0	H	Hot	6H	N	U	3	30	30	30
2012	8/7/2012	1314	6	20	H	Hot	6H	N	U	1	4	4	4
2012	8/7/2012	1314	6	20	H	Hot	6H	N	U	2	2	2	2
2012	8/7/2012	1314	6	20	H	Hot	6H	N	U	3	5	5	5
2012	8/7/2012	1314	6	40	H	Hot	6H	N	U	1	0	0	0.5
2012	8/7/2012	1314	6	40	H	Hot	6H	N	U	2	3	3	3
2012	8/7/2012	1314	6	40	H	Hot	6H	N	U	3	3	3	3
2012	8/7/2012	1314	6	60	H	Hot	6H	N	U	1	9	9	9
2012	8/7/2012	1314	6	60	H	Hot	6H	N	U	2	24	24	24
2012	8/7/2012	1314	6	60	H	Hot	6H	N	U	3	3	3	3
2012	8/7/2012	1314	6	80	H	Hot	6H	N	U	1	7	7	7
2012	8/7/2012	1314	6	80	H	Hot	6H	N	U	2	1000	400	400
2012	8/7/2012	1314	6	80	H	Hot	6H	N	U	3	0	0	0.5
2012	8/7/2012	1314	6	100	H	Hot	6H	N	U	1	0	0	0.5
2012	8/7/2012	1314	6	100	H	Hot	6H	N	U	2	6	6	6
2012	8/7/2012	1314	6	100	H	Hot	6H	N	U	3	4	4	4
2012	8/2/2012	1309	7	0	H	Hot	7H	N	U	1	2	2	2
2012	8/2/2012	1309	7	0	H	Hot	7H	N	U	2	2	2	2
2012	8/2/2012	1309	7	0	H	Hot	7H	N	U	3	2	2	2
2012	8/2/2012	1309	7	20	H	Hot	7H	N	U	1	6	6	6
2012	8/2/2012	1309	7	20	H	Hot	7H	N	U	2	1	1	1
2012	8/2/2012	1309	7	20	H	Hot	7H	N	U	3	2	2	2
2012	8/2/2012	1309	7	40	H	Hot	7H	N	U	1	1	1	1
2012	8/2/2012	1309	7	40	H	Hot	7H	N	U	2	1	1	1
2012	8/2/2012	1309	7	40	H	Hot	7H	N	U	3	5	5	5
2012	8/2/2012	1309	7	60	H	Hot	7H	N	U	1	30	30	30
2012	8/2/2012	1309	7	60	H	Hot	7H	N	U	2	1	1	1
2012	8/2/2012	1309	7	60	H	Hot	7H	N	U	3	2	2	2

2012	8/2/2012	1309	7	80	H	Hot	7H	N	U	1	1	1	1
2012	8/2/2012	1309	7	80	H	Hot	7H	N	U	2	7	7	7
2012	8/2/2012	1309	7	80	H	Hot	7H	N	U	3	30	30	30
2012	8/2/2012	1309	7	100	H	Hot	7H	N	U	1	60	60	60
2012	8/2/2012	1309	7	100	H	Hot	7H	N	U	2	5	5	5
2012	8/2/2012	1309	7	100	H	Hot	7H	N	U	3	5	5	5
2012	8/1/2012	1308	8	0	H	Hot	8H	SE	U	1	31	31	31
2012	8/1/2012	1308	8	0	H	Hot	8H	SE	U	2	1000	400	400
2012	8/1/2012	1308	8	0	H	Hot	8H	SE	U	3	1000	400	400
2012	8/1/2012	1308	8	20	H	Hot	8H	SE	U	1	4	4	4
2012	8/1/2012	1308	8	20	H	Hot	8H	SE	U	2	2	2	2
2012	8/1/2012	1308	8	20	H	Hot	8H	SE	U	3	2	2	2
2012	8/1/2012	1308	8	40	H	Hot	8H	SE	U	1	2	2	2
2012	8/1/2012	1308	8	40	H	Hot	8H	SE	U	2	20	20	20
2012	8/1/2012	1308	8	40	H	Hot	8H	SE	U	3	28	28	28
2012	8/1/2012	1308	8	60	H	Hot	8H	SE	U	1	5	5	5
2012	8/1/2012	1308	8	60	H	Hot	8H	SE	U	2	13	13	13
2012	8/1/2012	1308	8	60	H	Hot	8H	SE	U	3	1000	400	400
2012	8/1/2012	1308	8	80	H	Hot	8H	SE	U	1	1	1	1
2012	8/1/2012	1308	8	80	H	Hot	8H	SE	U	2	2	2	2
2012	8/1/2012	1308	8	80	H	Hot	8H	SE	U	3	1	1	1
2012	8/1/2012	1308	8	100	H	Hot	8H	SE	U	1	7	7	7
2012	8/1/2012	1308	8	100	H	Hot	8H	SE	U	2	4	4	4
2012	8/1/2012	1308	8	100	H	Hot	8H	SE	U	3	5	5	5
2012	7/25/2012	1301	9	0	M	Hot	9M	SE	L	1	2	2	2
2012	7/25/2012	1301	9	0	M	Hot	9M	SE	L	2	1	1	1
2012	7/25/2012	1301	9	0	M	Hot	9M	SE	L	3	1	1	1
2012	7/25/2012	1301	9	20	M	Hot	9M	SE	L	1	1	1	1
2012	7/25/2012	1301	9	20	M	Hot	9M	SE	L	2	0	0	0.5
2012	7/25/2012	1301	9	20	M	Hot	9M	SE	L	3	0	0	0.5
2012	7/25/2012	1301	9	40	M	Hot	9M	SE	L	1	1	1	1
2012	7/25/2012	1301	9	40	M	Hot	9M	SE	L	2	2	2	2
2012	7/25/2012	1301	9	40	M	Hot	9M	SE	L	3	2	2	2
2012	7/25/2012	1301	9	60	M	Hot	9M	SE	L	1	1	1	1
2012	7/25/2012	1301	9	60	M	Hot	9M	SE	L	2	1	1	1

2012	7/25/2012	1301	9	60	M	Hot	9M	SE	L	3	0	0	0.5
2012	7/25/2012	1301	9	80	M	Hot	9M	SE	L	1	0	0	0.5
2012	7/25/2012	1301	9	80	M	Hot	9M	SE	L	2	0	0	0.5
2012	7/25/2012	1301	9	80	M	Hot	9M	SE	L	3	1	1	1
2012	7/25/2012	1301	9	100	M	Hot	9M	SE	L	1	0	0	0.5
2012	7/25/2012	1301	9	100	M	Hot	9M	SE	L	2	2	2	2
2012	7/25/2012	1301	9	100	M	Hot	9M	SE	L	3	3	3	3
2012	8/2/2012	1309	10	0	H	Hot	10H	S	U	1	2	2	2
2012	8/2/2012	1309	10	0	H	Hot	10H	S	U	2	1000	400	400
2012	8/2/2012	1309	10	0	H	Hot	10H	S	U	3	2	2	2
2012	8/2/2012	1309	10	20	H	Hot	10H	S	U	1	7	7	7
2012	8/2/2012	1309	10	20	H	Hot	10H	S	U	2	1000	400	400
2012	8/2/2012	1309	10	20	H	Hot	10H	S	U	3	1000	400	400
2012	8/2/2012	1309	10	40	H	Hot	10H	S	U	1	5	5	5
2012	8/2/2012	1309	10	40	H	Hot	10H	S	U	2	1000	400	400
2012	8/2/2012	1309	10	40	H	Hot	10H	S	U	3	2	2	2
2012	8/2/2012	1309	10	60	H	Hot	10H	S	U	1	4	4	4
2012	8/2/2012	1309	10	60	H	Hot	10H	S	U	2	1000	400	400
2012	8/2/2012	1309	10	60	H	Hot	10H	S	U	3	5	5	5
2012	8/2/2012	1309	10	80	H	Hot	10H	S	U	1	1000	400	400
2012	8/2/2012	1309	10	80	H	Hot	10H	S	U	2	1000	400	400
2012	8/2/2012	1309	10	80	H	Hot	10H	S	U	3	1000	400	400
2012	8/2/2012	1309	10	100	H	Hot	10H	S	U	1	8	8	8
2012	8/2/2012	1309	10	100	H	Hot	10H	S	U	2	1	1	1
2012	8/2/2012	1309	10	100	H	Hot	10H	S	U	3	1000	400	400
2012	8/9/2012	1316	11	0	M	Hot	11M	NW	U	1	1	1	1
2012	8/9/2012	1316	11	0	M	Hot	11M	NW	U	2	1	1	1
2012	8/9/2012	1316	11	0	M	Hot	11M	NW	U	3	1	1	1
2012	8/9/2012	1316	11	20	M	Hot	11M	NW	U	1	2	2	2
2012	8/9/2012	1316	11	20	M	Hot	11M	NW	U	2	2	2	2
2012	8/9/2012	1316	11	20	M	Hot	11M	NW	U	3	5	5	5
2012	8/9/2012	1316	11	40	M	Hot	11M	NW	U	1	1	1	1
2012	8/9/2012	1316	11	40	M	Hot	11M	NW	U	2	1	1	1
2012	8/9/2012	1316	11	40	M	Hot	11M	NW	U	3	1	1	1
2012	8/9/2012	1316	11	60	M	Hot	11M	NW	U	1	2	2	2

2012	8/9/2012	1316	11	60	M	Hot	11M	NW	U	2	15	15	15
2012	8/9/2012	1316	11	60	M	Hot	11M	NW	U	3	20	20	20
2012	8/9/2012	1316	11	80	M	Hot	11M	NW	U	1	13	13	13
2012	8/9/2012	1316	11	80	M	Hot	11M	NW	U	2	12	12	12
2012	8/9/2012	1316	11	80	M	Hot	11M	NW	U	3	8	8	8
2012	8/9/2012	1316	11	100	M	Hot	11M	NW	U	1	0	0	0.5
2012	8/9/2012	1316	11	100	M	Hot	11M	NW	U	2	0	0	0.5
2012	8/9/2012	1316	11	100	M	Hot	11M	NW	U	3	1	1	1
2012	8/6/2012	1313	12	0	H	Hot	12H	S	U	1	2	2	2
2012	8/6/2012	1313	12	0	H	Hot	12H	S	U	2	125	125	125
2012	8/6/2012	1313	12	0	H	Hot	12H	S	U	3	1	1	1
2012	8/6/2012	1313	12	20	H	Hot	12H	S	U	1	30	30	30
2012	8/6/2012	1313	12	20	H	Hot	12H	S	U	2	1	1	1
2012	8/6/2012	1313	12	20	H	Hot	12H	S	U	3	15	15	15
2012	8/6/2012	1313	12	40	H	Hot	12H	S	U	1	4	4	4
2012	8/6/2012	1313	12	40	H	Hot	12H	S	U	2	2	2	2
2012	8/6/2012	1313	12	40	H	Hot	12H	S	U	3	10	10	10
2012	8/6/2012	1313	12	60	H	Hot	12H	S	U	1	120	120	120
2012	8/6/2012	1313	12	60	H	Hot	12H	S	U	2	60	60	60
2012	8/6/2012	1313	12	60	H	Hot	12H	S	U	3	125	125	125
2012	8/6/2012	1313	12	80	H	Hot	12H	S	U	1	3	3	3
2012	8/6/2012	1313	12	80	H	Hot	12H	S	U	2	9	9	9
2012	8/6/2012	1313	12	80	H	Hot	12H	S	U	3	185	185	185
2012	8/6/2012	1313	12	100	H	Hot	12H	S	U	1	1	1	1
2012	8/6/2012	1313	12	100	H	Hot	12H	S	U	2	2	2	2
2012	8/6/2012	1313	12	100	H	Hot	12H	S	U	3	8	8	8
2012	7/31/2012	1307	13	0	M	Hot	13M	S	L	1	3	3	3
2012	7/31/2012	1307	13	0	M	Hot	13M	S	L	2	1	1	1
2012	7/31/2012	1307	13	0	M	Hot	13M	S	L	3	1	1	1
2012	7/31/2012	1307	13	20	M	Hot	13M	S	L	1	2	2	2
2012	7/31/2012	1307	13	20	M	Hot	13M	S	L	2	1	1	1
2012	7/31/2012	1307	13	20	M	Hot	13M	S	L	3	3	3	3
2012	7/31/2012	1307	13	40	M	Hot	13M	S	L	1	6	6	6
2012	7/31/2012	1307	13	40	M	Hot	13M	S	L	2	0	0	0.5
2012	7/31/2012	1307	13	40	M	Hot	13M	S	L	3	0	0	0.5

2012	7/31/2012	1307	13	60	M	Hot	13M	S	L	1	1	1	1
2012	7/31/2012	1307	13	60	M	Hot	13M	S	L	2	2	2	2
2012	7/31/2012	1307	13	60	M	Hot	13M	S	L	3	2	2	2
2012	7/31/2012	1307	13	80	M	Hot	13M	S	L	1	1	1	1
2012	7/31/2012	1307	13	80	M	Hot	13M	S	L	2	2	2	2
2012	7/31/2012	1307	13	80	M	Hot	13M	S	L	3	2	2	2
2012	7/31/2012	1307	13	100	M	Hot	13M	S	L	1	0	0	0.5
2012	7/31/2012	1307	13	100	M	Hot	13M	S	L	2	0	0	0.5
2012	7/31/2012	1307	13	100	M	Hot	13M	S	L	3	0	0	0.5
2012	7/30/2012	1306	14	0	N	Cool	14N	S	L	1	9	9	9
2012	7/30/2012	1306	14	0	N	Cool	14N	S	L	2	16	16	16
2012	7/30/2012	1306	14	0	N	Cool	14N	S	L	3	3	3	3
2012	7/30/2012	1306	14	20	N	Cool	14N	S	L	1	2	2	2
2012	7/30/2012	1306	14	20	N	Cool	14N	S	L	2	1	1	1
2012	7/30/2012	1306	14	20	N	Cool	14N	S	L	3	0	0	0.5
2012	7/30/2012	1306	14	40	N	Cool	14N	S	L	1	1	1	1
2012	7/30/2012	1306	14	40	N	Cool	14N	S	L	2	0	0	0.5
2012	7/30/2012	1306	14	40	N	Cool	14N	S	L	3	0	0	0.5
2012	7/30/2012	1306	14	60	N	Cool	14N	S	L	1	1	1	1
2012	7/30/2012	1306	14	60	N	Cool	14N	S	L	2	0	0	0.5
2012	7/30/2012	1306	14	60	N	Cool	14N	S	L	3	0	0	0.5
2012	7/30/2012	1306	14	80	N	Cool	14N	S	L	1	0	0	0.5
2012	7/30/2012	1306	14	80	N	Cool	14N	S	L	2	0	0	0.5
2012	7/30/2012	1306	14	80	N	Cool	14N	S	L	3	0	0	0.5
2012	7/30/2012	1306	14	100	N	Cool	14N	S	L	1	0	0	0.5
2012	7/30/2012	1306	14	100	N	Cool	14N	S	L	2	0	0	0.5
2012	7/30/2012	1306	14	100	N	Cool	14N	S	L	3	0	0	0.5
2012	8/1/2012	1308	15	0	H	Hot	15H	SE	U	1	1	1	1
2012	8/1/2012	1308	15	0	H	Hot	15H	SE	U	2	2	2	2
2012	8/1/2012	1308	15	0	H	Hot	15H	SE	U	3	2	2	2
2012	8/1/2012	1308	15	20	H	Hot	15H	SE	U	1	1	1	1
2012	8/1/2012	1308	15	20	H	Hot	15H	SE	U	2	2	2	2
2012	8/1/2012	1308	15	20	H	Hot	15H	SE	U	3	3	3	3
2012	8/1/2012	1308	15	40	H	Hot	15H	SE	U	1	9	9	9
2012	8/1/2012	1308	15	40	H	Hot	15H	SE	U	2	33	33	33

2012	8/1/2012	1308	15	40	H	Hot	15H	SE	U	3	21	21	21
2012	8/1/2012	1308	15	60	H	Hot	15H	SE	U	1	2	2	2
2012	8/1/2012	1308	15	60	H	Hot	15H	SE	U	2	4	4	4
2012	8/1/2012	1308	15	60	H	Hot	15H	SE	U	3	7	7	7
2012	8/1/2012	1308	15	80	H	Hot	15H	SE	U	1	3	3	3
2012	8/1/2012	1308	15	80	H	Hot	15H	SE	U	2	3	3	3
2012	8/1/2012	1308	15	80	H	Hot	15H	SE	U	3	5	5	5
2012	8/1/2012	1308	15	100	H	Hot	15H	SE	U	1	7	7	7
2012	8/1/2012	1308	15	100	H	Hot	15H	SE	U	2	3	3	3
2012	8/1/2012	1308	15	100	H	Hot	15H	SE	U	3	3	3	3
2012	8/13/2012	1320	20	0	H	Hot	20H	NW	U	1	12	12	12
2012	8/13/2012	1320	20	0	H	Hot	20H	NW	U	2	11	11	11
2012	8/13/2012	1320	20	0	H	Hot	20H	NW	U	3	8	8	8
2012	8/13/2012	1320	20	20	H	Hot	20H	NW	U	1	4	4	4
2012	8/13/2012	1320	20	20	H	Hot	20H	NW	U	2	8	8	8
2012	8/13/2012	1320	20	20	H	Hot	20H	NW	U	3	12	12	12
2012	8/13/2012	1320	20	40	H	Hot	20H	NW	U	1	7	7	7
2012	8/13/2012	1320	20	40	H	Hot	20H	NW	U	2	6	6	6
2012	8/13/2012	1320	20	40	H	Hot	20H	NW	U	3	4	4	4
2012	8/13/2012	1320	20	60	H	Hot	20H	NW	U	1	25	25	25
2012	8/13/2012	1320	20	60	H	Hot	20H	NW	U	2	5	5	5
2012	8/13/2012	1320	20	60	H	Hot	20H	NW	U	3	2	2	2
2012	8/13/2012	1320	20	80	H	Hot	20H	NW	U	1	3	3	3
2012	8/13/2012	1320	20	80	H	Hot	20H	NW	U	2	3	3	3
2012	8/13/2012	1320	20	80	H	Hot	20H	NW	U	3	3	3	3
2012	8/13/2012	1320	20	100	H	Hot	20H	NW	U	1	5	5	5
2012	8/13/2012	1320	20	100	H	Hot	20H	NW	U	2	10	10	10
2012	8/13/2012	1320	20	100	H	Hot	20H	NW	U	3	6	6	6
2012	8/9/2012	1316	21	0	ML	Cool	21ML	N	L	1	2	2	2
2012	8/9/2012	1316	21	0	ML	Cool	21ML	N	L	2	20	20	20
2012	8/9/2012	1316	21	0	ML	Cool	21ML	N	L	3	60	60	60
2012	8/9/2012	1316	21	20	ML	Cool	21ML	N	L	1	0	0	0.5
2012	8/9/2012	1316	21	20	ML	Cool	21ML	N	L	2	0	0	0.5
2012	8/9/2012	1316	21	20	ML	Cool	21ML	N	L	3	2	2	2
2012	8/9/2012	1316	21	40	ML	Cool	21ML	N	L	1	20	20	20

2012	8/9/2012	1316	21	40	ML	Cool	21ML	N	L	2	1	1	1
2012	8/9/2012	1316	21	40	ML	Cool	21ML	N	L	3	1	1	1
2012	8/9/2012	1316	21	60	ML	Cool	21ML	N	L	1	1	1	1
2012	8/9/2012	1316	21	60	ML	Cool	21ML	N	L	2	1	1	1
2012	8/9/2012	1316	21	60	ML	Cool	21ML	N	L	3	1	1	1
2012	8/9/2012	1316	21	80	ML	Cool	21ML	N	L	1	1	1	1
2012	8/9/2012	1316	21	80	ML	Cool	21ML	N	L	2	1	1	1
2012	8/9/2012	1316	21	80	ML	Cool	21ML	N	L	3	1	1	1
2012	8/9/2012	1316	21	100	ML	Cool	21ML	N	L	1	0	0	0.5
2012	8/9/2012	1316	21	100	ML	Cool	21ML	N	L	2	0	0	0.5
2012	8/9/2012	1316	21	100	ML	Cool	21ML	N	L	3	0	0	0.5
2012	8/13/2012	1320	22	0	MH	Hot	22MH	N	U	1	4	4	4
2012	8/13/2012	1320	22	0	MH	Hot	22MH	N	U	2	2	2	2
2012	8/13/2012	1320	22	0	MH	Hot	22MH	N	U	3	3	3	3
2012	8/13/2012	1320	22	20	MH	Hot	22MH	N	U	1	2	2	2
2012	8/13/2012	1320	22	20	MH	Hot	22MH	N	U	2	2	2	2
2012	8/13/2012	1320	22	20	MH	Hot	22MH	N	U	3	3	3	3
2012	8/13/2012	1320	22	40	MH	Hot	22MH	N	U	1	2	2	2
2012	8/13/2012	1320	22	40	MH	Hot	22MH	N	U	2	7	7	7
2012	8/13/2012	1320	22	40	MH	Hot	22MH	N	U	3	1	1	1
2012	8/13/2012	1320	22	60	MH	Hot	22MH	N	U	1	0	0	0.5
2012	8/13/2012	1320	22	60	MH	Hot	22MH	N	U	2	2	2	2
2012	8/13/2012	1320	22	60	MH	Hot	22MH	N	U	3	3	3	3
2012	8/13/2012	1320	22	80	MH	Hot	22MH	N	U	1	1	1	1
2012	8/13/2012	1320	22	80	MH	Hot	22MH	N	U	2	2	2	2
2012	8/13/2012	1320	22	80	MH	Hot	22MH	N	U	3	3	3	3
2012	8/13/2012	1320	22	100	MH	Hot	22MH	N	U	1	1	1	1
2012	8/13/2012	1320	22	100	MH	Hot	22MH	N	U	2	1	1	1
2012	8/13/2012	1320	22	100	MH	Hot	22MH	N	U	3	1	1	1
2012	8/8/2012	1315	23	0	H	Hot	23H	N	U	1	0	0	0.5
2012	8/8/2012	1315	23	0	H	Hot	23H	N	U	2	0	0	0.5
2012	8/8/2012	1315	23	0	H	Hot	23H	N	U	3	0	0	0.5
2012	8/8/2012	1315	23	20	H	Hot	23H	N	U	1	0	0	0.5
2012	8/8/2012	1315	23	20	H	Hot	23H	N	U	2	1	1	1
2012	8/8/2012	1315	23	20	H	Hot	23H	N	U	3	1	1	1

2012	8/8/2012	1315	23	40	H	Hot	23H	N	U	1	1	1	1
2012	8/8/2012	1315	23	40	H	Hot	23H	N	U	2	1	1	1
2012	8/8/2012	1315	23	40	H	Hot	23H	N	U	3	1	1	1
2012	8/8/2012	1315	23	60	H	Hot	23H	N	U	1	0	0	0.5
2012	8/8/2012	1315	23	60	H	Hot	23H	N	U	2	0	0	0.5
2012	8/8/2012	1315	23	60	H	Hot	23H	N	U	3	0	0	0.5
2012	8/8/2012	1315	23	80	H	Hot	23H	N	U	1	0	0	0.5
2012	8/8/2012	1315	23	80	H	Hot	23H	N	U	2	1	1	1
2012	8/8/2012	1315	23	80	H	Hot	23H	N	U	3	1	1	1
2012	8/8/2012	1315	23	100	H	Hot	23H	N	U	1	0	0	0.5
2012	8/8/2012	1315	23	100	H	Hot	23H	N	U	2	0	0	0.5
2012	8/8/2012	1315	23	100	H	Hot	23H	N	U	3	0	0	0.5
2013	7/17/2013	1658	1	0	H	Hot	1H	SE	L	1	44	44	44
2013	7/17/2013	1658	1	0	H	Hot	1H	SE	L	2	44	44	44
2013	7/17/2013	1658	1	0	H	Hot	1H	SE	L	3	26.7	26.7	26.7
2013	7/17/2013	1658	1	20	H	Hot	1H	SE	L	1	27.3	27.3	27.3
2013	7/17/2013	1658	1	20	H	Hot	1H	SE	L	2	20.7	20.7	20.7
2013	7/17/2013	1658	1	20	H	Hot	1H	SE	L	3	27	27	27
2013	7/17/2013	1658	1	40	H	Hot	1H	SE	L	1	2.7	2.7	2.7
2013	7/17/2013	1658	1	40	H	Hot	1H	SE	L	2	2.7	2.7	2.7
2013	7/17/2013	1658	1	40	H	Hot	1H	SE	L	3	1	1	1
2013	7/17/2013	1658	1	60	H	Hot	1H	SE	L	1	2.3	2.3	2.3
2013	7/17/2013	1658	1	60	H	Hot	1H	SE	L	2	2.3	2.3	2.3
2013	7/17/2013	1658	1	60	H	Hot	1H	SE	L	3	3	3	3
2013	7/17/2013	1658	1	80	H	Hot	1H	SE	L	1	1.3	1.3	1.3
2013	7/17/2013	1658	1	80	H	Hot	1H	SE	L	2	2	2	2
2013	7/17/2013	1658	1	80	H	Hot	1H	SE	L	3	2.3	2.3	2.3
2013	7/17/2013	1658	1	100	H	Hot	1H	SE	L	1	1.7	1.7	1.7
2013	7/17/2013	1658	1	100	H	Hot	1H	SE	L	2	1.3	1.3	1.3
2013	7/17/2013	1658	1	100	H	Hot	1H	SE	L	3	1.7	1.7	1.7
2013	7/8/2013	1649	3	0	M	Hot	3M	NW	L	1	2.4	2.4	2.4
2013	7/8/2013	1649	3	0	M	Hot	3M	NW	L	2	2.5	2.5	2.5
2013	7/8/2013	1649	3	0	M	Hot	3M	NW	L	3	2.7	2.7	2.7
2013	7/8/2013	1649	3	20	M	Hot	3M	NW	L	1	60	60	60
2013	7/8/2013	1649	3	20	M	Hot	3M	NW	L	2	3	3	3

2013	7/8/2013	1649	3	20	M	Hot	3M	NW	L	3	6	6	6
2013	7/8/2013	1649	3	40	M	Hot	3M	NW	L	1	2.3	2.3	2.3
2013	7/8/2013	1649	3	40	M	Hot	3M	NW	L	2	3.7	3.7	3.7
2013	7/8/2013	1649	3	40	M	Hot	3M	NW	L	3	3.7	3.7	3.7
2013	7/8/2013	1649	3	60	M	Hot	3M	NW	L	1	3	3	3
2013	7/8/2013	1649	3	60	M	Hot	3M	NW	L	2	7	7	7
2013	7/8/2013	1649	3	60	M	Hot	3M	NW	L	3	27	27	27
2013	7/8/2013	1649	3	80	M	Hot	3M	NW	L	1	4	4	4
2013	7/8/2013	1649	3	80	M	Hot	3M	NW	L	2	3.3	3.3	3.3
2013	7/8/2013	1649	3	80	M	Hot	3M	NW	L	3	2	2	2
2013	7/8/2013	1649	3	100	M	Hot	3M	NW	L	1	60	60	60
2013	7/8/2013	1649	3	100	M	Hot	3M	NW	L	2	4	4	4
2013	7/8/2013	1649	3	100	M	Hot	3M	NW	L	3	4	4	4
2013	7/18/2013	1659	5	0	M	Hot	5M	W	L	1	6.7	6.7	6.7
2013	7/18/2013	1659	5	0	M	Hot	5M	W	L	2	22.3	22.3	22.3
2013	7/18/2013	1659	5	0	M	Hot	5M	W	L	3	58.7	58.7	58.7
2013	7/18/2013	1659	5	20	M	Hot	5M	W	L	1	9	9	9
2013	7/18/2013	1659	5	20	M	Hot	5M	W	L	2	22	22	22
2013	7/18/2013	1659	5	20	M	Hot	5M	W	L	3	43.7	43.7	43.7
2013	7/18/2013	1659	5	40	M	Hot	5M	W	L	1	2	2	2
2013	7/18/2013	1659	5	40	M	Hot	5M	W	L	2	6	6	6
2013	7/18/2013	1659	5	40	M	Hot	5M	W	L	3	2.7	2.7	2.7
2013	7/18/2013	1659	5	60	M	Hot	5M	W	L	1	60	60	60
2013	7/18/2013	1659	5	60	M	Hot	5M	W	L	2	60	60	60
2013	7/18/2013	1659	5	60	M	Hot	5M	W	L	3	24	24	24
2013	7/18/2013	1659	5	80	M	Hot	5M	W	L	1	44.3	44.3	44.3
2013	7/18/2013	1659	5	80	M	Hot	5M	W	L	2	43.7	43.7	43.7
2013	7/18/2013	1659	5	80	M	Hot	5M	W	L	3	10.7	10.7	10.7
2013	7/18/2013	1659	5	100	M	Hot	5M	W	L	1	41.3	41.3	41.3
2013	7/18/2013	1659	5	100	M	Hot	5M	W	L	2	41	41	41
2013	7/18/2013	1659	5	100	M	Hot	5M	W	L	3	60	60	60
2013	7/9/2013	1650	9	0	M	Hot	9M	SE	L	1	1	1	1
2013	7/9/2013	1650	9	0	M	Hot	9M	SE	L	2	6	6	6
2013	7/9/2013	1650	9	0	M	Hot	9M	SE	L	3	6.3	6.3	6.3
2013	7/9/2013	1650	9	20	M	Hot	9M	SE	L	1	4.3	4.3	4.3

2013	7/9/2013	1650	9	20	M	Hot	9M	SE	L	2	4.7	4.7	4.7
2013	7/9/2013	1650	9	20	M	Hot	9M	SE	L	3	2.3	2.3	2.3
2013	7/9/2013	1650	9	40	M	Hot	9M	SE	L	1	5	5	5
2013	7/9/2013	1650	9	40	M	Hot	9M	SE	L	2	6	6	6
2013	7/9/2013	1650	9	40	M	Hot	9M	SE	L	3	8	8	8
2013	7/9/2013	1650	9	60	M	Hot	9M	SE	L	1	3.3	3.3	3.3
2013	7/9/2013	1650	9	60	M	Hot	9M	SE	L	2	9.7	9.7	9.7
2013	7/9/2013	1650	9	60	M	Hot	9M	SE	L	3	4.7	4.7	4.7
2013	7/9/2013	1650	9	80	M	Hot	9M	SE	L	1	12	12	12
2013	7/9/2013	1650	9	80	M	Hot	9M	SE	L	2	3	3	3
2013	7/9/2013	1650	9	80	M	Hot	9M	SE	L	3	3.7	3.7	3.7
2013	7/9/2013	1650	9	100	M	Hot	9M	SE	L	1	41	41	41
2013	7/9/2013	1650	9	100	M	Hot	9M	SE	L	2	60	60	60
2013	7/9/2013	1650	9	100	M	Hot	9M	SE	L	3	55.1	55.1	55.1
2013	7/16/2013	1657	10	0	H	Hot	10H	S	U	1	16	16	16
2013	7/16/2013	1657	10	0	H	Hot	10H	S	U	2	14.3	14.3	14.3
2013	7/16/2013	1657	10	0	H	Hot	10H	S	U	3	12.3	12.3	12.3
2013	7/16/2013	1657	10	20	H	Hot	10H	S	U	1	1	1	1
2013	7/16/2013	1657	10	20	H	Hot	10H	S	U	2	1	1	1
2013	7/16/2013	1657	10	20	H	Hot	10H	S	U	3	1	1	1
2013	7/16/2013	1657	10	40	H	Hot	10H	S	U	1	1	1	1
2013	7/16/2013	1657	10	40	H	Hot	10H	S	U	2	1.7	1.7	1.7
2013	7/16/2013	1657	10	40	H	Hot	10H	S	U	3	1.3	1.3	1.3
2013	7/16/2013	1657	10	60	H	Hot	10H	S	U	1	1.7	1.7	1.7
2013	7/16/2013	1657	10	60	H	Hot	10H	S	U	2	1.7	1.7	1.7
2013	7/16/2013	1657	10	60	H	Hot	10H	S	U	3	2	2	2
2013	7/16/2013	1657	10	80	H	Hot	10H	S	U	1	7.7	7.7	7.7
2013	7/16/2013	1657	10	80	H	Hot	10H	S	U	2	4.3	4.3	4.3
2013	7/16/2013	1657	10	80	H	Hot	10H	S	U	3	5	5	5
2013	7/16/2013	1657	10	100	H	Hot	10H	S	U	1	2.7	2.7	2.7
2013	7/16/2013	1657	10	100	H	Hot	10H	S	U	2	2.7	2.7	2.7
2013	7/16/2013	1657	10	100	H	Hot	10H	S	U	3	3.3	3.3	3.3
2013	7/17/2013	1658	11	0	M	Hot	11M	NW	U	1	38.7	38.7	38.7
2013	7/17/2013	1658	11	0	M	Hot	11M	NW	U	2	6.7	6.7	6.7
2013	7/17/2013	1658	11	0	M	Hot	11M	NW	U	3	27.3	27.3	27.3

2013	7/17/2013	1658	11	20	M	Hot	11M	NW	U	1	27	27	27
2013	7/17/2013	1658	11	20	M	Hot	11M	NW	U	2	31.3	31.3	31.3
2013	7/17/2013	1658	11	20	M	Hot	11M	NW	U	3	36.7	36.7	36.7
2013	7/17/2013	1658	11	40	M	Hot	11M	NW	U	1	10	10	10
2013	7/17/2013	1658	11	40	M	Hot	11M	NW	U	2	25	25	25
2013	7/17/2013	1658	11	40	M	Hot	11M	NW	U	3	21.3	21.3	21.3
2013	7/17/2013	1658	11	60	M	Hot	11M	NW	U	1	7.3	7.3	7.3
2013	7/17/2013	1658	11	60	M	Hot	11M	NW	U	2	4.3	4.3	4.3
2013	7/17/2013	1658	11	60	M	Hot	11M	NW	U	3	4.3	4.3	4.3
2013	7/17/2013	1658	11	80	M	Hot	11M	NW	U	1	2.3	2.3	2.3
2013	7/17/2013	1658	11	80	M	Hot	11M	NW	U	2	3.7	3.7	3.7
2013	7/17/2013	1658	11	80	M	Hot	11M	NW	U	3	3.3	3.3	3.3
2013	7/17/2013	1658	11	100	M	Hot	11M	NW	U	1	6.7	6.7	6.7
2013	7/17/2013	1658	11	100	M	Hot	11M	NW	U	2	4.3	4.3	4.3
2013	7/17/2013	1658	11	100	M	Hot	11M	NW	U	3	6	6	6
2013	7/9/2013	1650	15	0	H	Hot	15H	SE	U	1	60	60	60
2013	7/9/2013	1650	15	0	H	Hot	15H	SE	U	2	180	180	180
2013	7/9/2013	1650	15	0	H	Hot	15H	SE	U	3	180	180	180
2013	7/9/2013	1650	15	20	H	Hot	15H	SE	U	1	26	26	26
2013	7/9/2013	1650	15	20	H	Hot	15H	SE	U	2	39	39	39
2013	7/9/2013	1650	15	20	H	Hot	15H	SE	U	3	45.3	45.3	45.3
2013	7/9/2013	1650	15	40	H	Hot	15H	SE	U	1	47.3	47.3	47.3
2013	7/9/2013	1650	15	40	H	Hot	15H	SE	U	2	60	60	60
2013	7/9/2013	1650	15	40	H	Hot	15H	SE	U	3	40.3	40.3	40.3
2013	7/9/2013	1650	15	60	H	Hot	15H	SE	U	1	4	4	4
2013	7/9/2013	1650	15	60	H	Hot	15H	SE	U	2	4	4	4
2013	7/9/2013	1650	15	60	H	Hot	15H	SE	U	3	7	7	7
2013	7/9/2013	1650	15	80	H	Hot	15H	SE	U	1	3.7	3.7	3.7
2013	7/9/2013	1650	15	80	H	Hot	15H	SE	U	2	4.9	4.9	4.9
2013	7/9/2013	1650	15	80	H	Hot	15H	SE	U	3	17	17	17
2013	7/9/2013	1650	15	100	H	Hot	15H	SE	U	1	108	108	108
2013	7/9/2013	1650	15	100	H	Hot	15H	SE	U	2	33.3	33.3	33.3
2013	7/9/2013	1650	15	100	H	Hot	15H	SE	U	3	15.7	15.7	15.7
2012	7/18/2013	1659	20	0	H	Hot	20H	NW	U	1	2	2	2
2012	7/18/2013	1659	20	0	H	Hot	20H	NW	U	2	2.3	2.3	2.3

2012	7/18/2013	1659	20	0	H	Hot	20H	NW	U	3	3.7	3.7	3.7
2012	7/18/2013	1659	20	20	H	Hot	20H	NW	U	1	2.5	2.5	2.5
2012	7/18/2013	1659	20	20	H	Hot	20H	NW	U	2	7	7	7
2012	7/18/2013	1659	20	20	H	Hot	20H	NW	U	3	4	4	4
2012	7/18/2013	1659	20	40	H	Hot	20H	NW	U	1	1.7	1.7	1.7
2012	7/18/2013	1659	20	40	H	Hot	20H	NW	U	2	1.7	1.7	1.7
2012	7/18/2013	1659	20	40	H	Hot	20H	NW	U	3	4	4	4
2012	7/18/2013	1659	20	60	H	Hot	20H	NW	U	1	2.3	2.3	2.3
2012	7/18/2013	1659	20	60	H	Hot	20H	NW	U	2	40.7	40.7	40.7
2012	7/18/2013	1659	20	60	H	Hot	20H	NW	U	3	22	22	22
2012	7/18/2013	1659	20	80	H	Hot	20H	NW	U	1	3.3	3.3	3.3
2012	7/18/2013	1659	20	80	H	Hot	20H	NW	U	2	6.7	6.7	6.7
2013	7/18/2013	1659	20	80	H	Hot	20H	NW	U	3	4.3	4.3	4.3
2013	7/18/2013	1659	20	100	H	Hot	20H	NW	U	1	2.3	2.3	2.3
2013	7/18/2013	1659	20	100	H	Hot	20H	NW	U	2	1.3	1.3	1.3
2013	7/18/2013	1659	20	100	H	Hot	20H	NW	U	3	4	4	4
2013	7/16/2013	1657	21	0	ML	Cool	21ML	N	L	1	16	16	16
2013	7/16/2013	1657	21	0	ML	Cool	21ML	N	L	2	17.7	17.7	17.7
2013	7/16/2013	1657	21	0	ML	Cool	21ML	N	L	3	9.3	9.3	9.3
2013	7/16/2013	1657	21	20	ML	Cool	21ML	N	L	1	29.3	29.3	29.3
2013	7/16/2013	1657	21	20	ML	Cool	21ML	N	L	2	41	41	41
2013	7/16/2013	1657	21	20	ML	Cool	21ML	N	L	3	56.7	56.7	56.7
2013	7/16/2013	1657	21	40	ML	Cool	21ML	N	L	1	4	4	4
2013	7/16/2013	1657	21	40	ML	Cool	21ML	N	L	2	22	22	22
2013	7/16/2013	1657	21	40	ML	Cool	21ML	N	L	3	24.7	24.7	24.7
2013	7/16/2013	1657	21	60	ML	Cool	21ML	N	L	1	1.7	1.7	1.7
2013	7/16/2013	1657	21	60	ML	Cool	21ML	N	L	2	1.3	1.3	1.3
2013	7/16/2013	1657	21	60	ML	Cool	21ML	N	L	3	3	3	3
2013	7/16/2013	1657	21	80	ML	Cool	21ML	N	L	1	54	54	54
2013	7/16/2013	1657	21	80	ML	Cool	21ML	N	L	2	50.3	50.3	50.3
2013	7/16/2013	1657	21	80	ML	Cool	21ML	N	L	3	36.3	36.3	36.3
2013	7/16/2013	1657	21	100	ML	Cool	21ML	N	L	1	9	9	9
2013	7/16/2013	1657	21	100	ML	Cool	21ML	N	L	2	7	7	7
2013	7/16/2013	1657	21	100	ML	Cool	21ML	N	L	3	8	8	8
2013	7/16/2013	1657	22	0	MH	Hot	22MH	N	U	1	2	2	2

2013	7/16/2013	1657	22	0	MH	Hot	22MH	N	U	2	1.7	1.7	1.7
2013	7/16/2013	1657	22	0	MH	Hot	22MH	N	U	3	2	2	2
2013	7/16/2013	1657	22	20	MH	Hot	22MH	N	U	1	16.3	16.3	16.3
2013	7/16/2013	1657	22	20	MH	Hot	22MH	N	U	2	6.7	6.7	6.7
2013	7/16/2013	1657	22	20	MH	Hot	22MH	N	U	3	3.3	3.3	3.3
2013	7/16/2013	1657	22	40	MH	Hot	22MH	N	U	1	1.3	1.3	1.3
2013	7/16/2013	1657	22	40	MH	Hot	22MH	N	U	2	2	2	2
2013	7/16/2013	1657	22	40	MH	Hot	22MH	N	U	3	3.3	3.3	3.3
2013	7/16/2013	1657	22	60	MH	Hot	22MH	N	U	1	9.3	9.3	9.3
2013	7/16/2013	1657	22	60	MH	Hot	22MH	N	U	2	8.3	8.3	8.3
2013	7/16/2013	1657	22	60	MH	Hot	22MH	N	U	3	29	29	29
2013	7/16/2013	1657	22	80	MH	Hot	22MH	N	U	1	60	60	60
2013	7/16/2013	1657	22	80	MH	Hot	22MH	N	U	2	60	60	60
2013	7/16/2013	1657	22	80	MH	Hot	22MH	N	U	3	60	60	60
2013	7/16/2013	1657	22	100	MH	Hot	22MH	N	U	1	3	3	3
2013	7/16/2013	1657	22	100	MH	Hot	22MH	N	U	2	5	5	5
2013	7/16/2013	1657	22	100	MH	Hot	22MH	N	U	3	8	8	8

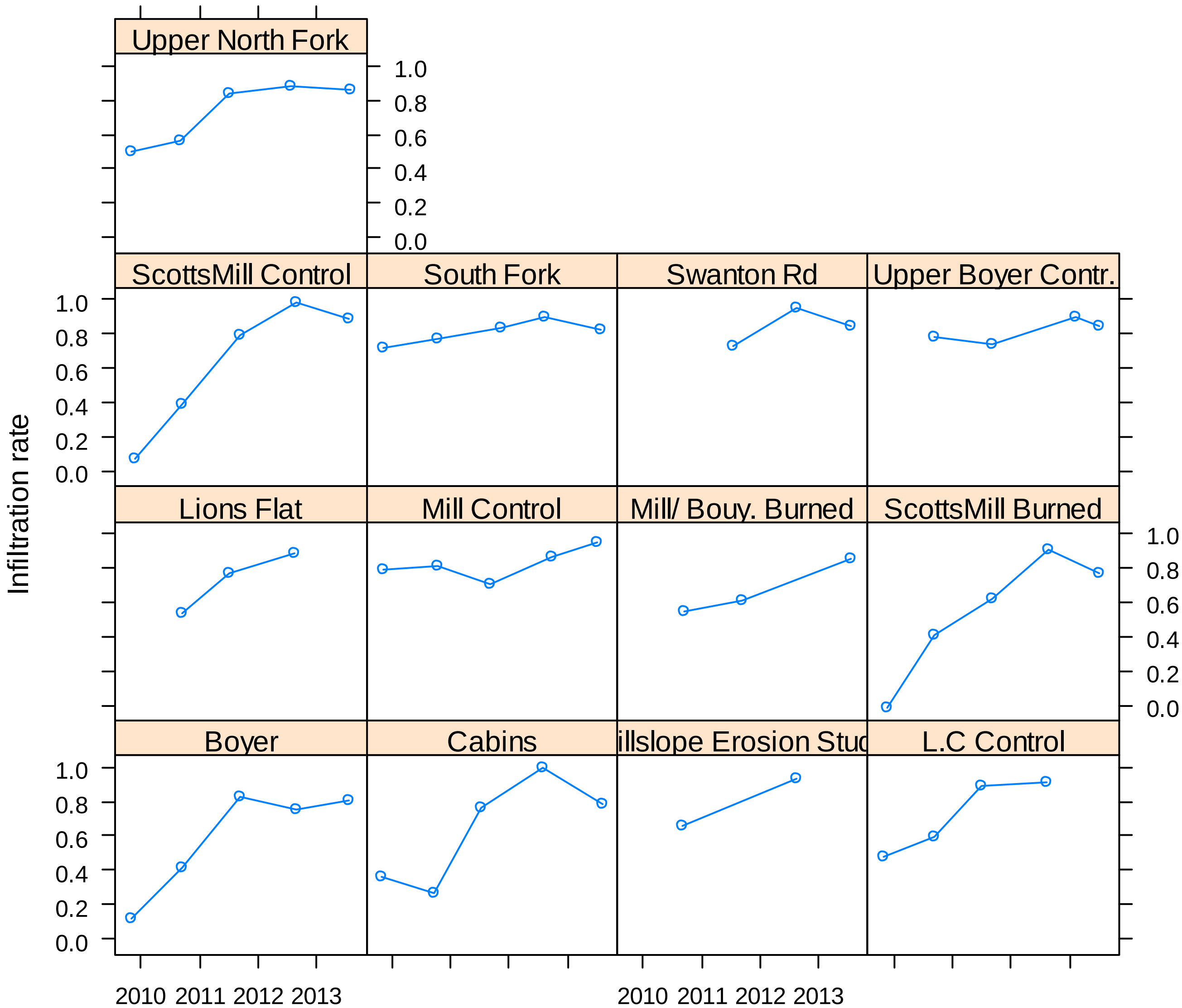
Appendix I. Rainfall Simulation Data utilized in R

Site Number	Site Name	Date	Rainfall Rate (L/min)	Runoff Rate (L/min)	Infiltration Rate (L/min)	Runoff Ratio	Soil Type	Slope (%)	Veg Type	Burn Severity	Year	Day Number from 1/1/2009	Simplified Veg Type
sitenum	sitename	date	rain.rate	ro.rate	inf.rate	ro.ratio	soil	slope	veg	burn.sev	year	time	v3
2N	Swanton Rd	7/13/2011	0.741	0.012	0.729	0.0160	MS	60	RW	None	2011	923	RW
2N	Swanton Rd	8/22/2012	0.962	0.010	0.951	0.0108	MS	60	RW	None	2012	1329	RW
2N	Swanton Rd	7/23/2013	0.857	0.011	0.846	0.0115	MS	60	RW	None	2013	1664	RW
4N	L.C Control	10/28/2009	0.622	0.140	0.482	0.1101	MS	70	RW/DF	None	2009	300	RW
4N	L.C Control	9/8/2010	0.711	0.121	0.590	0.1609	MS	88	RW/DF	None	2010	615	RW
4N	L.C Control	7/6/2011	0.910	0.020	0.890	0.0207	MS	65	RW/DF	None	2011	916	RW
4N	L.C Control	8/13/2012	0.928	0.017	0.911	0.0173	MS	70	RW/DF	None	2012	1320	RW
5M	Cabins	10/29/2009	0.737	0.374	0.363	0.3423	MS/SS	61	RW/DF	Moderate	2009	301	RW
5M	Cabins	9/15/2010	0.562	0.295	0.266	0.2597	MS/SS	65	RW/DF	Moderate	2010	622	RW
5M	Cabins	7/6/2011	0.760	0.000	0.760	0.0028	MS/SS	47	RW/DF	Moderate	2011	916	RW
5M	Cabins	7/26/2012	1.008	0.013	0.995	0.0121	MS/SS	63	RW/DF	Moderate	2012	1302	RW
5M	Cabins	8/2/2013	0.790	0.006	0.784	0.0063	MS/SS	56	RW/DF	Moderate	2013	1674	RW
6L	Upper North Fork	10/30/2009	0.877	0.373	0.504	0.3724	Granitic	50	RW/DF	Low	2009	302	RW
6L	Upper North Fork	9/2/2010	0.736	0.170	0.566	0.1987	Granitic	47	RW/DF	Low	2010	609	RW
6L	Upper North Fork	7/5/2011	0.840	0.000	0.840	0.0000	Granitic	40	RW/DF	Low	2011	915	RW
6L	Upper North Fork	7/25/2012	0.897	0.017	0.880	0.0168	Granitic	52	RW/DF	Low	2012	1301	RW
6L	Upper North Fork	7/31/2013	0.865	0.002	0.863	0.0022	Granitic	50	RW/DF	Low	2013	1672	RW
7M	South Fork	11/2/2009	0.793	0.081	0.713	0.1380	MS	54	RW/TO	Moderate	2009	305	RW
7M	South Fork	10/9/2010	0.905	0.136	0.769	0.1562	MS	48	RW/TO	Moderate	2010	646	RW
7M	South Fork	11/7/2011	0.843	0.014	0.829	0.0228	MS	47	RW/TO	Moderate	2011	1040	RW
7M	South Fork	8/14/2012	0.899	0.002	0.898	0.0013	MS	46	RW/TO	Moderate	2012	1321	RW
7M	South Fork	7/25/2013	0.830	0.011	0.819	0.0106	MS	45	RW/TO	Moderate	2013	1666	RW
8H	Boyer	11/4/2009	0.884	0.769	0.115	0.7009	MS	60	KP/MZ	High	2009	307	KP
8H	Boyer	9/10/2010	0.823	0.405	0.419	0.4049	MS	47	KP/MZ	High	2010	617	KP
8H	Boyer	9/8/2011	0.872	0.046	0.826	0.0406	MS	49	KP/MZ	High	2011	980	KP
8H	Boyer	8/29/2012	0.763	0.015	0.748	0.0167	MS	49	KP/MZ	High	2012	1336	KP
8H	Boyer	7/16/2013	0.846	0.045	0.801	0.0505	MS	50	KP/MZ	High	2013	1657	KP

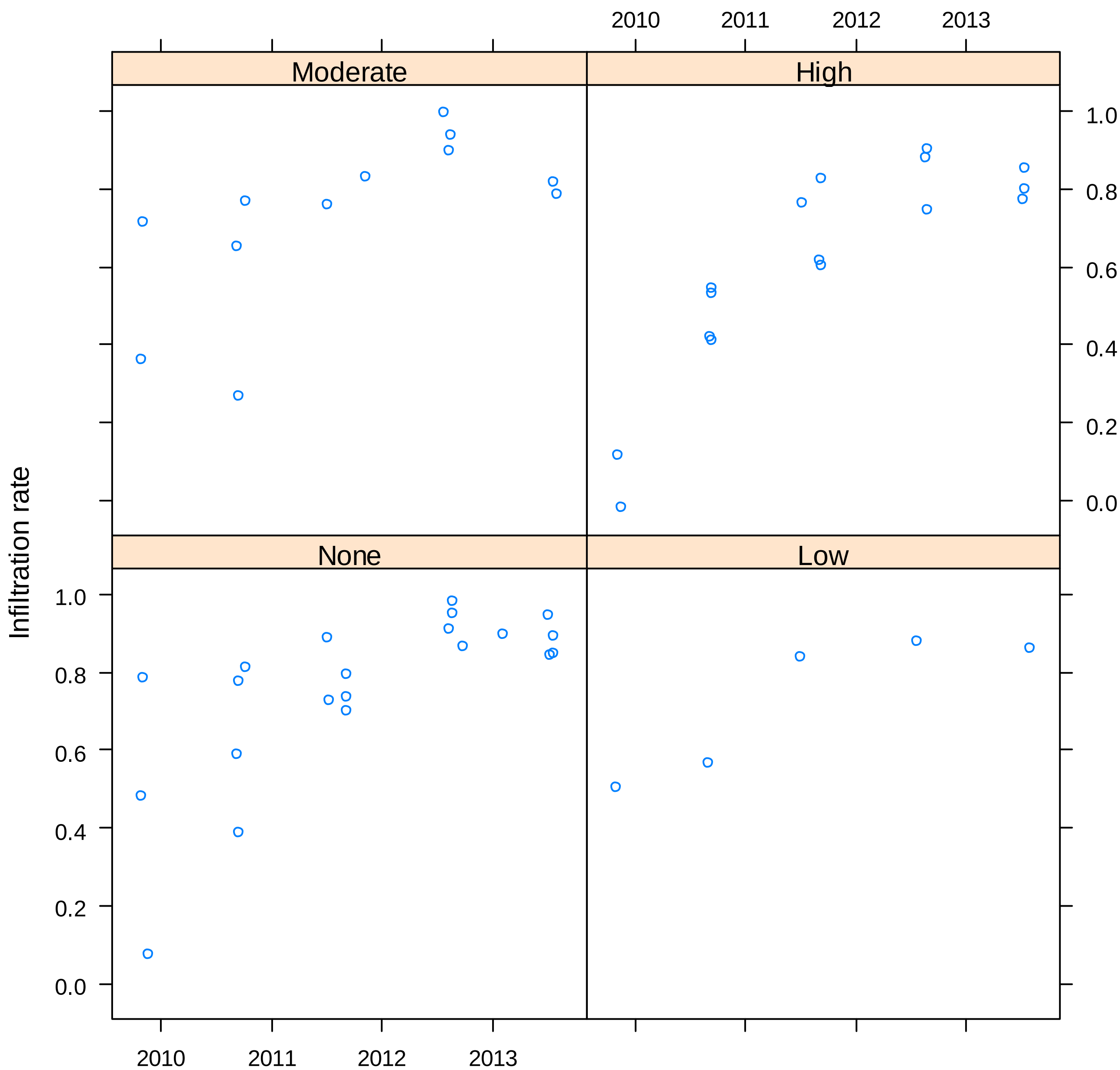
9N	Mill Control	11/4/2009	0.896	0.112	0.784	0.1150	Granitic	55	KP/MZ	None	2009	307	KP
9N	Mill Control	10/9/2010	0.896	0.082	0.814	0.0881	Granitic	60	KP/MZ	None	2010	646	KP
9N	Mill Control	9/7/2011	0.715	0.014	0.701	0.0185	MS/SS	65	KP/MZ	None	2011	979	KP
9N	Mill Control	9/25/2012	0.882	0.018	0.864	0.0184	MS/SS	65	KP/MZ	None	2012	1363	KP
9N	Mill Control	7/3/2013	0.963	0.014	0.948	0.0139	MS/SS	62	KP/MZ	None	2013	1644	KP
10H	ScottsMill Burned	11/18/2009	0.902	0.922	0.000	0.8160	MS	40	KP/MZ	High	2009	321	KP
10H	ScottsMill Burned	9/13/2010	0.760	0.349	0.411	0.2773	MS	45	KP/MZ	High	2010	620	KP
10H	ScottsMill Burned	9/6/2011	0.642	0.028	0.614	0.0335	MS	27	KP/MZ	High	2011	978	KP
10H	ScottsMill Burned	8/27/2012	0.933	0.031	0.902	0.0211	MS	36	KP/MZ	High	2012	1334	KP
10H	ScottsMill Burned	7/11/2013	0.792	0.021	0.771	0.0217	MS	36	KP/MZ	High	2013	1652	KP
11N	ScottsMill Control	11/19/2009	0.901	0.825	0.076	0.8281	MS	30	KP/MZ	None	2009	322	KP
11N	ScottsMill Control	9/13/2010	0.840	0.451	0.389	0.1896	MS	40	KP/MZ	None	2010	620	KP
11N	ScottsMill Control	9/6/2011	0.800	0.006	0.794	0.0075	MS	17	KP/MZ	None	2011	978	KP
11N	ScottsMill Control	8/23/2012	0.993	0.009	0.984	0.0081	MS	30	KP/MZ	None	2012	1330	KP
11N	ScottsMill Control	7/22/2013	0.914	0.022	0.892	0.0214	MS	36	KP/MZ	None	2013	1663	KP
12N	Upper Boyer Contr.	9/14/2010	0.860	0.084	0.776	0.0783	Granitic	38	TO	None	2010	621	TO
12N	Upper Boyer Contr.	9/7/2011	0.745	0.008	0.738	0.0081	Granitic	46	TO	None	2011	979	TO
12N	Upper Boyer Contr.	2/5/2013	0.900	0.002	0.898	0.0019	Granitic	46	TO	None	2013	1496	TO
12N	Upper Boyer Contr.	7/9/2013	0.851	0.008	0.843	0.0089	Granitic	45	TO	None	2013	1650	TO
13H	Lions Flat	9/15/2010	0.727	0.194	0.533	0.2180	MS	65	TO	High	2010	622	TO
13H	Lions Flat	7/7/2011	0.810	0.045	0.765	0.0515	MS	60	TO	High	2011	917	TO
13H	Lions Flat	8/20/2012	0.888	0.005	0.882	0.0055	MS	50	TO	High	2012	1327	TO
14M	Hillslope Erosion Study	9/8/2010	0.733	0.080	0.654	0.0874	MS	72	RW/TO	Moderate	2010	615	RW
14M	Hillslope Erosion Study	8/16/2012	0.939	0.002	0.937	0.0040	MS	70	RW/TO	Moderate	2012	1323	RW
15H	Mill/ Bouy. Burned	9/14/2010	0.856	0.310	0.546	0.2580	MS	38	KP/MZ	High	2010	621	KP
15H	Mill/ Bouy. Burned	9/8/2011	0.656	0.051	0.605	0.0650	MS	36	KP/MZ	High	2011	980	KP
15H	Mill/ Bouy. Burned	7/17/2013	0.890	0.035	0.855	0.0358	MS	35	KP/MZ	High	2013	1658	KP

Appendix J. R Code and output for rainfall simulation dataset.

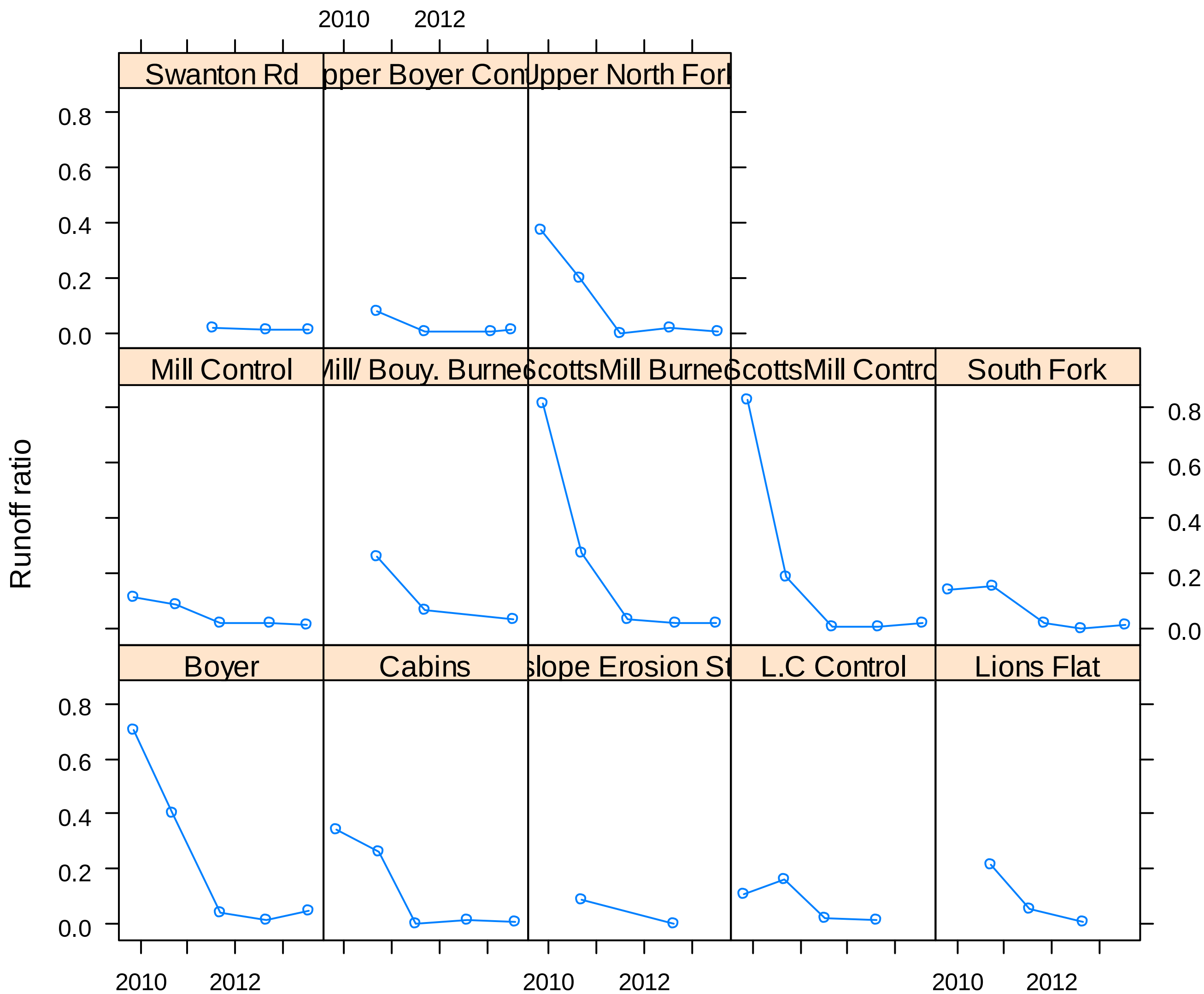
```
library("chron")
library("lattice")
library("car")
library(nlme)

raindat.old <- raindat
# Note well the replicated measurement at Upper Boyer in 2013 was entered
# in "rainsim2013.csv" as one averaged record instead of two.
# Runoff ratio was calc'ed as the ratio of total runoff to total rainfall
# Also the negative infiltration rate for site 10 in 2009 was set to zero.
raindat <- read.csv("rainsim2013.csv")
raindat$sitenum <- paste(format(raindat$sitenum,width=2),
substring(raindat$burn.sev,1,1), sep="")
raindat$sitenum <- ordered(raindat$sitenum)
raindat$burn.sev <- ordered(raindat$burn.sev, levels = c("None","Low","Moderate","High"))
raindat$date <- dates(as.character(raindat$date))
raindat$year <- years(raindat$date)
raindat$time <- as.numeric(raindat$date - dates("1/1/2009"))
# In the first round, results varied somewhat depending on the time shift
# raindat$time <- as.numeric(raindat$date)
xyplot(inf.rate ~ date | sitename, data=raindat, type="b",xlab="",ylab="Infiltration
rate")
```


Upper North Fork
ScottsMill Control
South Fork
Swanton Rd
Upper Boyer Contr.
Lions Flat
Mill Control
Mill/ Bouy. Burned
ScottsMill Burned
Boyer
Cabins
illslope Erosion Stud
L.C Control
Infiltration rate
0.0
0.2
0.4
0.6
0.8
1.0
2010 2011 2012 2013

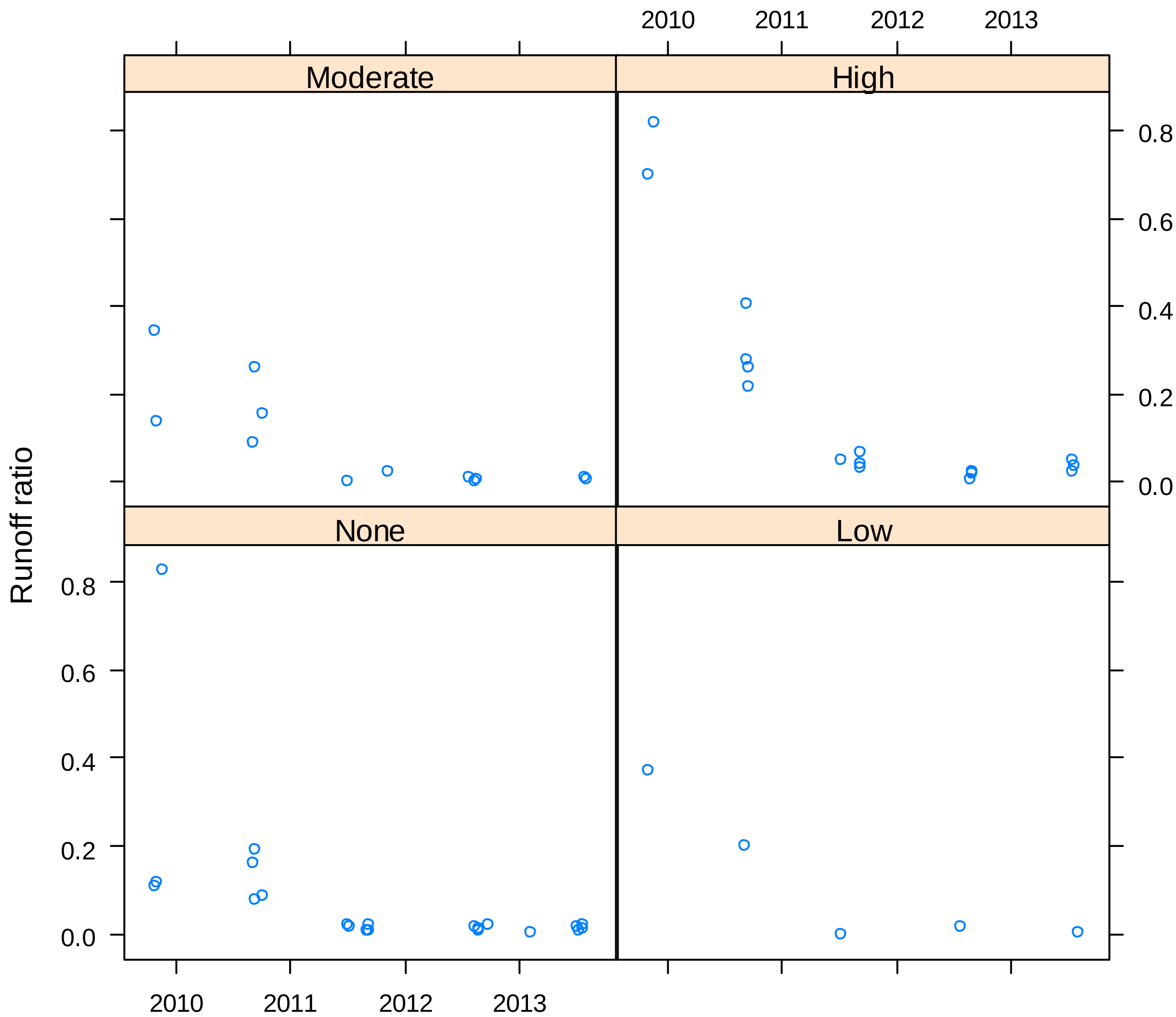
```
xyplot(inf.rate ~ date | burn.sev, data=raindat,ylab="Infiltration rate",xlab="")
```




```
xyplot(ro.ratio ~ date | sitename, data=raindat, type="b",xlab="",ylab="Runoff ratio")
```

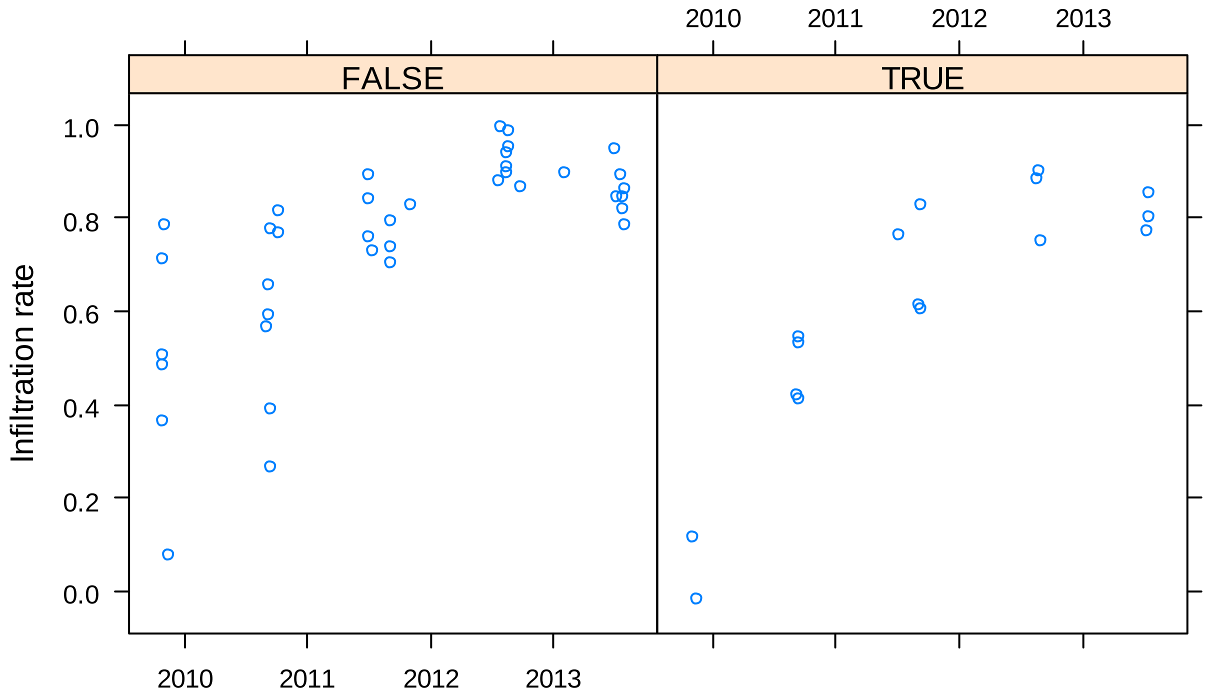



```
# Boyer and Scott's Mill Burned were both hot burns.  The other hot burns:  Mill/Bouy.
and Lions Flat were not measured in the first year so might have followed the same
pattern.  Cabins is a moderate burn and UNF is a Low intensity burn, and these do show
the expected reduced response but in the same pattern.  The bugaboo is that the Burned
and Control at Scott's Mill behaved identically.

xyplot(ro.ratio ~ date | burn.sev, data=raindat,xlab="",ylab="Runoff ratio")
```

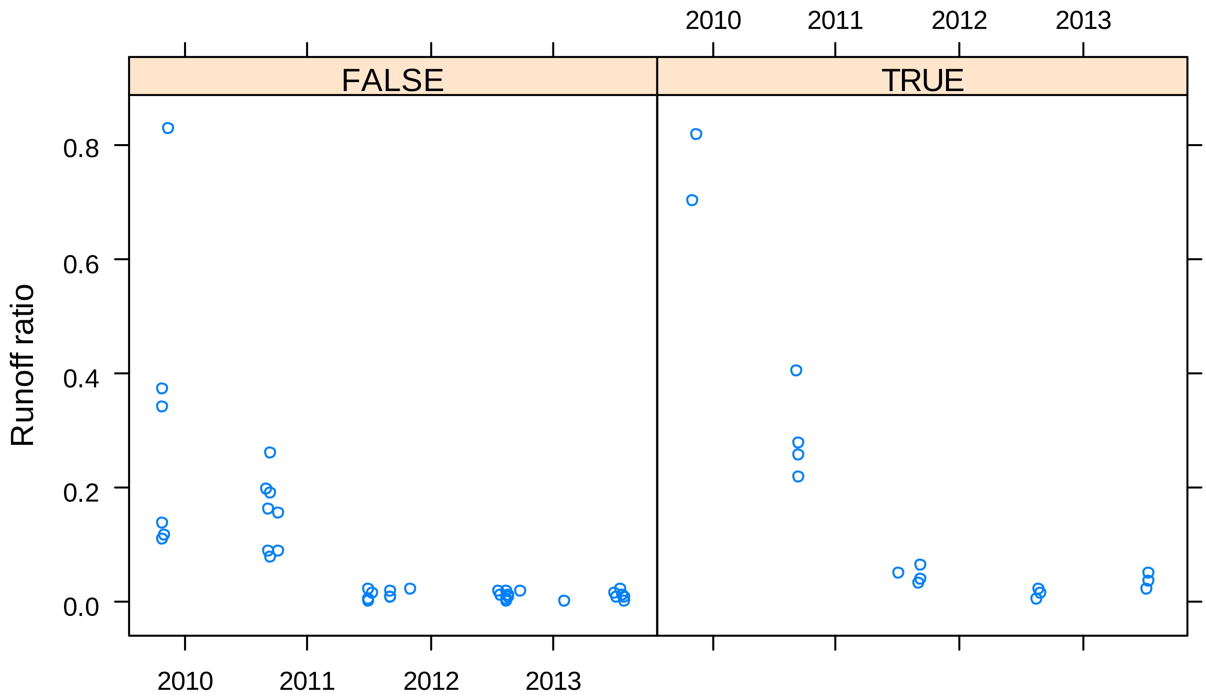



```
Bugaboo is the 2009 point in None (from ScottsMill Control)
Notes say "Natural Hydrophobicity Observed".  Could it be due to ash fall?

What would have really enhanced this study is more measurements in 2009.
```

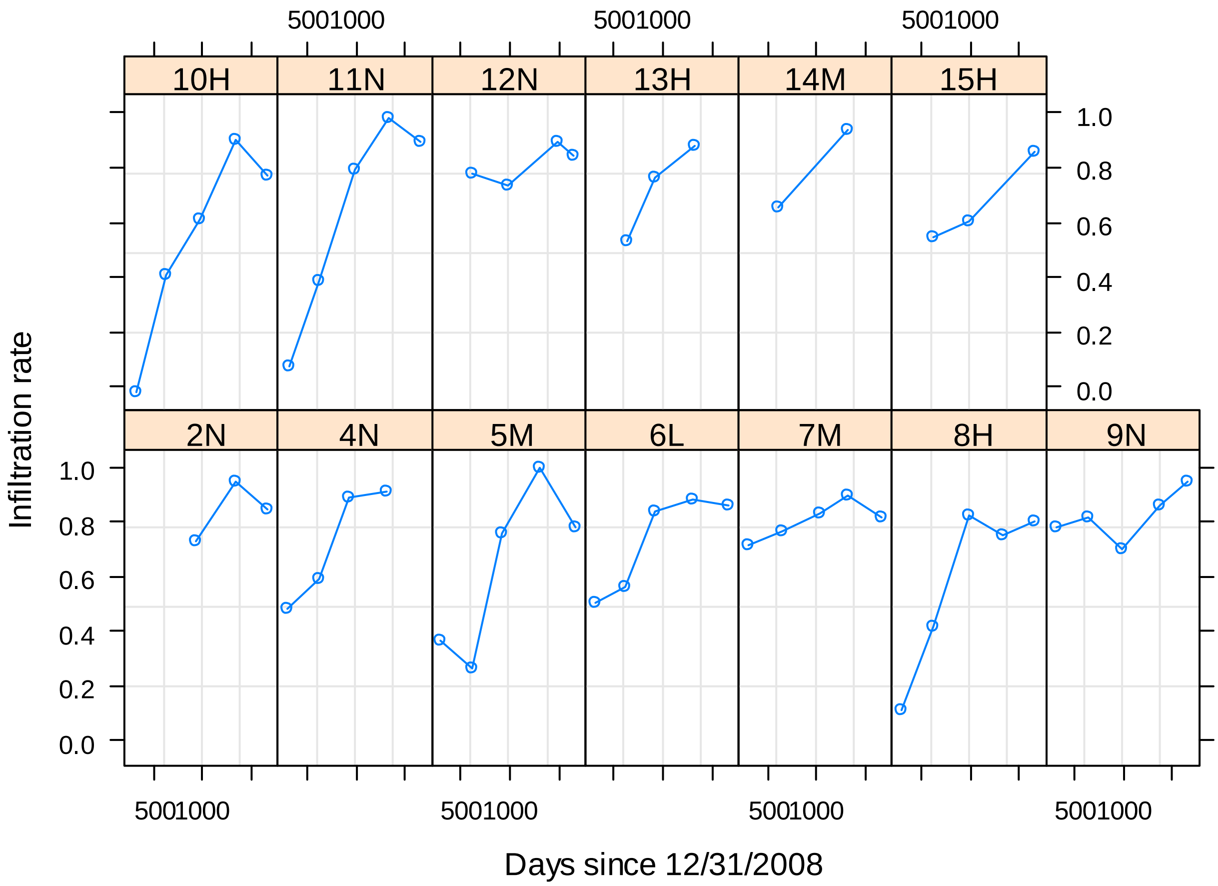
```
xyplot(inf.rate ~ date | burn.sev=="High", data=raindat, xlab="", ylab="Infiltration
rate")
```



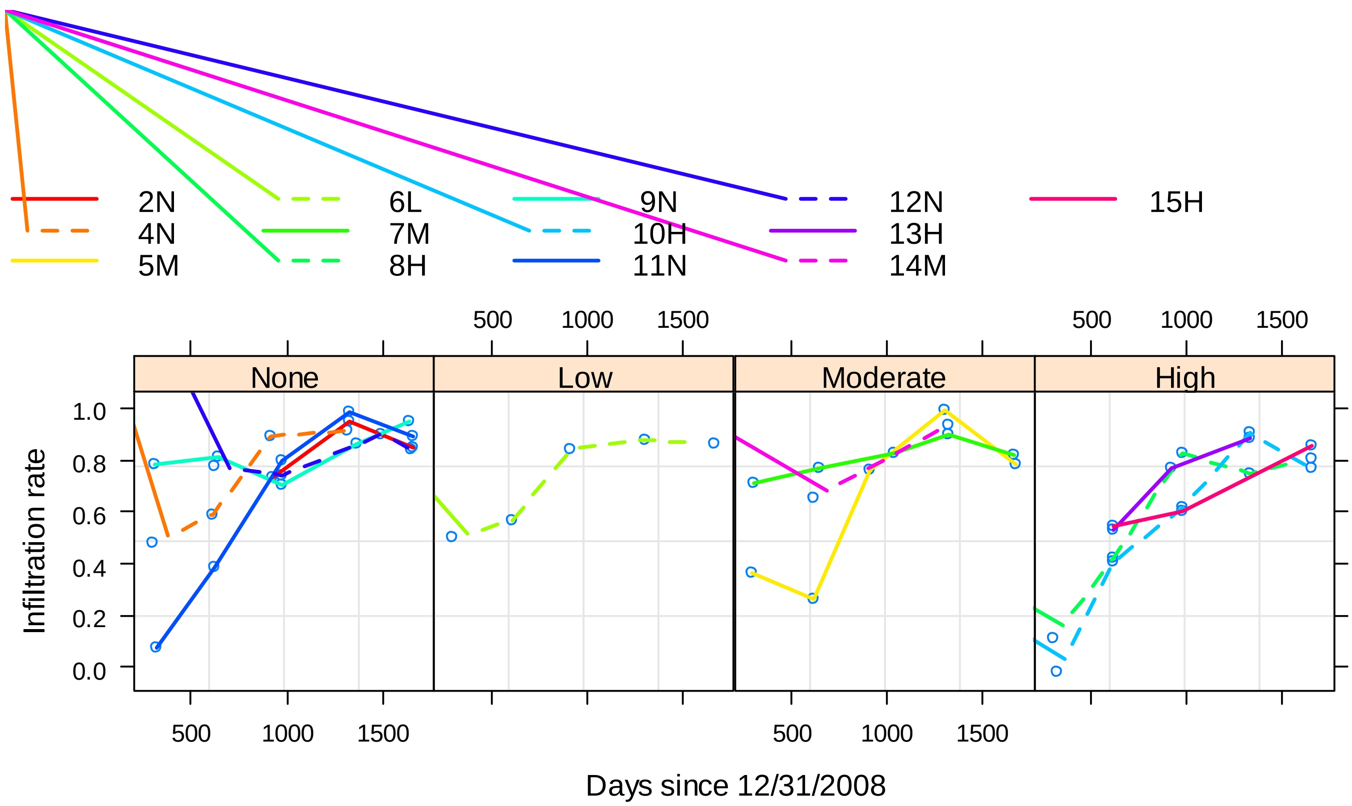

```
xyplot(ro.ratio ~ date | burned, data=raindat, xlab="", ylab="Runoff ratio")
```




```
raindat.gd <- groupedData(inf.rate ~ time | sitenum, outer = ~ burn.sev, data=raindat)

,
```

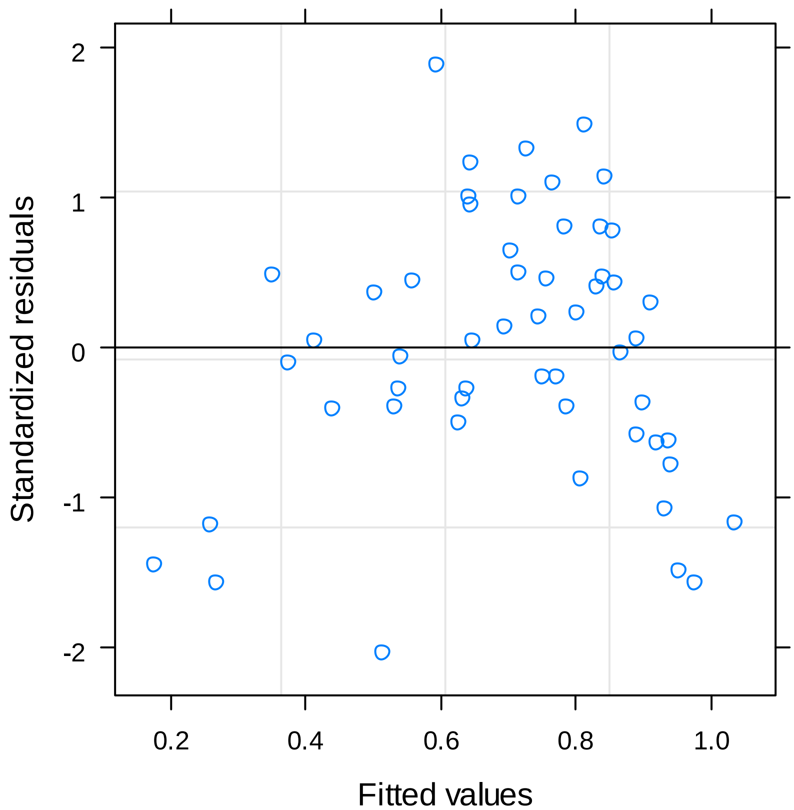



```
# The above is similar to an xy plot shown earlier.

superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(13)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
trellis.par.set("superpose.line",superpose.line)

plot(raindat.gd, outer=T, aspect=1, layout=c(4,1),xlab="Days since
12/31/2008",ylab="Infiltration rate")
```

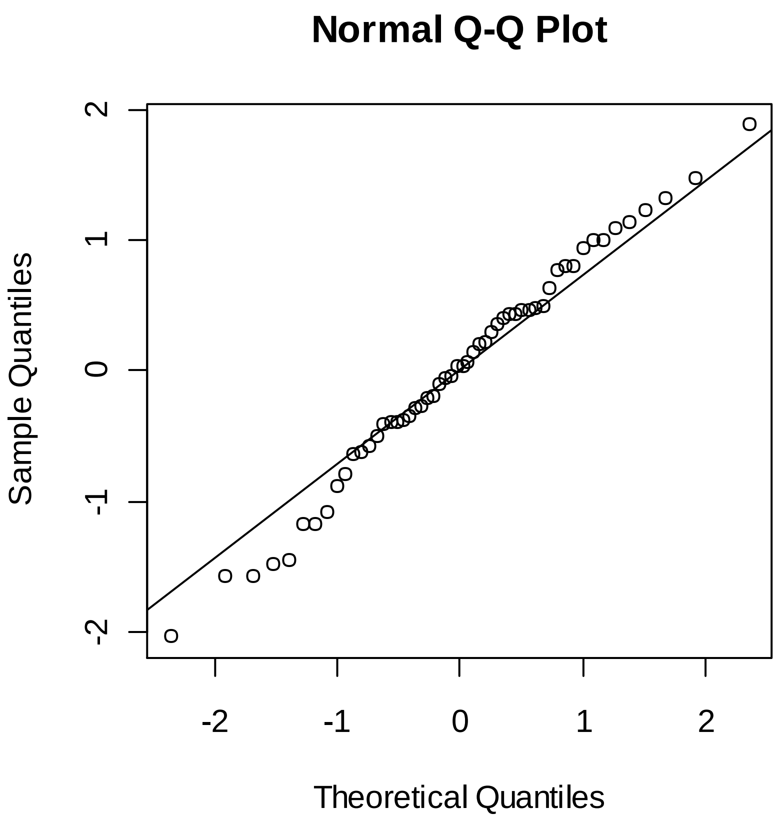



```
options(contrasts= c("contr.treatment", "contr.treatment"))
# Forces ordered factors to use treatment contrasts
# Note this affects the p-values in the summary
ir.fit1 <- lme(inf.rate ~  time * burn.sev, raindat.gd, random = ~ time)

anova(ir.fit1)
# Note: by default anova does sequential tests, i.e. each p-value is the significance of
the given variable when added to a model defined by the variables listed above that
variable. i.e. it tests the variables entering the model in the specific sequence shown
              numDF denDF   F-value p-value
(Intercept)       1    37 1430.7228  <.0001
time              1    37   30.6441  <.0001
burn.sev          3     9    1.3518  0.3182
time:burn.sev     3    37    0.4545  0.7157
# Only time is significant
# Burn severity and its interaction with time is not

anova(ir.fit1,type="marginal")
# The marginal p-values compare the full model to a model that omits the variable on that
line. i.e. it tests each variable as the final variable added to the model.
              numDF denDF   F-value p-value
(Intercept)       1    37 12.137905  0.0013
time              1    37  8.816425  0.0052
```

```
burn.sev            3      9  0.902008  0.4773
time:burn.sev       3     37  0.454490  0.7157
```



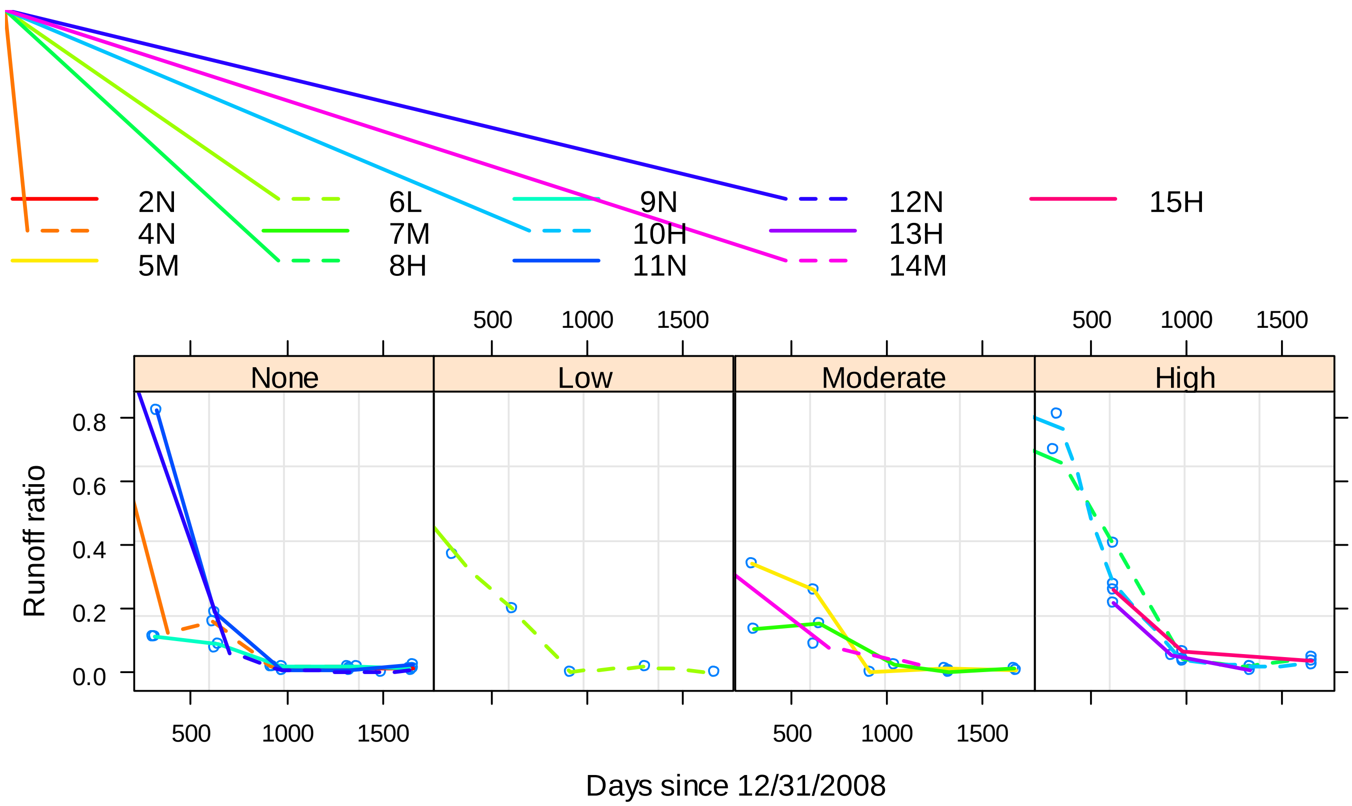

```
qqnorm(resid(ir.fit1,type="p"))
qqline(resid(ir.fit1,type="p"))
```



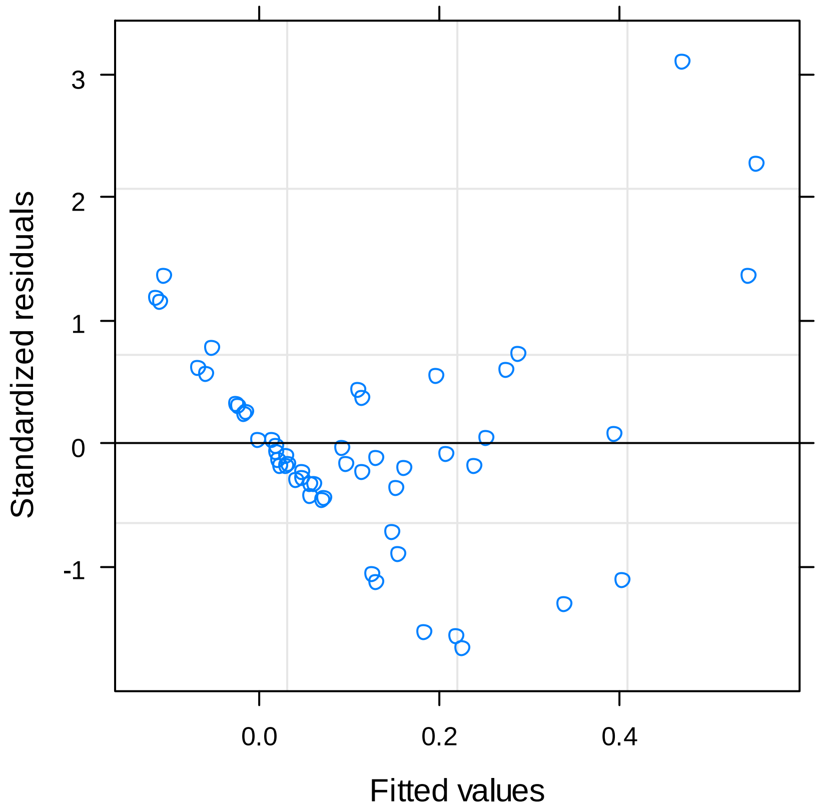

```
ir.fit1a <- update(ir.fit1, weights = varPower())
anova(ir.fit1,ir.fit1a)
         Model df      AIC      BIC    logLik   Test   L.Ratio p-value
ir.fit1      1 12 42.09187 64.03557 -9.045936
ir.fit1a     2 13 43.38869 67.16103 -8.694347 1 vs 2 0.7031784  0.4017
# No need for the variance function; residuals distribution is OK

# Try contrasting High burn severity with all the other levels
ir.fit2 <- lme(inf.rate ~  time * (burn.sev=="High"), raindat.gd, random = ~ time)

anova(ir.fit2)
                        numDF denDF   F-value p-value
(Intercept)                 1    39 1552.4170  <.0001
time                        1    39   37.2899  <.0001
burn.sev == "High"          1    11    4.5467  0.0564
time:burn.sev == "High"     1    39    1.6424  0.2076

anova(ir.fit2,type="marginal")
                        numDF denDF   F-value p-value
(Intercept)                 1    39 27.480131  <.0001
time                        1    39 19.029008  0.0001
burn.sev == "High"          1    11  3.334351  0.0951
time:burn.sev == "High"     1    39  1.642429  0.2076

# There is not a significant difference in the rate of change of infiltration between
High burn severity and all the others.
```

```
# But of course there is a time trend in the High severity burns, and it seems more
pronounced than at least the Moderate and Low burn levels:

summary(lme(inf.rate ~  time, raindat.gd, subset=burn.sev=="High", random = ~ time))

Fixed effects: inf.rate ~ time
                 Value  Std.Error DF  t-value p-value
(Intercept) 0.13776845 0.10190876 11 1.351880  0.2036
time        0.00048317 0.00008477 11 5.699884  0.0001
Number of Observations: 16
Number of Groups: 4

summary(lme(inf.rate ~  time, raindat.gd, subset=burn.sev=="Moderate", random = ~ time))
                Value  Std.Error DF  t-value p-value
(Intercept) 0.4606963 0.17103663  8 2.693553  0.0273
time        0.0002825 0.00013327  8 2.119978  0.0668
Number of Observations: 12
Number of Groups: 3

summary(lme(inf.rate ~  time, raindat.gd, subset=burn.sev=="Low", random = ~ time))
                Value  Std.Error DF  t-value p-value
(Intercept) 0.4485548 0.15037046  3 2.982998  0.0585
time        0.0002939 0.00013977  3 2.102499  0.1263
Number of Observations: 5
Number of Groups: 1

summary(lme(inf.rate ~  time, raindat.gd, subset=burn.sev=="None", random = ~ time))
                Value  Std.Error DF  t-value p-value
(Intercept) 0.4672122 0.14662133 15 3.186523  0.0061
time        0.0002936 0.00011443 15 2.565956  0.0215
Number of Observations: 21
Number of Groups: 5

# But as the coefficient of time:burn.sevHigh in ir.fit1 shows, High and None aren't
significantly different

time:burn.sevHigh      0.0001525 0.00015295 37  0.996788  0.3253

# WE could have done this with simple regression, although it ignores the relation
between observations from the same site.  Conclusions are similar though.

ir.lm1 <- lm(inf.rate ~ time * burn.sev, data=raindat)
Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)            4.223e-01  8.330e-02   5.069 6.96e-06 ***
time                   3.246e-04  7.380e-05   4.398 6.41e-05 ***
burn.sevLow            2.630e-02  1.744e-01   0.151   0.8808
burn.sevModerate       2.367e-02  1.334e-01   0.177   0.8599
burn.sevHigh          -3.057e-01  1.264e-01  -2.418   0.0196 *
time:burn.sevLow      -3.075e-05  1.604e-04  -0.192   0.8488
time:burn.sevModerate -3.172e-05  1.213e-04  -0.262   0.7949
time:burn.sevHigh      1.732e-04  1.143e-04   1.515   0.1366
# Looks like high is different than None this time, but the interaction still is NOT

# Contrast None and High directly
```

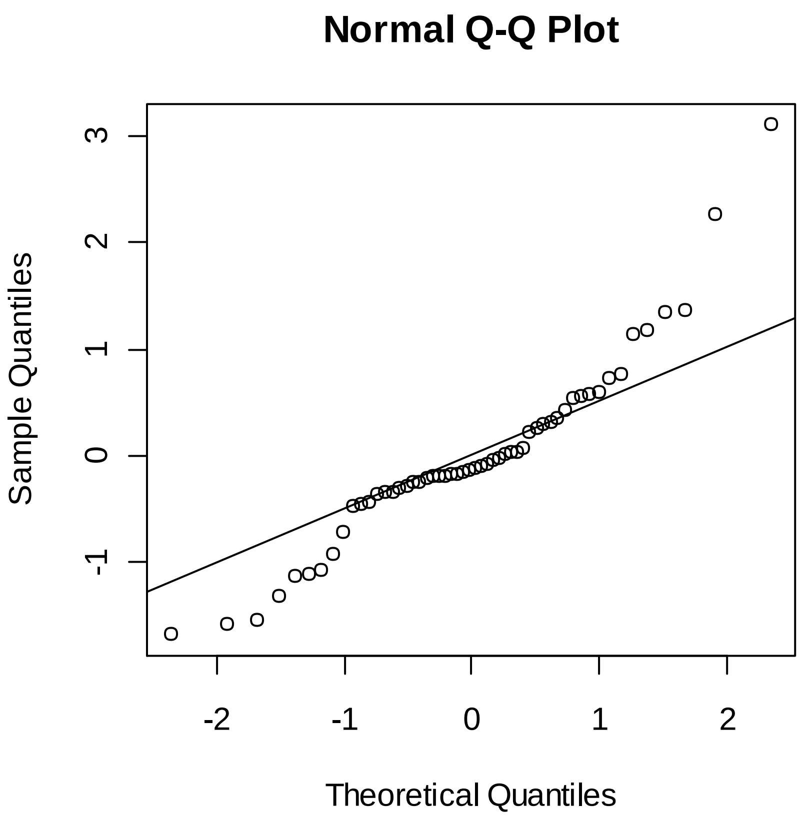
```
summary(lm(inf.rate ~ time * burn.sev, data=raindat, subset=burn.sev %in%
c("None","High")))
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)        4.223e-01  8.250e-02   5.119 1.30e-05 ***
time               3.246e-04  7.309e-05   4.441 9.48e-05 ***
burn.sevHigh      -3.057e-01  1.252e-01  -2.442   0.0202 *
time:burn.sevHigh  1.732e-04  1.132e-04   1.530   0.1356
# Agrees with above except in degrees of freedom

# Contrast High and all others
summary(lm(inf.rate ~ time * (burn.sev=="High"), data=raindat))
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                  4.336e-01  5.747e-02   7.545 8.46e-10 ***
time                         3.106e-04  5.190e-05   5.983 2.32e-07 ***
burn.sev == "High"TRUE      -3.171e-01  1.079e-01  -2.939  0.00498 **
time:burn.sev == "High"TRUE  1.872e-04  9.856e-05   1.899  0.06330 .
# The interaction is NOT significant, so the time trend does not depend on burn severity

# Back to mixed effects modeling. What happens if Scotts Mill Control is dropped from the
analysis?
anova(lme(inf.rate ~  time * burn.sev, raindat.gd, random = ~ time, subset=
sitenum!="11N"))
              numDF denDF   F-value p-value
(Intercept)       1    33 1368.3174  <.0001
time              1    33   37.4461  <.0001
burn.sev          3     8    1.8869  0.2102
time:burn.sev     3    33    1.4896  0.2354
# Burn severity and its interaction is still not significant

# What if just observation 38 is dropped from the analysis
anova(lme(inf.rate ~  time * burn.sev, raindat.gd, random = ~ time, subset= -38))
              numDF denDF   F-value p-value
(Intercept)       1    36 1484.1907  <.0001
time              1    36   39.2095  <.0001
burn.sev          3     9    1.7686  0.2229
time:burn.sev     3    36    0.9831  0.4115

# Omit Scotts Mill Control from the model that contrasts High with all the others
anova(lme(inf.rate ~  time * (burn.sev=="High"), raindat.gd, random = ~ time,
subset=sitenum!="11N"))
                        numDF denDF   F-value p-value
(Intercept)                 1    35 1479.4521  <.0001
time                        1    35   43.4146  <.0001
burn.sev == "High"          1    10    5.7872   0.037
time:burn.sev == "High"     1    35    4.5493   0.040
# Only now does it look barely significant.

=================================================================================
# What about runoff ratio as a response

raindat.gd2 <- groupedData(ro.ratio ~ time | sitenum, outer = ~ burn.sev, data=raindat)
plot(raindat.gd2, outer=T, aspect=1, layout=c(4,1), xlab="Days since
12/31/2008",ylab="Runoff ratio")
```



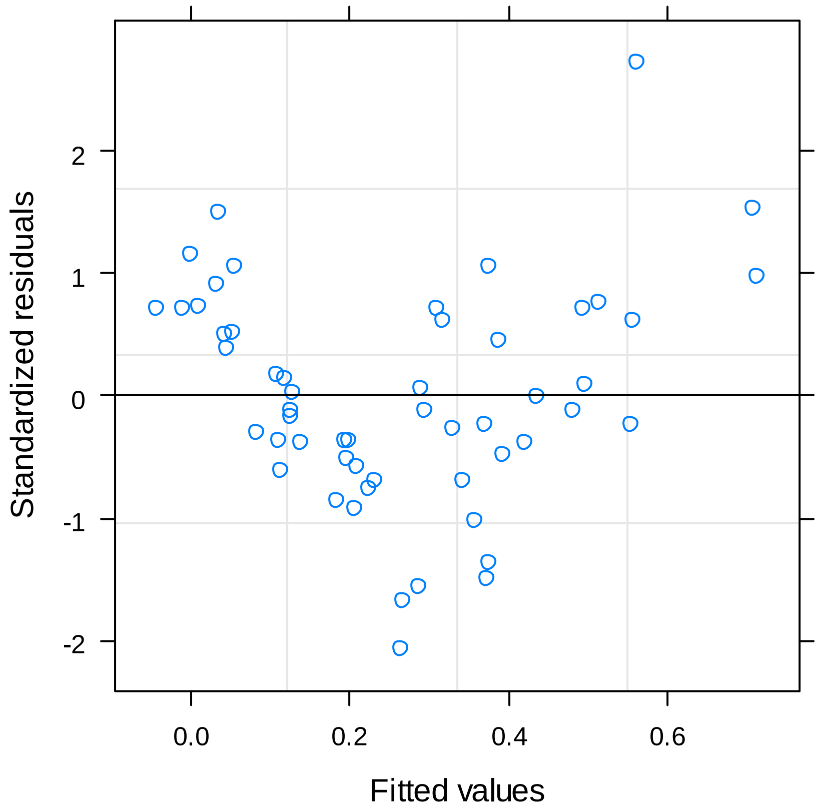

```
# So 2012 and 2013 look like post-recovery years similar to 2011 (irrespective of burn
intensity.  This analysis looks even more sensitive to the 2009 point at Scotts Mill
Control

ro.fit1 <- lme(ro.ratio ~  time * burn.sev, raindat.gd2, random = ~ time)
plot(ro.fit1)
```



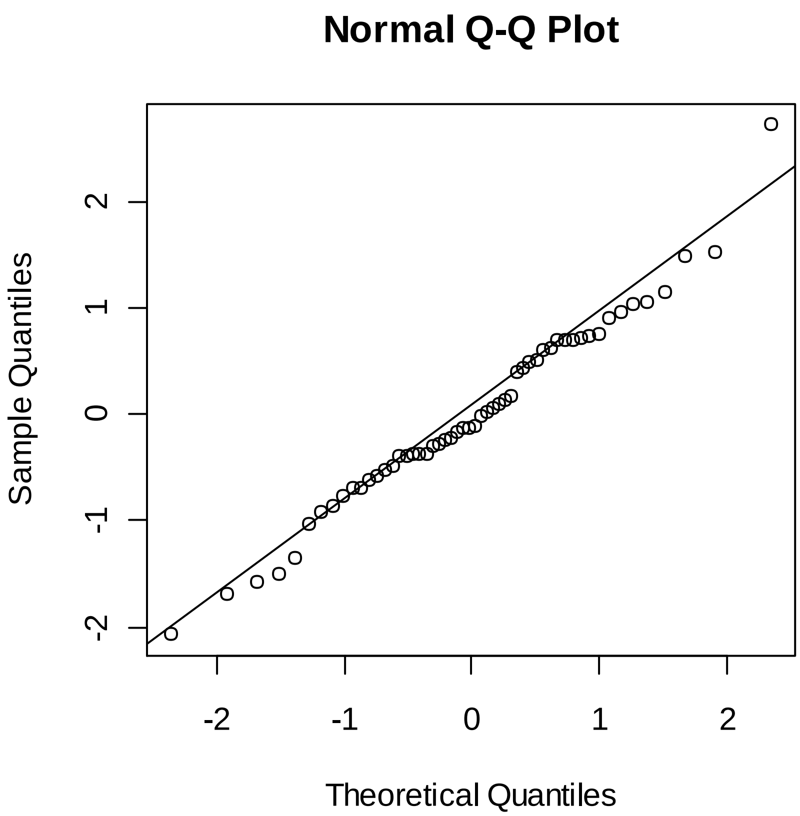

```
qqnorm(resid(ro.fit1,type="p"))
qqline(resid(ro.fit1,type="p"))
```




```
# Not a good residuals distribution
# Try transforming the response; cannot do logarithms because one of the responses=0
ro.fit2 <- lme(sqrt(ro.ratio) ~  time * burn.sev, raindat.gd2, random = ~ time)
```



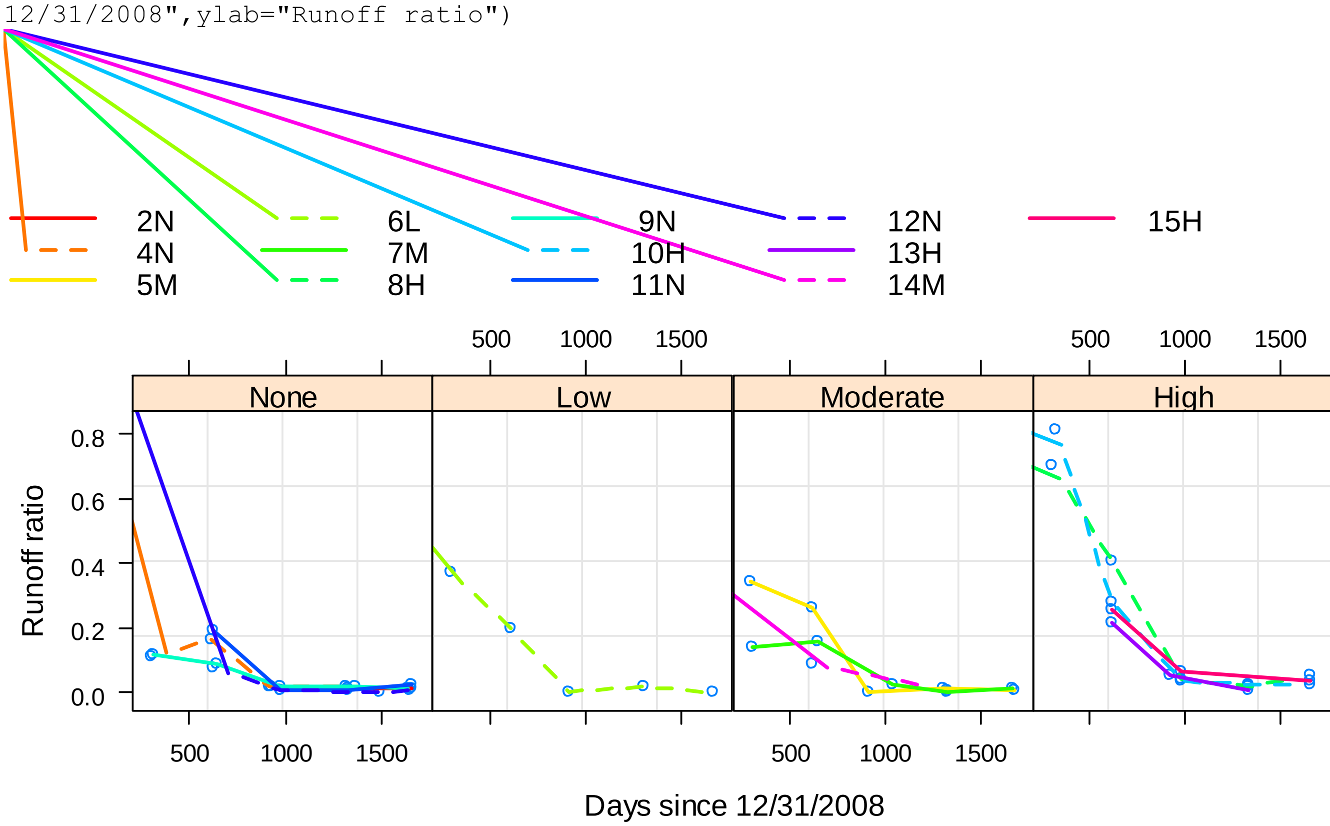
Standardized residuals
Fitted values
2
1
0
-1
-2
0.0
0.2
0.4
0.6



Residuals are much closer to a normal distribution. The outlier is 11N 2009.

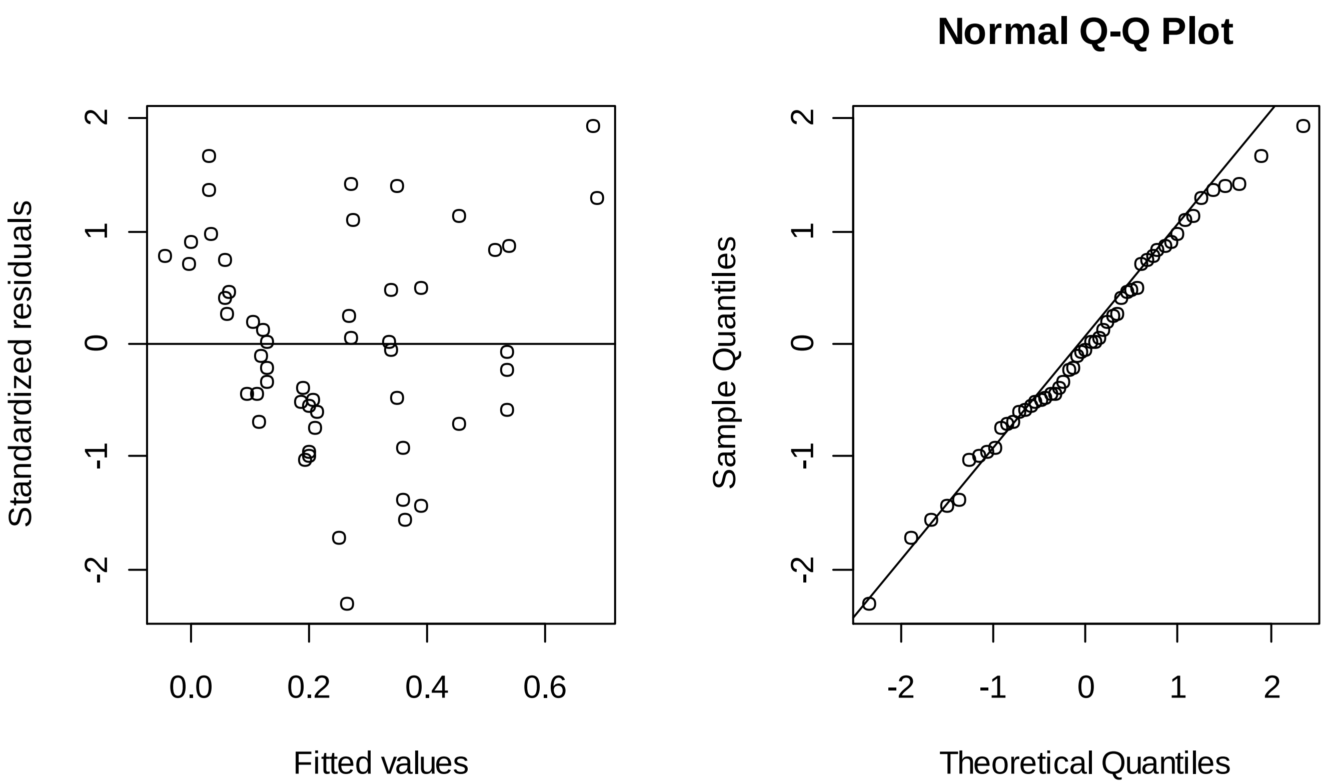
```
anova(ro.fit2)
              numDF denDF   F-value p-value
(Intercept)       1    37 110.07016  <.0001
time              1    37  56.27666  <.0001
burn.sev          3     9   1.89646  0.2007
time:burn.sev     3    37   0.87861  0.4610
anova(ro.fit2,type="marginal")
              numDF denDF   F-value p-value
(Intercept)       1    37 27.779296  <.0001
time              1    37 13.178069  0.0009
burn.sev          3     9  1.737430  0.2288
time:burn.sev     3    37  0.878608  0.4610
# Burn severity and its interaction are not significant

# Contrast High burn severity with others
ro.fit2a <- lme(sqrt(ro.ratio) ~  time * (burn.sev=="High"), raindat.gd2, random = ~
time)
anova(ro.fit2a,type="sequential")
                          numDF denDF   F-value p-value
(Intercept)                   1    39 139.97077  <.0001
time                          1    39  67.20444  <.0001
burn.sev == "High"            1    11   7.01215  0.0227
time:burn.sev == "High"       1    39   2.48822  0.1228

# Contrast Unburned with others
```

```
ro.fit2b <- lme(sqrt(ro.ratio) ~  time * (burn.sev=="None"), raindat.gd2, random = ~time)
anova(ro.fit2b)
                          numDF denDF  F-value p-value
(Intercept)                   1    39 75.24670  <.0001
time                          1    39 54.58454  <.0001
burn.sev == "None"            1    11  0.72694  0.4121
time:burn.sev == "None"       1    39  1.62048  0.2106

# Contrast "High" and "None"
ro.fit2c <- lme(sqrt(ro.ratio) ~  time * (burn.sev=="High"), raindat.gd2, random = ~time,
subset=burn.sev %in% c("High","None"))
anova(ro.fit2c)
                          numDF denDF  F-value p-value
(Intercept)                   1    26 73.92108  <.0001
time                          1    26 34.16429  <.0001
burn.sev == "High"            1     7  3.64807  0.0978
time:burn.sev == "High"       1    26  2.15876  0.1538
# Burn severity does not affect the trend in any of the above (interaction NS)

# What if just one outlier is discarded, first year at site 11N
plot(raindat.gd2, outer=T, aspect=1, layout=c(4,1), subset=-38,xlab="Days since
12/31/2008",ylab="Runoff ratio")
```




```
ro.fit3 <- lme(sqrt(ro.ratio) ~  time * burn.sev, raindat.gd2, random = ~ time, subset=-
38)
```

```
par(mfrow=c(1,2))
plot(fitted(ro.fit3), resid(ro.fit3,type="p"),xlab="Fitted values",ylab="Standardized
residuals")
abline(0,0)
qqresid(ro.fit3)
```




```
# Very nice distribution of residuals

anova(ro.fit3)
              numDF denDF   F-value p-value
(Intercept)       1    36 251.61640  <.0001
time              1    36  97.94409  <.0001
burn.sev          3     9   5.44986  0.0206
time:burn.sev     3    36   3.62551  0.0220

anova(ro.fit3,type="marginal")
              numDF denDF  F-value p-value
(Intercept)       1    36 35.04656  <.0001
time              1    36 12.15793  0.0013
burn.sev          3     9  6.83808  0.0107
time:burn.sev     3    36  3.62551  0.0220
# NOW there is a significant interaction


# Only in the runoff model and only when observation 38 is dropped does there appear to
ba a significant interaction between burn severity and time.  This makes sense looking at
the data
```

For infiltration rate models, the interaction was only significant when (1) Scotts Mill Control was entirely removed from the analysis, AND only in the model contrasting "High" burn severity with all others. And only marginally significant (p=0.04). Hence not very convincing at all.

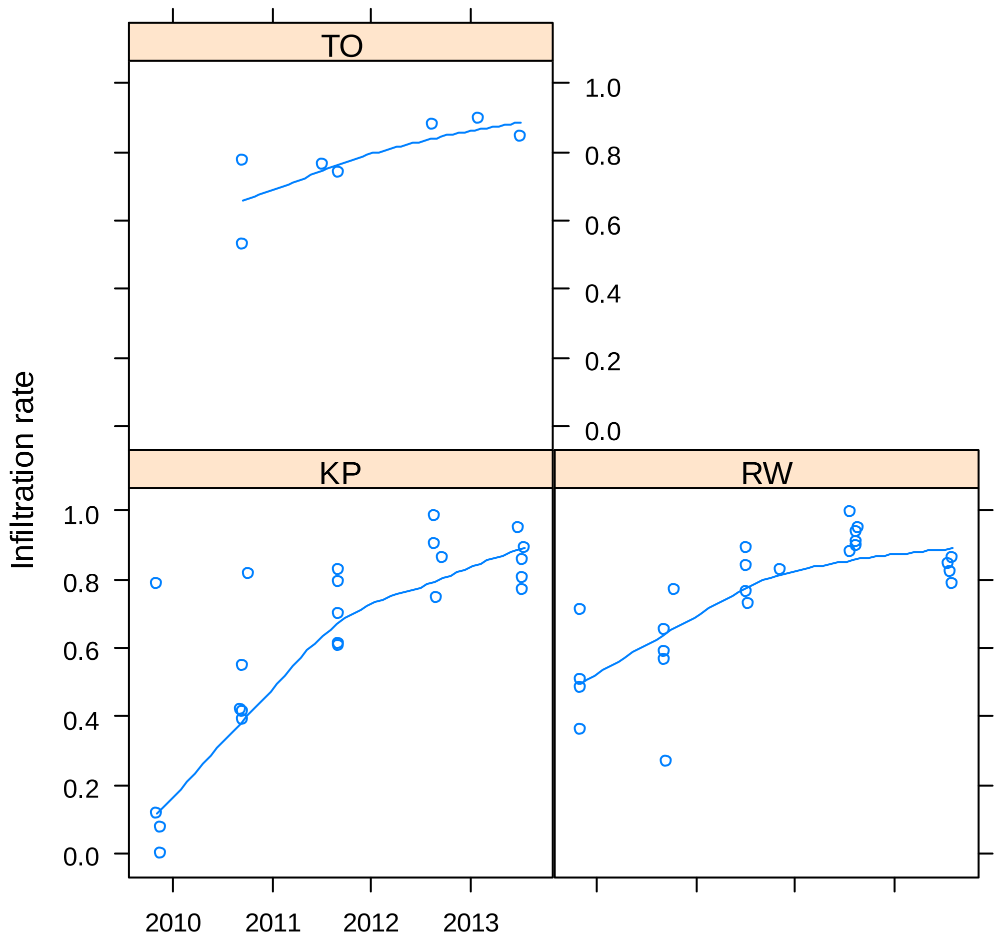
Wikipedia calls this multilevel modeling
http://en.wikipedia.org/wiki/Multilevel_modeling_for_repeated_measures
More generally it's a subcategory of mixed-effects models

If we had measurements from every site each year it could be analyzed as a repeated measures nested ANOVA, with sites nested within burn levels. But the unbalanced nature makes it even more difficult to analyze than usual for repeated measures analyses. You can disaggregate and analyze each burn level individually (which I did above using ***subset***), but you still have a random effect from each site; it doesn't represent the fact that each site might have its own regression line. Or you could ignore that and just look for differences between the trends at each burn level (which I did above using ***lm***).

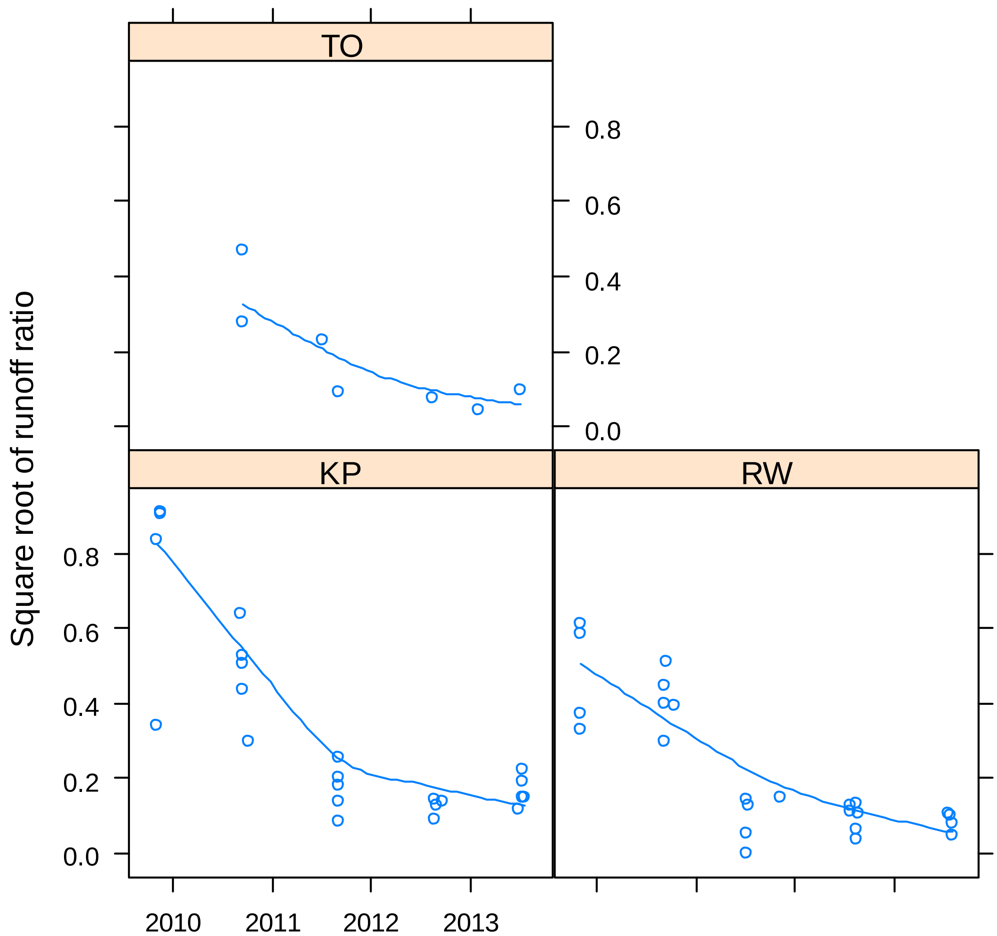
Recommend coding so that all site descriptors are invariant at a site. I've done that for burn severity and some others.
Refer to section 3.2.1 Bodyweight data set pp 104-106, 221, 427

II. Analyze fixed-effects of veg type and slope

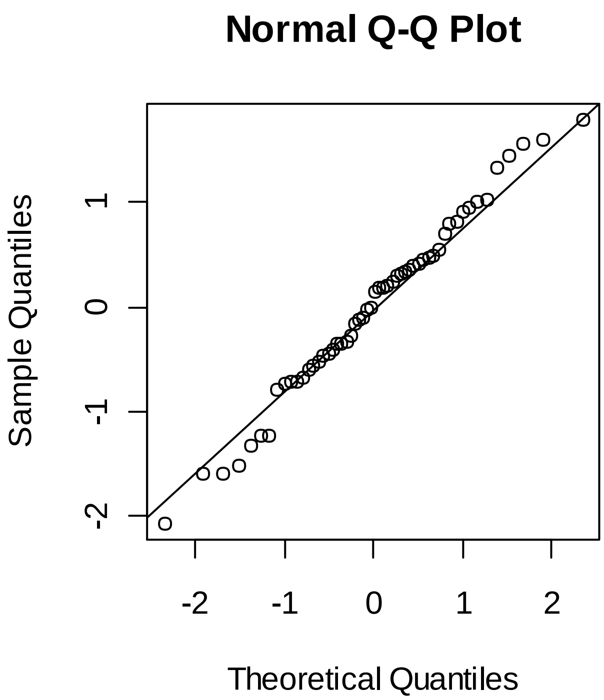
```
> table(raindat$veg)

KP/manz.       RW    RW/DF    RW/TO       TO
      23        3       14        7        7

# Define coarse veg type
raindat$v3 <- factor(substr(raindat$veg,1,2))
raindat.gd3 <- groupedData(inf.rate ~ time | sitenum, outer = ~ v3, data=raindat.gd)


> table(raindat$v3)

KP RW TO
23 24  7

# Look at the time trend for each veg type

library(lattice)

xyplot(inf.rate ~ date | v3, data=raindat,ylab="Infiltration rate",xlab="",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
```

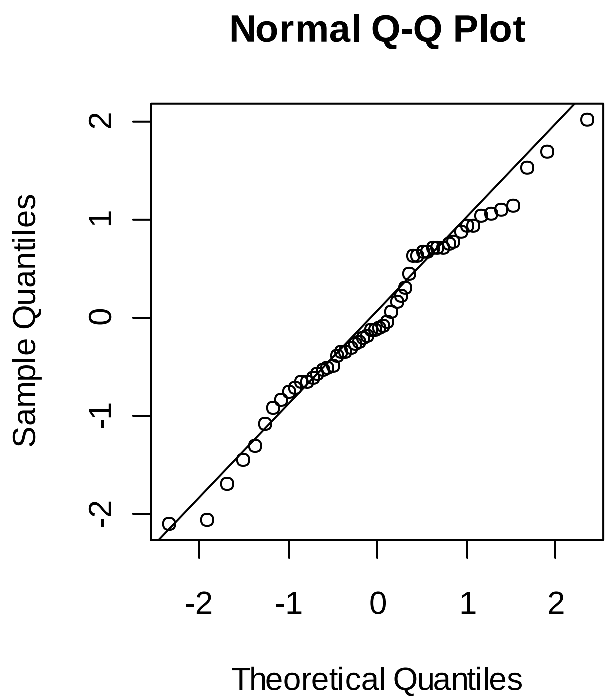



```
xyplot(sqrt(ro.ratio) ~ date | v3, data=raindat,ylab="Square root of runoff
ratio",xlab="",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
```

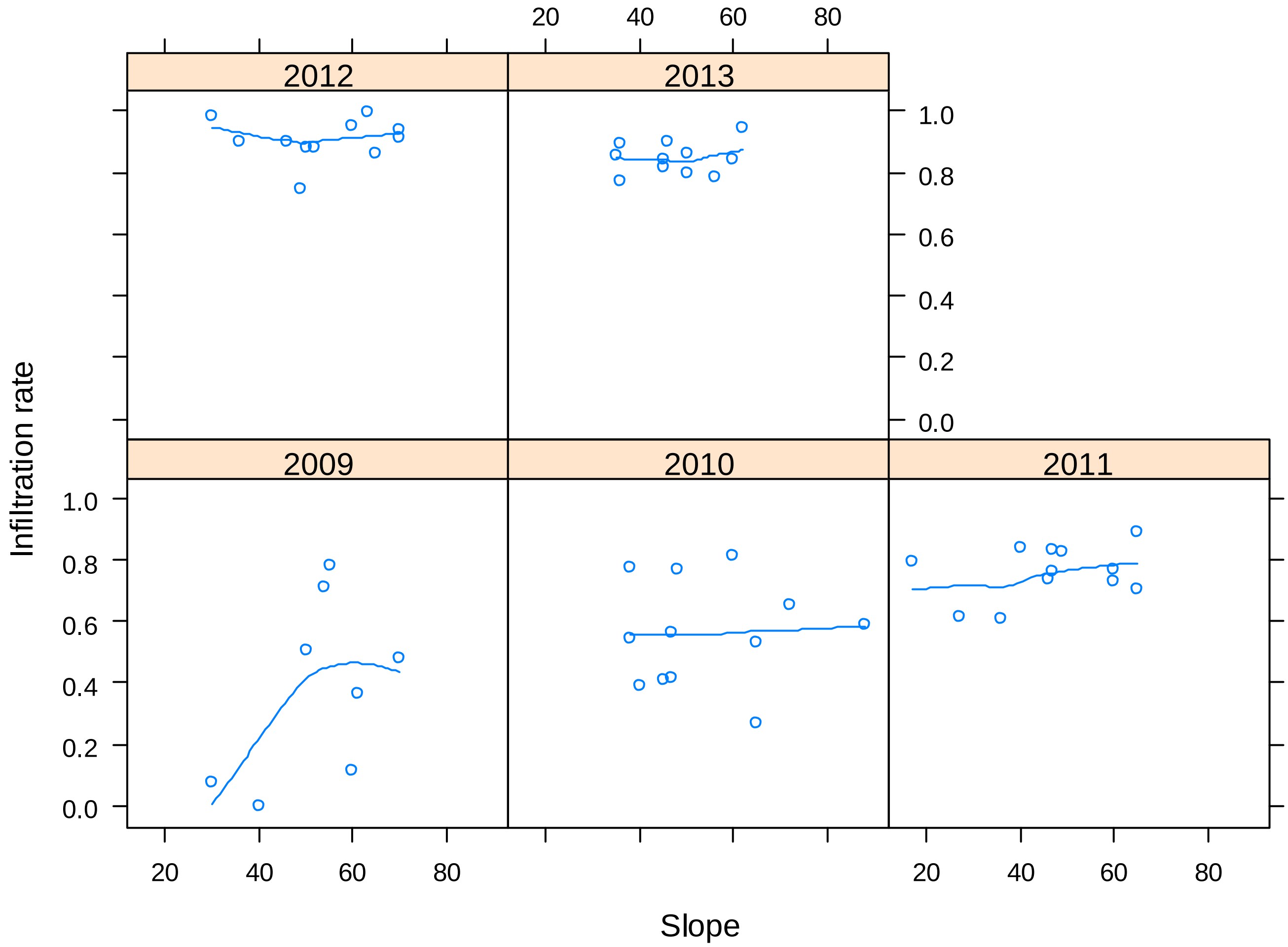



```
# Doesn't look like there is a vegetation effect

ir.vegfit <- lme(inf.rate ~  time * v3, raindat.gd3, random = ~ time)
ro.vegfit <- lme(sqrt(ro.ratio) ~  time * v3, raindat.gd3, random = ~ time)
par(mfrow=c(1,2))
qqresid(ir.vegfit)
qqresid(ro.vegfit)
```

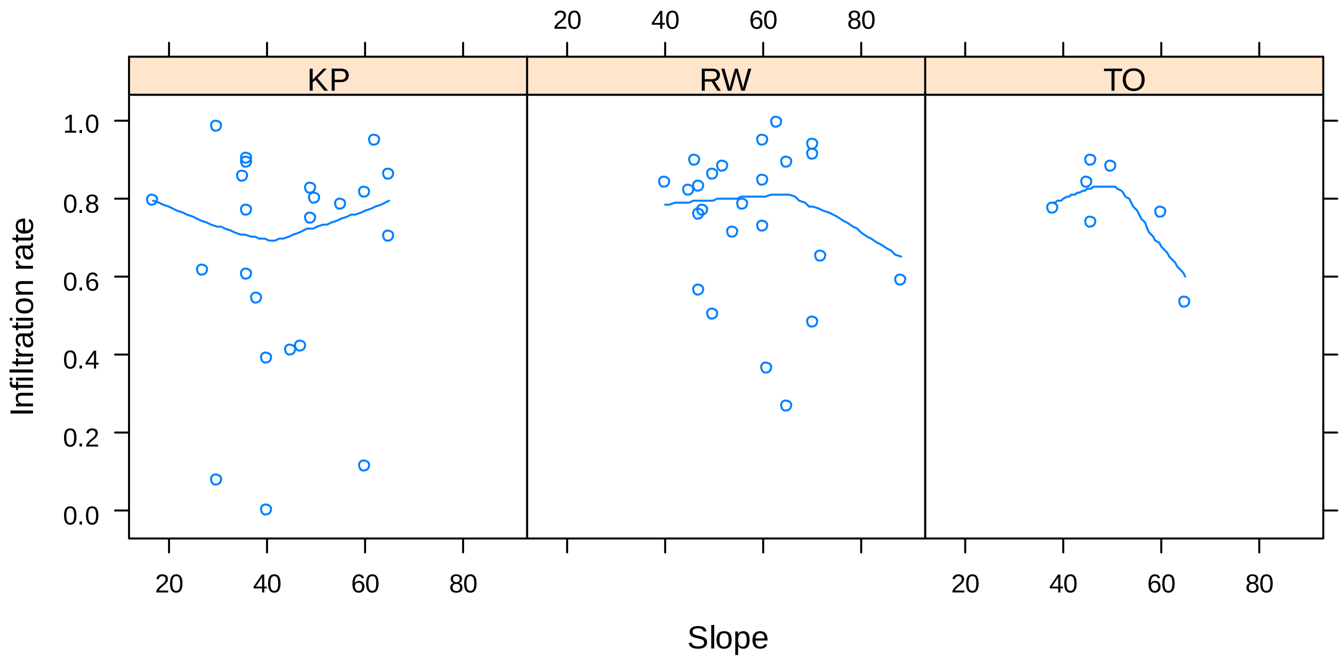




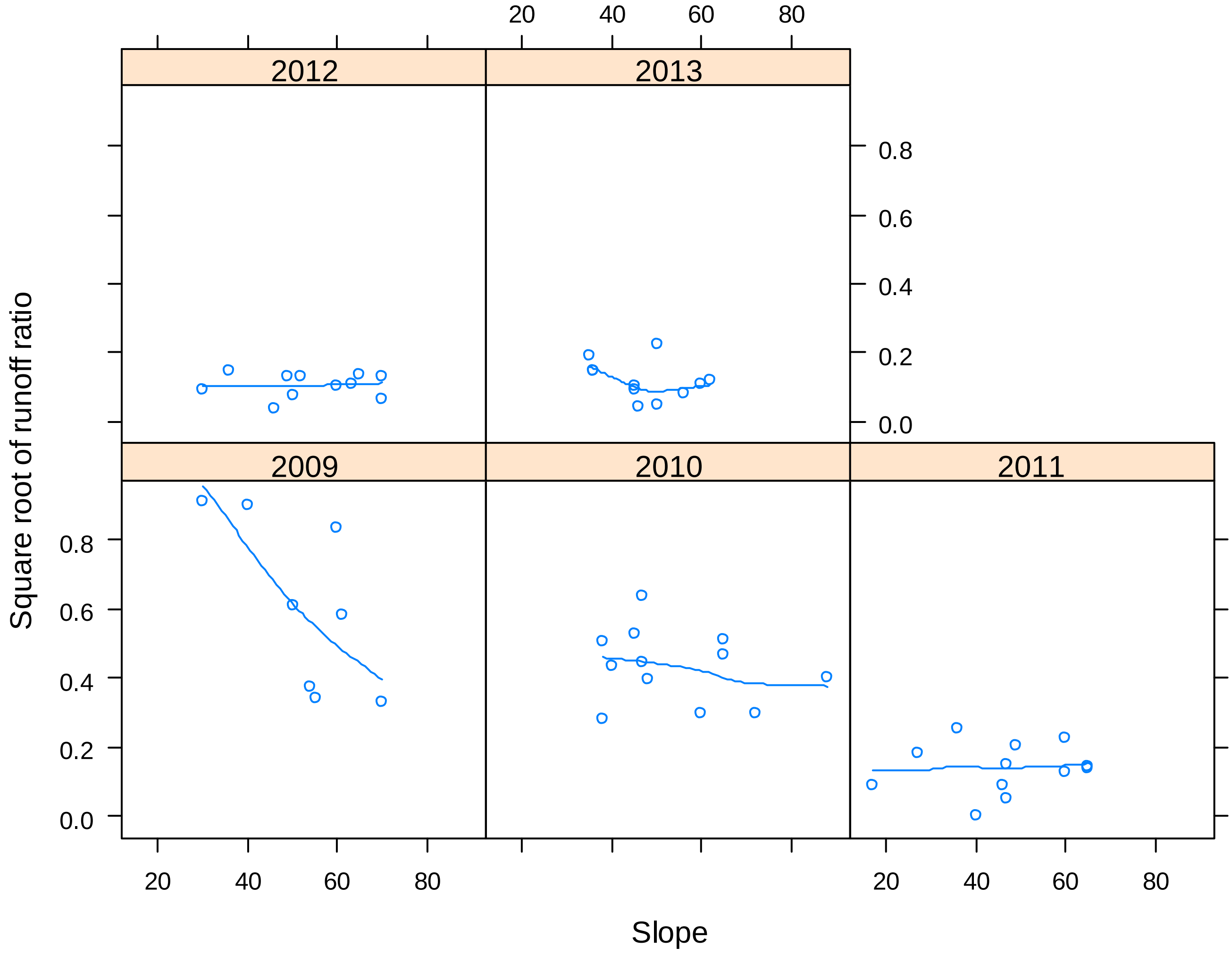

```
# These look pretty good

anova(ir.vegfit)
            numDF denDF   F-value p-value
(Intercept)     1    38 1374.4628  <.0001
time            1    38   35.6230  <.0001
v3              2    10    1.0775  0.3769
time:v3         2    38    1.0059  0.3753
# Vegetation and its interaction with time are not significant for infiltration rate

anova(ro.vegfit)
            numDF denDF   F-value p-value
(Intercept)     1    38 111.81047  <.0001
time            1    38  54.76643  <.0001
v3              2    10   3.04192  0.0929
time:v3         2    38   0.71506  0.4956
# Vegetation and its interaction with time are not significant for runoff ratio


# Test for a slope effect

xyplot(inf.rate ~ slope | year, data=raindat,ylab="Infiltration rate",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
xyplot(inf.rate ~ slope | v3, data=raindat,ylab="Infiltration rate",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
```

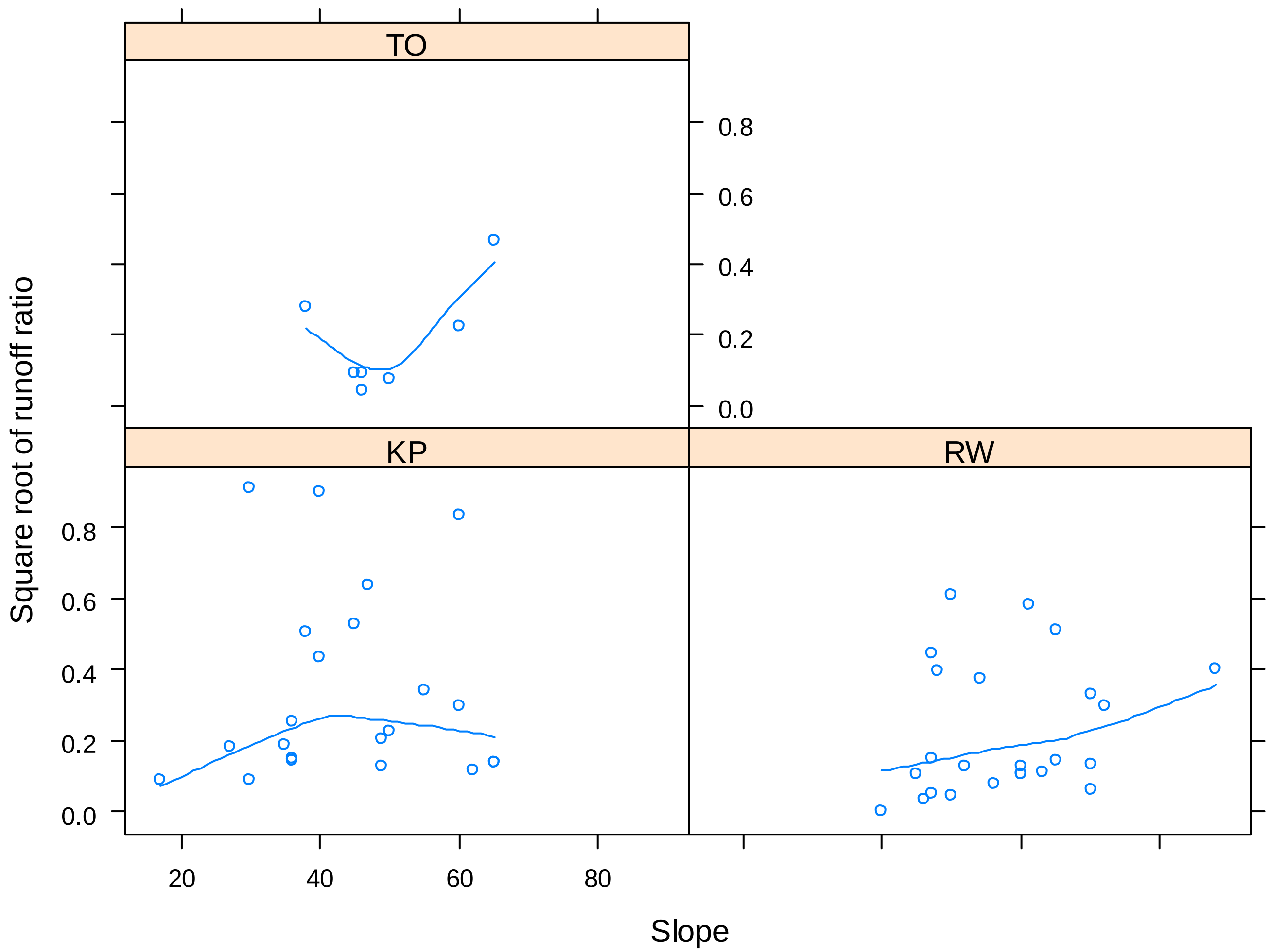


2012
2013
2009
2010
2011
Infiltration rate
Slope
0.0
0.2
0.4
0.6
0.8
1.0
20
40
60
80

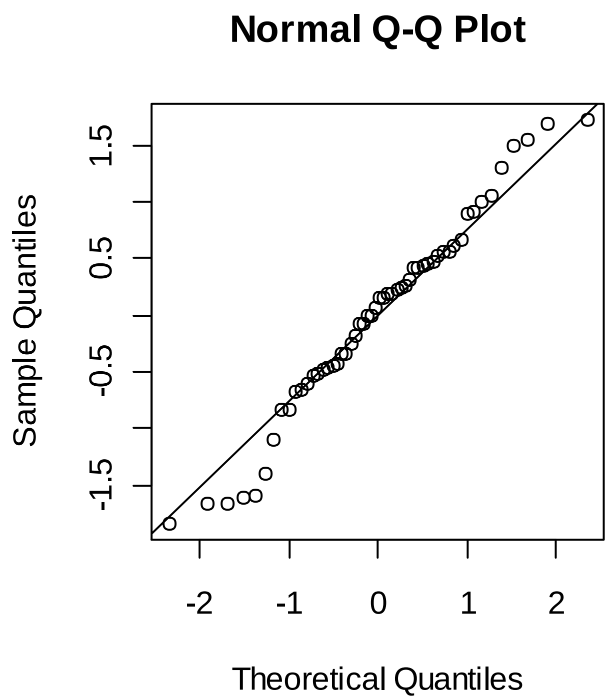


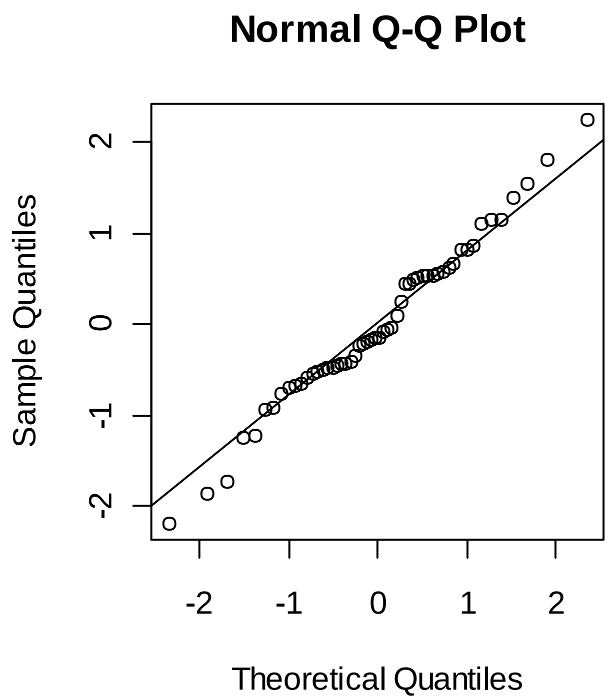

```
xyplot(sqrt(ro.ratio) ~ slope | year, data=raindat,ylab="Square root of runoff
ratio",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})

xyplot(sqrt(ro.ratio) ~ slope | v3, data=raindat,ylab="Square root of runoff ratio
",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
```


2012
2013
2009
2010
2011
Square root of runoff ratio
Slope
0.0
0.2
0.4
0.6
0.8
20
40
60
80



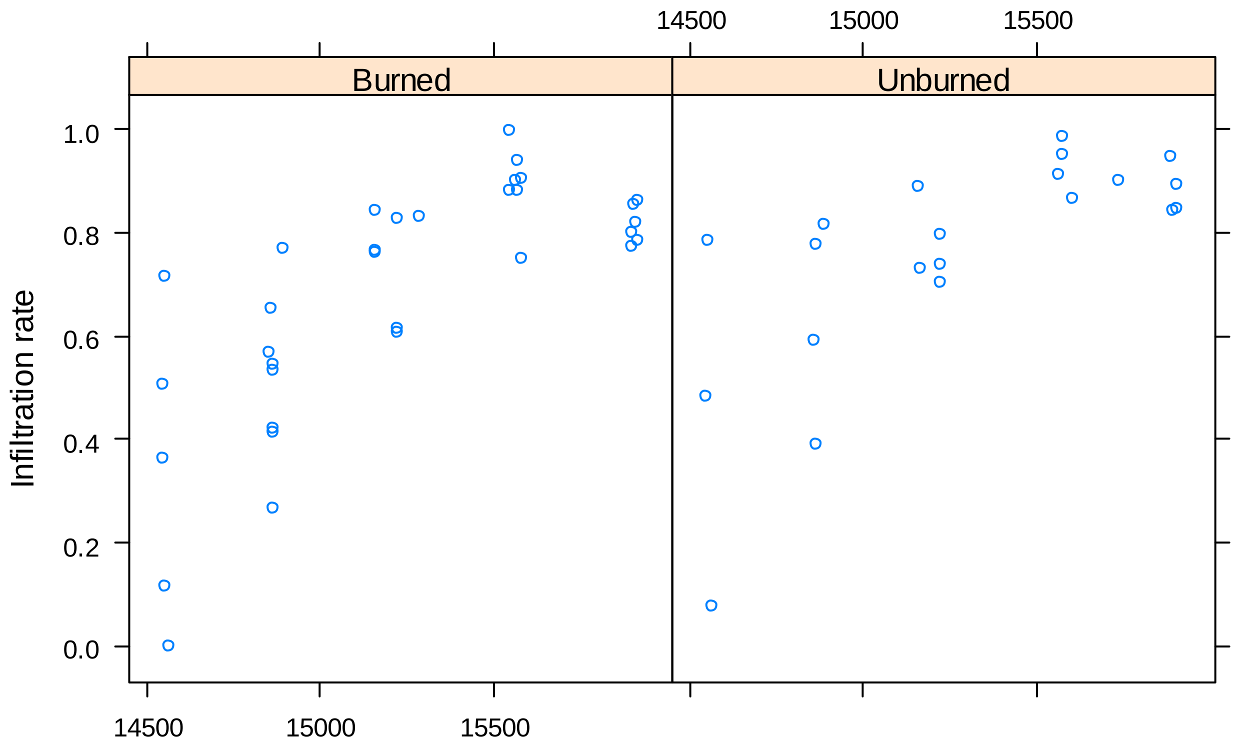

```
ir.slopefit <- lme(inf.rate ~  time*slope, raindat.gd3, random = ~ time)
ro.slopefit <- lme(sqrt(ro.ratio) ~  time*slope, raindat.gd3, random = ~ time)
```



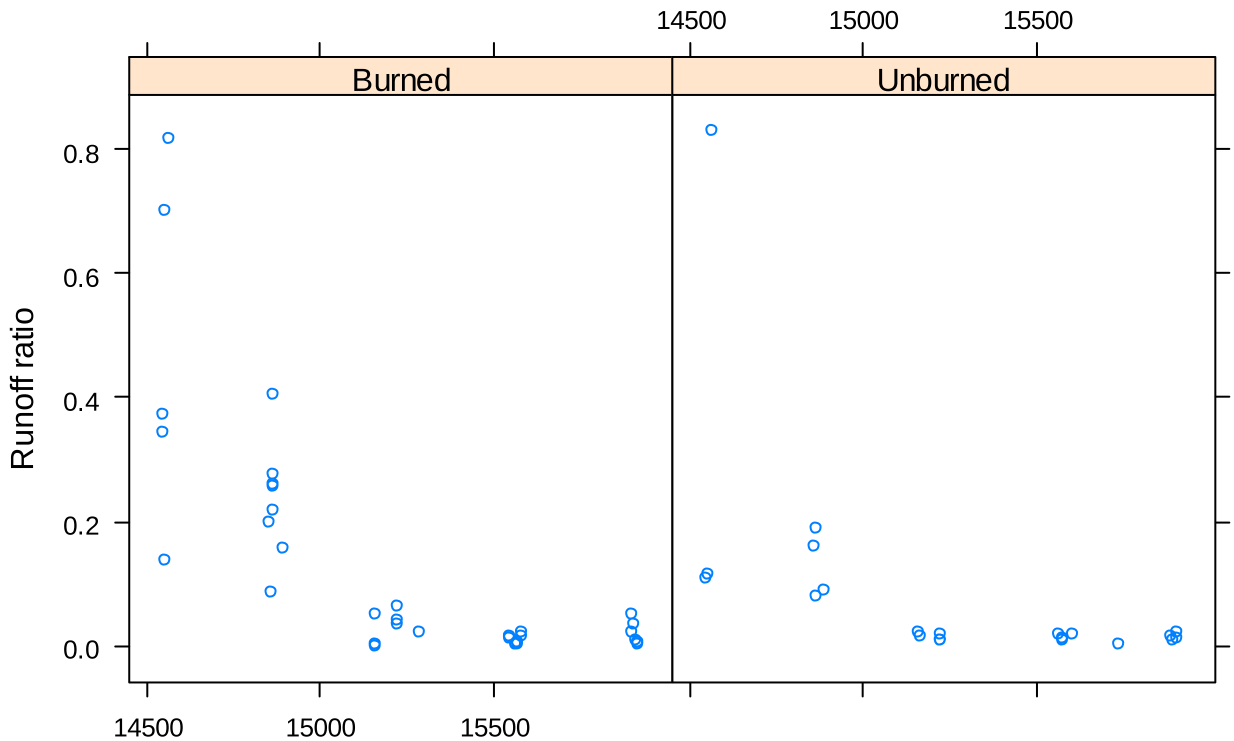



```
> anova(ir.slopefit)
            numDF denDF   F-value p-value
(Intercept)     1    38 1464.1077  <.0001
time            1    38   25.7454  <.0001
slope           1    38    0.0107  0.9181
time:slope      1    38    1.8020  0.1874

> anova(ro.slopefit)
            numDF denDF  F-value p-value
(Intercept)     1    38 50.27700  <.0001
time            1    38 49.58711  <.0001
slope           1    38  0.41476  0.5234
time:slope      1    38  0.01192  0.9136
# No slope effect

# Fixed effects models
> anova(lm(sqrt(ro.ratio) ~ slope*v3, data=raindat))
Analysis of Variance Table

Response: sqrt(ro.ratio)
          Df Sum Sq  Mean Sq F value Pr(>F)
slope      1 0.0000 0.000000  0.0000 0.9983
v3         2 0.2281 0.114048  2.2784 0.1134
slope:v3   2 0.0456 0.022800  0.4555 0.6368
Residuals 48 2.4026 0.050055

> anova(lm(inf.rate ~ slope*v3, data=raindat))
Analysis of Variance Table

Response: inf.rate
          Df  Sum Sq  Mean Sq F value Pr(>F)
```

```
slope      1 0.00468 0.004675  0.0848 0.7721
v3         2 0.15675 0.078374  1.4218 0.2513
slope:v3   2 0.06985 0.034924  0.6336 0.5351
Residuals 48 2.64596 0.055124
# No slope or vegetation effects

ir.slopefit <- lme(inf.rate ~  slope*v3, raindat.gd3, random = ~ 1)
anova(ir.slopev3fit,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1    38 10.939733  0.0021
slope           1    38  0.159537  0.6918
v3              2    10  1.120235  0.3639
slope:v3        2    38  0.633560  0.5362

ro.slopefit <- lme(sqrt(ro.ratio) ~  slope*v3, raindat.gd3, random = ~ 1)
anova(ro.slopev3fit,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1    38 3.539286  0.0676
slope           1    38 0.009734  0.9219
v3              2    10 1.007054  0.3995
slope:v3        2    38 0.455492  0.6376


==========================================================================
Contrasting Unburned with Burned sites
==========================================================================

# Create a factor so that labels on xyplot will be clear
burned <- factor(raindat$burn.sev == "None", labels=c("Burned","Unburned"))

xyplot(inf.rate ~ date | burned, data=raindat, xlab="", ylab="Infiltration rate")
```

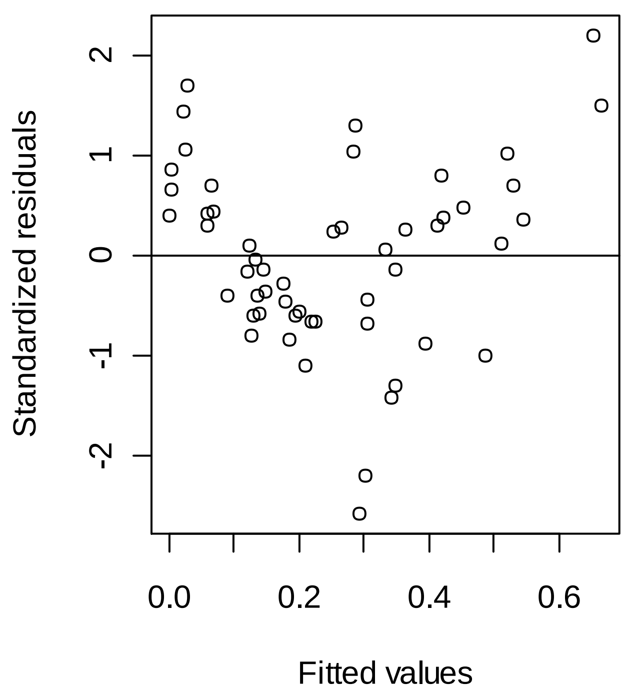


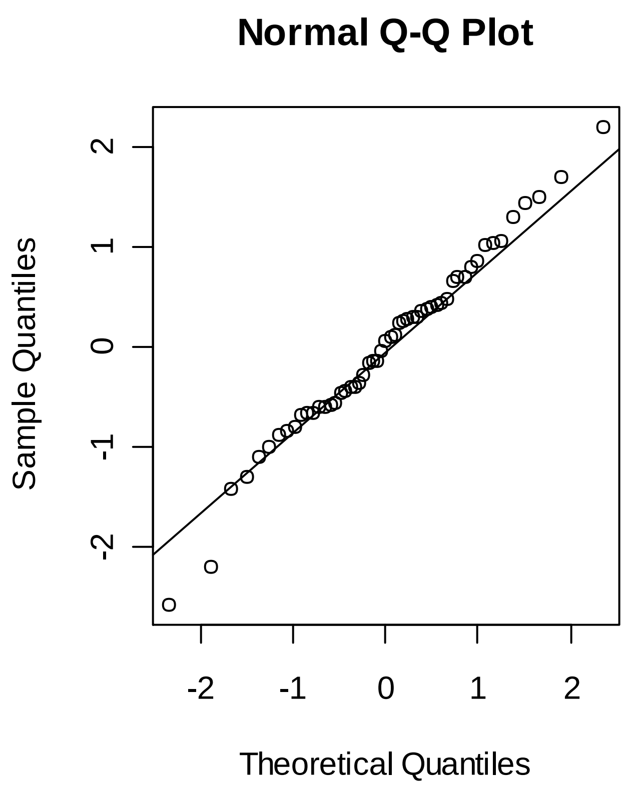

```
xyplot(ro.ratio ~ date | burned, data=raindat, xlab="", ylab="Runoff ratio")
```




```
# Looks like there is a good chance runoff ratio is significantly affected by the above
burn dichotomy.

# Contrast Unburned with all others
anova(lme(inf.rate ~  time * (burn.sev=="None"), raindat.gd, random = ~
time),type="marginal")
                        numDF denDF   F-value p-value
(Intercept)                 1    39  9.685144  0.0035
time                        1    39 22.416925  <.0001
burn.sev == "None"          1    11  0.703450  0.4195
time:burn.sev == "None"     1    39  0.286395  0.5956

# The interaction is NOT significant, so the time trend does not depend on burn severity.
The main effect of burning is not even significant.

# Try omitting Scotts Mill Control
anova(lme(inf.rate ~  time * (burn.sev=="None"), raindat.gd, subset= sitenum!="11N",
random = ~ time),type="marginal")
                        numDF denDF  F-value p-value
(Intercept)                 1    35 13.45058  0.0008
time                        1    35 32.31901  <.0001
burn.sev == "None"          1    10  3.41879  0.0942
time:burn.sev == "None"     1    35  2.36307  0.1332
# Still not significant

# Runoff ratio
anova(lme(sqrt(ro.ratio) ~  time * (burn.sev=="None"), raindat.gd2, random = ~
time),type="marginal")
                        numDF denDF  F-value p-value
```

```
(Intercept)                 1    39 78.10397  <.0001
time                        1    39 43.14031  <.0001
burn.sev == "None"          1    11  2.22278  0.1641
time:burn.sev == "None"     1    39  1.62048  0.2106
# Again, neither burning nor its interaction with time is significant

# Try omitting observation 38
anova(lme(sqrt(ro.ratio) ~  time * (burn.sev=="None"), raindat.gd2, subset=-38, random =
~ time),type="marginal")
                        numDF denDF   F-value p-value
(Intercept)                 1    38 130.92437  <.0001
time                        1    38  69.00563  <.0001
burn.sev == "None"          1    11   8.31619  0.0149
time:burn.sev == "None"     1    38   6.45318  0.0153
# Yes now these variables are significant but not strongly

tmpfit <- lme(sqrt(ro.ratio) ~  time * (burn.sev=="None"), raindat.gd2, subset=-38,
random = ~ time)
plot(fitted(tmpfit), resid(tmpfit,type="p"),xlab="Fitted values",ylab="Standardized
residuals")
abline(0,0)
qqresid(tmpfit)  # Nice normal residuals, just a couple of outliers in the lower tail
```



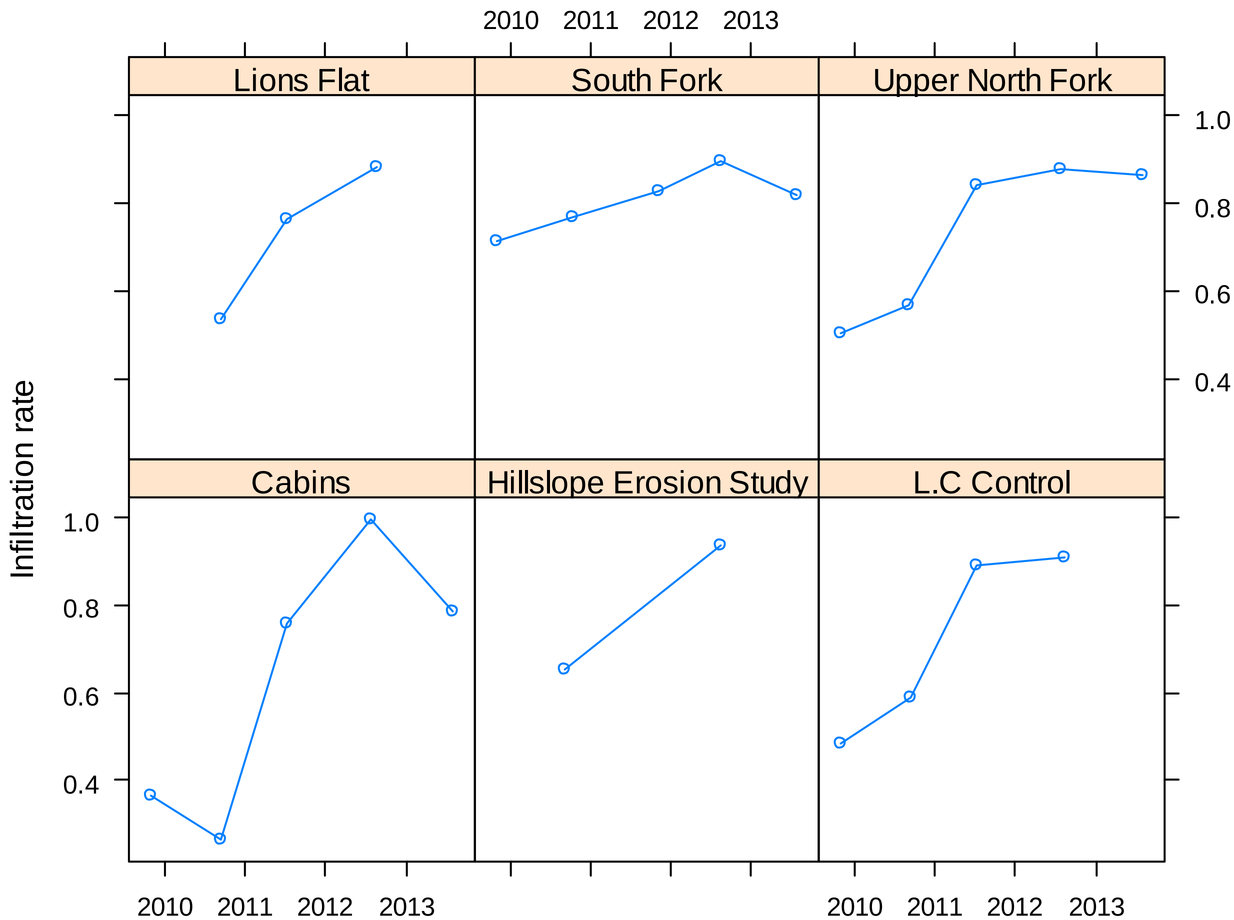



```
Results for the Unburned/Burned dichotomy are consistent with the analyses in which burn
severity was a categorical variable with 4 levels.

# Only in the runoff model and only when observation 38 is dropped does there appear to
ba a significant interaction between burn severity and time.
```

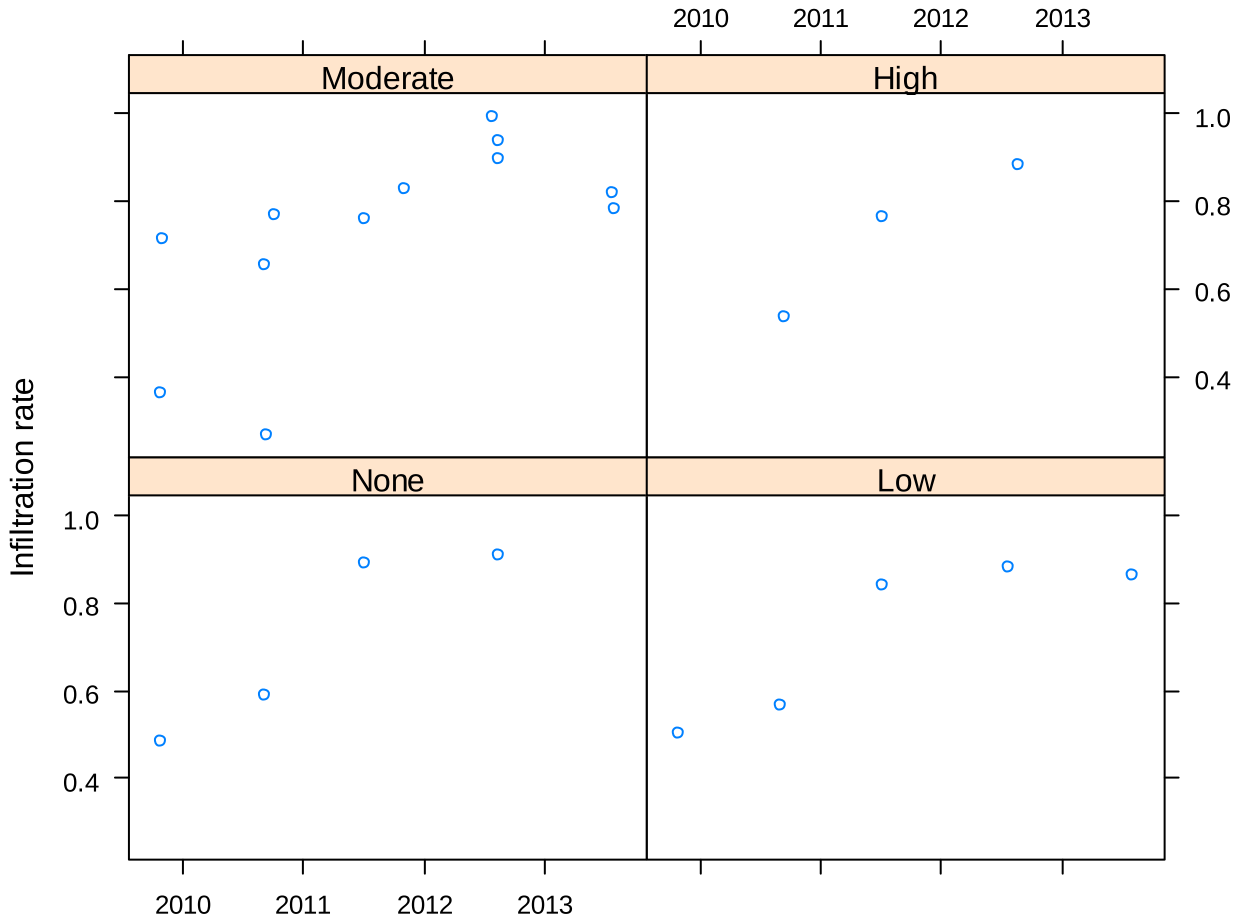
```
# For infiltration rate models, the interaction not significant regardless of the
inclusion of Scotts Mill Control or observation 38.
```

Little Creek Sites

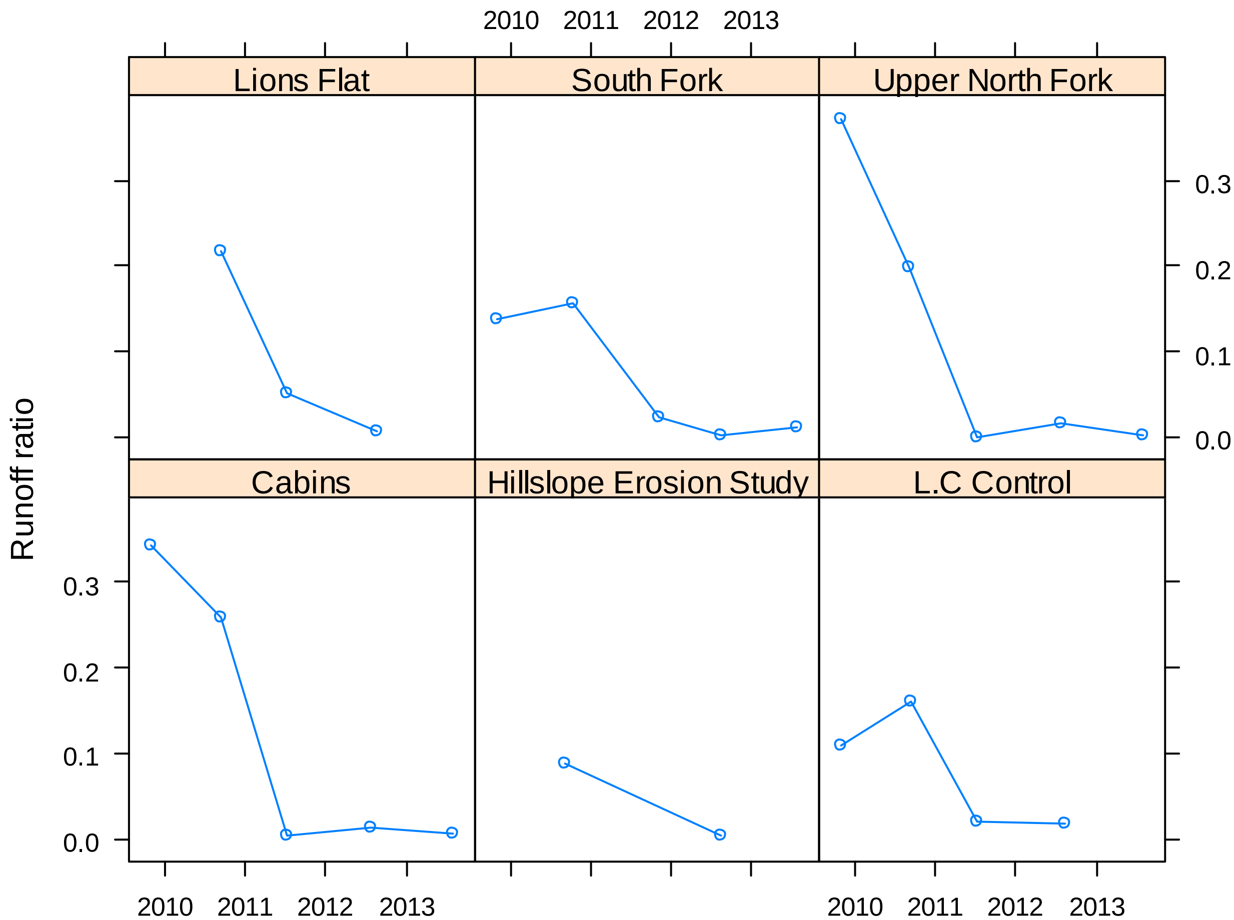
```
library("chron")
library("lattice")
library("car")
library(nlme)

# Create new data frame Little Creek sites only
4N: Little Creek
5M: Cabins
6L: UNF
7M: South Fork
13H: Lions Flat
14M: Hillslope

# First trim leading and trailing white space from site numbers
trim <- function (x) gsub("^\\s+|\\s+$", "", x)
raindat$sitenum <- trim(raindat$sitenum)
# Next extract the Little Creek sites
rainlit <- raindat[raindat$sitenum %in% c("4N","5M","6L","7M","13H","14M"),]
# Eliminate unused categories
rainlit$sitenum <- factor(rainlit$sitenum)
rainlit$sitename <- factor(rainlit$sitename)
table(rainlit$sitenum)

13H 14M  4N  5M  6L  7M
  3   2   4   5   5   5

xyplot(inf.rate ~ date | sitename, data=rainlit, type="b",xlab="",ylab="Infiltration
rate")
```



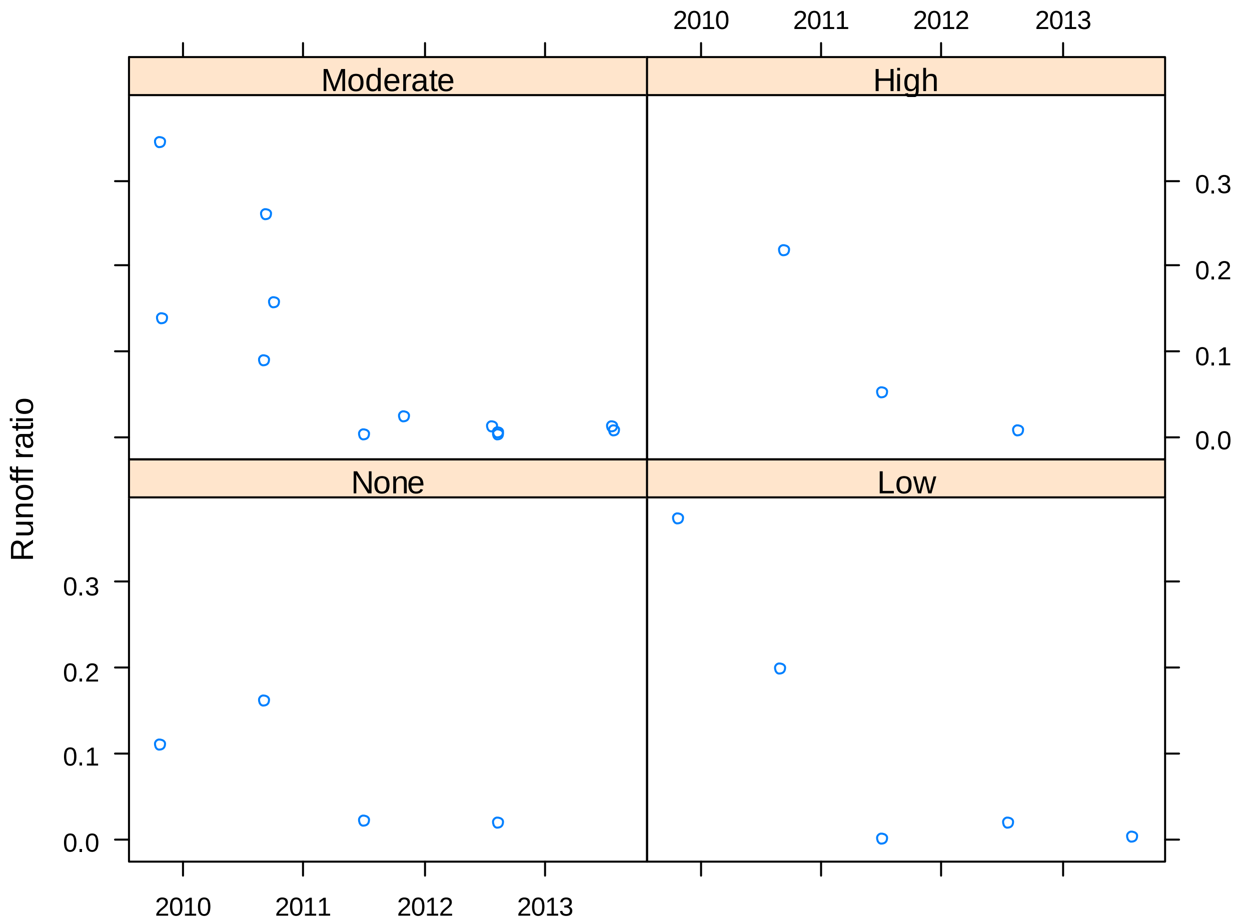

```
# Infiltration rate increasing at all sites

xyplot(inf.rate ~ date | burn.sev, data=rainlit,ylab="Infiltration rate",xlab="")
```



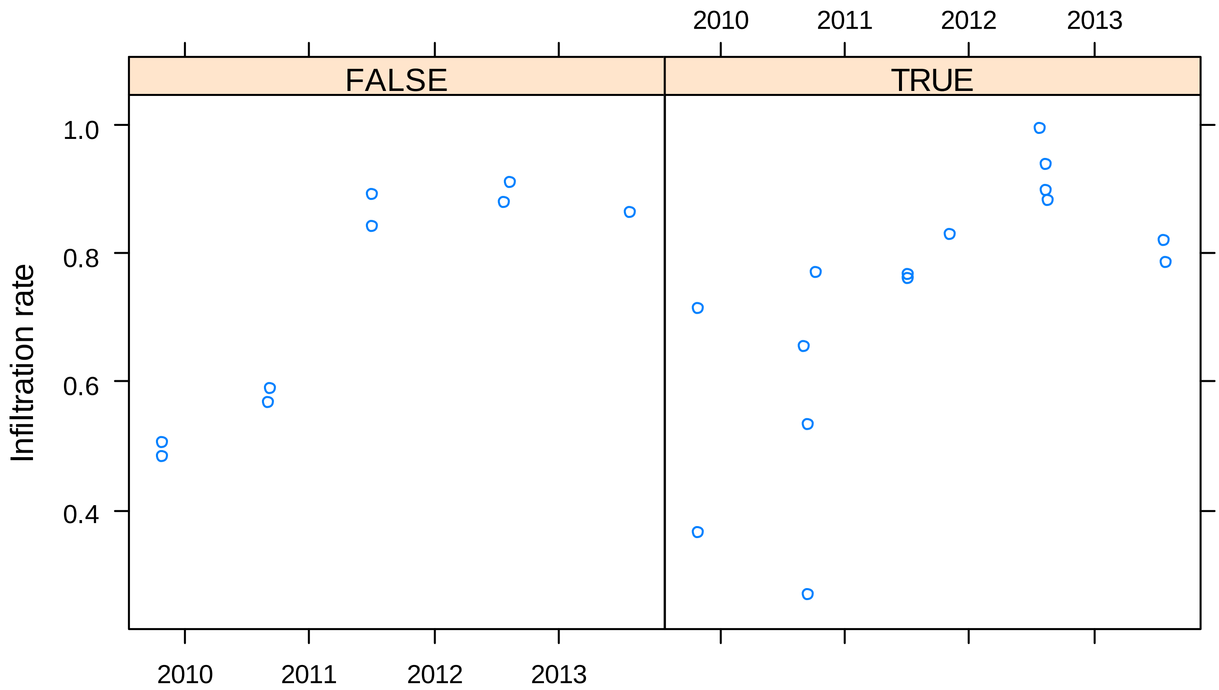

```
# The number of Moderates and Lows is unchanged.  None and High are highly depleted.
# Lions Flat is the only hot burn and LC Control is the only unburned

xyplot(ro.ratio ~ date | sitename, data=rainlit, type="b",xlab="",ylab="Runoff ratio")
```



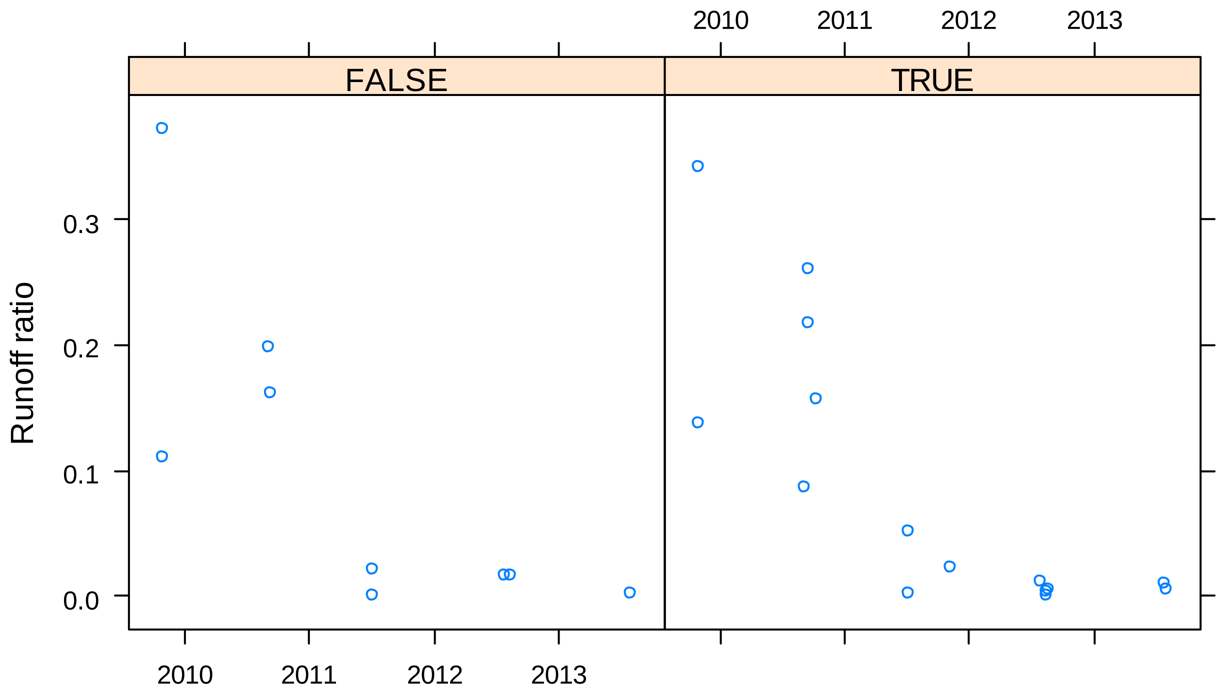

```
# Lions Flat is the only hot burn, UNF is a Low intensity burn, LC Control did not burn
# Runoff ratio decreasing at all sites

xyplot(ro.ratio ~ date | burn.sev, data=rainlit,xlab="",ylab="Runoff ratio")
```



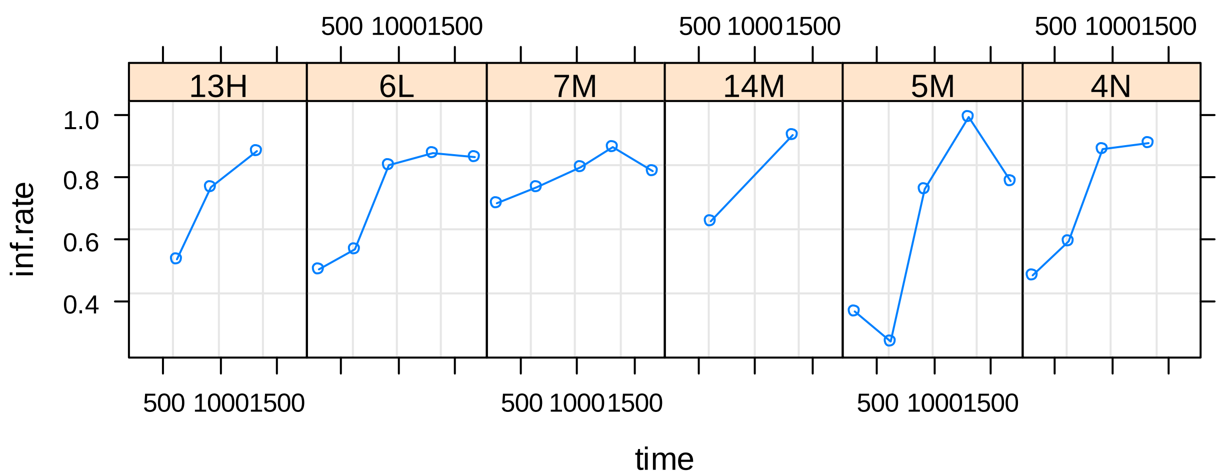

```
# Because of the sample sizes, it doesn't make sense to contrast High or None with the
other categories.  Contrast (High and Moderate) with (None and Low)

xyplot(inf.rate ~ date | burn.sev%in% c("High","Moderate"), data=rainlit, xlab="",
ylab="Infiltration rate")
```




```
# TRUE indicates High and Moderate burn severity; does not look important

xyplot(ro.ratio ~ date | burn.sev%in% c("High","Moderate"), data=rainlit, xlab="",
ylab="Runoff ratio")
```

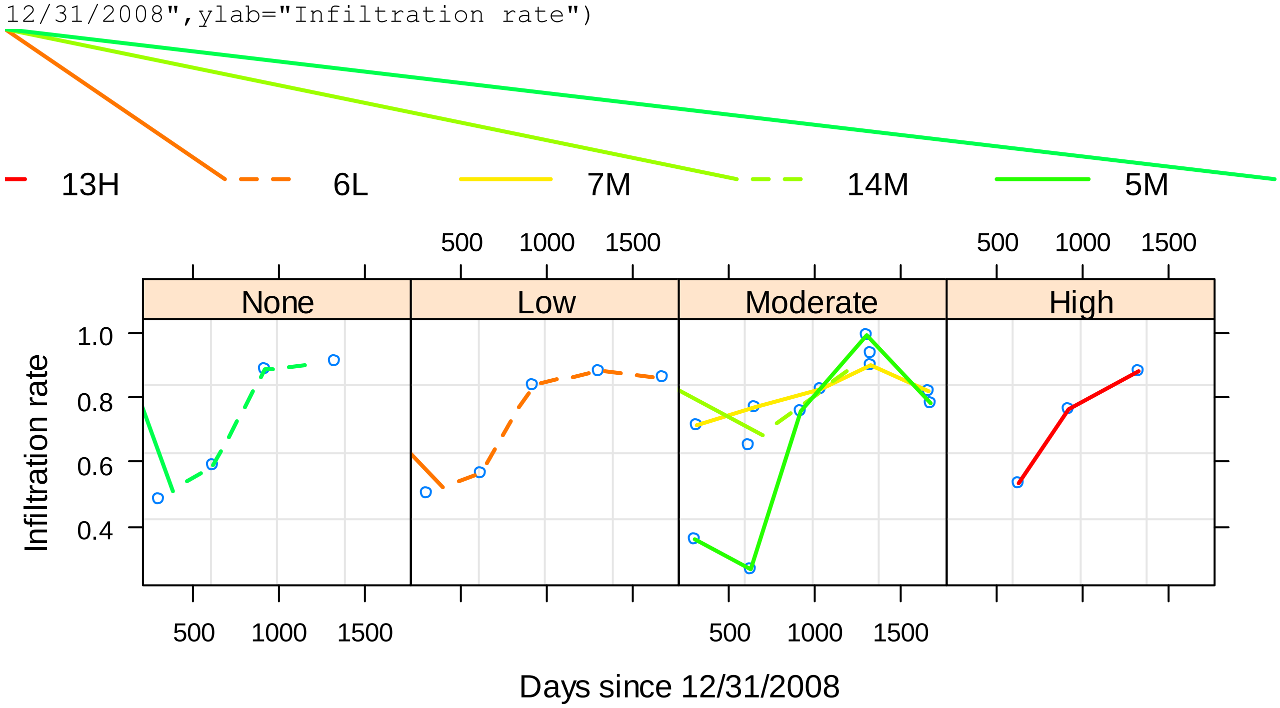



```
rainlit.gd <- groupedData(inf.rate ~ time | sitenum, outer = ~ burn.sev, data=rainlit)
plot(rainlit.gd,layout=c(6,1))
```



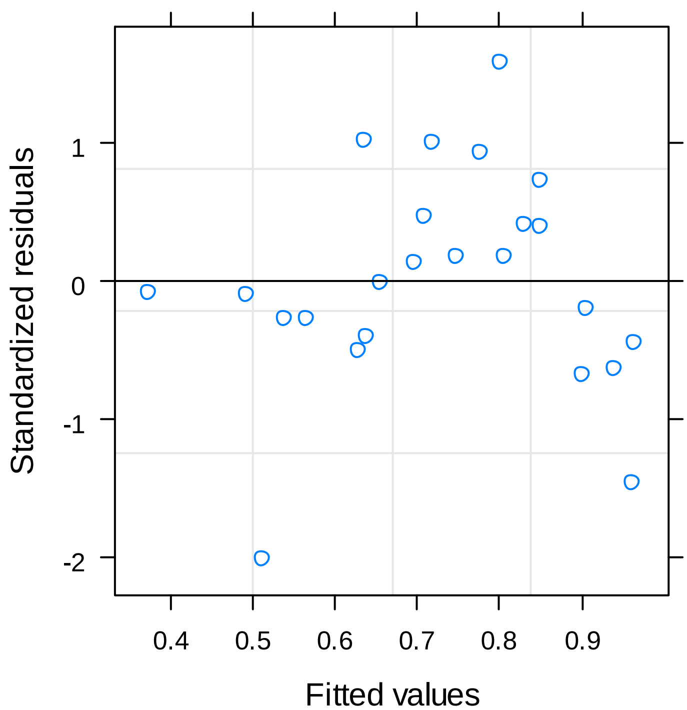

```
# The above is similar to an xy plot shown earlier.
```

```
# It's obvious that there is not going to be a statistical difference between the time
trends for different burn severity classes

superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(13)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
trellis.par.set("superpose.line",superpose.line)

plot(rainlit.gd, outer=T, aspect=1, layout=c(4,1),xlab="Days since
12/31/2008",ylab="Infiltration rate")
```

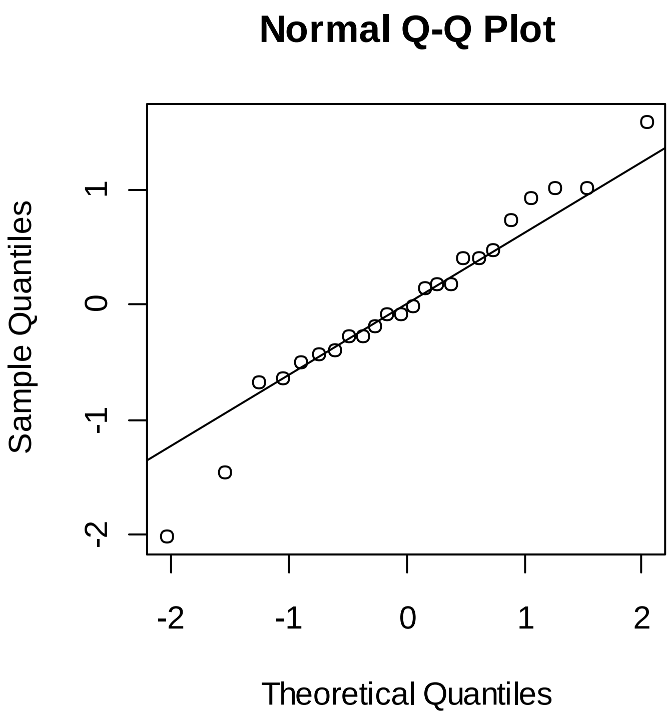



```
options(contrasts= c("contr.treatment", "contr.treatment"))
# Forces ordered factors to use treatment contrasts
# Note this affects the p-values in the summary
ir.LCfit1 <- lme(inf.rate ~  time * burn.sev, rainlit.gd, random = ~ time)

anova(ir.LCfit1)
# Note: by default anova does sequential tests, i.e. each p-value is the significance of
the given variable when added to a model defined by the variables listed above that
variable. i.e. it tests the variables entering the model in the specific sequence shown
              numDF denDF  F-value p-value
(Intercept)       1    14 486.7144  <.0001
time              1    14  12.2920  0.0035
burn.sev          3     2   0.2543  0.8549
time:burn.sev     3    14   0.2454  0.8632
# Only time is significant
# Burn severity and its interaction with time is not
```

```
anova(ir.LCfit1,type="marginal")
# The marginal p-values compare the full model to a model that omits the variable on that
line. i.e. it tests each variable as the final variable added to the model.
              numDF denDF  F-value p-value
(Intercept)       1    14 1.611484  0.2250
time              1    14 3.875314  0.0691
burn.sev          3     2 0.108829  0.9474
time:burn.sev     3    14 0.245375  0.8632
# Burn severity and its interaction with time are not significant
```



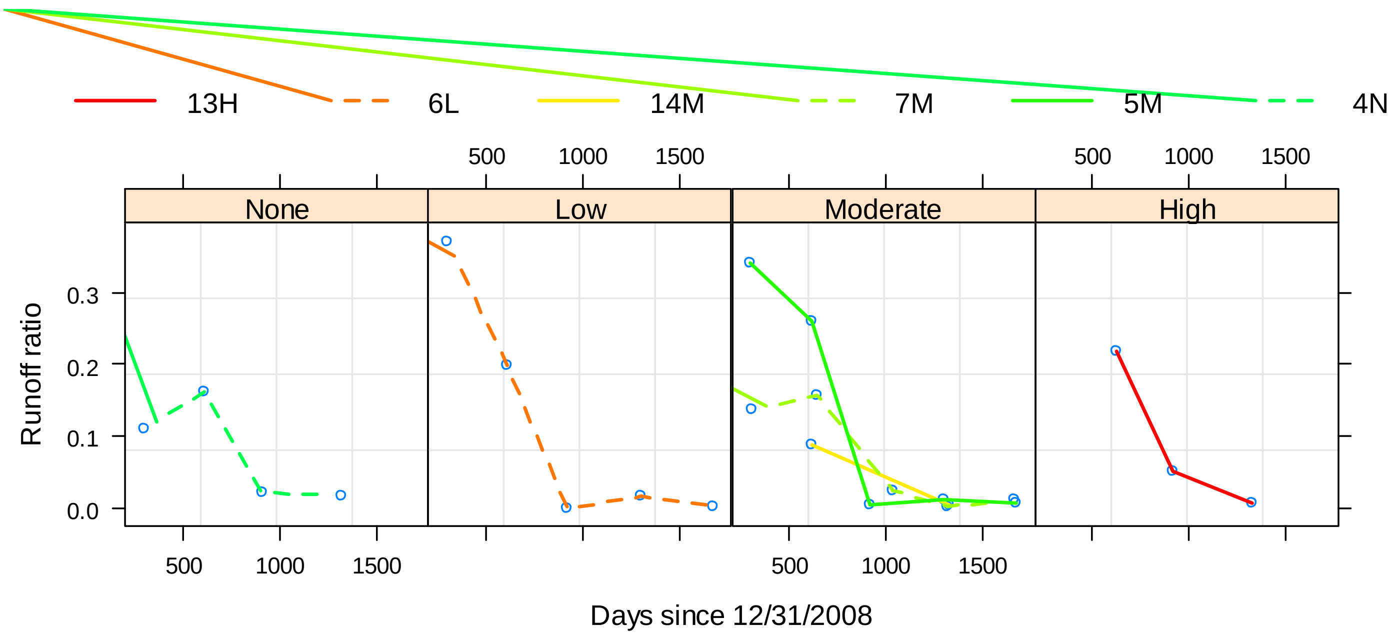

```
qqnorm(resid(ir.LCfit1,type="p"))
qqline(resid(ir.LCfit1,type="p"))
```



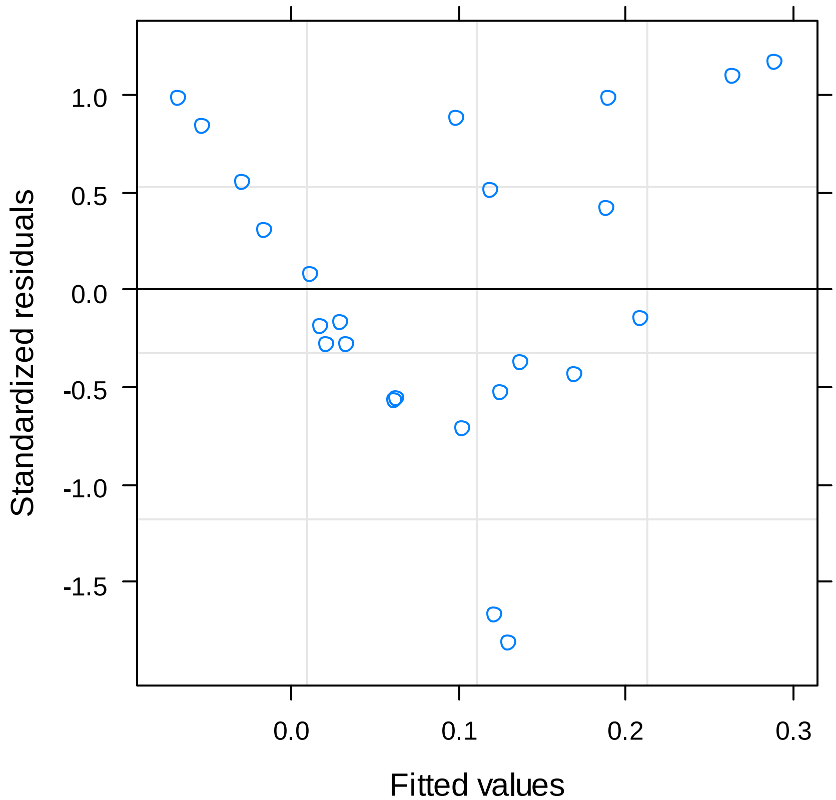

```
# Try contrasting High/Moderate burn severity with Low/None
ir.LCfit2 <- lme(inf.rate ~  time * (burn.sev=="High" | burn.sev=="Moderate"),
data=rainlit.gd, random = ~ time)

anova(ir.LCfit2)
                                              numDF denDF  F-value p-value
(Intercept)                                       1    16 650.4481  <.0001
time                                              1    16  17.7786  0.0007
burn.sev == "High" | burn.sev == "Moderate"       1     4   0.1784  0.6944
time:burn.sev == "High" | burn.sev == "Moderate"  1    16   0.0400  0.8440

anova(ir.LCfit2,type="marginal")
                                              numDF denDF  F-value p-value
(Intercept)                                       1    16 8.513564  0.0101
time                                              1    16 7.677507  0.0136
burn.sev == "High" | burn.sev == "Moderate"       1     4 0.001548  0.9705
time:burn.sev == "High" | burn.sev == "Moderate"  1    16 0.040012  0.8440

# There is not a significant difference in the rate of change of infiltration between
High/Moderate burn severities and Low/None.

# But it does look like there is a time trend regardless of burn severity

summary(lme(inf.rate ~  time, rainlit.gd, random = ~ time))

Fixed effects: inf.rate ~ time
                Value  Std.Error DF  t-value p-value
(Intercept) 0.4289482 0.08124626 17 5.279606   1e-04
```

```
time          0.0003207 0.00006958 17 4.608703   3e-04
Number of Observations: 24
Number of Groups: 6

summary(lme(ro.ratio ~  time, rainlit.gd, random = ~ time))
Fixed effects: ro.ratio ~ time
                   Value  Std.Error DF   t-value p-value
(Intercept)  0.27154266 0.04581059 17  5.927508   0e+00
time        -0.00019147 0.00003943 17 -4.855538   1e-04
Number of Observations: 24
Number of Groups: 6

=================================================================================
```
What about **runoff ratio** as a response

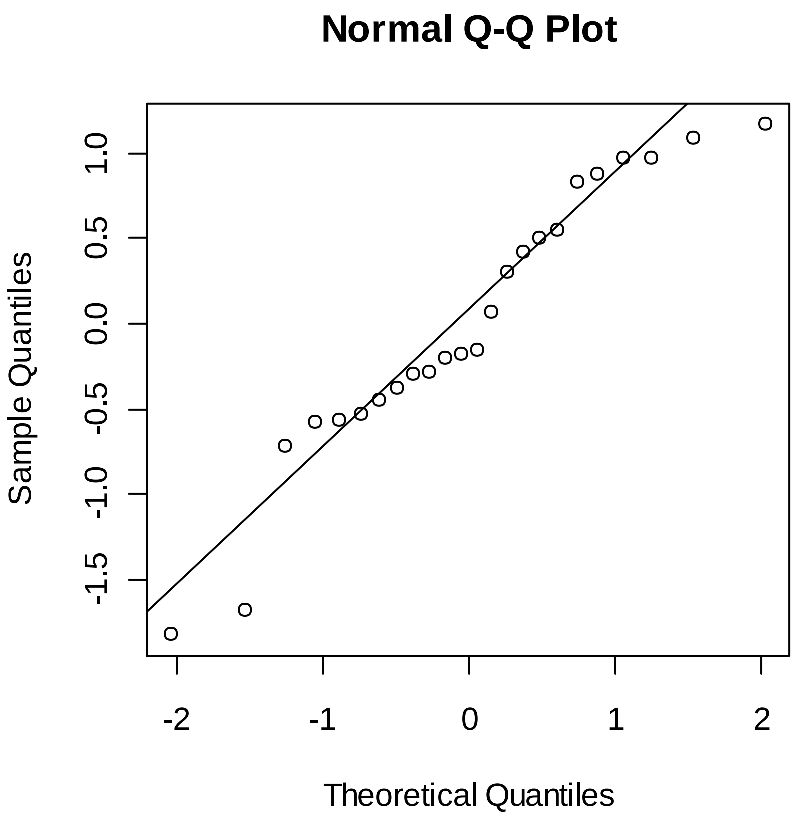
```
rainlit.gd2 <- groupedData(ro.ratio ~ time | sitenum, outer = ~ burn.sev, data=rainlit)
plot(rainlit.gd2, outer=T, aspect=1, layout=c(4,1), xlab="Days since
12/31/2008",ylab="Runoff ratio",auto.key=list(columns=3))
```



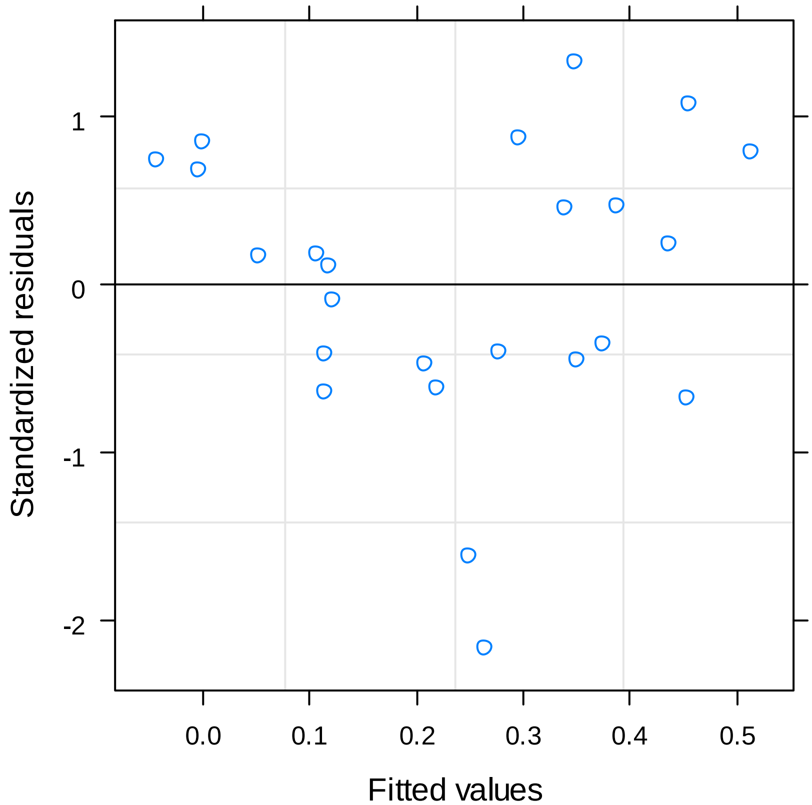

```
# 2012 and 2013 look like post-recovery years similar to 2011 (irrespective of burn
intensity.
ro.LCfit1 <- lme(ro.ratio ~  time * burn.sev, rainlit.gd2, random = ~ time)
plot(ro.LCfit1)
```



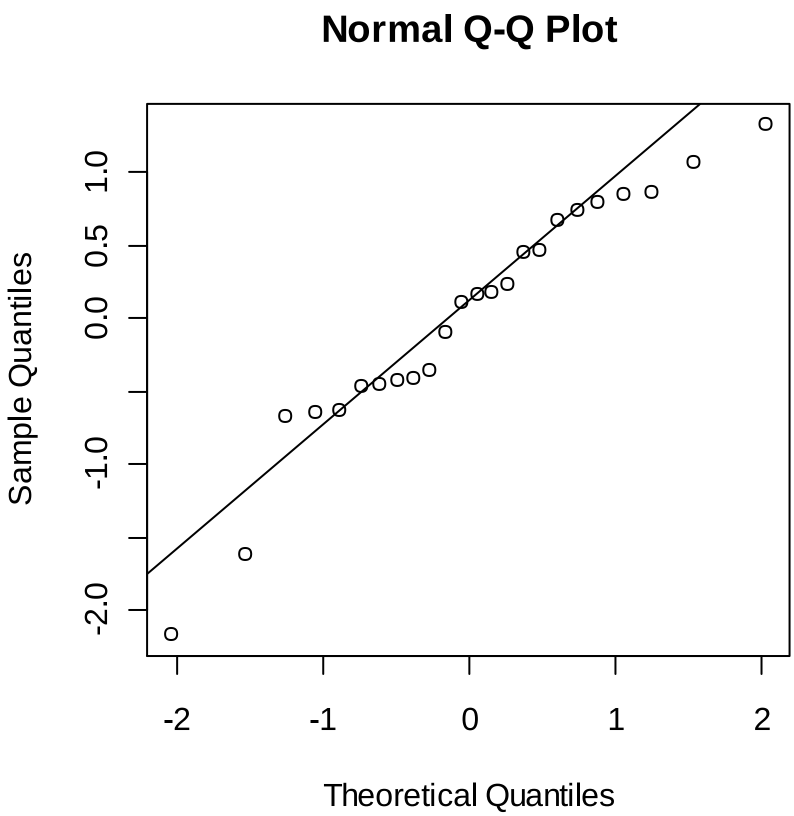

```
# The outliers below -1.5 are sites 5M and 6L in 2011, because the trend is non-linear

qqnorm(resid(ro.LCfit1,type="p"))
qqline(resid(ro.LCfit1,type="p"))
```




```
# Not a good residuals distribution
# Try transforming the response; cannot do logarithms because one of the responses=0
ro.LCfit2 <- lme(sqrt(ro.ratio) ~  time * burn.sev, rainlit.gd2, random = ~ time)
```



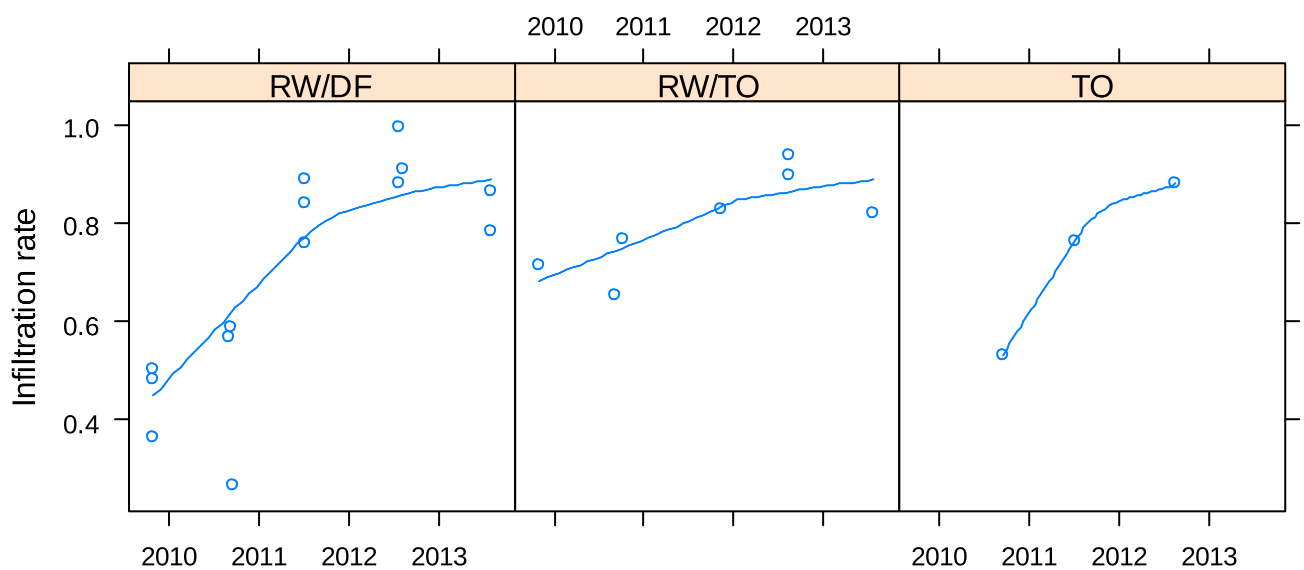
Standardized residuals
Fitted values
1
0
-1
-2
0.0
0.1
0.2
0.3
0.4
0.5




```
# Not really an improvement, but linearity of the time trend is improved (see next
section for plots)

> anova(ro.LCfit2)
              numDF denDF  F-value p-value
(Intercept)       1    14 92.92428  <.0001
time              1    14 38.14187  <.0001
burn.sev          3     2  0.20550  0.8856
time:burn.sev     3    14  0.43664  0.7302
> anova(ro.LCfit2,type="marginal")
              numDF denDF  F-value p-value
(Intercept)       1    14 58.26406  <.0001
time              1    14 22.72458  0.0003
burn.sev          3     2  0.59316  0.6769
time:burn.sev     3    14  0.43664  0.7302
# Burn severity and its interaction are not significant

# Contrast High and Moderate burn severity with Low and None
ro.LCfit2 <- lme(inf.rate ~  time * (burn.sev=="High" | burn.sev=="Moderate"),
data=rainlit.gd, random = ~ time)

anova(ro.LCfit2)
                                                numDF denDF  F-value p-value
(Intercept)                                         1    16 650.4481  <.0001
time                                                1    16  17.7786  0.0007
burn.sev == "High" | burn.sev == "Moderate"         1     4   0.1784  0.6944
time:burn.sev == "High" | burn.sev == "Moderate"    1    16   0.0400  0.8440
```

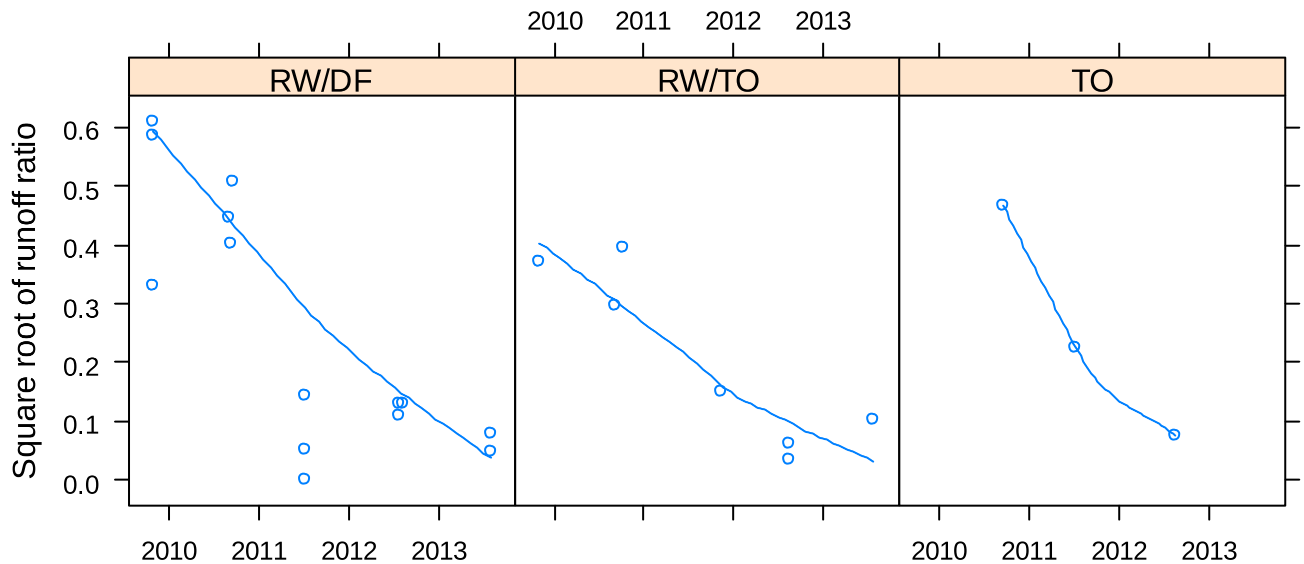
```
anova(ro.LCfit2,type="marginal")
                                                 numDF denDF  F-value p-value
(Intercept)                                          1    16 8.513564  0.0101
time                                                 1    16 7.677507  0.0136
burn.sev == "High" | burn.sev == "Moderate"          1     4 0.001548  0.9705
time:burn.sev == "High" | burn.sev == "Moderate"     1    16 0.040012  0.8440
# Burn severity does not affect the trend
```

```
II.  Analyze fixed-effects of veg type and slope

table(rainlit$veg)
KP/manz.       RW    RW/DF    RW/TO       TO
       0        0       14        7        3
table(rainlit$v3)
KP RW TO
 0 21  3
# Use original veg types, as they are more balanced than simplified v3

# Look at the time trend for each veg type

rainlit$veg <- factor(rainlit$veg)
rainlit$v3 <- factor(rainlit$v3)
xyplot(inf.rate ~ date | veg, data=rainlit,ylab="Infiltration rate",xlab="",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
},layout=c(3,1))
```

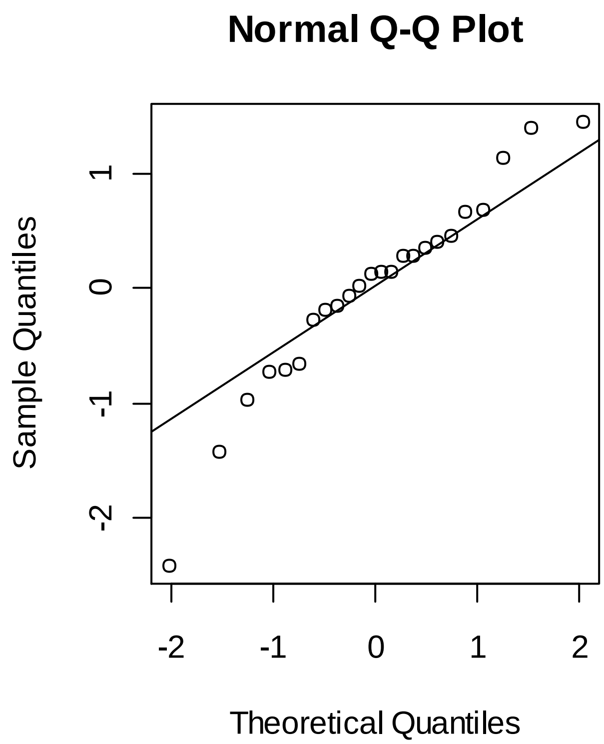


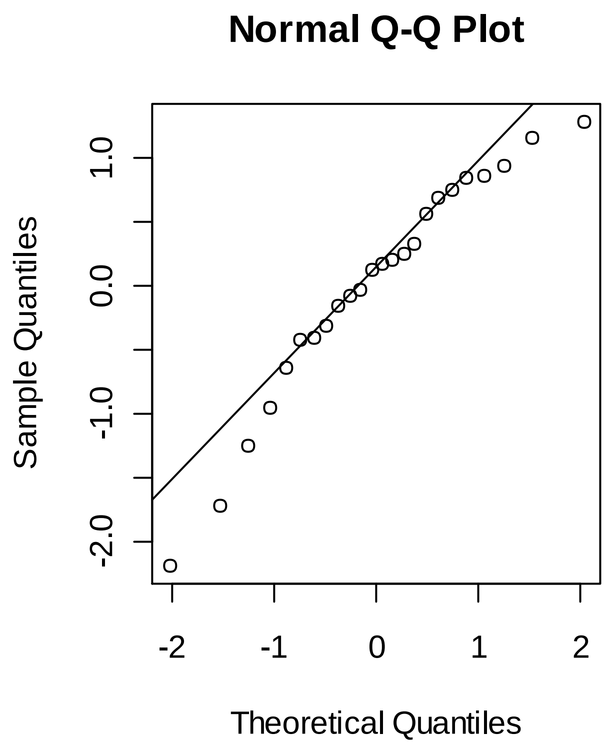

```
# RW/DF had some lower infiltration rates initially but finished as high or higher
# than the other veg types.  It might have a stronger trend
```

```
xyplot(sqrt(ro.ratio) ~ date | veg, data=rainlit,ylab="Square root of runoff
ratio",xlab="",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
```



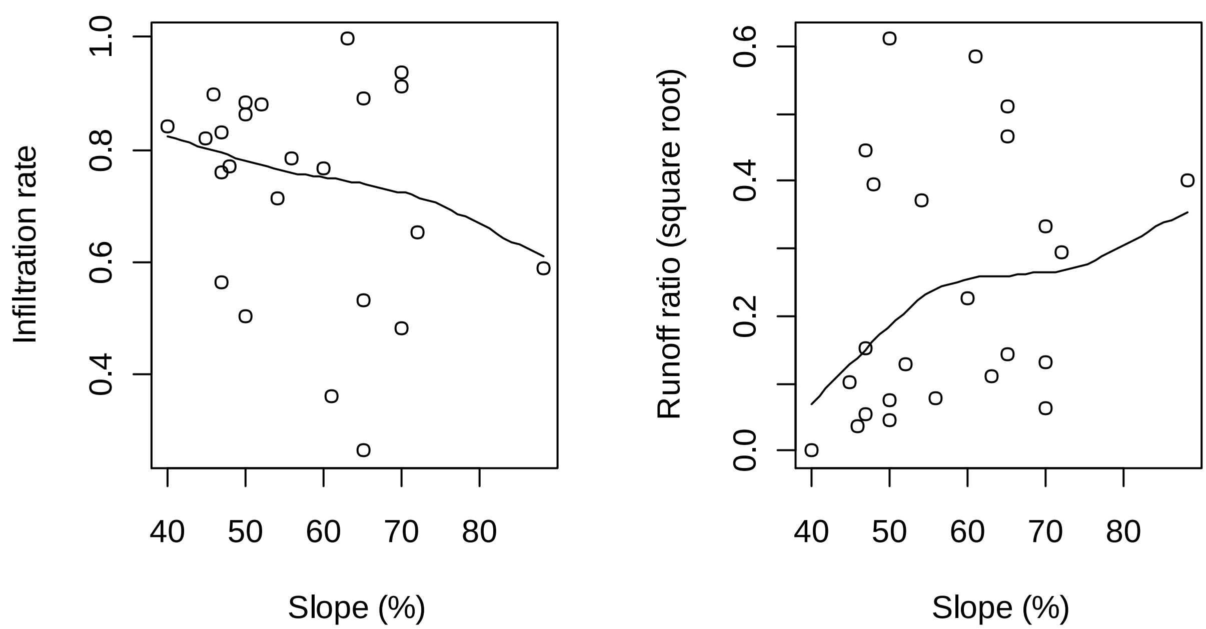

```
# These are more linear.  Still doesn't look like there is a vegetation effect.
# Althought RW/DF might have a stronger trend than the others.

ir.vegfit <- lme(inf.rate ~  time * veg, rainlit.gd, random = ~ time)
ro.vegfit <- lme(sqrt(ro.ratio) ~  time * veg, rainlit.gd, random = ~ time)
par(mfrow=c(1,2))
qqresid(ir.vegfit)
qqresid(ro.vegfit)
```



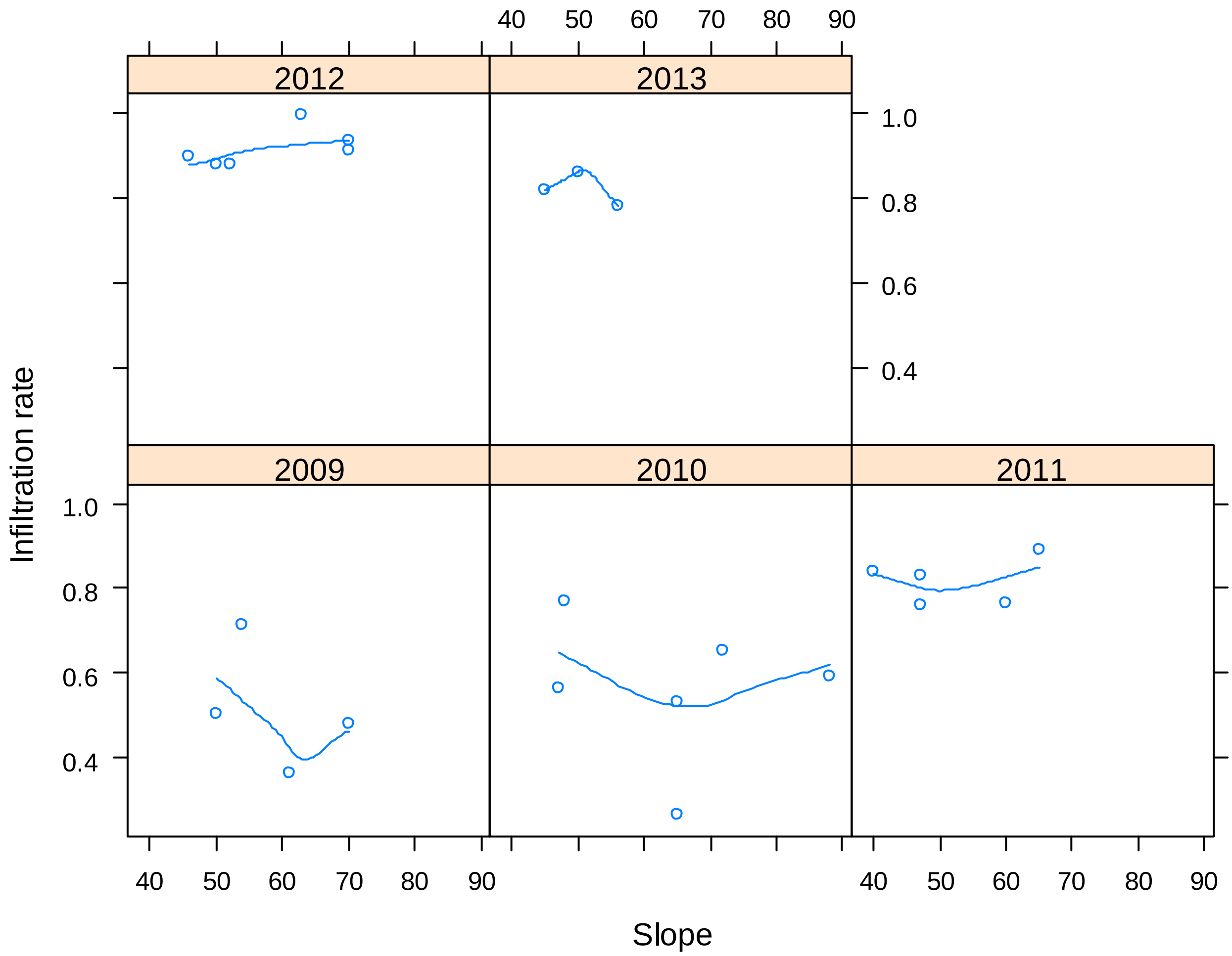



```
# These don't look so great, so be conservative in interpreting hypothesis tests

anova(ir.vegfit)
            numDF denDF  F-value p-value
(Intercept)     1    15 649.4583  <.0001
time            1    15  30.9063  0.0001
veg             2     3   0.8673  0.5044
time:veg        2    15   1.7563  0.2064

anova(ir.vegfit,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1    15 21.703659  0.0003
time            1    15 27.340946  0.0001
veg             2     3  2.557302  0.2248
time:veg        2    15  1.756308  0.2064
# Vegetation and its interaction with time are not significant for infiltration rate

anova(ro.vegfit)
            numDF denDF   F-value p-value
(Intercept)     1    15 101.95755  <.0001
time            1    15  41.84969  <.0001
veg             2     3   0.18267  0.8417
time:veg        2    15   0.65187  0.5352

anova(ro.vegfit,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1    15 72.74647  <.0001
time            1    15 29.08184  0.0001
veg             2     3  0.82158  0.5194
```

```
time:veg        2    15  0.65187  0.5352
# Vegetation and its interaction with time are not significant for runoff ratio

# Collapse into two veg classes: RW/DF vs TO and RW/TO
rainlit.gd$v2 <- rainlit.gd$veg=="RW/DF"
ir.vegfit <- lme(inf.rate ~  time * v2, rainlit.gd, random = ~ time)
ro.vegfit <- lme(sqrt(ro.ratio) ~  time * v2, rainlit.gd, random = ~ time)

anova(ir.vegfit)
            numDF denDF  F-value p-value
(Intercept)     1    16 657.5591  <.0001
time            1    16  25.5035  0.0001
v2              1     4   0.8097  0.4191
time:v2         1    16   1.2597  0.2783

anova(ro.vegfit)
            numDF denDF   F-value p-value
(Intercept)     1    16 104.93132  <.0001
time            1    16  43.07030  <.0001
v2              1     4   0.08866  0.7807
time:v2         1    16   0.15410  0.6998
# Still no significant vegetation effect or interaction

# Test for a slope effect
par(mfrow=c(1,2))
scatter.smooth(rainlit$slope, rainlit$inf.rate, type="p", xlab="Slope (%)",
ylab="Infiltration rate",span=0.9)
scatter.smooth(rainlit$slope, sqrt(rainlit$ro.ratio), type="p", xlab="Slope (%)",
ylab="Runoff ratio (square root)",span=0.9)
```

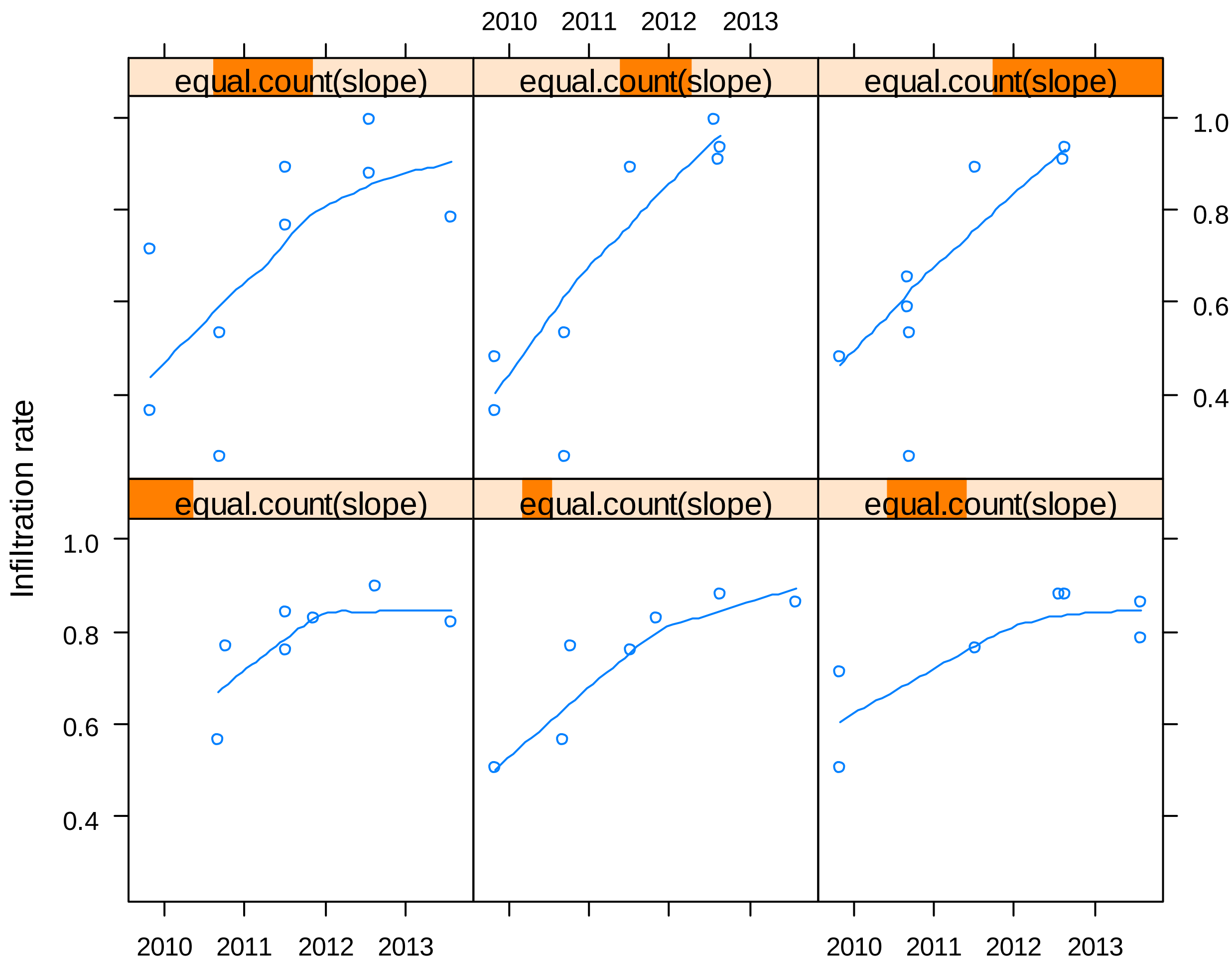


```
xyplot(inf.rate ~ slope | year, data=rainlit,ylab="Infiltration rate",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
```

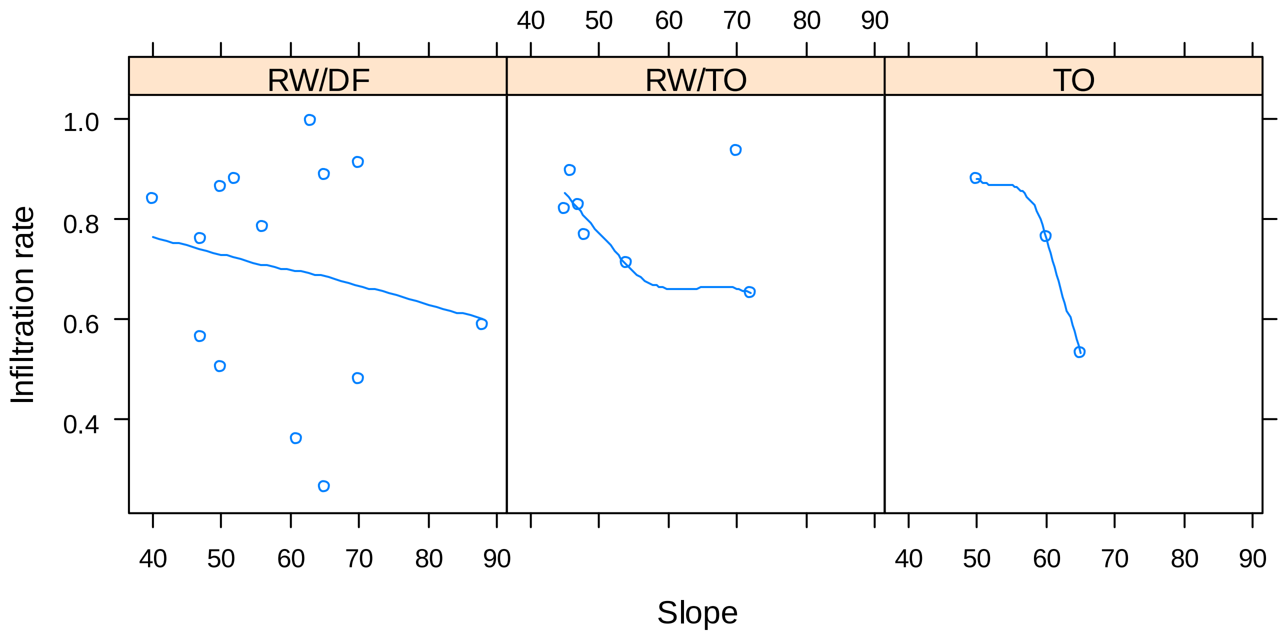



```
# There don't appear to be any slope effects

# Plot infiltration vs time for overlapping slope classes with equal counts
xyplot(inf.rate ~ date | equal.count(slope), data=rainlit,ylab="Infiltration
rate",xlab="",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})

# Look at the 6 slope classes shown in the next plot
equal.count(rainlit$slope)

Data:
 [1] 70 88 65 70 61 65 47 63 56 50 47 40 52 50 54 48 47 46 45 65 60 50 72 70
```

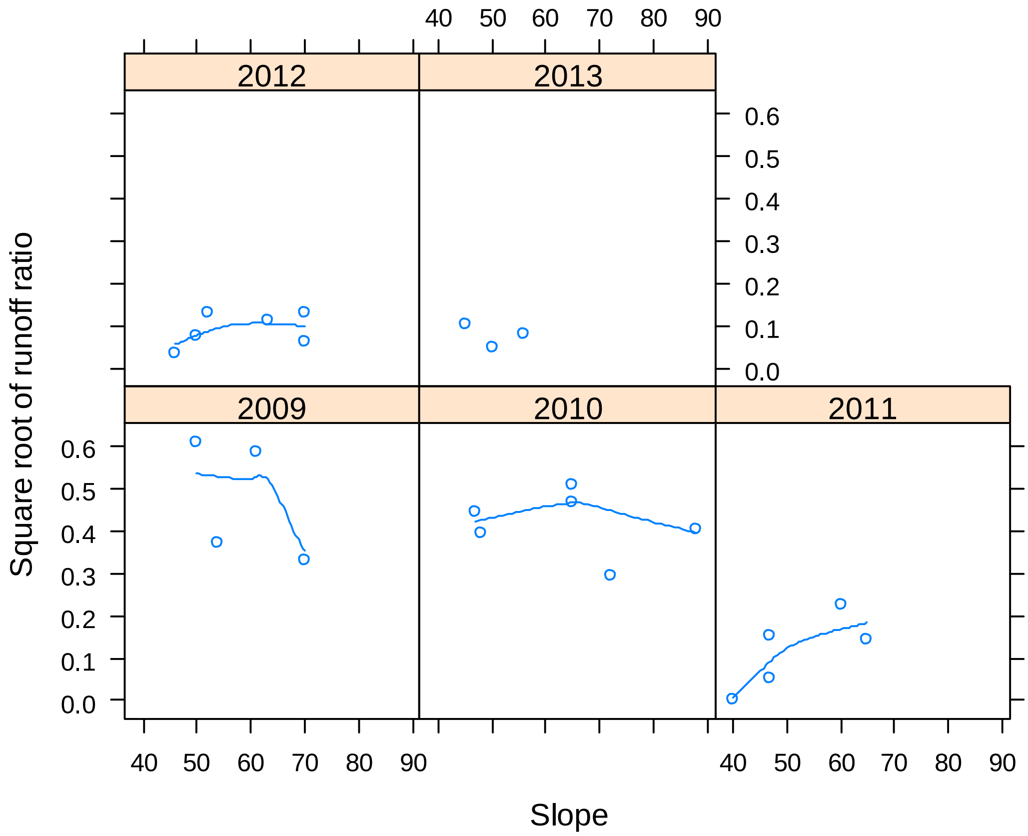
```
Intervals:
   min  max count
1 39.5 48.5     7
2 46.5 50.5     7
3 49.5 60.5     7
4 51.5 65.5     9
5 60.5 70.5     8
6 64.5 88.5     8

Overlap between adjacent intervals:
[1] 4 3 4 5 6
```



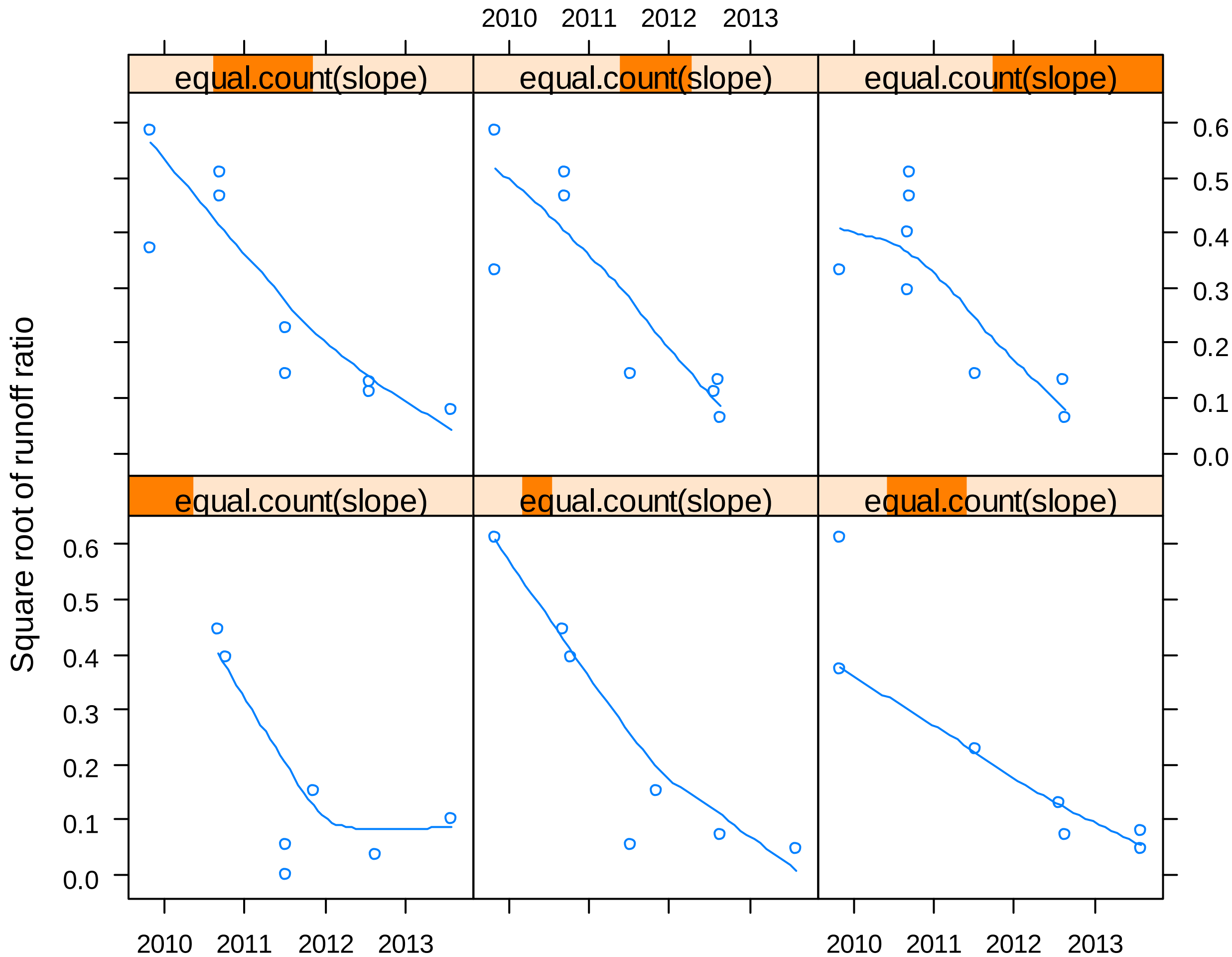

```
# The trend may be a bit stronger on steeper sites (steepest is upper right frame)


xyplot(inf.rate ~ slope | veg, data=rainlit,ylab="Infiltration rate",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
},layout=c(3,1))
```



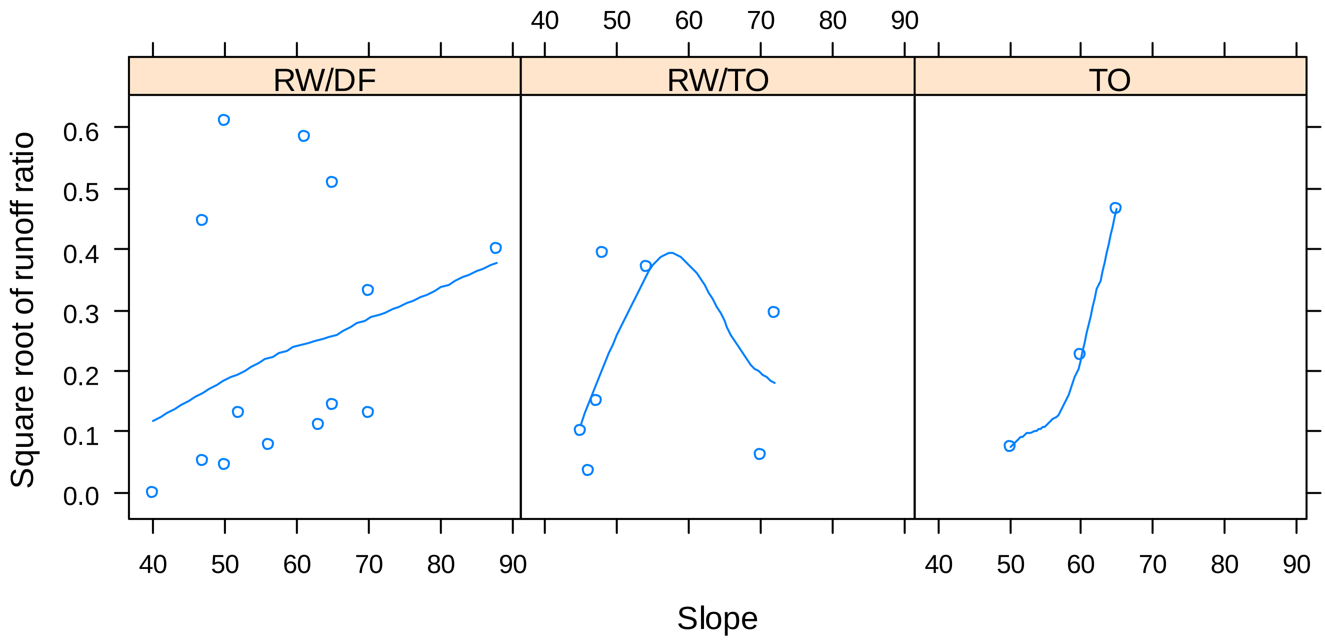

```
xyplot(sqrt(ro.ratio) ~ slope | year, data=rainlit,ylab="Square root of runoff
ratio",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
}, lattice.options = list(panel.error = "warning"))
```



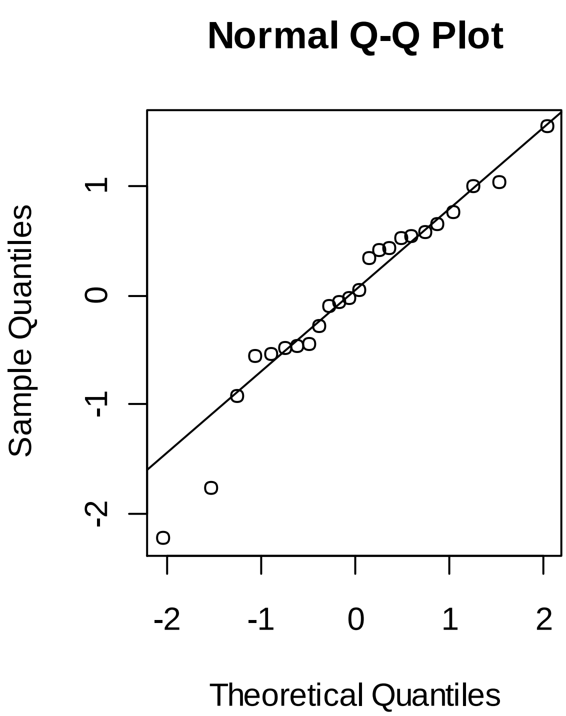

```
xyplot(sqrt(ro.ratio) ~ date | equal.count(slope), data=rainlit,ylab="Square root of
runoff ratio",xlab="",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
})
```

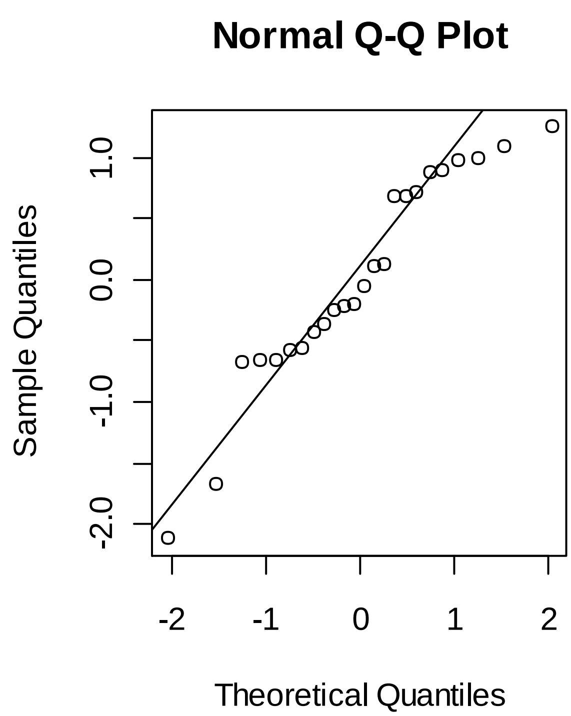



```
# I don't see an effect of slope on the runoff ratio or its trend

xyplot(sqrt(ro.ratio) ~ slope | (veg=="RW/DF"), data=rainlit,ylab="Square root of runoff
ratio ",xlab="Slope",
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
},layout=c(2,1))
```



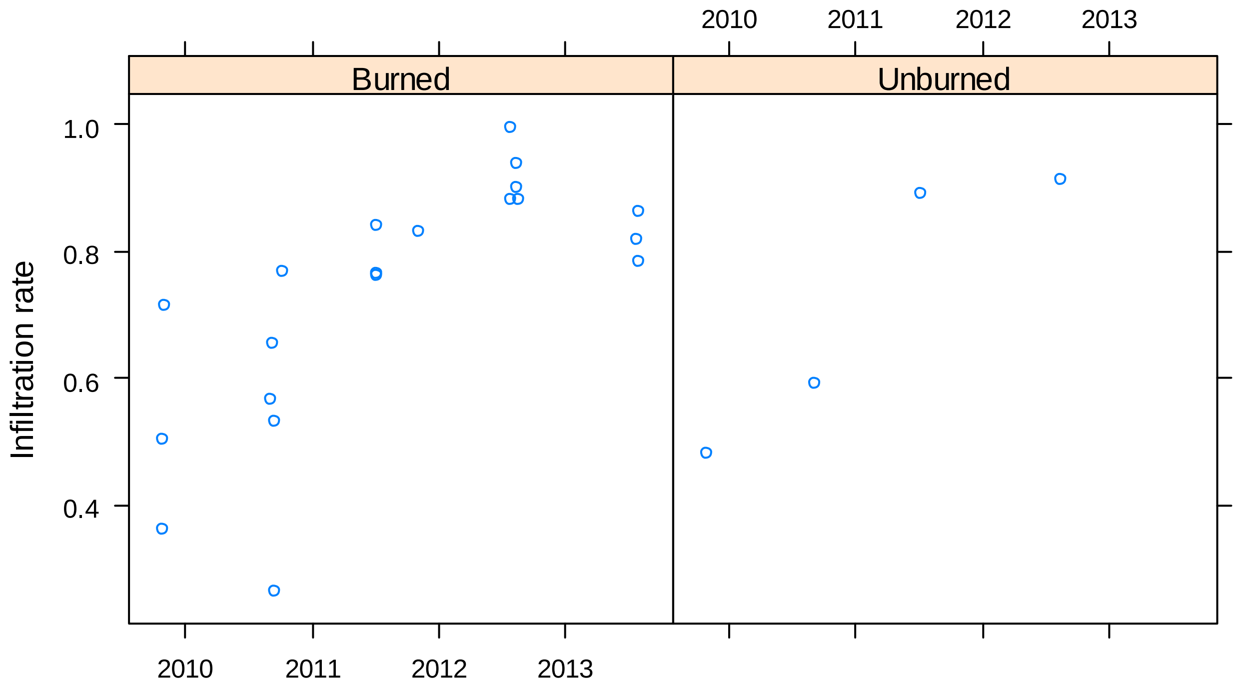

```
two()
ir.slopefit <- lme(inf.rate ~  time*slope, rainlit.gd, random = ~ time)
ro.slopefit <- lme(sqrt(ro.ratio) ~  time*slope, rainlit.gd, random = ~ time)
```





```
anova(ir.slopefit)
            numDF denDF  F-value p-value
(Intercept)     1    15 683.4679  <.0001
time            1    15  26.9456  0.0001
slope           1    15   0.2152  0.6494
time:slope      1    15   6.8852  0.0192

anova(ir.slopefit,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1    15 13.030153  0.0026
time            1    15  2.830827  0.1132
slope           1    15  6.664455  0.0208
time:slope      1    15  6.885166  0.0192
# Although a couple of these are significant, I am not convinced that anything is going
on.  See above graph of Infiltration rate vs slope by year

# Try refitting either just slope, or just time:slope interaction
> anova(lme(inf.rate ~  time + time:slope, rainlit.gd, random = ~ time))
            numDF denDF  F-value p-value
(Intercept)     1    16 660.7608  <.0001
time            1    16  21.4235  0.0003
time:slope      1    16   0.1779  0.6788
> anova(lme(inf.rate ~  time + slope, rainlit.gd, random = ~ time))
            numDF denDF  F-value p-value
(Intercept)     1    16 640.9889  <.0001
time            1    16  21.1910  0.0003
slope           1    16   0.1903  0.6685
# It seems these variables are only significant when considered together

anova(ro.slopefit)
            numDF denDF  F-value p-value
(Intercept)     1    15 39.71884  <.0001
time            1    15 29.62347  0.0001
slope           1    15  2.18261  0.1603
time:slope      1    15  0.48555  0.4966

anova(ro.slopefit,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1    15 0.0477218  0.8300
time            1    15 0.0364329  0.8512
slope           1    15 1.4512424  0.2470
time:slope      1    15 0.4855517  0.4966
# No slope effect on runoff ratio

# Test the interaction of slope and vegetation
ir.slopevegfit <- lme(inf.rate ~  veg*slope, rainlit.gd, random = ~ time)
ro.slopevegfit <- lme(sqrt(ro.ratio) ~  veg*slope, rainlit.gd, random = ~ time)
> ir.slopevegfit <- lme(inf.rate ~  veg*slope, rainlit.gd, random = ~ time)
Error in lme.formula(inf.rate ~ veg * slope, rainlit.gd, random = ~time) :
  nlminb problem, convergence error code = 1
  message = iteration limit reached without convergence (9)
> ro.slopevegfit <- lme(sqrt(ro.ratio) ~  veg*slope, rainlit.gd, random = ~ time)
Error in lme.formula(sqrt(ro.ratio) ~ veg * slope, rainlit.gd, random = ~time) :
  nlminb problem, convergence error code = 1
  message = iteration limit reached without convergence (9)
==========================================================================
Contrasting Unburned with Burned sites
```

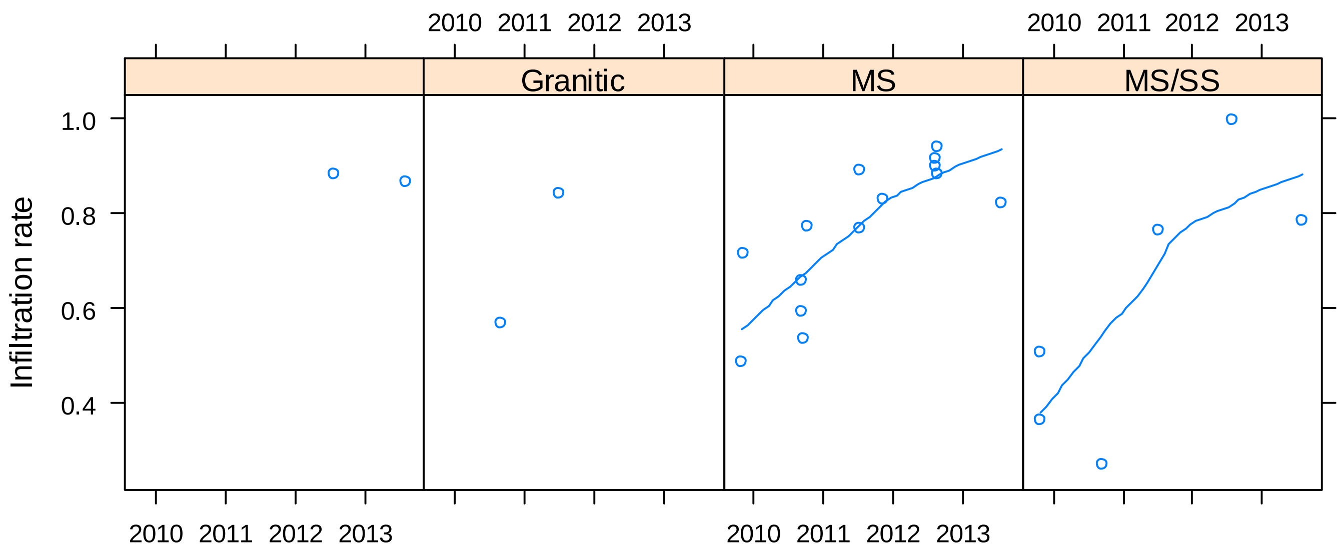
```
==========================================================================

# Create a factor so that labels on xyplot will be clear
burned <- factor(rainlit$burn.sev == "None", labels=c("Burned","Unburned"))

xyplot(inf.rate ~ date | burned, data=rainlit, xlab="", ylab="Infiltration rate")
```



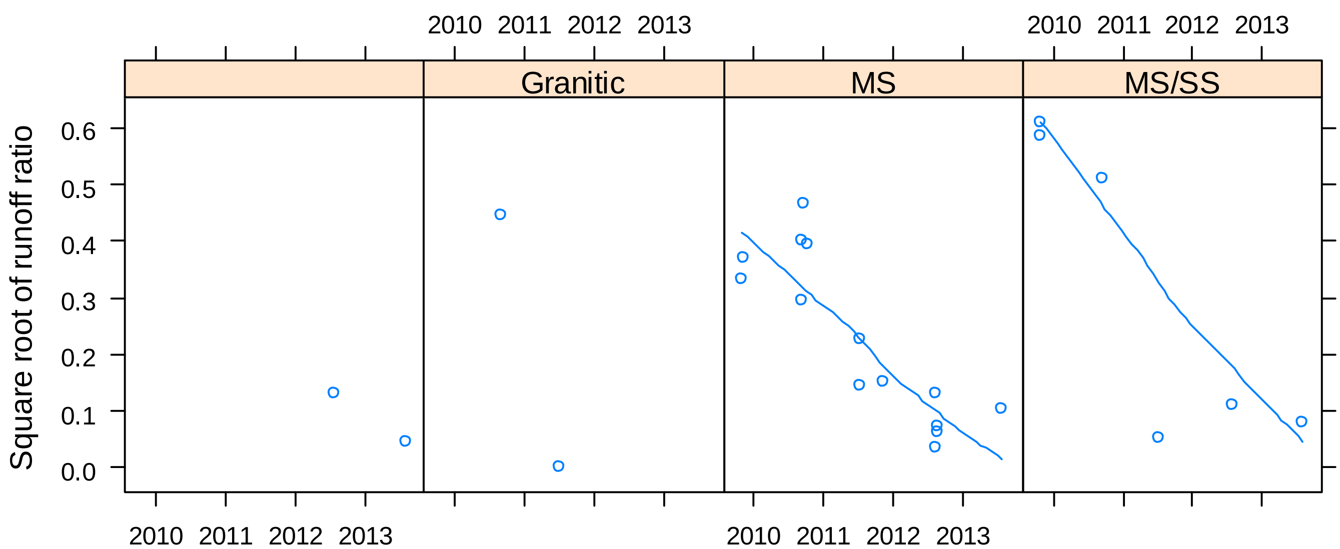

```
xyplot(ro.ratio ~ date | burned, data=rainlit, xlab="", ylab="Runoff ratio")
```


```
# There aren't enough unburned sites to permit a statistical comparison, but it's
# easy enough to re-run the commands to see that there's no significant difference

# Contrast Unburned with all others
anova(lme(inf.rate ~  time * (burn.sev=="None"), rainlit.gd, random = ~
time),type="marginal")
                        numDF denDF   F-value p-value
(Intercept)                 1    16 19.446606  0.0004
time                        1    16 14.155253  0.0017
burn.sev == "None"          1     4  0.123682  0.7428
time:burn.sev == "None"     1    16  0.558565  0.4657

# The interaction is NOT significant, so the time trend does not depend on burn severity.
The main effect of burning is not even significant.

# Runoff ratio
anova(lme(sqrt(ro.ratio) ~  time * (burn.sev=="None"), rainlit.gd, random = ~
time),type="marginal")
                        numDF denDF  F-value p-value
(Intercept)                 1    16 99.04408  <.0001
time                        1    16 43.36663  <.0001
burn.sev == "None"          1     4  1.02459  0.3687
time:burn.sev == "None"     1    16  0.54153  0.4725
# Again, neither burning nor its interaction with time is significant


====================================================================
Contrasting soil types

table(rainlit.gd$soil)
```

```
         Granitic       MS    MS/SS
       2        2       14        6
# Two soil types are unspecified. These are for site 6L in 2012-2013.

rainlit.gd[rainlit.gd$soil=="",]
Grouped Data: inf.rate ~ time | sitenum
   sitenum         sitename  date rain.rate ro.rate inf.rate ro.ratio soil slope   veg
burn.sev year
16      6L Upper North Fork 15546     0.897   0.017    0.880   0.0168         52 RW/DF
Low 2012
17      6L Upper North Fork 15917     0.865   0.002    0.863   0.0022         50 RW/DF
Low 2013
   time v3
16 1301 RW
17 1672 RW
# The undefined soils are at site 6

> rainlit.gd[rainlit.gd$sitenum=="6L",]
Grouped Data: inf.rate ~ time | sitenum
   sitenum         sitename  date rain.rate ro.rate inf.rate ro.ratio     soil slope
veg burn.sev
13      6L Upper North Fork 14547     0.877   0.373    0.504   0.3724    MS/SS    50
RW/DF      Low
14      6L Upper North Fork 14854     0.736   0.170    0.566   0.1987 Granitic    47
RW/DF      Low
15      6L Upper North Fork 15160     0.840   0.000    0.840   0.0000 Granitic    40
RW/DF      Low
16      6L Upper North Fork 15546     0.897   0.017    0.880   0.0168             52
RW/DF      Low
17      6L Upper North Fork 15917     0.865   0.002    0.863   0.0022             50
RW/DF      Low
   year time v3
13 2009  302 RW
14 2010  609 RW
15 2011  915 RW
16 2012 1301 RW
17 2013 1672 RW
# Site 6 apparently has at least 2 different soil types

table(rainlit.gd$sitenum, rainlit.gd$soil)
        Granitic MS MS/SS
  13H 0        0  3     0
  6L  2        2  0     1
  7M  0        0  5     0
  14M 0        0  2     0
  5M  0        0  0     5
  4N  0        0  4     0


xyplot(inf.rate ~ date | soil, data=rainlit,ylab="Infiltration rate",xlab=" ",
lattice.options = list(panel.error = "warning"),
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
},layout=c(4,1))
```




```
xyplot(sqrt(ro.ratio) ~ date | soil, data=rainlit,ylab="Square root of runoff ratio
",xlab=" ", lattice.options = list(panel.error = "warning"),
    panel=function(x,y) {
        panel.xyplot(x,y)
        panel.loess(x,y,span=1)
},layout=c(4,1))
```




```
ir.soilfit <- lme(inf.rate ~  time*soil, rainlit.gd, random = ~ time)
ro.soilfit <- lme(sqrt(ro.ratio) ~  time*soil, rainlit.gd, random = ~ time)

> anova(ir.soilfit,type="marginal")
            numDF denDF   F-value p-value
```

```
(Intercept)     1    11 1.6708843  0.2226
time            1    11 0.0001238  0.9913
soil            3    11 0.8430121  0.4984
time:soil       3    11 0.6226004  0.6150
> anova(ro.soilfit,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1    11 0.5586946  0.4705
time            1    11 0.3538313  0.5640
soil            3    11 2.6561603  0.1003
time:soil       3    11 2.5591137  0.1084
# Soil does not significantly affect either response nor their trends

# Re-test soils after combining Granitic and unspecified soils
rainlit.gd$s3 <- as.character(rainlit.gd$soil)
rainlit.gd$s3[!(rainlit.gd$soil %in% c("MS","MS/SS"))] <- "Other"
rainlit.gd$s3 <- factor(rainlit.gd$s3)
table(rainlit.gd$s3)
   MS MS/SS Other
   14     6     4

ir.soilfit <- lme(inf.rate ~  time*s3, rainlit.gd, random = ~ time)
ro.soilfit <- lme(sqrt(ro.ratio) ~  time*s3, rainlit.gd, random = ~ time)
> anova(ir.soilfit,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1    13 19.568794  0.0007
time            1    13  8.447856  0.0123
s3              2    13  0.619964  0.5531
time:s3         2    13  0.065316  0.9371
> anova(ro.soilfit,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1    13 46.08301  <.0001
time            1    13 16.36743  0.0014
s3              2    13  1.48998  0.2615
time:s3         2    13  0.73908  0.4966
```

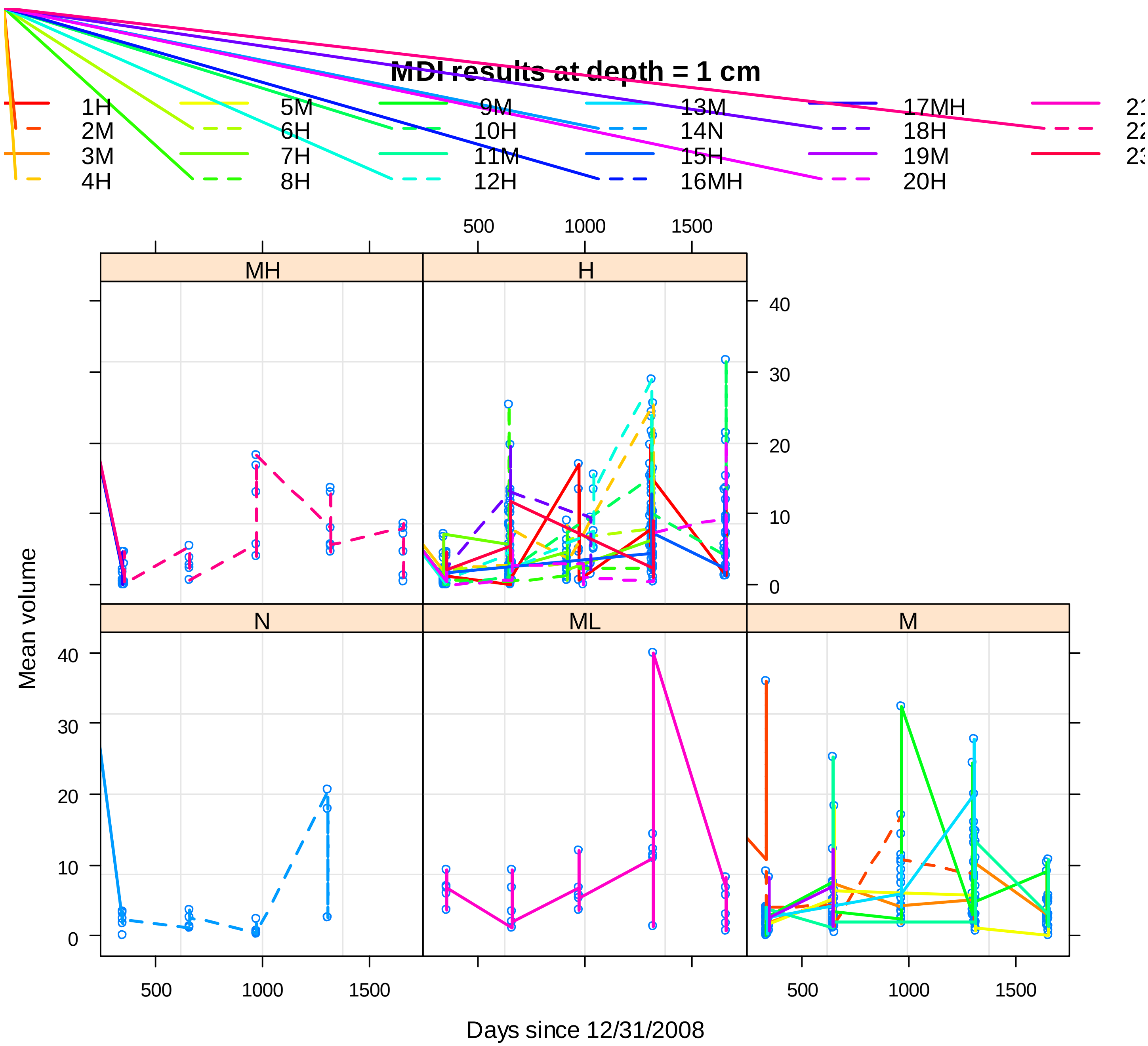
There is a significant uptrend in infiltration rates from 2010 to 2013 and corresponding downtrend in runoff ratios.

We've tested burn severity (detailed classes and Burned/Unburned dichotomy), vegetation, slope, and soils for effects on both responses, and for effects on the trends. The ONLY significant effects found were the effects of slope on infiltration rate and trend (i.e. time:slope interaction). Their significance was not strong (p=0.02), neither slope nor its time interaction were significant by themselves, and no effects of slope were found on runoff ratio.

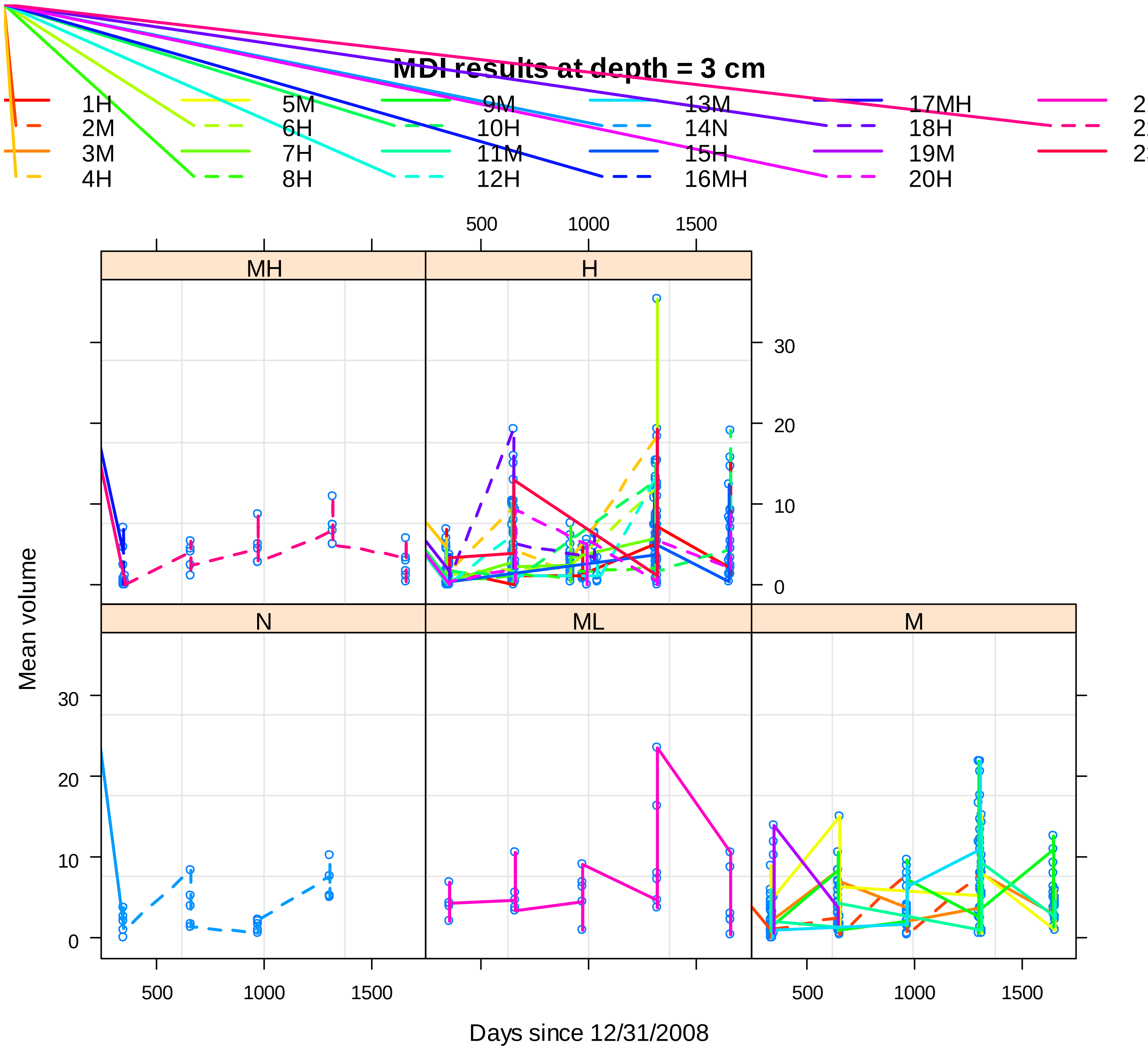
Appendix K. R Code and Output for the MDI Dataset.

Effects of Burn Severity

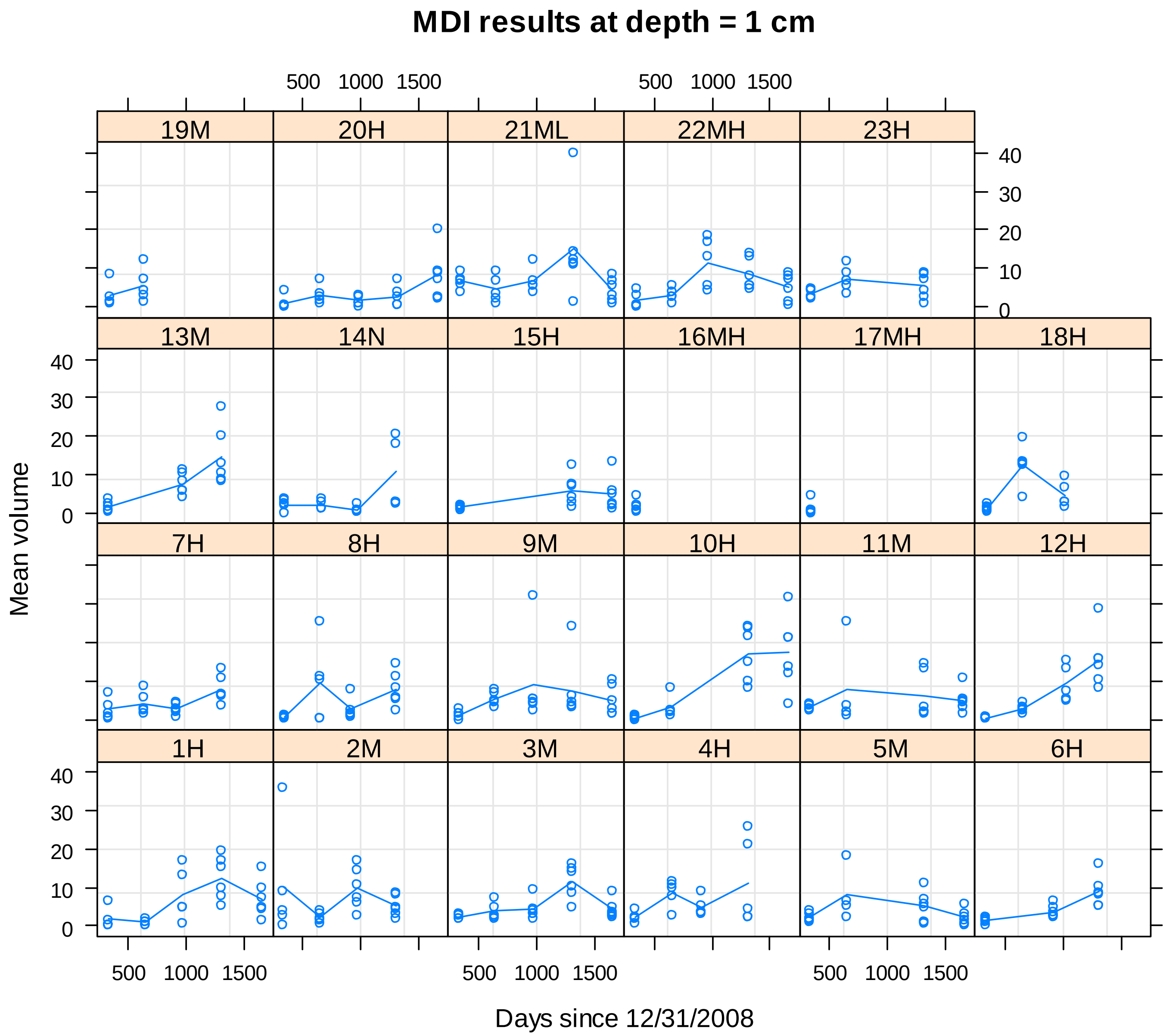
```
library("chron")
library("lattice")
library(nlme)

read.csv("mdi13.csv",as.is=T) -> mdi13

mdi13$date <- dates(mdi13$date)
mdi13$daynum <- as.numeric(mdi13$date)
mdi13$dist <- ordered(sapply(strsplit(mdi13$site.dist,"/"),function(x)
x[2]),levels=as.character(seq(0,100,20)))
mdi13$burn.sev <-
ordered(mdi13$burn.sev,levels=c("UB","M/L","M","H/M","H"),labels=c("N","ML","M","MH","H")
)
mdi13$site <- ordered(paste(format(mdi13$sitenum,width=2),
substring(mdi13$burn.sev,1,2), sep=""))
mdi13$aspect <- factor(mdi13$aspect)
mdi13$slope.pos <- ordered(mdi13$slope.pos,levels=c("L","ML","M","U"))
mdi13$repel <- factor(mdi13$repel)
mdi13$burn.sev2 <- mdi13$burn %in% c("M","MH","H")
mdi13$burn.sev2 <- factor(mdi13$burn.sev2,labels=c("Cool","Hot"))

  year     date sitenum site.dist burn.sev aspect slope.pos depth vol1 vol2 vol3 meanvol
1 2013 07/17/13       1       1/0        H     SE         L     1    0    3    1    1.33
2 2013 07/17/13       1       1/0        H     SE         L     3    3    2    1    2.00
3 2013 07/17/13       1      1/20        H     SE         L     1   16   11    2    9.67
   repel daynum dist site burn.sev2
1 Strong  15903    0   1H       Hot
2 Strong  15903    0   1H       Hot
3   None  15903   20   1H       Hot

# There are fewer sites and slope positions but rbind will expand the levels
mdi.old <- mdi
mdi <- rbind(mdi.old, mdi13)
mdi$daynum08 <- mdi$daynum - as.numeric(dates("1/1/2009"))

superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(23)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
trellis.par.set("superpose.line",superpose.line)

mdi.gd.old <- mdi.gd
mdi.gd <- groupedData(meanvol ~ daynum | site , outer = ~ burn.sev, data=mdi)

tmp <- mdi.gd[mdi.gd$depth==1, ]; tmp$daynum <- tmp$daynum -
as.numeric(dates("1/1/2009"))
plot(tmp, aspect=1, outer=T, xlab="Days since 12/31/2008",ylab="Mean volume",main="MDI
results at depth = 1 cm")
# Multiple measurements on a transect show up as vertical segments in plot
```



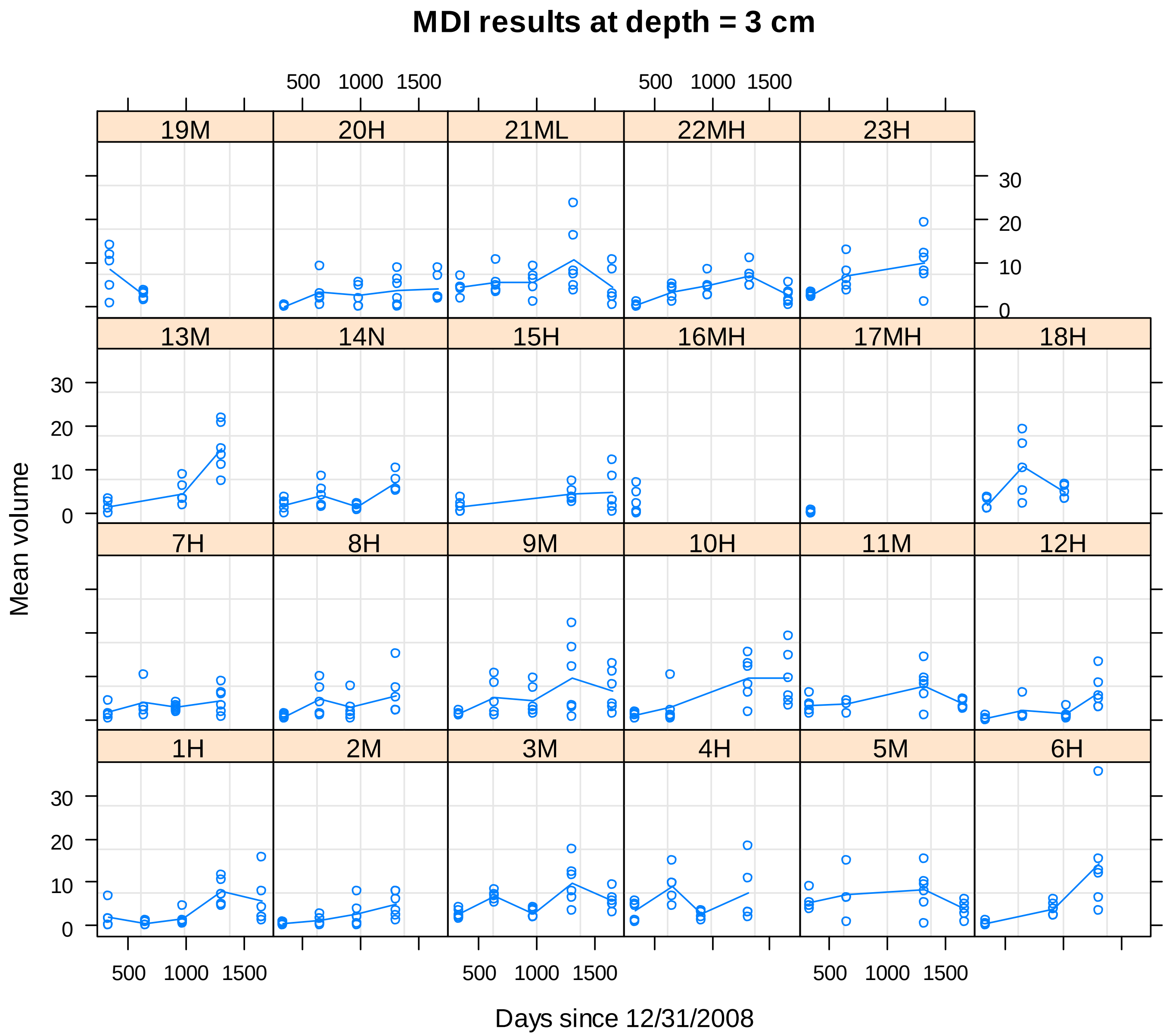

```
tmp <- mdi.gd[mdi.gd$depth==3, ]; tmp$daynum <- tmp$daynum -
as.numeric(dates("1/1/2009"))
plot(tmp, aspect=1, outer=T ,xlab="Days since 12/31/2008",ylab="Mean volume", main="MDI
results at depth = 3 cm")
```



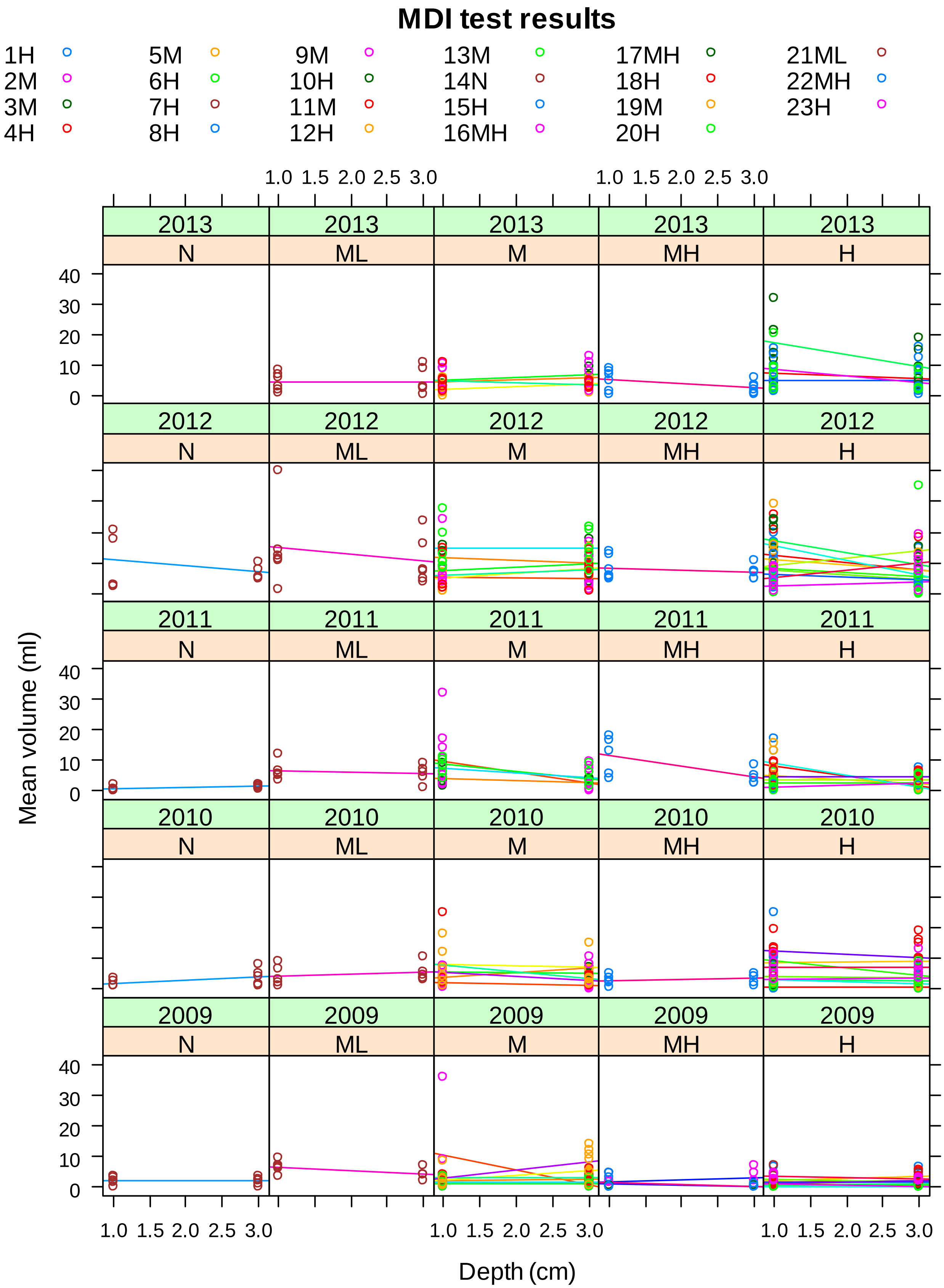

```
tmp <- mdi.gd[mdi.gd$depth==1, ]; tmp$daynum <- tmp$daynum -
as.numeric(dates("1/1/2009"))
plot(tmp, aspect=1, layout=c(6,4), xlab="Days since 12/31/2008",ylab="Mean
volume",main="MDI results at depth = 1 cm")
```



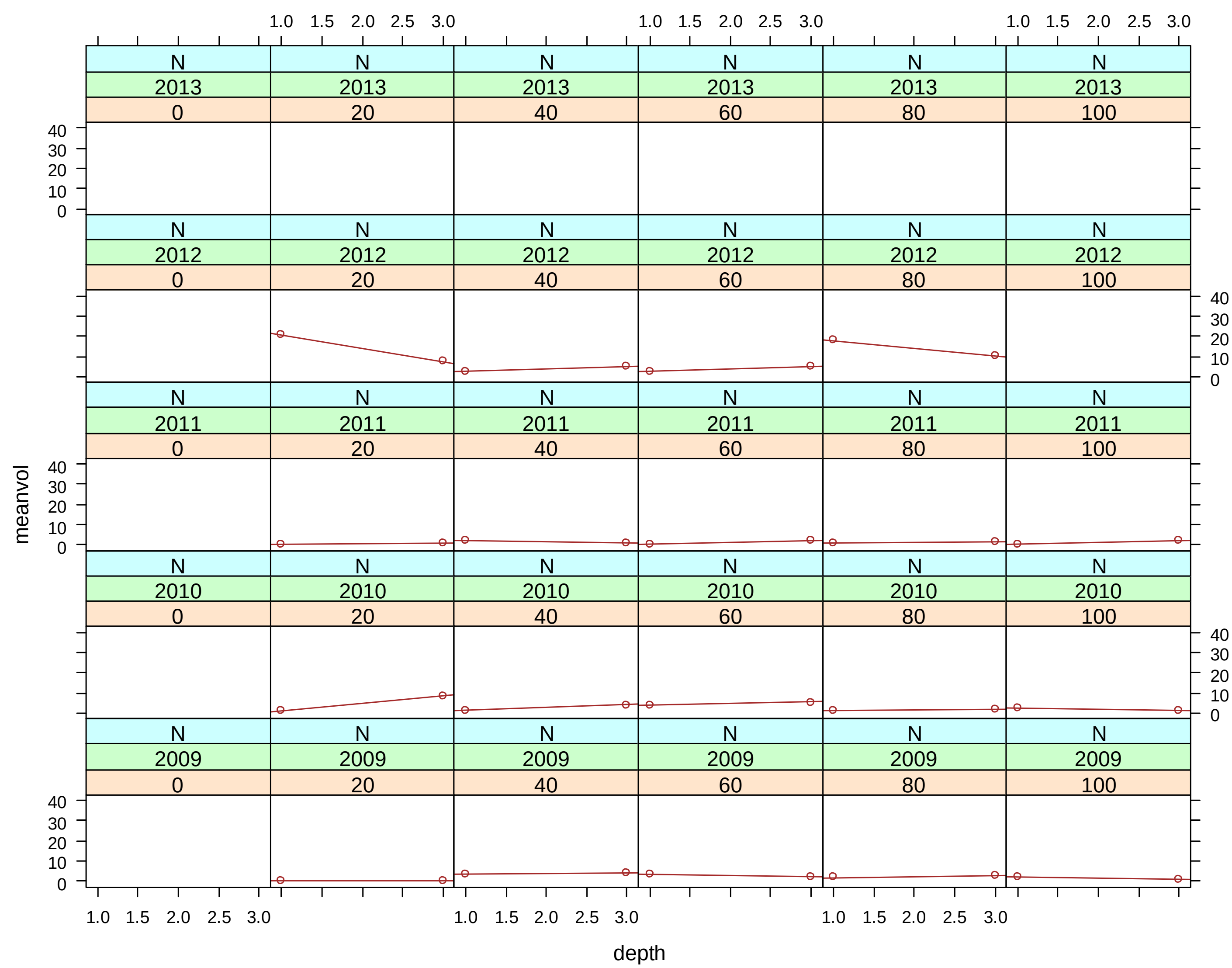

```
tmp <- mdi.gd[mdi.gd$depth==3, ]; tmp$daynum <- tmp$daynum -
as.numeric(dates("1/1/2009"))
plot(tmp, aspect=1, layout=c(6,4), xlab="Days since 12/31/2008",ylab="Mean
volume",main="MDI results at depth = 3 cm")
```

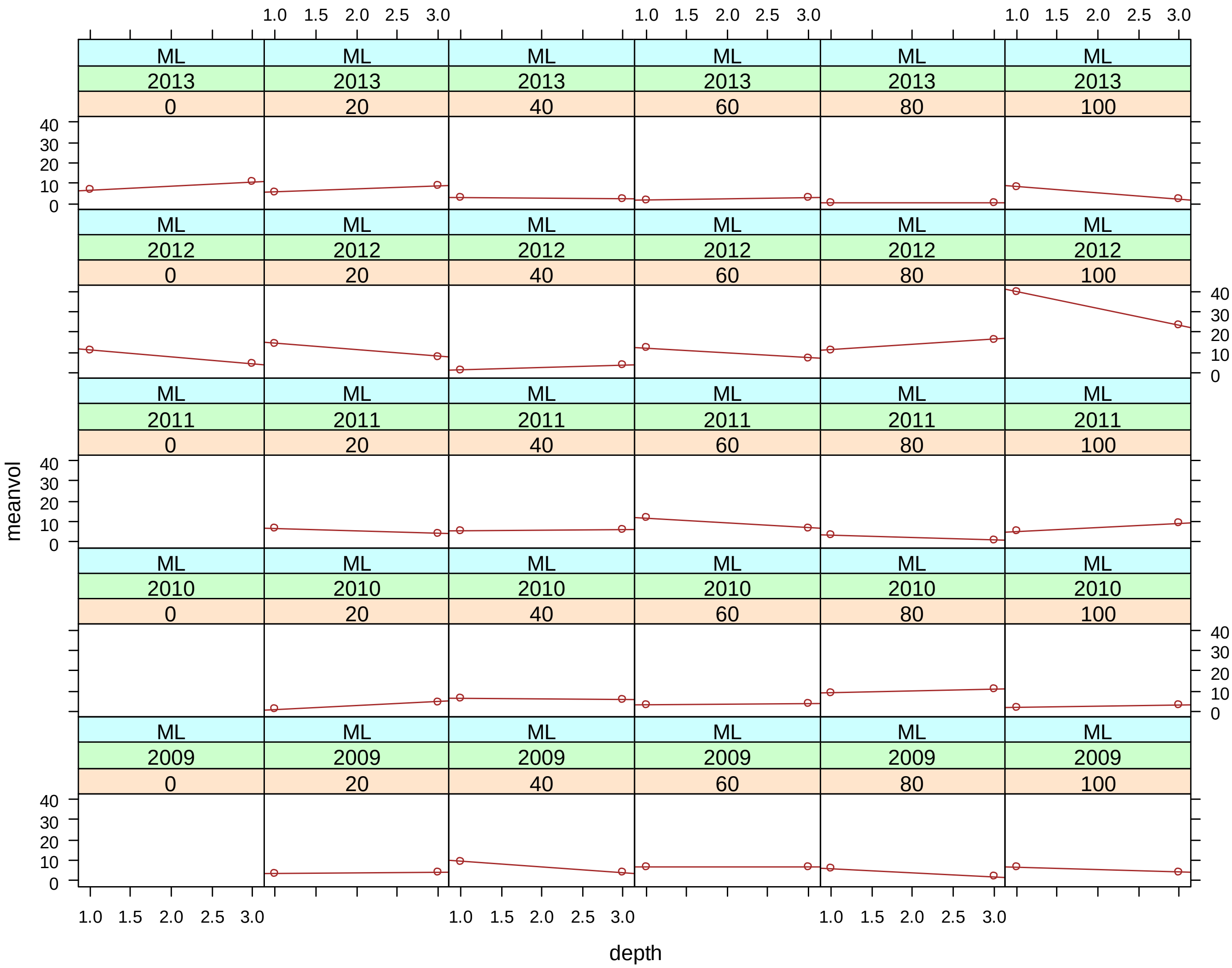


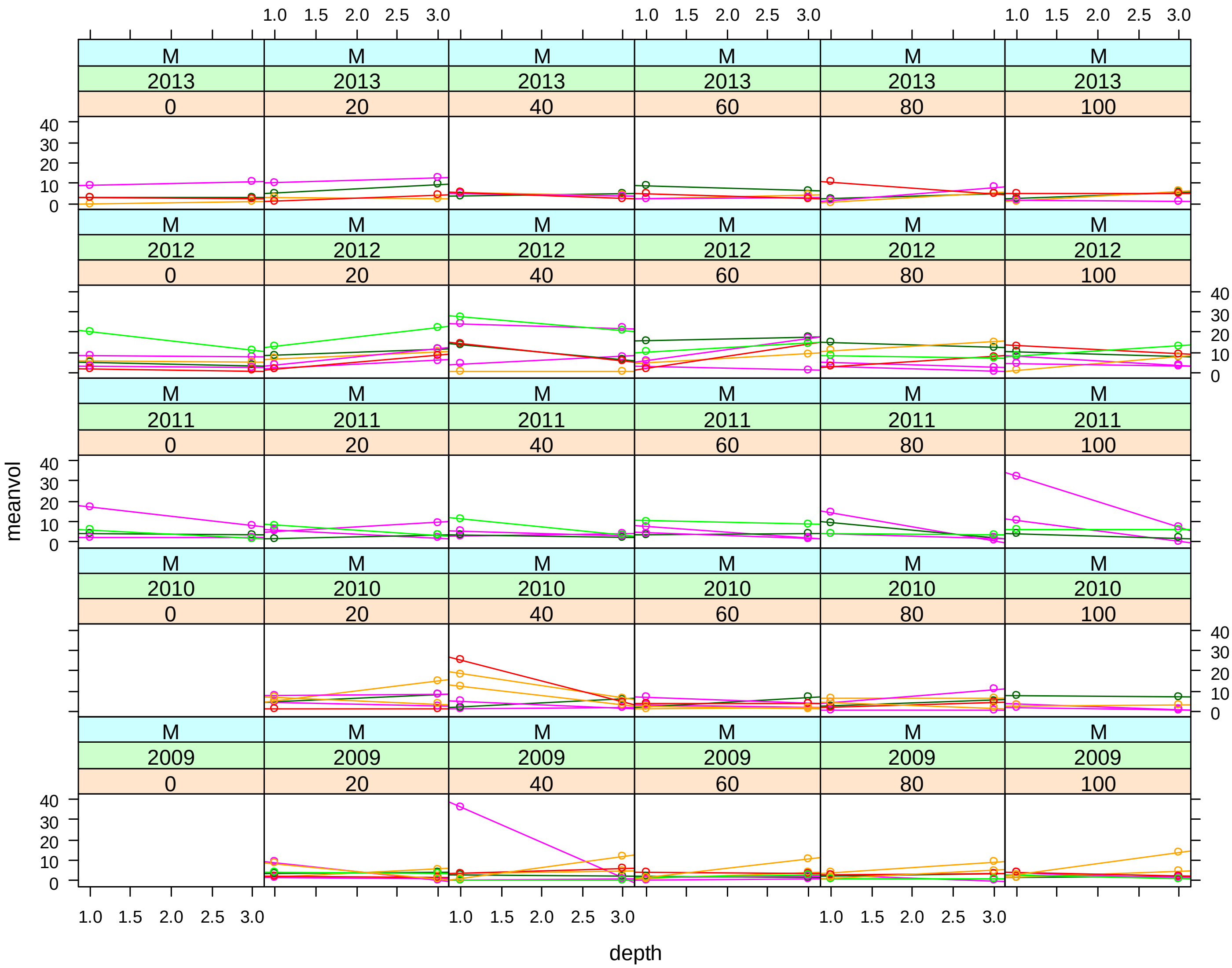

```
superpose.line$lwd <- 1
superpose.line$lty <- 1
trellis.par.set("superpose.line",superpose.line)
xyplot(meanvol ~ depth | burn.sev*factor(year), data=mdi, groups=site,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.lmline")
      panel.superpose(x,y,subscripts,groups, "panel.xyplot")
   }, subset = depth %in% c(1,3), xlab = "Depth (cm)", ylab="Mean volume (ml)", main="MDI
test results", auto.key=list(columns=7)
)
```

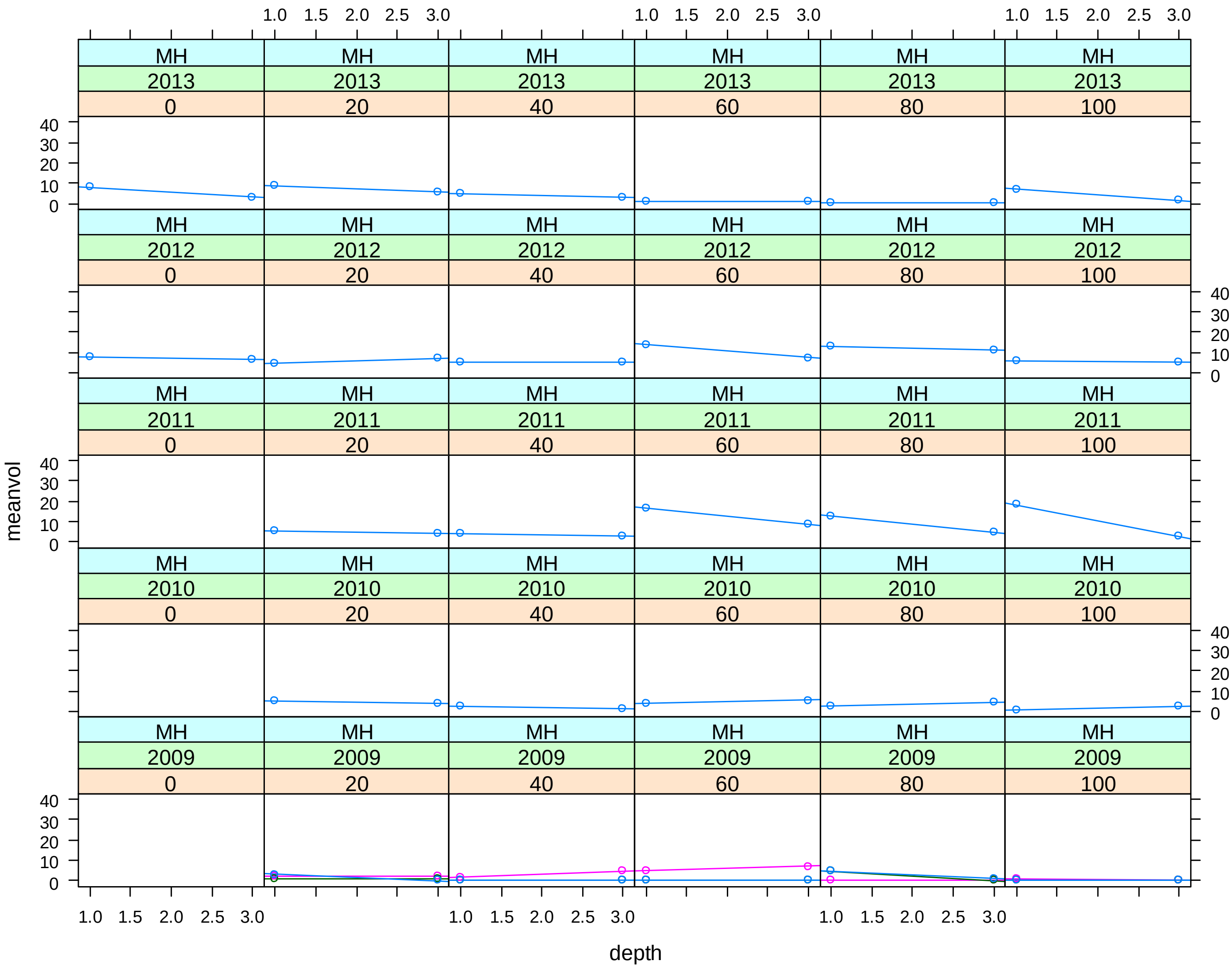

MDI test results
1H
2M
3M
4H
5M
6H
7H
8H
9M
10H
11M
12H
13M
14N
15H
16MH
17MH
18H
19M
20H
21ML
22MH
23H
2013
2012
2011
2010
2009
N
ML
M
MH
H
Mean volume (ml)
Depth (cm)
1.0 1.5 2.0 2.5 3.0
0 10 20 30 40

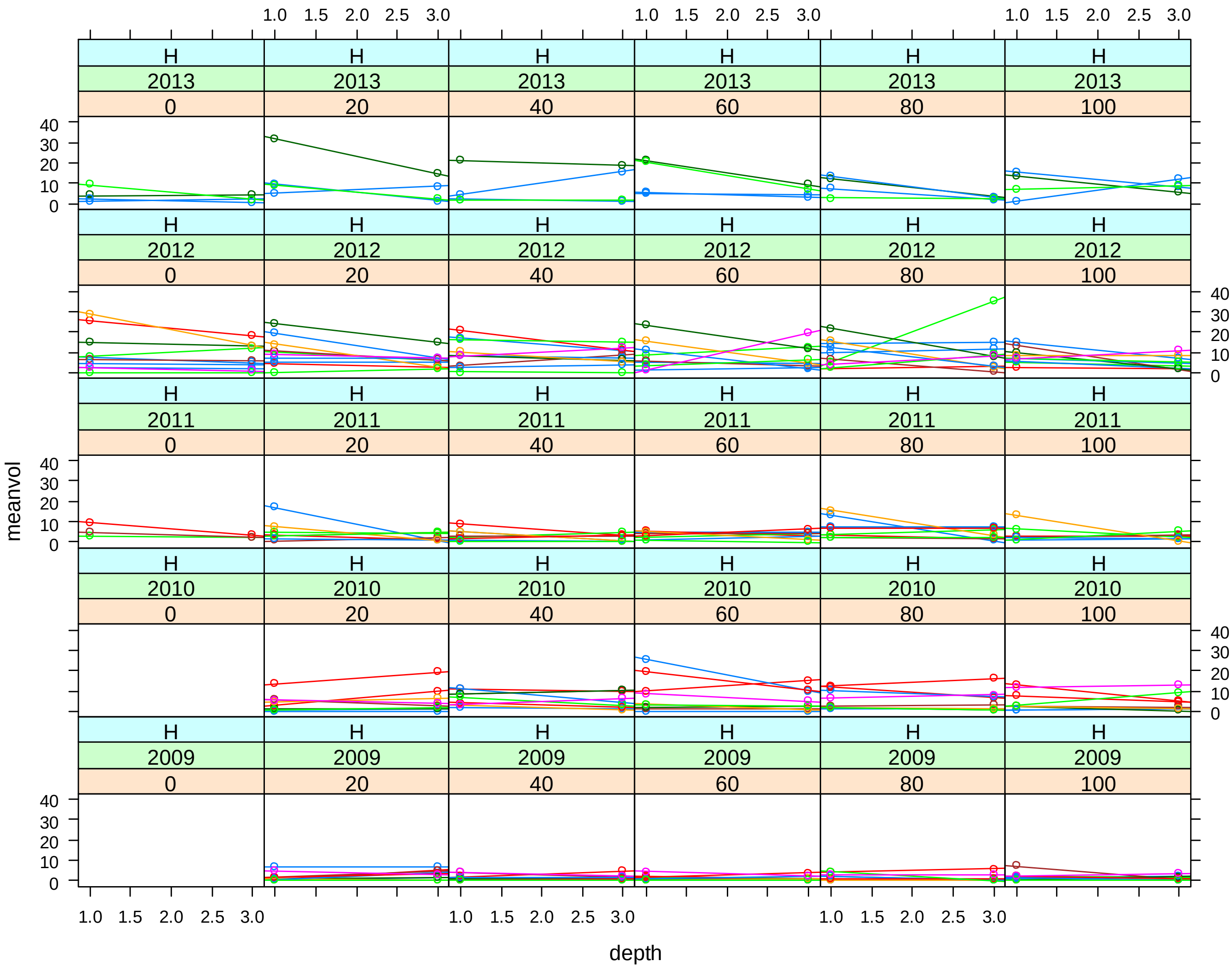
```
# Not much effect from depth

# 3-way plot layout
par(ask=T)
xyplot(meanvol  ~  depth  |  factor(dist)*factor(year)*burn.sev,  data=mdi,  groups=site,
aspect=0.5,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
   }, subset=depth %in% c(1,3)
)
```



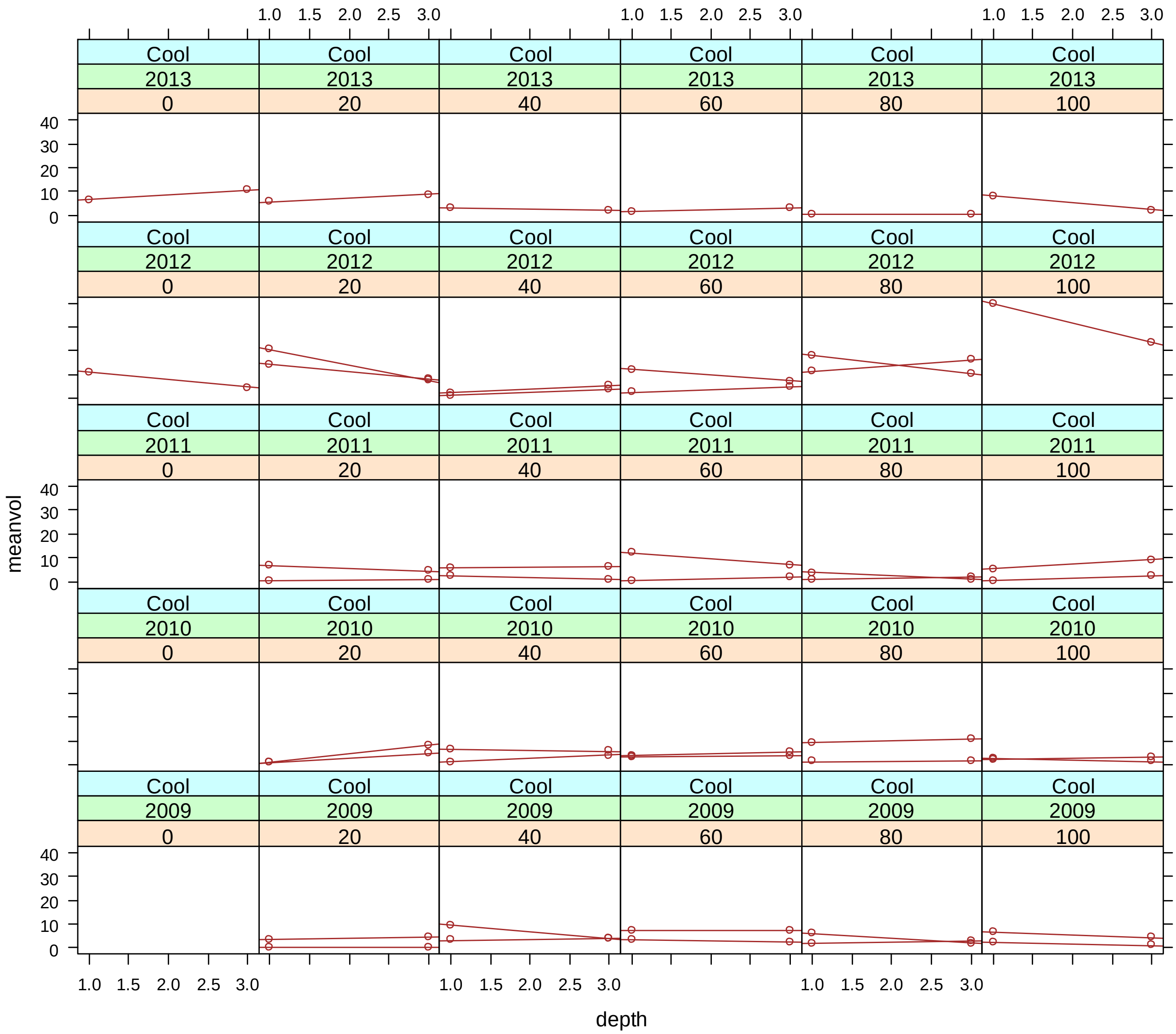

ML
2013
2012
2011
2010
2009
0
20
40
60
80
100
meanvol
depth
1.0
1.5
2.0
2.5
3.0
0
10
20
30
40

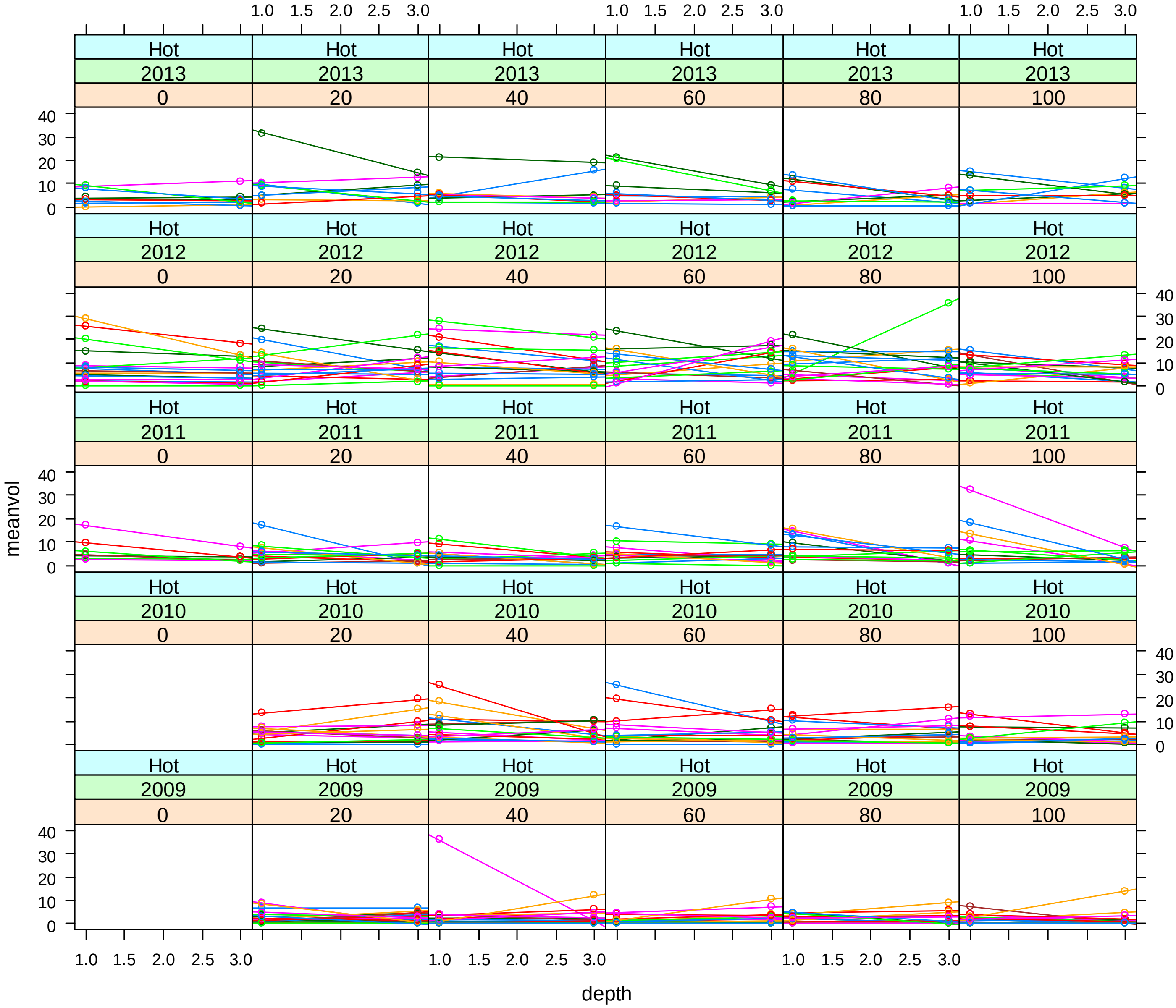

M
2013
2012
2011
2010
2009
0
20
40
60
80
100
meanvol
depth
0
10
20
30
40
1.0
1.5
2.0
2.5
3.0


MH
2013
2012
2011
2010
2009
0
20
40
60
80
100
meanvol
depth
0
10
20
30
40
1.0
1.5
2.0
2.5
3.0

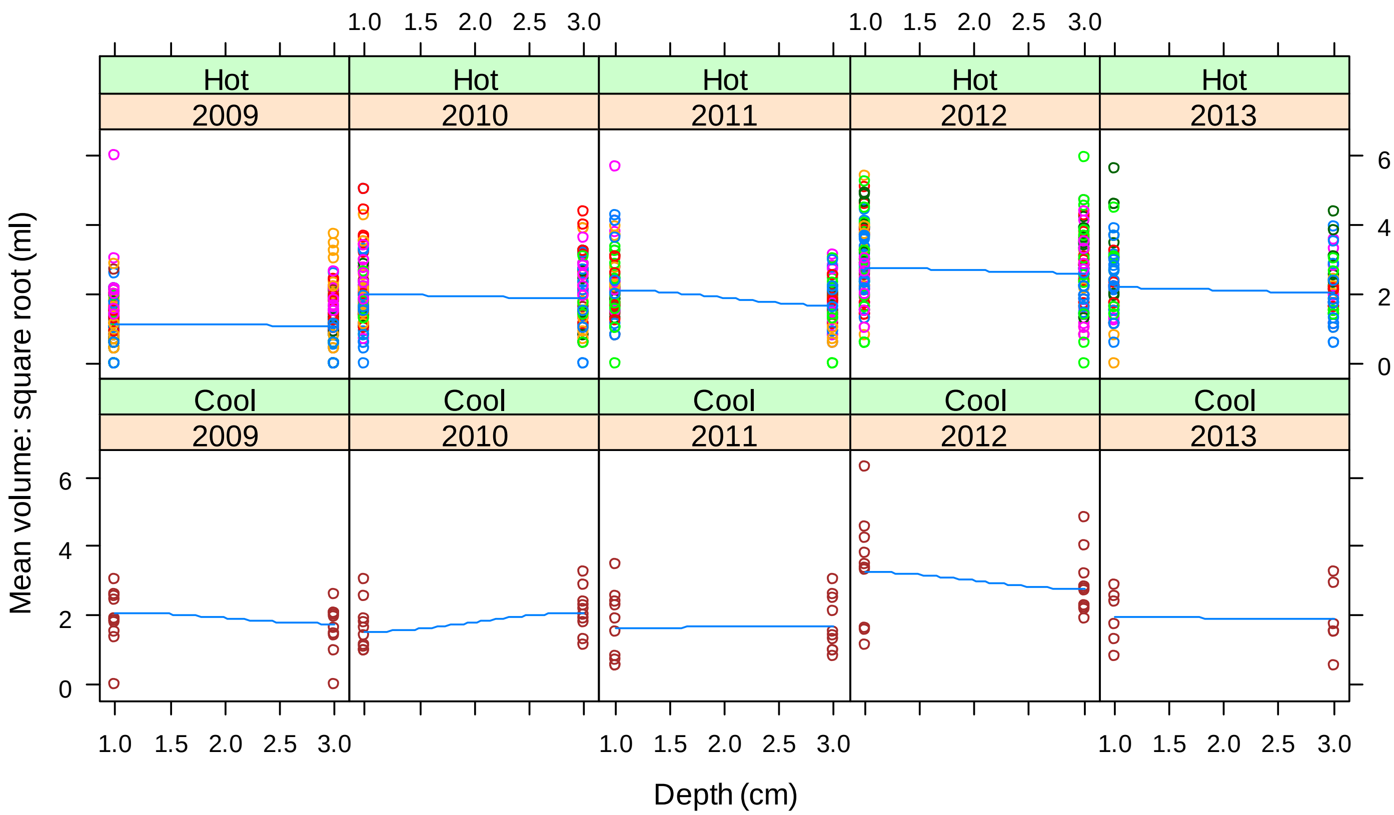


```
xyplot(meanvol  ~  depth  |  factor(dist)*factor(year)*burn.sev2,  data=mdi,  groups=site,
aspect=0.6,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
   }, subset=depth %in% c(1,3)
)
```

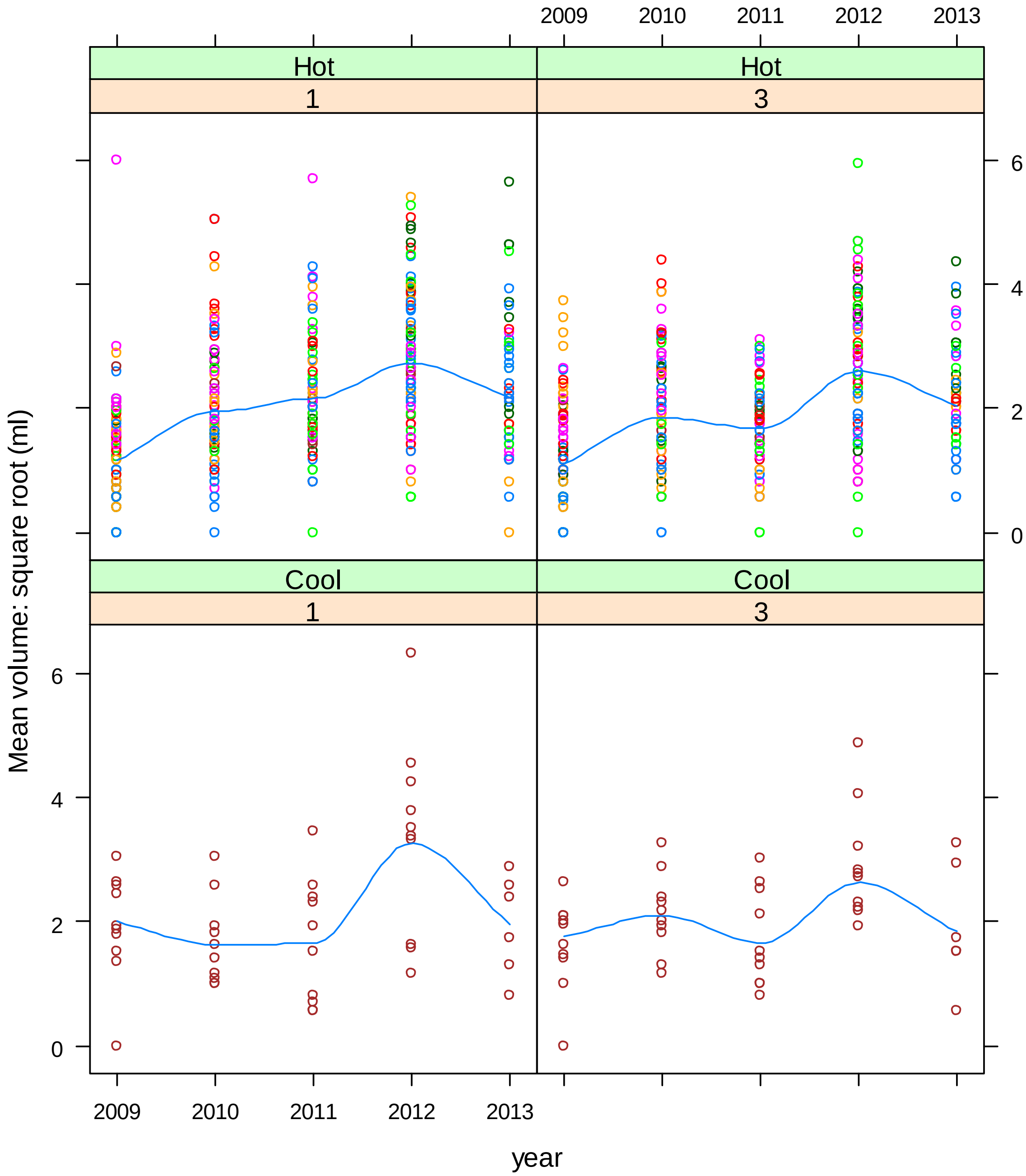

meanvol
depth
Cool
2013
2012
2011
2010
2009
0
20
40
60
80
100
1.0
1.5
2.0
2.5
3.0
0
10
20
30
40




```
# Collapse over transect distance
xyplot(sqrt(meanvol) ~ depth | factor(year)*burn.sev2, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
       panel.superpose(x,y, subscripts, groups, "panel.xyplot")
       panel.loess(x,y,xpan=1)
   }, subset=depth %in% c(1,3), xlab="Depth (cm)", ylab="Mean volume: square root (ml)"
)
```

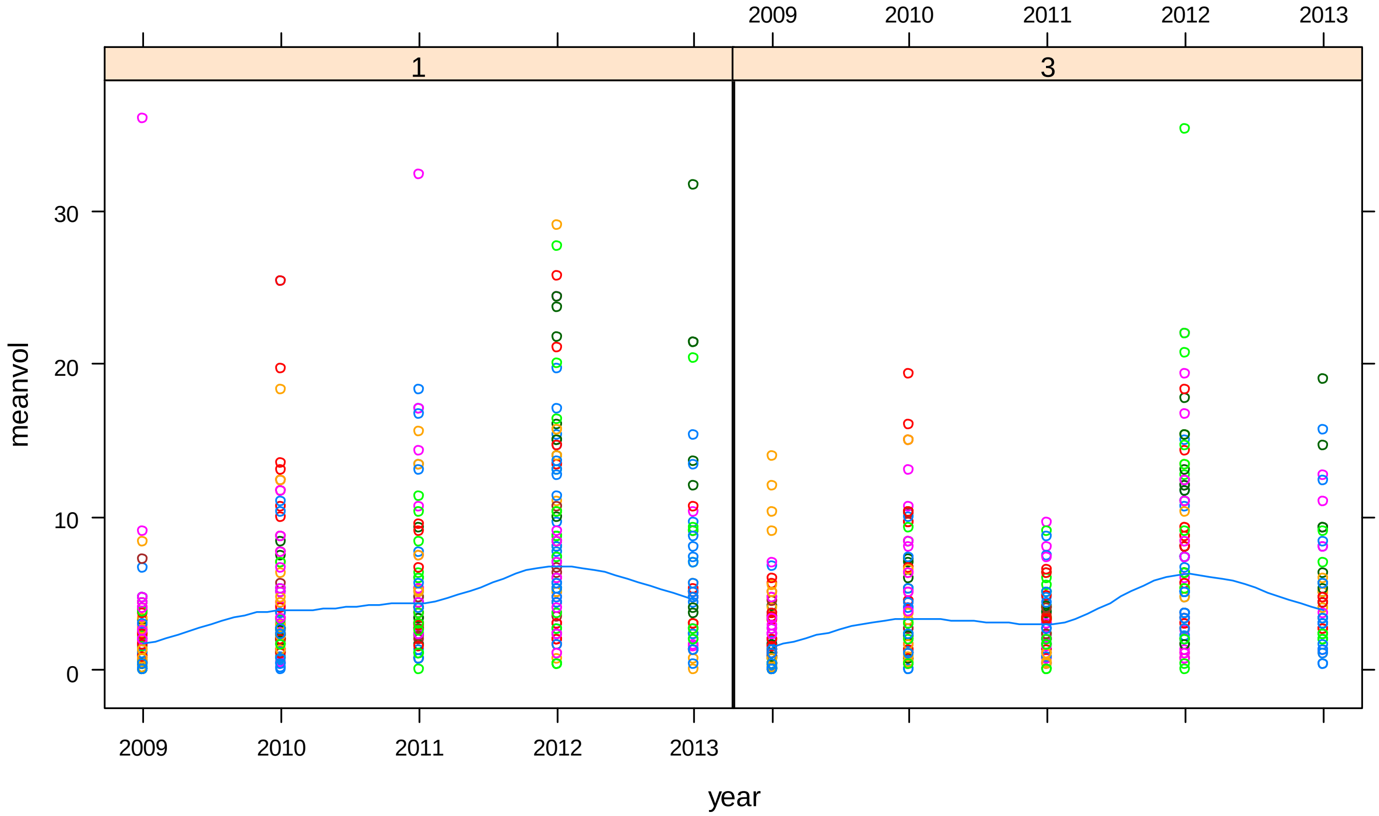



```
# Look at the effect of time by depth
xyplot(sqrt(meanvol) ~ year | factor(depth)*burn.sev2, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
      panel.superpose(x,y,subscripts,groups, "panel.xyplot")
      panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3),ylab="Mean volume: square root (ml)")
```

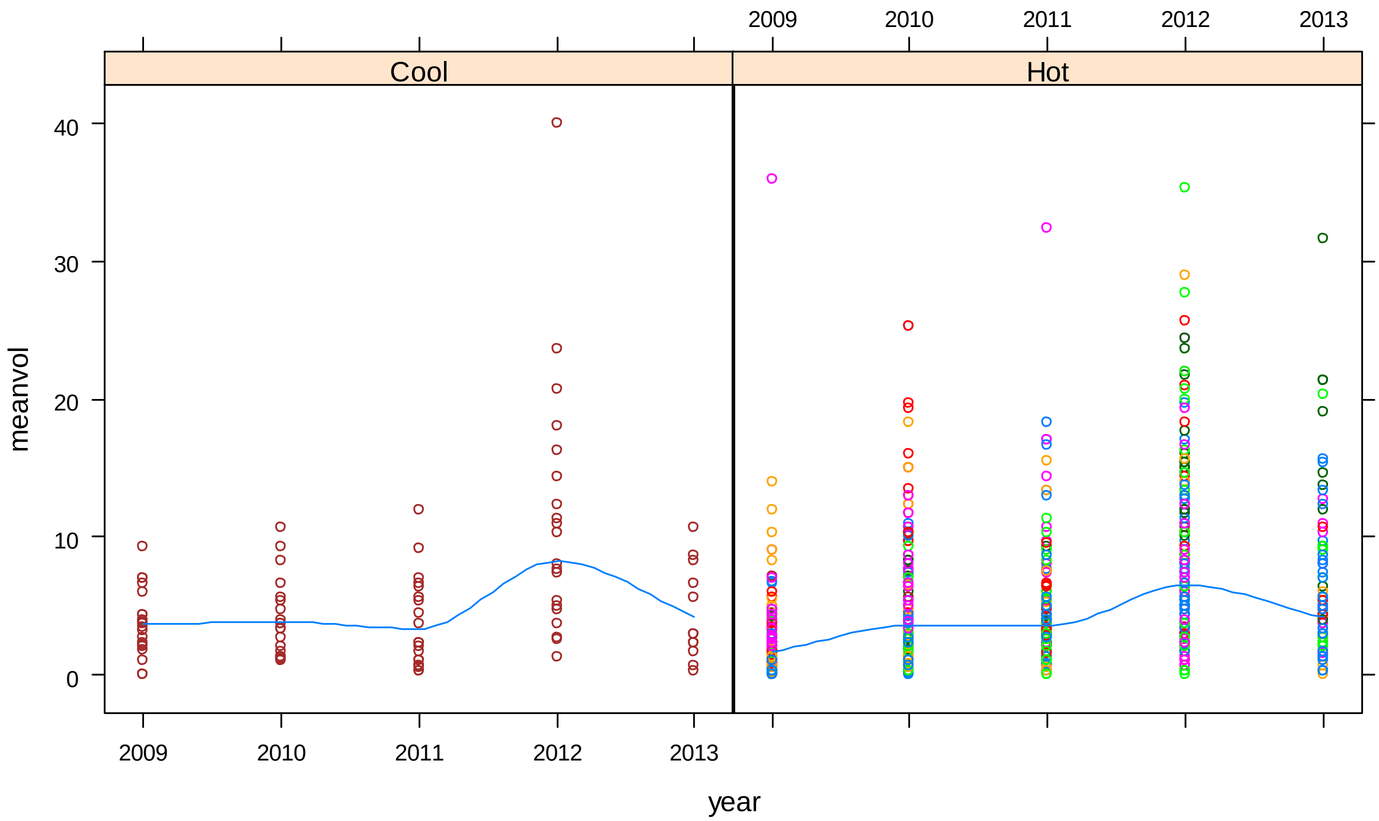


Before I saw the 2013 data I thought there was an increase in volume over time regardless of burn severity. Now I'm not so sure. In the Cool categories, volume seems to have dropped back to what was normal in 2009-2011. Need to get the data points to appear in the "Hot" frames above

```
xyplot(meanvol ~ year | factor(depth), data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
      panel.superpose(x,y,subscripts,groups, "panel.xyplot")
      panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3) & burn.sev2=="Hot")
```

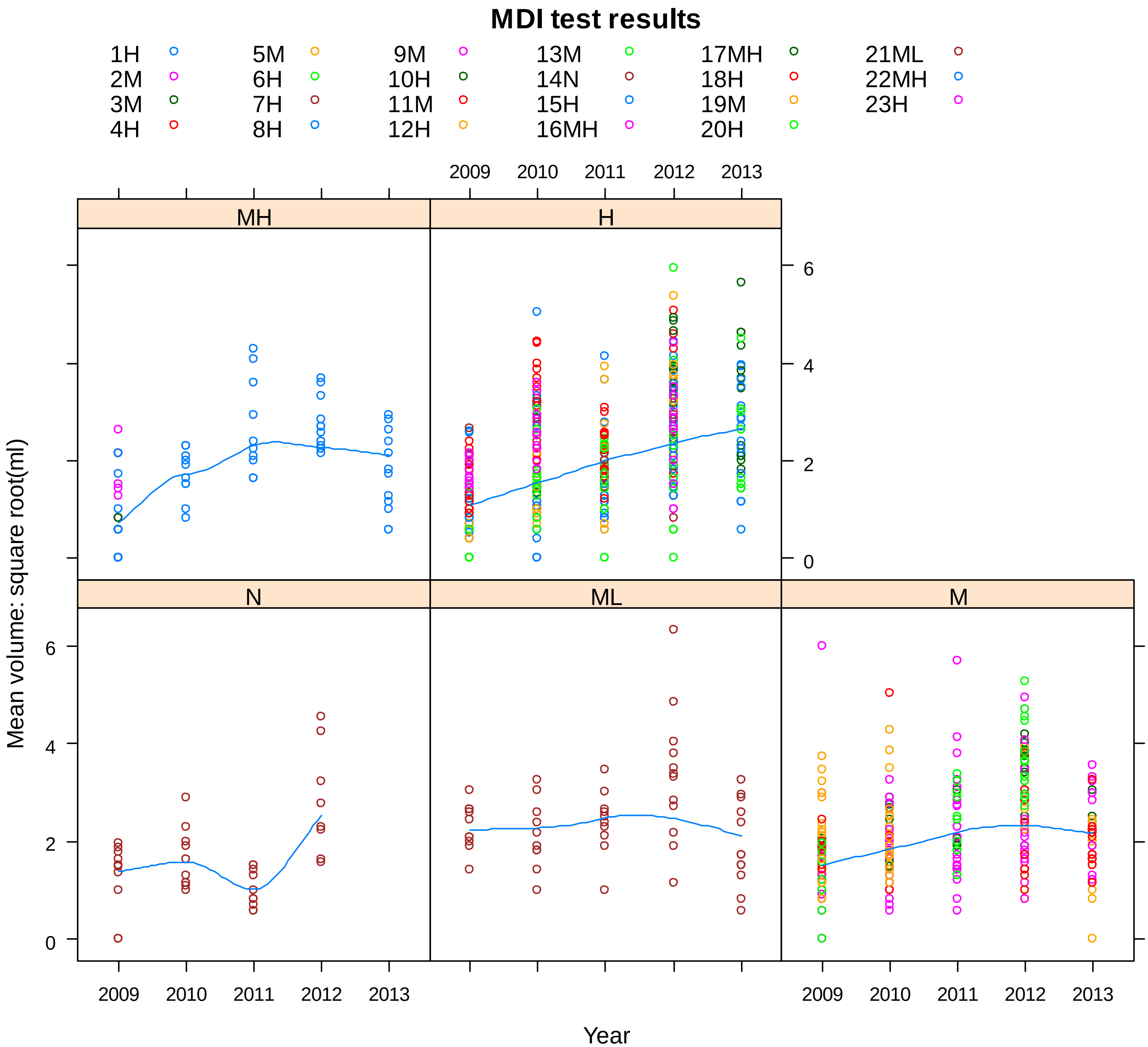



```
# Collapse over both transect distance and depth
xyplot(meanvol ~ year | burn.sev2, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
         # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.33)
         panel.superpose(x,y,subscripts,groups, "panel.xyplot")
         panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3)
)
```

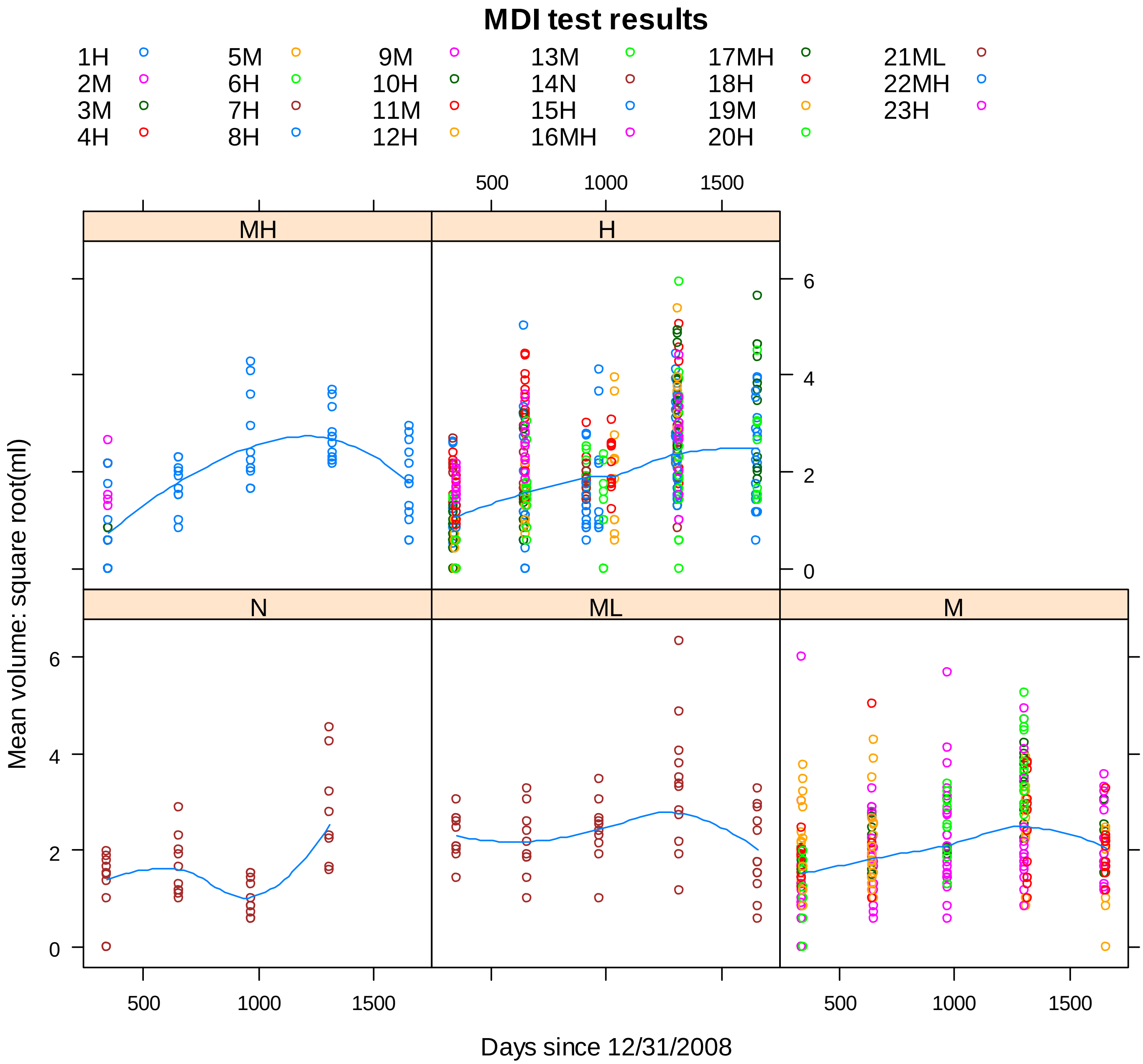



```
xyplot(sqrt(meanvol) ~ year | burn.sev2, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
         # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.33)
         panel.superpose(x,y,subscripts,groups, "panel.xyplot")
         panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3)
)


# Repeat with original burn categories, loess line, and sqrt(meanvol)
xyplot(sqrt(meanvol) ~ factor(year) | burn.sev, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
```

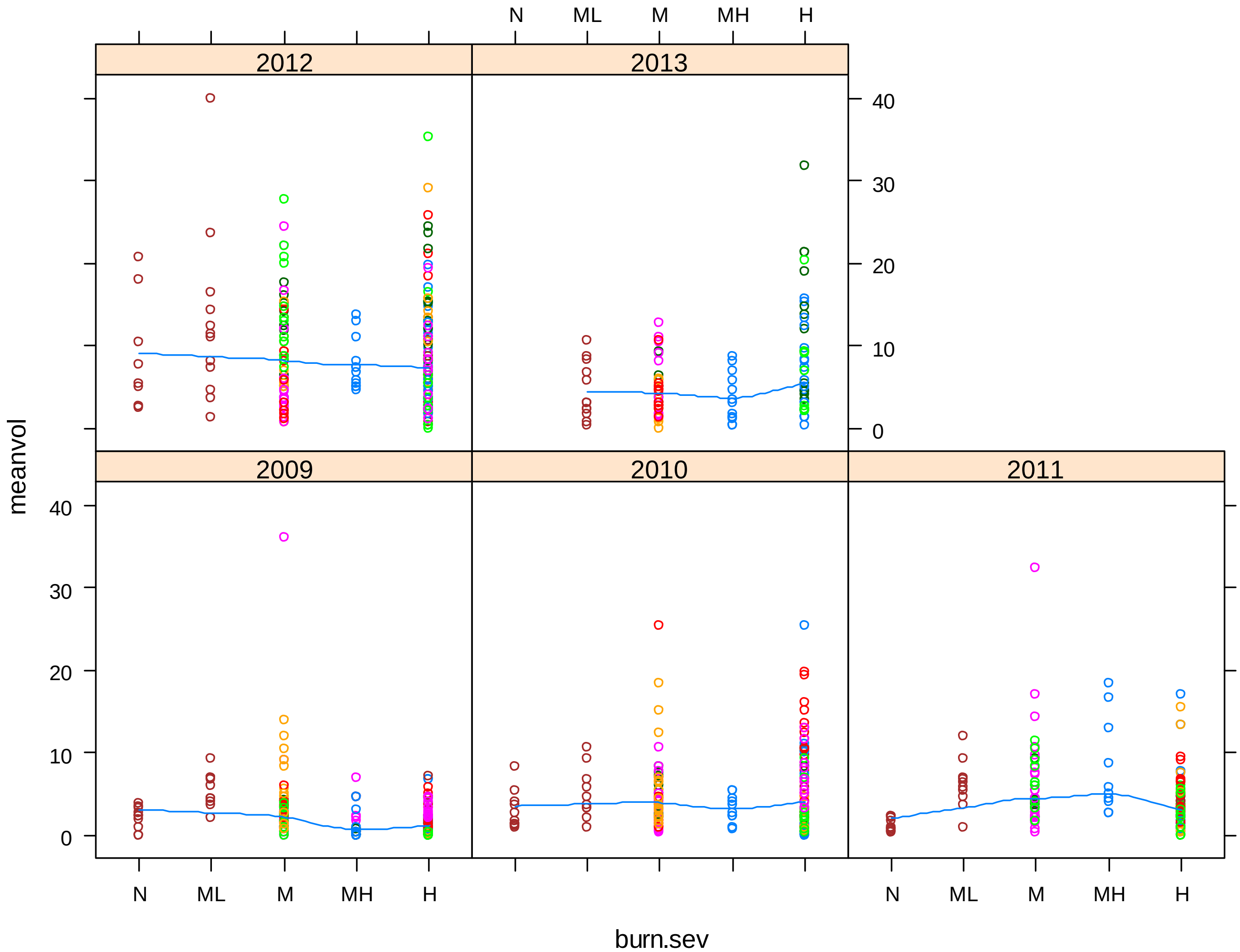
```
            panel.loess(x,y,span=0.67)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Year", ylab="Mean volume: square root(ml)", auto.key=list(columns=7)
)
```




```
# Plot against day number instead of year for a bit more resolution
xyplot(sqrt(meanvol) ~ daynum08 | burn.sev, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Days since 12/31/2008", ylab="Mean volume: square root(ml)",
auto.key=list(columns=7)
)
```



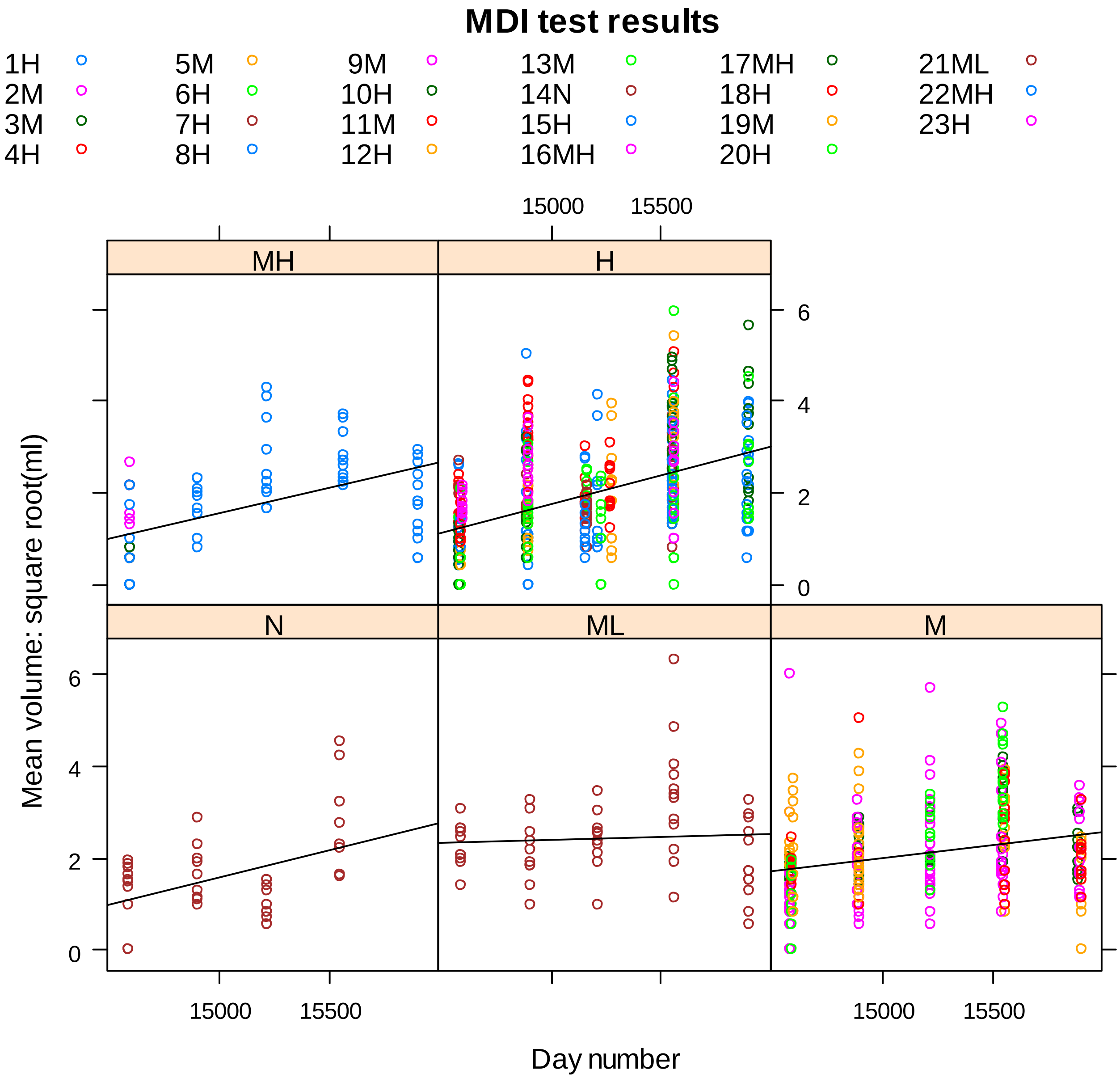

```
# Compare original burn categories for each year
xyplot(sqrt(meanvol) ~ burn.sev | factor(year), data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.xyplot")
      panel.loess(x,y,span=0.67)
   }, subset=depth %in% c(1,3)
)
```




```
======================================================================

# Would like to test the interaction between daynum and burn severity
mdi.gd <- groupedData(meanvol ~ daynum | site/dist, outer = ~ burn.sev,
data=mdi[mdi$depth %in% c(1,3),])
options(contrasts=c("contr.treatment","contr.treatment"))
mdi.fit0 <- lme(sqrt(meanvol) ~ daynum*burn.sev, data=mdi.gd, random=~1)
mdi.fit1 <- lme(sqrt(meanvol) ~ daynum*burn.sev, data=mdi.gd, random=~daynum)
anova(mdi.fit0,mdi.fit1)
         Model df      AIC      BIC    logLik   Test  L.Ratio p-value
mdi.fit0     1 13 2620.657 2683.088 -1297.328
mdi.fit1     2 17 2609.412 2691.052 -1287.706 1 vs 2 19.24527   7e-04
# So we definitely need a random effect on daynum, i.e. the time trend depends randomly
on site and transect location within site.
```

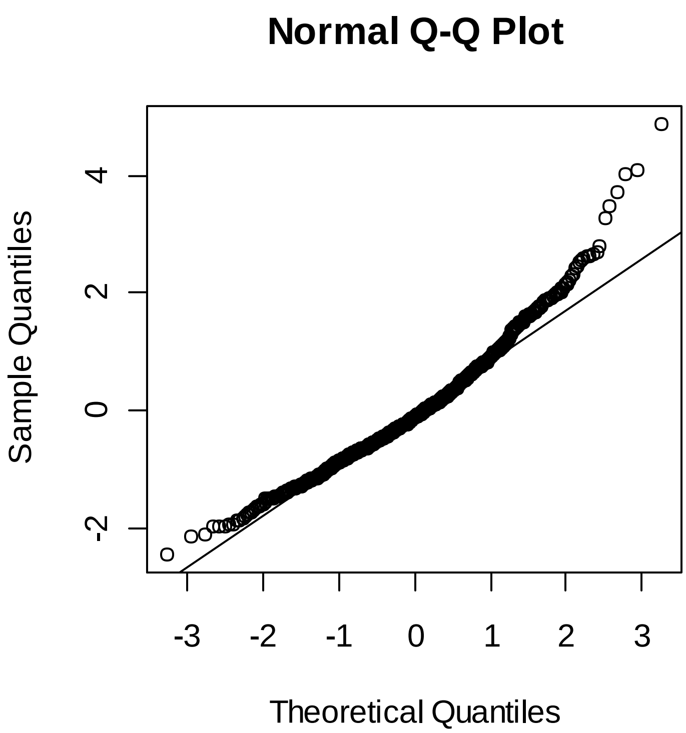
```
# Do we need the nesting of transect within site?
mdi.gd0 <- groupedData(meanvol ~ daynum | site, outer = ~ burn.sev, data=mdi[mdi$depth
%in% c(1,3),])

mdi.fit00 <- lme(sqrt(meanvol) ~ daynum*burn.sev, data=mdi.gd0, random=~1)
mdi.fit01 <- update(mdi.fit00, random=~daynum)

anova(mdi.fit0,mdi.fit00)
          Model df      AIC      BIC    logLik   Test L.Ratio p-value
mdi.fit0      1 13 2620.657 2683.088 -1297.328
mdi.fit00     2 12 2620.912 2678.541 -1298.456 1 vs 2 2.25501  0.1332
# The nesting is not significant at the intercept level

anova(mdi.fit1,mdi.fit01)
          Model df      AIC      BIC    logLik   Test  L.Ratio p-value
mdi.fit1      1 17 2609.412 2691.052 -1287.706
mdi.fit01     2 14 2623.304 2690.537 -1297.652 1 vs 2 19.89242   2e-04
# But the nesting is significant for its effect on daynum

# Look at the fixed effects using conditional F tests
#
# Sequential tests test each term as it is added sequentially to the model
> anova(mdi.fit1, type="sequential")
                numDF denDF  F-value p-value
(Intercept)         1   771 715.9803  <.0001
daynum              1   771 133.8000  <.0001
burn.sev            4    18   2.0361  0.1322
daynum:burn.sev     4   771   5.0264  0.0005

# Marginal tests delete each term from the full model
> anova(mdi.fit1, type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   771 4.132986  0.0424
daynum              1   771 5.014182  0.0254
burn.sev            4    18 5.264591  0.0055
daynum:burn.sev     4   771 5.026393  0.0005

# Add depth to the model
mdi.fit2 <- update(mdi.fit1, sqrt(meanvol) ~ daynum*burn.sev + depth)
# Try to add a random effect for depth

mdi.fit2a <- update(mdi.fit2a, random=list(site=~daynum+depth, dist=~-1+daynum))
mdi.fit2b <- update(mdi.fit2a, random=list(site=~daynum+depth, dist=~-1+daynum+depth))
# Fail
mdi.fit2b <- update(mdi.fit2a, random=list(site=~daynum+depth, dist=~daynum))
anova(mdi.fit2,mdi.fit2a,mdi.fit2b)
          Model df      AIC      BIC    logLik   Test   L.Ratio p-value
mdi.fit2      1 18 2604.979 2691.403 -1284.490
mdi.fit2a     2 19 2579.282 2670.506 -1270.641 1 vs 2 27.697743  <.0001
mdi.fit2b     3 21 2577.887 2678.714 -1267.944 2 vs 3  5.394248  0.0674
# The random effect on depth is significant
# OK so we need random effects at the site level for the coefficients of daynum and depth
# And we need random effects for dist %in% site for the coefficient of daynum only
# We do not need a random effect for dist %in% site on the intercept

# Test interaction of depth with burn severity
```

```
mdi.fit2ab <- update(mdi.fit2a, ~ . +depth*burn.sev)
anova(mdi.fit2ab)
                numDF denDF  F-value p-value
(Intercept)         1   766 431.3538  <.0001
daynum              1   766  38.9971  <.0001
burn.sev            4    18   1.2257  0.3348
depth               1   766   5.4838  0.0194
daynum:burn.sev     4   766   1.4121  0.2281
burn.sev:depth      4   766   0.5577  0.6935
# The interaction is not significant.

anova(mdi.fit2a, type="sequential")
                numDF denDF  F-value p-value
(Intercept)         1   770 423.4428  <.0001
daynum              1   770  39.1426  <.0001
burn.sev            4    18   1.2091  0.3413
depth               1   770   5.9778  0.0147
daynum:burn.sev     4   770   1.4076  0.2296

anova(mdi.fit2a, type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   770 3.858137  0.0499
daynum              1   770 4.531298  0.0336
burn.sev            4    18 1.487035  0.2477
depth               1   770 5.768841  0.0165
daynum:burn.sev     4   770 1.407563  0.2296
# Only day number and depth are significant and not impressively so.
Burn severity and its interaction with trend is not significant

# Here's another view of the significance of each fixed effect
                       Value Std.Error  DF    t-value p-value
(Intercept)       -20.711915 10.544632 770 -1.9642140  0.0499
daynum              0.001496  0.000703 770  2.1286846  0.0336
burn.sevML         21.545700 13.827018  18  1.5582319  0.1366
burn.sevM          10.403742 11.138886  18  0.9340020  0.3627
burn.sevMH         10.214069 13.234017  18  0.7718041  0.4502
burn.sevH           2.838338 10.903636  18  0.2603112  0.7976
depth              -0.097614  0.040641 770 -2.4018412  0.0165
daynum:burn.sevML  -0.001378  0.000920 770 -1.4975657  0.1347
daynum:burn.sevM   -0.000662  0.000742 770 -0.8928316  0.3722
daynum:burn.sevMH  -0.000685  0.000886 770 -0.7727938  0.4399
daynum:burn.sevH   -0.000173  0.000726 770 -0.2382075  0.8118

# We can visualize this
xyplot(sqrt(meanvol) ~ daynum | burn.sev, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Day number", ylab="Mean volume: square root(ml)", auto.key=list(columns=7)
)
```



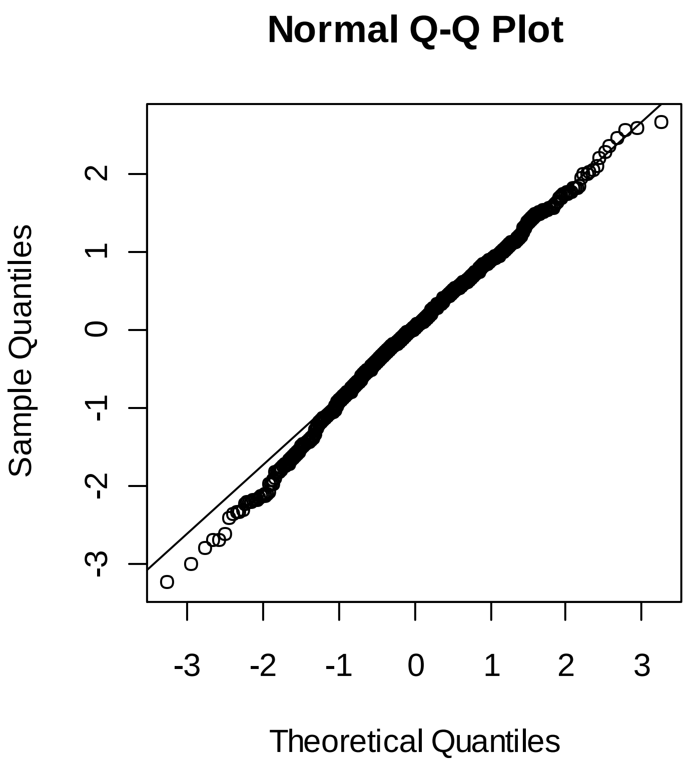

```
# The slopes are ordered the same as the burn classes, except for N.  If we had measured
the unburned sites in 2013 this would probably lower the slope for the unburned category
and maybe things would fall into line.
# We can try fitting the model without 2013
summary(update(mdi.fit2a, subset=year!="2013"))
daynum:burn.sevML  -0.000358  0.001060 650 -0.3374228  0.7359
daynum:burn.sevM   -0.000259  0.000815 650 -0.3179932  0.7506
daynum:burn.sevMH   0.000590  0.000990 650  0.5964904  0.5511
daynum:burn.sevH    0.000068  0.000794 650  0.0858701  0.9316
# That doesn't solve the problem because 2012 is high in the unburned class

#  In any case, among the burned sites we should see a pattern.
mdi.fit2ac <- update(mdi.fit2a, subset=burn.sev!="N")
anova(mdi.fit2ac,type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   738 0.004340  0.9475
```

```
daynum              1   738 0.048942  0.8250
burn.sev            3    18 1.832250  0.1774
depth               1   738 6.375243  0.0118
daynum:burn.sev     3   738 1.739358  0.1575

# The model assumes a linear effect for daynum. That's not really reasonable given the
pattern seen above.  What if we substitute year as a factor in place of daynum.  That
doesn't impose any kind of a form on the trend.

mdi.gd$year <- factor(mdi.gd$year)
tmp <- update(mdi.fit2a, sqrt(meanvol) ~ year*burn.sev + depth)
Error in MEEM(object, conLin, control$niterEM) :
  Singularity in backsolve at level 0, block 1
# Darn!  Well we could try modeling daynum as a quadratic but that will be harder to
interpret

# First look at the residuals distribution
qqresid(mdi.fit2a)
```

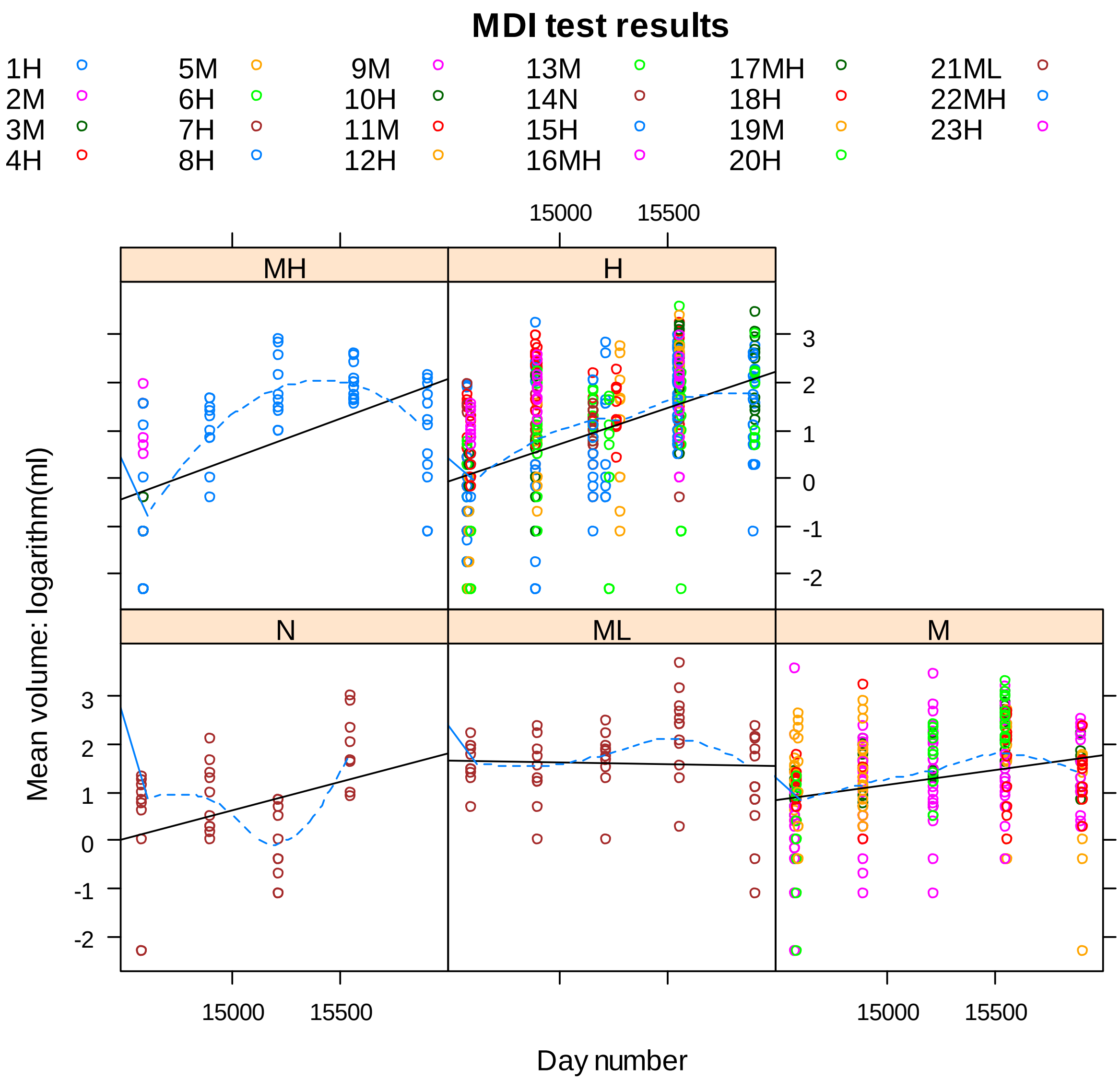



```
# Try modeling the logarithm, but there are zeroes to deal with
sum(mdi$meanvol==0)
[1] 33
min(mdi$meanvol[mdi$meanvol>0])
[1] 0.17

# Set the zeroes to 0.10
mdi.gd$meanvol2 <- mdi.gd$meanvol
mdi.gd$meanvol2[mdi.gd$meanvol==0] <- 0.10
mdi.logfit2a  <-  update(mdi.fit2a,  log(meanvol2)  ~  daynum  +  burn.sev  +  depth  +
daynum:burn.sev))
```

```
mdi.logfit2a  <-  update(mdi.fit2a,  log(meanvol2)  ~  daynum  +  burn.sev  +  depth  +
daynum:burn.sev)
Error in lme.formula(fixed = log(meanvol2) ~ daynum + burn.sev + depth +  :
  nlminb problem, convergence error code = 1
  message = iteration limit reached without convergence (9)

# Drop the random effect of site on depth to get convergence
# This model still has the transect within site random effect
mdi.logfit2a  <-  update(mdi.fit2a,  log(meanvol2)  ~  daynum  +  burn.sev  +  depth  +
daynum:burn.sev, random=~daynum)

anova(mdi.logfit2a) # Sequential
                numDF denDF   F-value p-value
(Intercept)         1   770 144.74715  <.0001
daynum              1   770 137.28548  <.0001
burn.sev            4    18   1.73627  0.1859
depth               1   770   8.32041  0.0040
daynum:burn.sev     4   770   6.50662  <.0001

anova(mdi.logfit2a,type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   770 3.628593  0.0572
daynum              1   770 4.064027  0.0442
burn.sev            4    18 6.729386  0.0017
depth               1   770 8.320410  0.0040
daynum:burn.sev     4   770 6.506619  <.0001
# The burn severity and its interaction have become significant
# and depth is even more so than it was.

# Retest the interaction between depth and burn severity
mdi.logfit2b <- update(mdi.logfit2a, ~ . + depth*burn.sev)

anova(mdi.logfit2b)
                numDF denDF   F-value p-value
(Intercept)         1   766 144.85504  <.0001
daynum              1   766 137.26354  <.0001
burn.sev            4    18   1.73714  0.1858
depth               1   766   8.34878  0.0040
daynum:burn.sev     4   766   6.49962  <.0001
burn.sev:depth      4   766   1.60722  0.1705
# Interaction burn.sev:depth not significatn

qqresid(mdi.logfit2a)
```




```
# That looks better

as.data.frame(fixef(mdi.logfit2a))
                  fixef(mdi.logfit2a)
(Intercept)             -1.668866e+01
daynum                   1.166340e-03
burn.sevML               1.946006e+01
burn.sevM                7.478379e+00
burn.sevMH              -5.867183e+00
burn.sevH               -7.632820e+00
depth                   -9.140327e-02
daynum:burn.sevML       -1.230902e-03
daynum:burn.sevM        -4.608035e-04
daynum:burn.sevMH        3.713781e-04
daynum:burn.sevH         5.179825e-04
# The slope coefficients are ordered the same as the burn severities
# except that the unburned is in the middle (where the signs change)

# We can visualize the model (except for the random effects and depth effect)
xyplot(log(meanvol2) ~ daynum | burn.sev, data=mdi.gd, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
            panel.loess(x,y,lty=2,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Day number", ylab="Mean volume: logarithm(ml)", auto.key=list(columns=7)
)
```



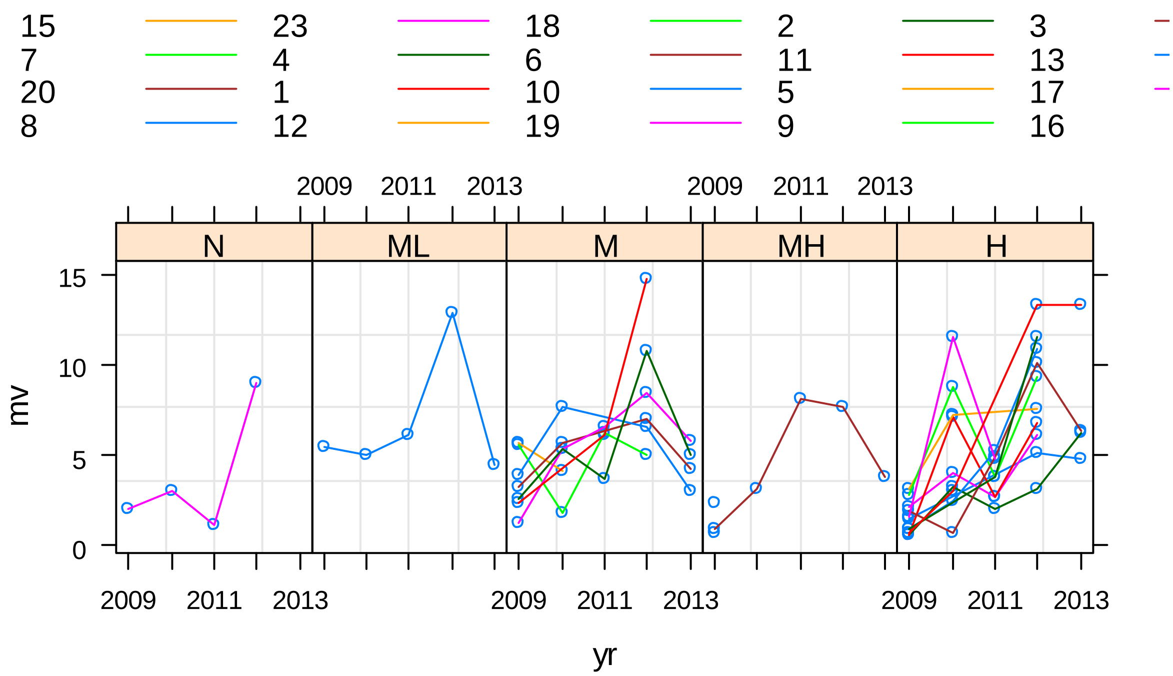

```
# Maybe we don't need a quadratic trend model.  Only the MH class seems to demand it.
# Here it is anyway
mdi.logfit3 <- update(mdi.logfit2a, ~ . + burn.sev*I(daynum^2))
anova(mdi.logfit3)
                     numDF denDF   F-value p-value
(Intercept)              1   765 145.87442  <.0001
daynum                   1   765  47.96116  <.0001
burn.sev                 4    18   0.86432  0.5040
depth                    1   765   9.39319  0.0023
I(daynum^2)              1   765  58.96132  <.0001
daynum:burn.sev          4   765   1.36828  0.2432
burn.sev:I(daynum^2)     4   765   9.01459  <.0001

anova(mdi.logfit3,type="marginal")
                     numDF denDF  F-value p-value
(Intercept)              1   765 4.845265  0.0280
daynum                   1   765 4.961891  0.0262
burn.sev                 4    18 9.177912  0.0003
```

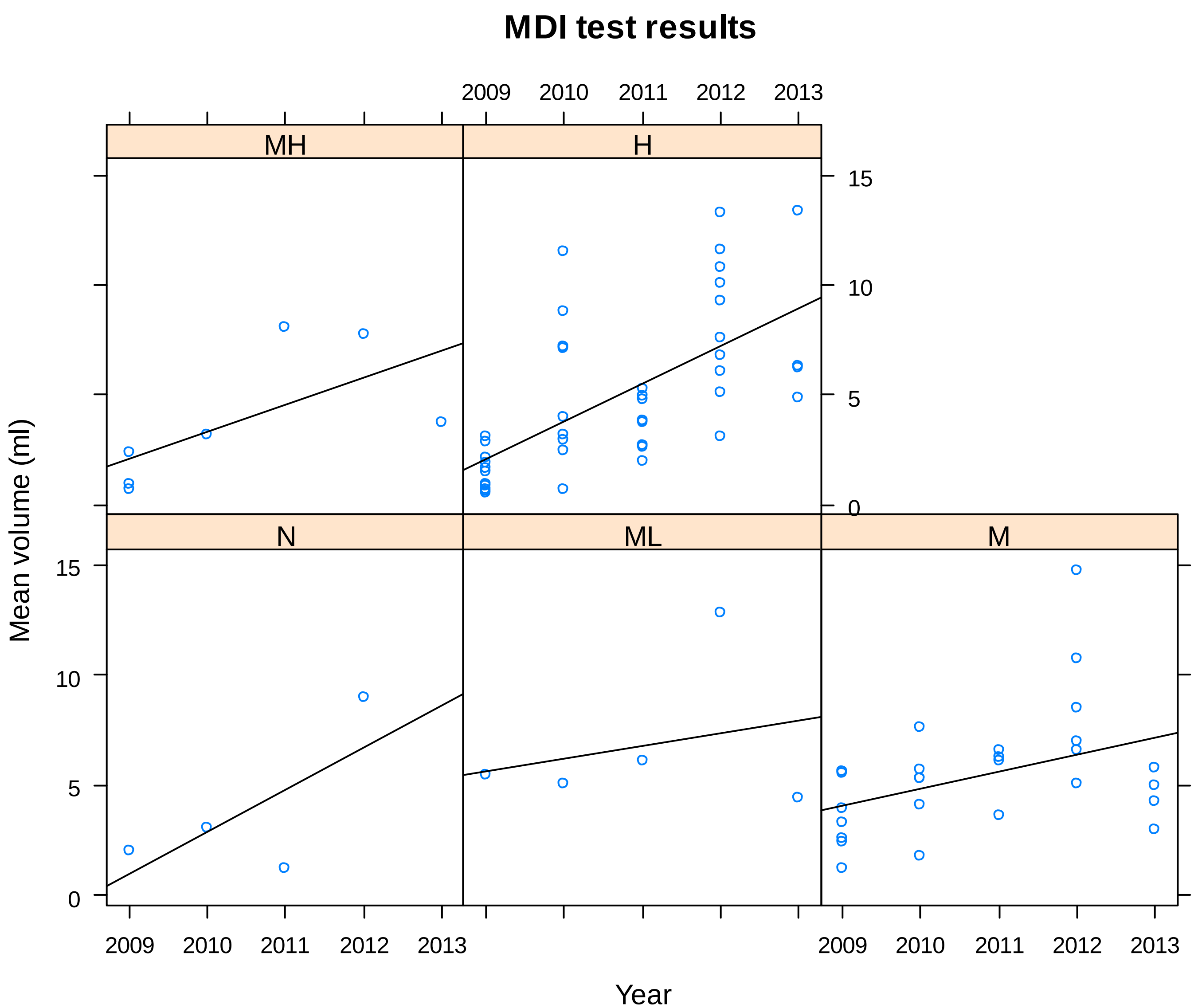
```
depth                    1   765 9.393185  0.0023
I(daynum^2)              1   765 5.087095  0.0244
daynum:burn.sev          4   765 9.100101  <.0001
burn.sev:I(daynum^2)     4   765 9.014588  <.0001
# Burn severity and its interactions are all significant

as.data.frame(fixef(mdi.logfit3))
                       fixef(mdi.logfit3)
(Intercept)                  7.088565e+02
daynum                      -9.526205e-02
burn.sevML                  -9.993453e+02
burn.sevM                   -1.006520e+03
burn.sevMH                  -1.854252e+03
burn.sevH                   -1.045688e+03
depth                       -9.140327e-02
I(daynum^2)                  3.202241e-06
daynum:burn.sevML            1.336908e-01
daynum:burn.sevM             1.339266e-01
daynum:burn.sevMH            2.446665e-01
daynum:burn.sevH             1.382569e-01
burn.sevML:I(daynum^2)      -4.464184e-06
burn.sevM:I(daynum^2)       -4.449961e-06
burn.sevMH:I(daynum^2)      -8.064157e-06
burn.sevH:I(daynum^2)       -4.566445e-06

# There aren't monotone patterns in the linear interactions (daynum:burn.sevXX)
# nor in the quadratic interaction coefficients (dayn.sevXX:I(daynum^2)
# Is this consistent with the results of the linear trend model?
# It's not clear if the quadratic trend model sheds any new light.

==========================================================

# Naïve standard linear regression model for comparison
mdi.lmfit1 <- lm(sqrt(meanvol) ~ daynum, data=mdi, subset=depth %in% c(1,3))
mdi.lmfit2 <- update(mdi.lmfit1, ~ . + burn.sev)
mdi.lmfit3 <- update(mdi.lmfit1, ~ . + daynum*burn.sev)
mdi.lmfit4 <- update(mdi.lmfit3, ~ . + depth)
anova(mdi.lmfit1, mdi.lmfit2, mdi.lmfit3,mdi.lmfit4)
Analysis of Variance Table

Model 1: sqrt(meanvol) ~ daynum
Model 2: sqrt(meanvol) ~ daynum + burn.sev
Model 3: sqrt(meanvol) ~ daynum + burn.sev + daynum:burn.sev
Model 4: sqrt(meanvol) ~ daynum + burn.sev + depth + daynum:burn.sev
  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1    908 917.99
2    904 900.47  4   17.5209 4.5526  0.001208 **
3    900 874.14  4   26.3337 6.8425 1.996e-05 ***
4    899 864.96  1    9.1711 9.5319  0.002081 **
# All terms highly significant

# What if we average over depth and transect?
# Now each combination of year and burn severity will have equal weight
# As long as that combination exists (N is missing in 2013)

attach(mdi)
tmp <- tapply(meanvol, list(sitenum, year), mean)
```

```
tmp
       2009     2010     2011      2012      2013
1  1.937000  0.73400 4.917000 10.111667  6.332500
2  5.516000  1.76800 6.278333  5.041667        NA
3  2.551000  5.30000 3.638333 10.722500  5.000000
4  2.832000  8.81900 3.784000  9.299000        NA
5  3.916000  7.64375       NA  6.610833  2.972500
6  0.950000       NA 3.833333 11.581667        NA
7  2.132000  3.96800 2.709167  6.070000        NA
8  0.617000  7.09800 2.633000  6.763333        NA
9  1.250000  5.30000 6.595833  8.500833  5.820000
10 0.666000  2.98300       NA 13.277500 13.332500
11 3.283000  5.72875       NA  6.972500  4.278333
12 0.867000  2.43300 5.266000 10.833333        NA
13 2.397692       NA 6.081667 14.750000        NA
14 2.050000  3.05000 1.183000  9.021250        NA
15 1.500000       NA       NA  5.111667  4.831667
16 2.367000       NA       NA        NA        NA
17 0.700000       NA       NA        NA        NA
18 1.633000 11.51600 4.766000        NA        NA
19 5.633000  4.13300       NA        NA        NA
20 0.532000  3.21700 2.000000  3.137500  6.249167
21 5.433000  5.03400 6.134000 12.832500  4.445000
22 0.933000  3.16600 8.101000  7.722500  3.750000
23 3.099000  7.18300       NA  7.581667        NA

mv <- as.vector(tmp)
yr <- rep(2009:2013,rep(23,5))
bs <- rep(substring(unique(site),3,4),5)
bs <- ordered(bs, levels=c("N","ML","M","MH","H"))
site <- rep(1:23,5)

mdi.mean <- data.frame(site, yr, bs, mv)
mdi.mean <- mdi.mean[!is.na(mdi.mean$mv), ]
detach(mdi)
mdi.mean.gd <- groupedData(mv ~ yr | site, outer=~bs, data=mdi.mean)
```

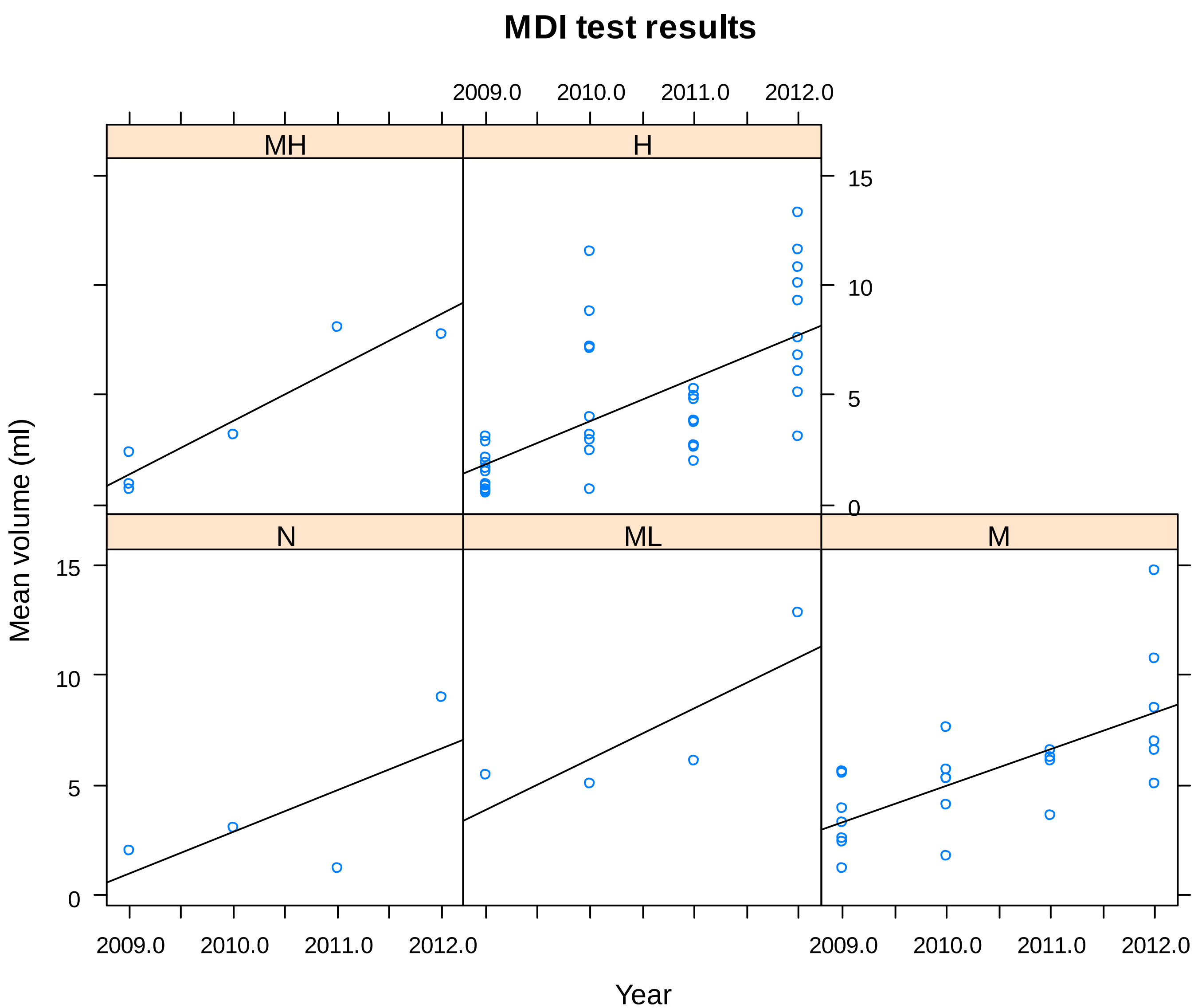
plot(mdi.mean.gd, outer=T, layout=c(5,1), aspect=1.5)

```
plot(mdi.mean.gd, outer=T, layout=c(5,1), aspect=1.5,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
  })

xyplot(mv ~ yr | bs, data=mdi.mean.gd, aspect=1,
   panel=function(x,y) {
            panel.xyplot(x,y)
            panel.lmline(x,y)
   }, main="MDI test results",
xlab="Year", ylab="Mean volume (ml)")
```


15
23
18
2
3
7
4
6
11
13
20
1
10
5
17
8
12
19
9
16
N
ML
M
MH
H
mv
yr
2009
2011
2013
0
5
10
15




```
# Re-do without 2013
xyplot(mv ~ yr | bs, data=mdi.mean.gd, aspect=1, subset=yr<2013,
   panel=function(x,y) {
            panel.xyplot(x,y)
            panel.lmline(x,y)
   }, main="MDI test results", xlab="Year", ylab="Mean volume (ml)")
```



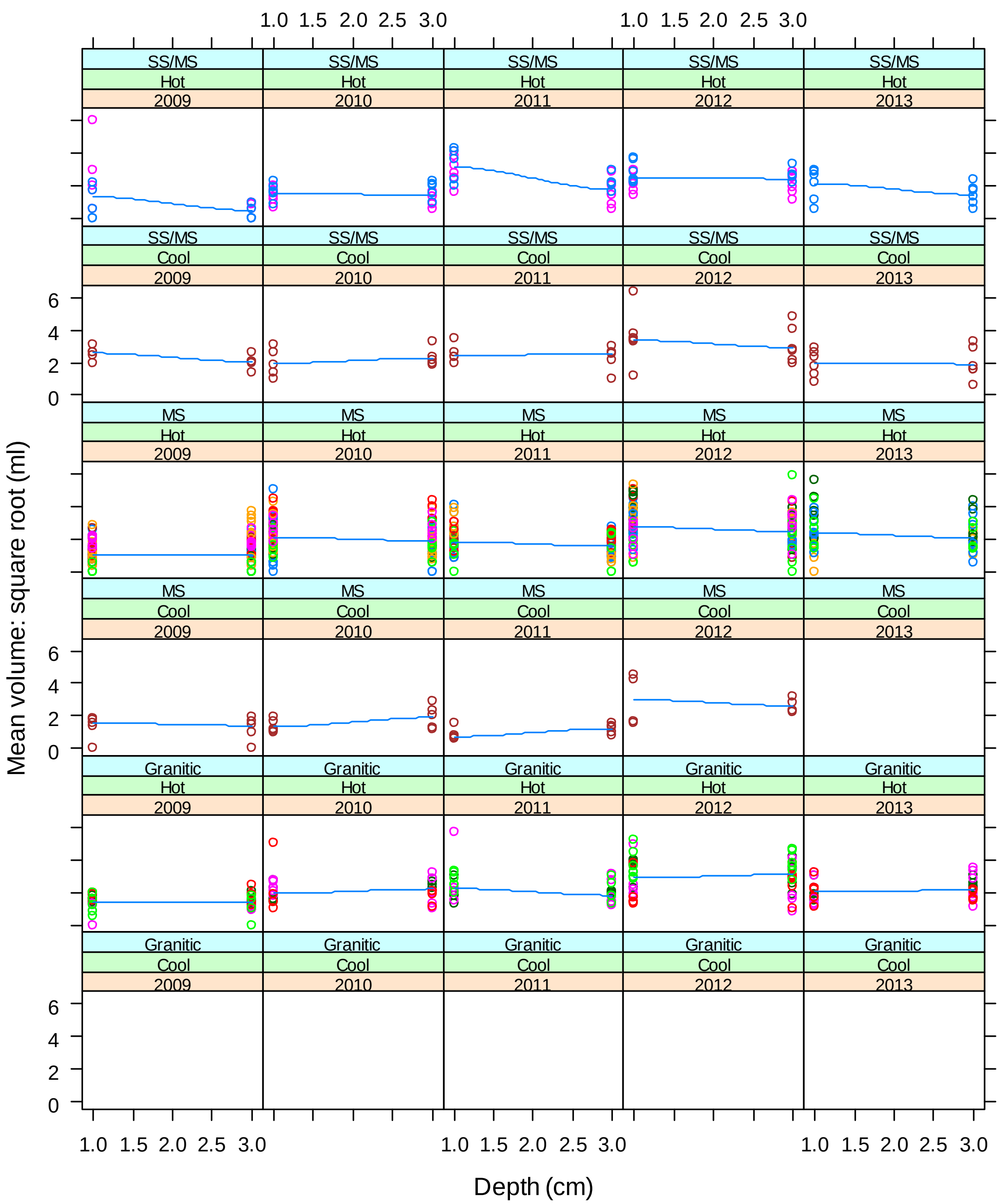

```
# Excluding 2013, the slopes are pretty similar each year
mdim.fit1 <- lme(mv ~ yr*bs, data=mdi.mean.gd, random=~yr)
# System is computationally singular.

mdim.fit1 <- lme(mv ~ yr*bs, data=mdi.mean.gd, random=~1)
summary(mdim.fit1)


Fixed effects: mv ~ yr * bs
                Value Std.Error DF    t-value p-value
(Intercept) -3825.523 2510.7877 57 -1.5236346  0.1331
yr              1.905    1.2488 57  1.5251587  0.1327
bsML         2661.394 3075.3293 18  0.8654013  0.3982
bsM          2264.364 2623.1288 18  0.8632301  0.3994
bsMH         1355.538 2882.6634 18  0.4702381  0.6438
bsH           384.128 2593.1714 18  0.1481306  0.8839
```

```
yr:bsML        -1.322    1.5295 57 -0.8646087  0.3909
yr:bsM         -1.126    1.3047 57 -0.8626961  0.3919
yr:bsMH        -0.674    1.4338 57 -0.4702057  0.6400
yr:bsH         -0.191    1.2898 57 -0.1478126  0.8830
# OK, but nothing is significant

# Or go to a pure fixed effects model
mdim.lmfit1 <- lm(mv ~ yr*bs, data=mdi.mean)
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept) -3825.5230  2510.7877  -1.524    0.132
yr             1.9047     1.2488   1.525    0.131
bsML         2661.3940  3075.3294   0.865    0.390
bsM          2264.3636  2623.1288   0.863    0.391
bsMH         1355.5380  2882.6634   0.470    0.640
bsH           384.1281  2593.1715   0.148    0.883
yr:bsML        -1.3224     1.5295  -0.865    0.390
yr:bsM         -1.1256     1.3047  -0.863    0.391
yr:bsMH        -0.6742     1.4338  -0.470    0.640
yr:bsH         -0.1906     1.2898  -0.148    0.883
# Again nothing is significant
# I would speculate that it is because this data set is much much smaller
```

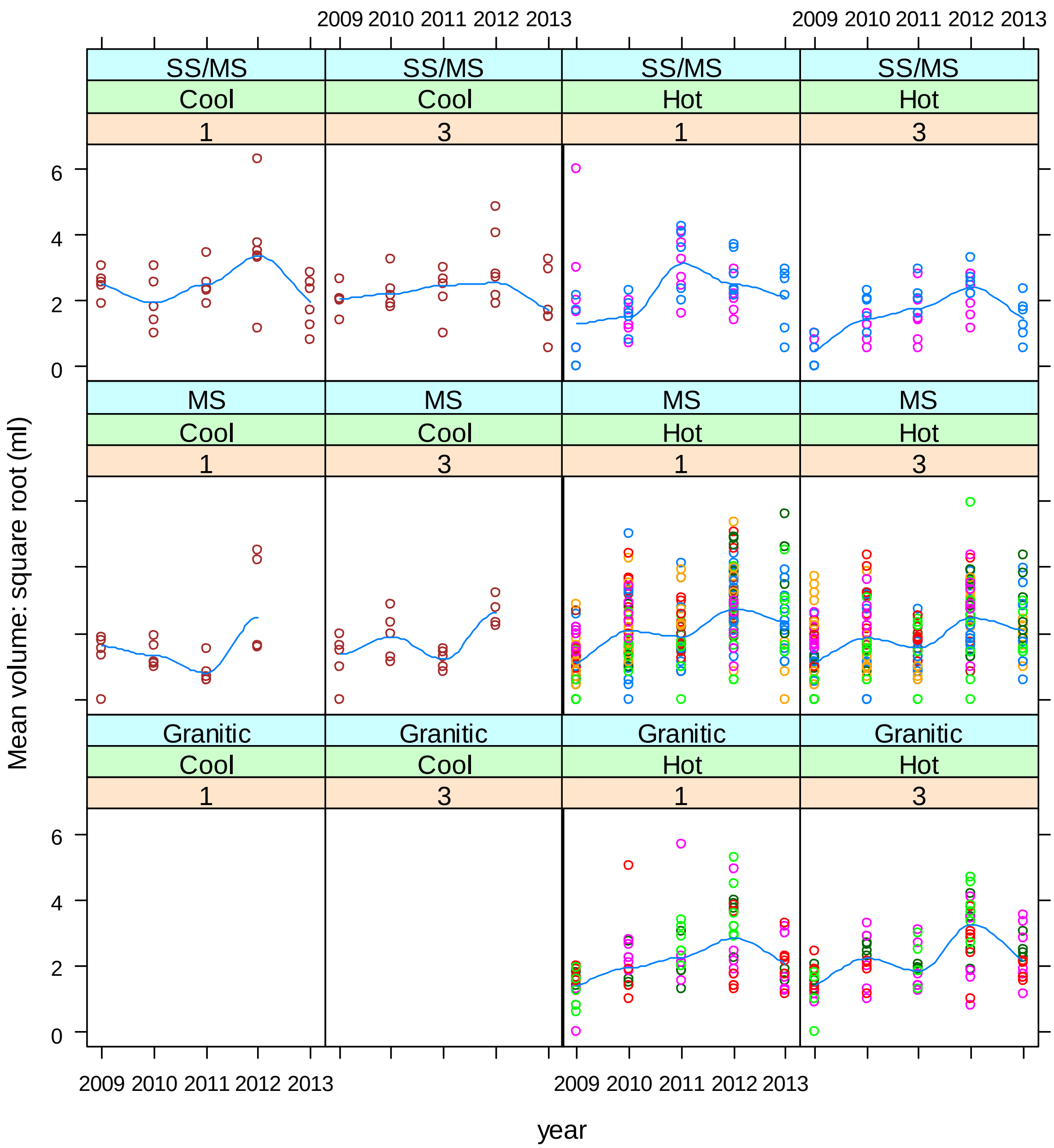
Effects of Soil Parent Material

```
library(nlme)
library(lattice)

table(soilveg$soil)

Granitic       MS    MS/SS       SS
       4       16        2        1


table(mdi$soil)

Granitic       MS    MS/SS       SS
     191      580       98       54


# Combine MS/SS and SS into "SS/MS" in new variable: s3

mdi$s3 <- as.character(mdi$soil)
mdi$s3[mdi$soil %in% c("MS/SS","SS")] <- "SS/MS"
mdi$s3 <- factor(mdi$s3)

table(mdi$s3)

Granitic       MS    SS/MS
     191      580      152


superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(23)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
```

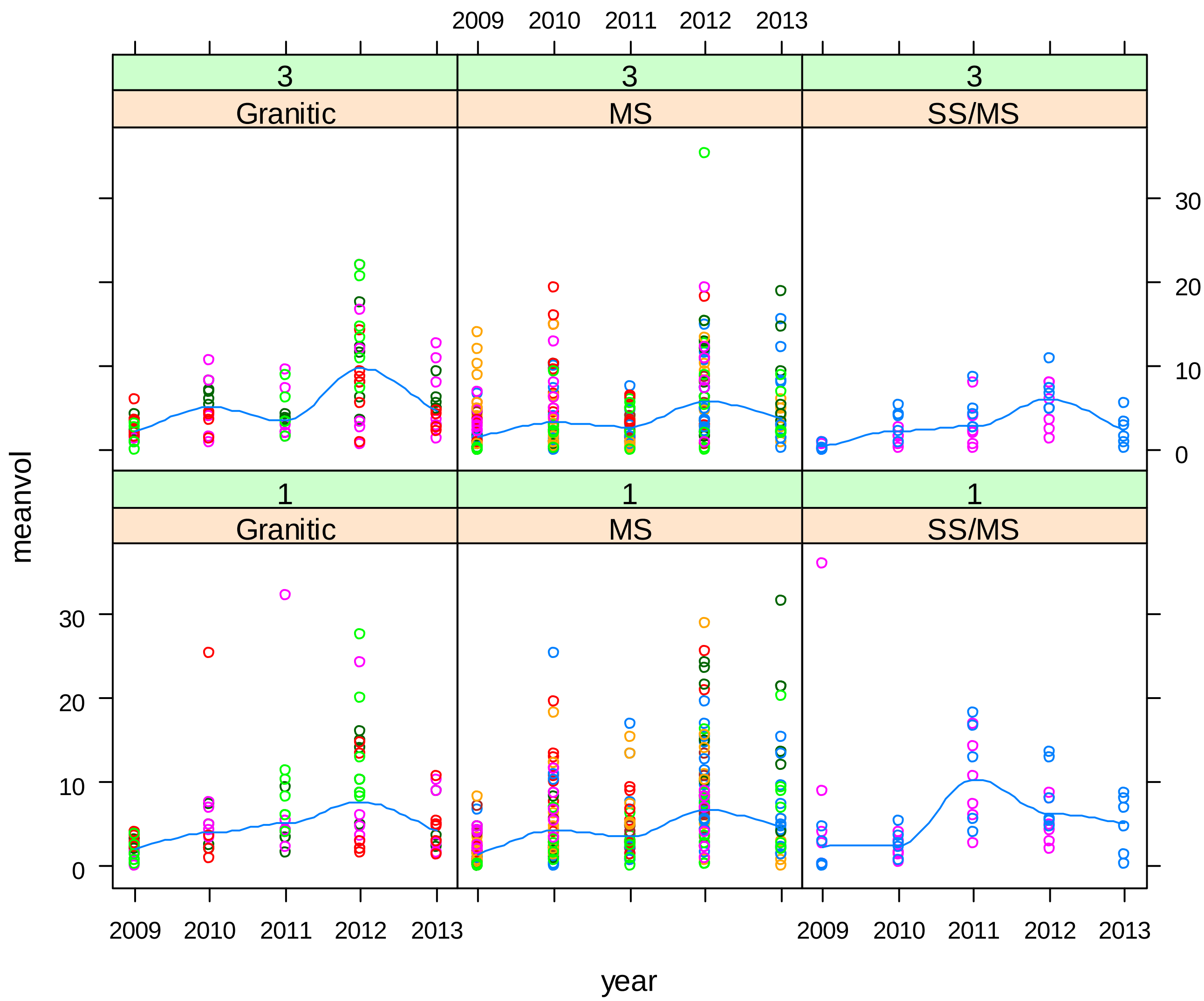
```
trellis.par.set("superpose.line",superpose.line)
# Collapse over transect distance
xyplot(sqrt(meanvol) ~ depth | factor(year)*burn.sev2*s3, data=mdi, groups=site,
   panel=function(x,y, subscripts, groups) {
       panel.superpose(x,y, subscripts, groups, "panel.xyplot")
       panel.loess(x,y,xpan=1)
   },  subset=depth  %in%  c(1,3),  xlab="Depth  (cm)",  ylab="Mean  volume:  square  root
(ml)",layout=c(5,6),   strip   =   strip.custom(par.strip.text   =   list(cex   =   0.66)),
par.settings = list(layout.heights=list(strip=0.66)))
```



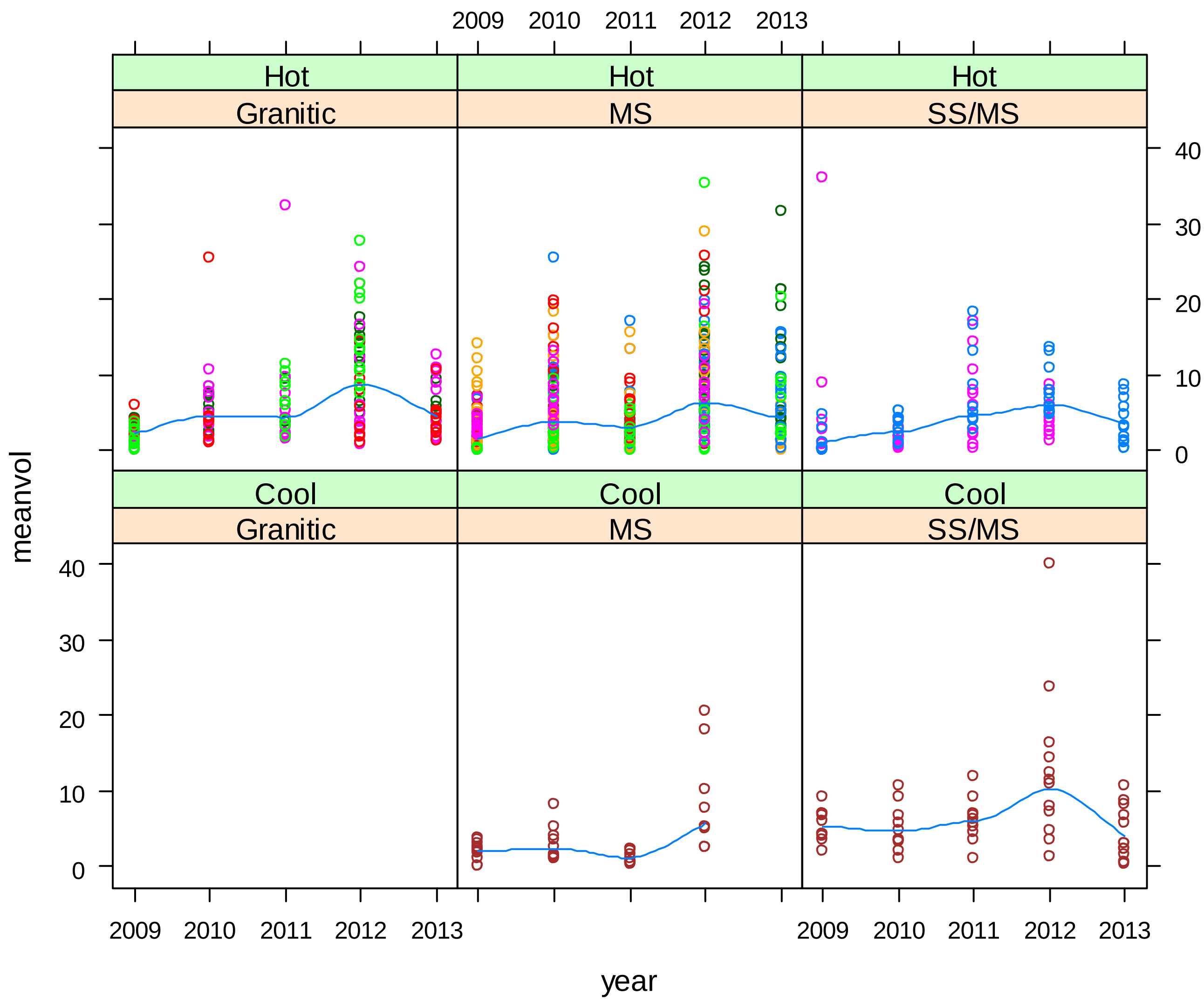
```
# Look at the effect of time by depth
xyplot(sqrt(meanvol)  ~  year  |  factor(depth)*burn.sev2*s3,  data=mdi,  groups=site,
aspect=1,
   panel=function(x,y, subscripts, groups) {
       # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
       panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3),ylab="Mean volume: square root (ml)",layout=c(4,3))
```



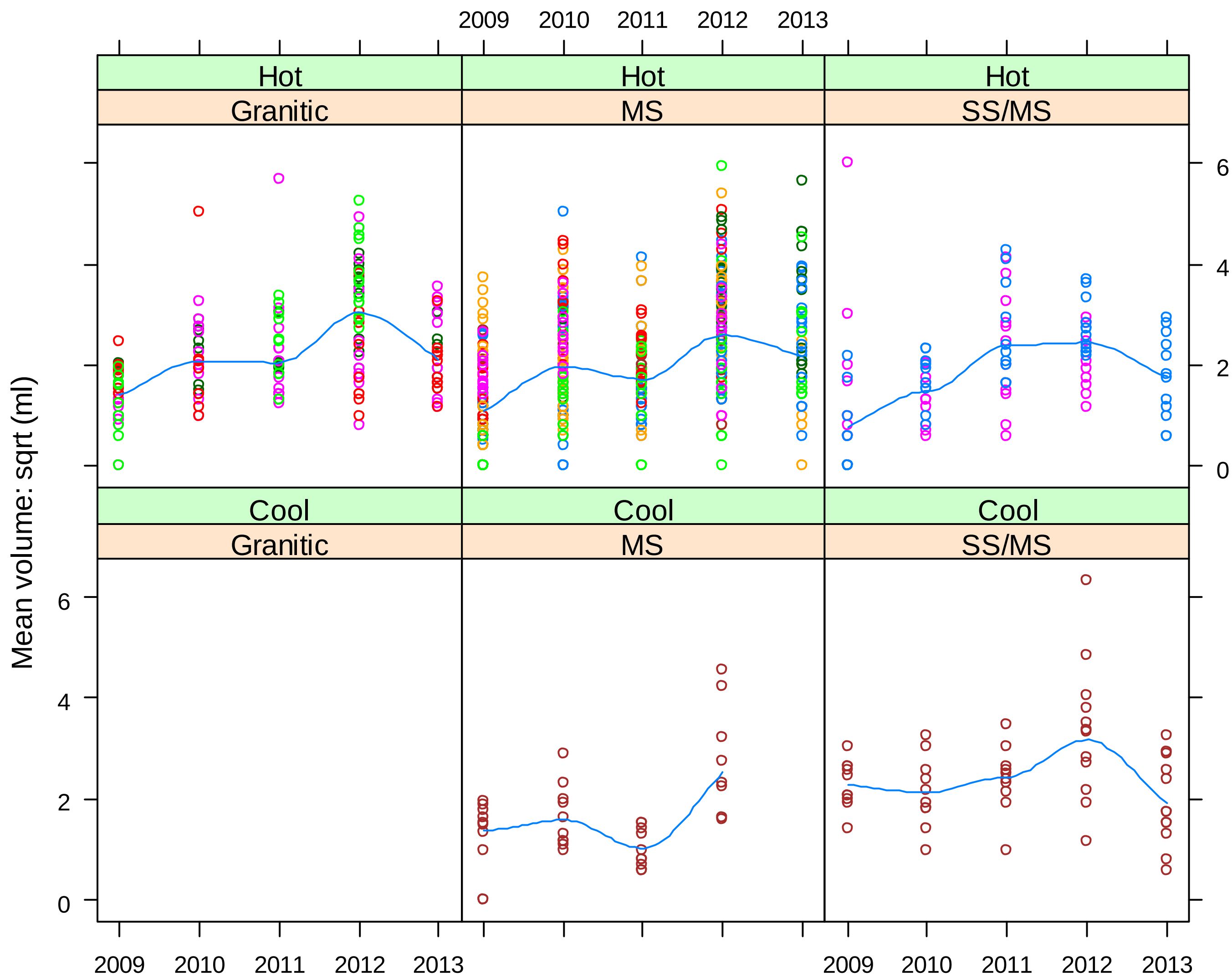

```
# Look closer at the "Hot" frames above

xyplot(meanvol ~ year | s3*factor(depth), data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
      panel.superpose(x,y,subscripts,groups, "panel.xyplot")
      panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3) & burn.sev2=="Hot")
```



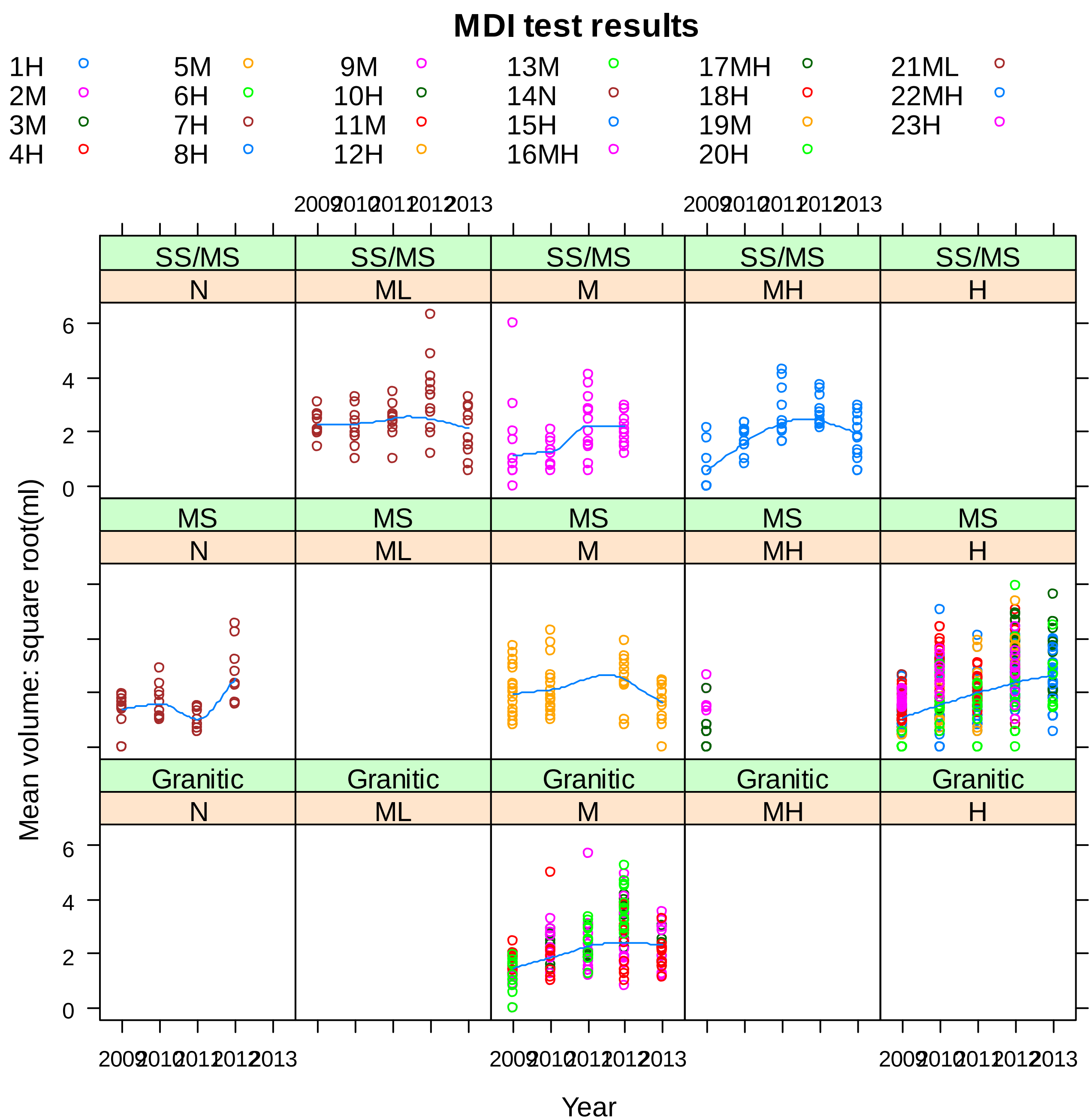

```
# Collapse over both transect distance and depth
xyplot(meanvol ~ year | s3*burn.sev2, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
         # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.33)
         panel.superpose(x,y,subscripts,groups, "panel.xyplot")
         panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3))
```



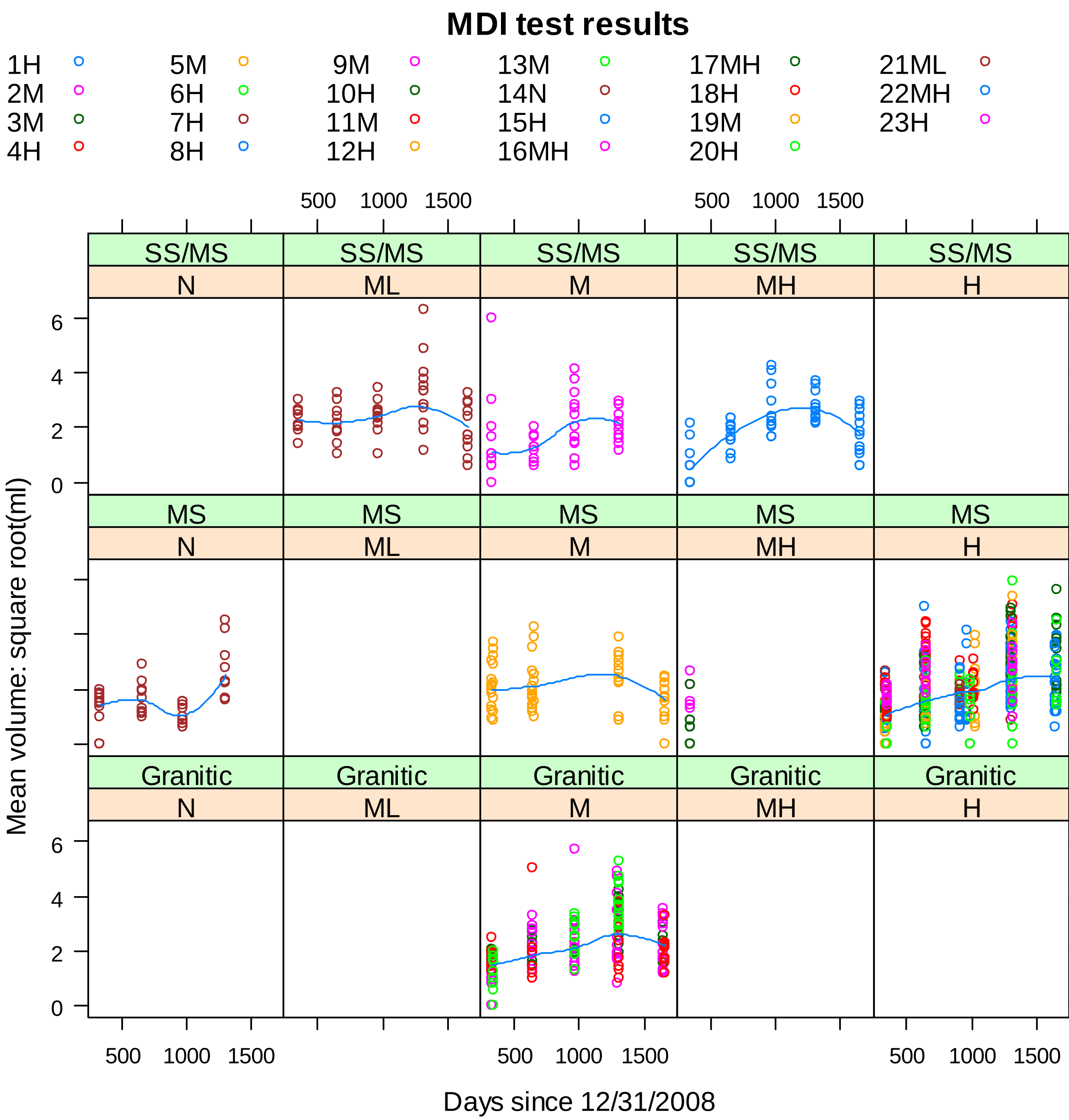

```
# Look at transformed responses (square roots)
xyplot(sqrt(meanvol) ~ year | s3*burn.sev2, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
         # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.33)
         panel.superpose(x,y,subscripts,groups, "panel.xyplot")
         panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3), xlab="", ylab="Mean volume: sqrt (ml)"
)
```



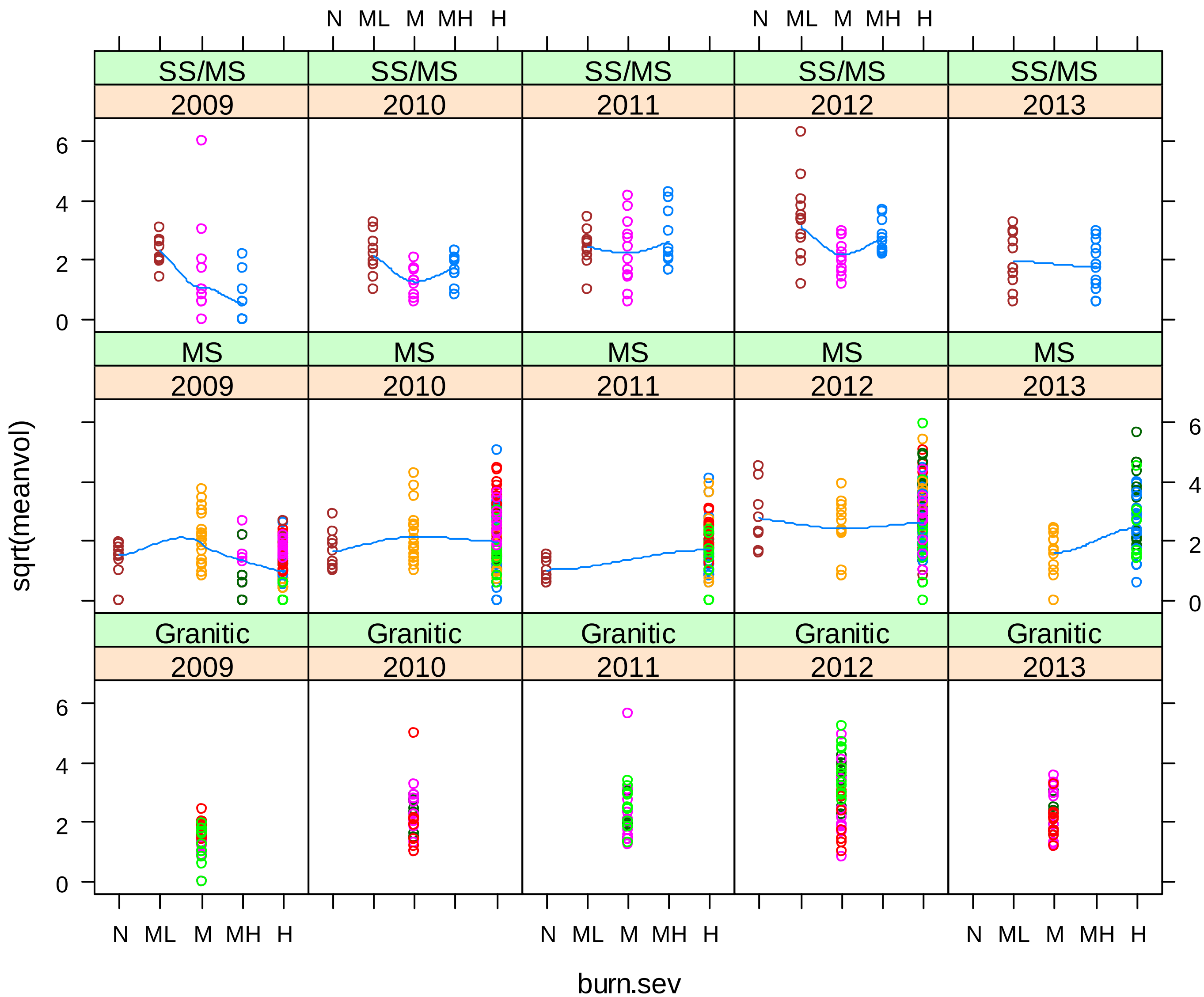

```
# Repeat with original burn categories, loess line, and sqrt(meanvol)
xyplot(sqrt(meanvol) ~ factor(year) | burn.sev*s3, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,span=0.67)
   }, subset=depth %in% c(1,3) & s3 !="To", main="MDI test results",
xlab="Year", ylab="Mean volume: square root(ml)", auto.key=list(columns=7)
)
```



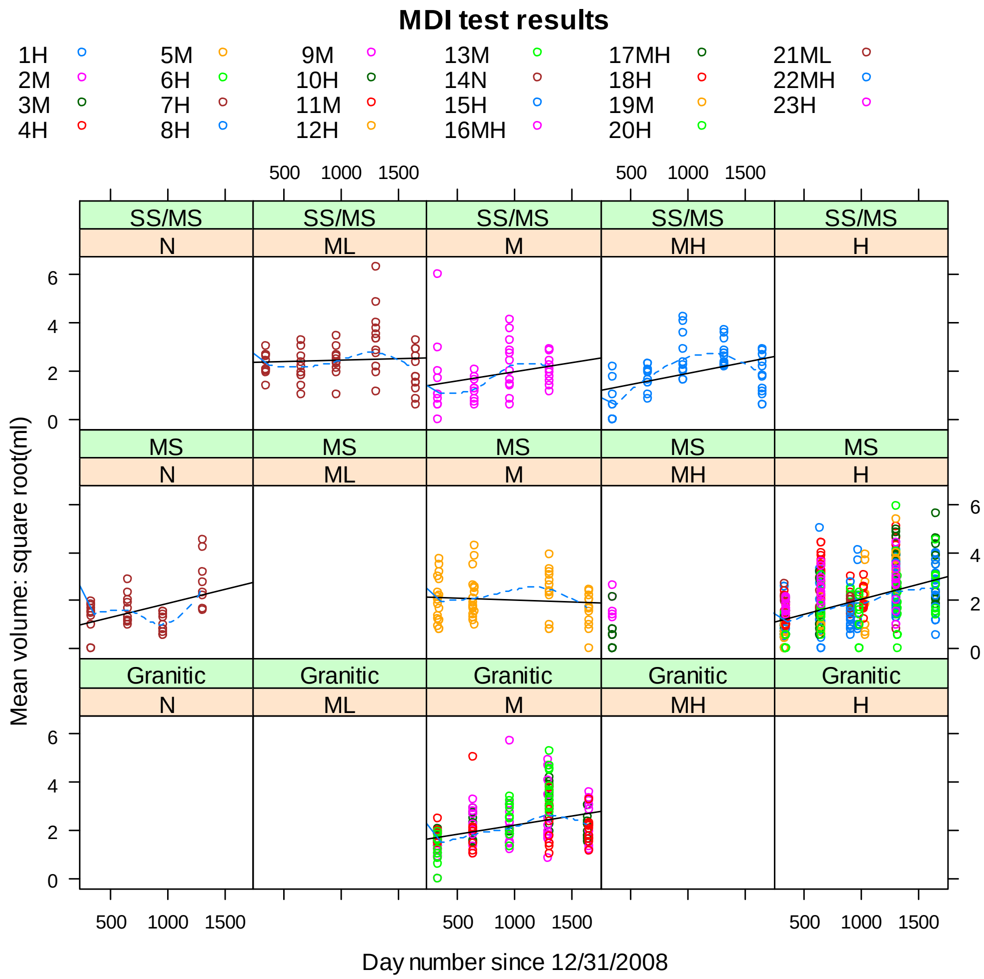

```
# Only category M is represented by all 3 soil types

# Plot against day number instead of year for a bit more resolution
xyplot(sqrt(meanvol) ~ daynum08 | burn.sev * s3, data=mdi, groups=site, aspect=1,
   lattice.options = list(panel.error = "warning"),
    panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Days    since    12/31/2008",    ylab="Mean    volume:    square    root(ml)",
auto.key=list(columns=7))
```



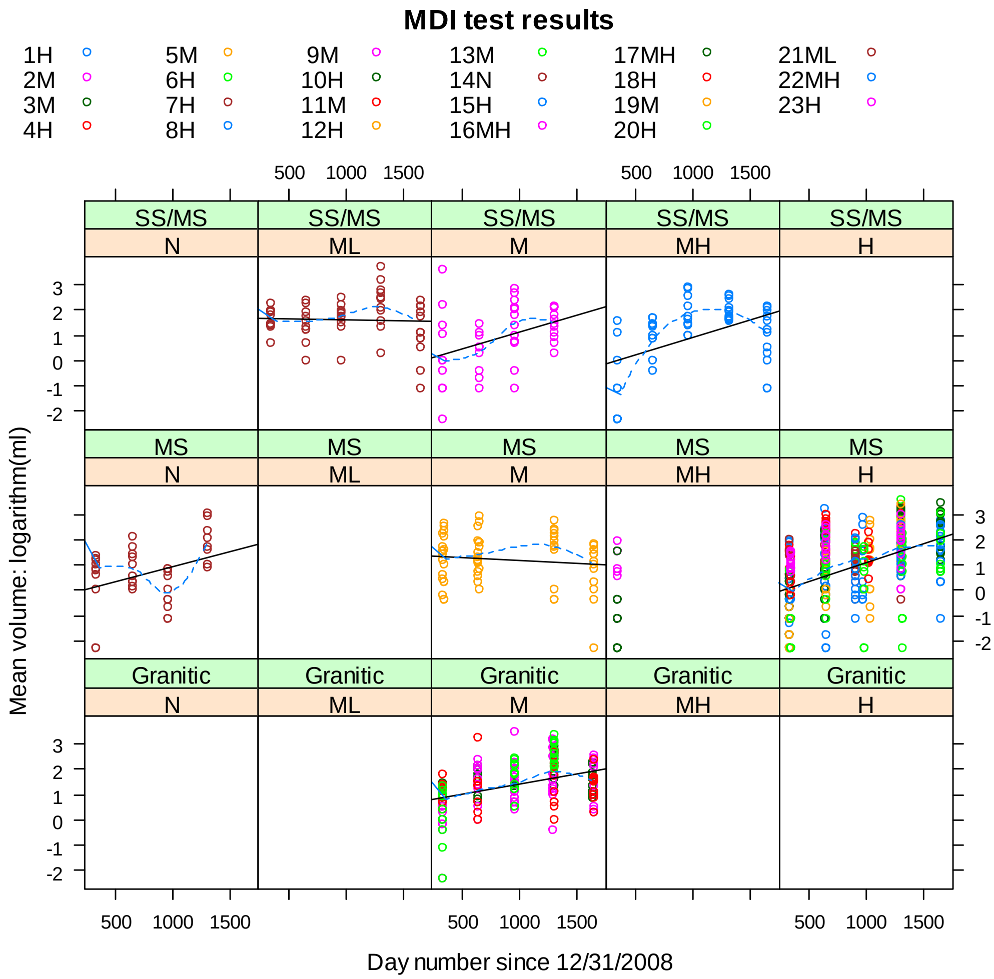

```
# Compare original burn categories for each year
# I had to increase the smoothing parameter to get sensible curves in frames that include
only 2 burn classes
xyplot(sqrt(meanvol) ~ burn.sev | factor(year) * s3, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.xyplot")
      panel.loess(x,y,span=1)
   }, subset=depth %in% c(1,3)
)
```




```
xyplot(sqrt(meanvol) ~ daynum08 | burn.sev*s3, data=mdi, groups=site, aspect=1,
   lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
            panel.loess(x,y,lty=2,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Day    number    since    12/31/2008",    ylab="Mean    volume:    square    root(ml)",
auto.key=list(columns=7)
)
```



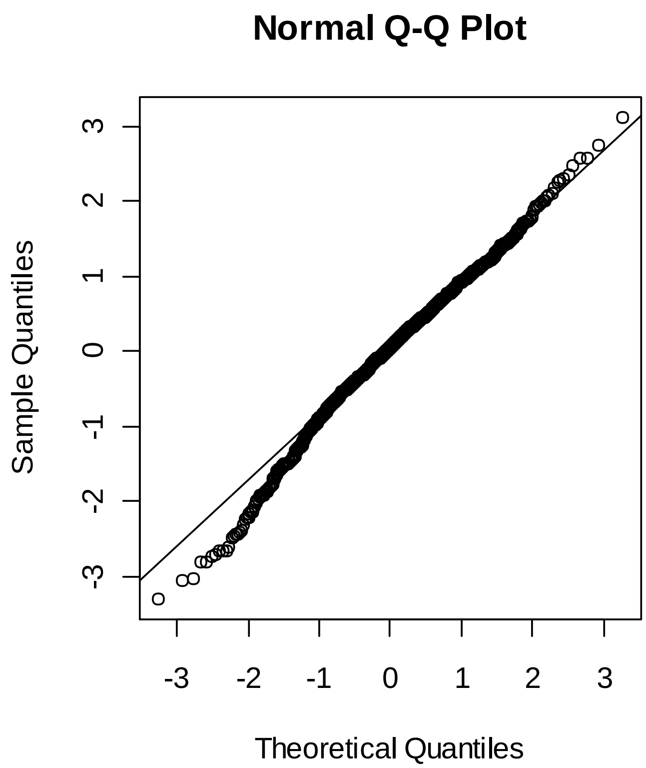

```
# Replot last one with log transformed response
mdi$meanvol2 <- mdi$meanvol
mdi$meanvol2[mdi$meanvol==0] <- 0.10
xyplot(log(meanvol2) ~ daynum08 | burn.sev * s3, data=mdi, groups=site, aspect=1,
   lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
            panel.loess(x,y,lty=2,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Day    number    since    12/31/2008",    ylab="Mean    volume:    logarithm(ml)",
auto.key=list(columns=7)
)
```

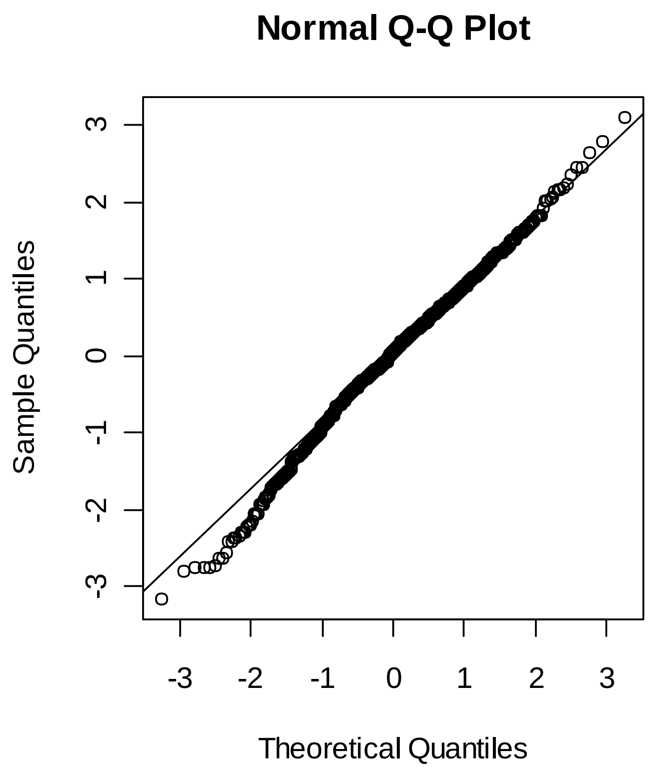



```
# Look further below for a plot of mean volume versus day number by soil type

==================================================================
# Mixed effects models
mdi.gd   <-   groupedData(meanvol  ~  daynum  |  site/dist,  outer  =  ~  burn.sev,
data=mdi[mdi$depth %in% c(1,3),])
options(contrasts=c("contr.treatment","contr.treatment"))

# Start with the random effects model that we had for the full data set/
# Try to add the random effect of site on depth.

mdi3.fit0  <-  mdi.logfit2a  <-  lme(log(meanvol2)  ~  daynum  +  burn.sev  +  depth  +
daynum:burn.sev, random=list(site=~daynum+depth, dist=~-1+daynum), data=mdi.gd)

# Failed to converge; tweak convergence criteria

mdi3.fit0  <-  lme(log(meanvol2)  ~  daynum  +  burn.sev  +  depth  +  daynum:burn.sev,
random=list(site=~daynum+depth,               dist=~-1+daynum),               data=mdi.gd,
control=list(msMaxIter=100))

# Compare to previously reported model
anova(mdi.logfit2a, mdi3.fit0)
             Model df      AIC      BIC    logLik   Test  L.Ratio p-value
```

```
mdi.logfit2a     1 18 2780.123 2866.546 -1372.062
mdi3.fit0        2 19 2749.584 2840.808 -1355.792 1 vs 2 32.53946  <.0001
# That's a good improvement

anova(mdi3.fit0,type="marginal")
                numDF denDF   F-value p-value
(Intercept)         1   770 16.384275  0.0001
daynum              1   770 18.756166  <.0001
burn.sev            4    18  2.291389  0.0994
depth               1   770  4.093988  0.0434
daynum:burn.sev     4   770  2.202098  0.0671
# Burn severity and its interaction with daynum are not significant
# Depth is marginally significant

# Retest the interaction between depth and burn severity
mdi3.fit1 <- update(mdi3.fit0, ~ . + depth*burn.sev)
# Fails to converge; tweak convergence criteria
mdi3.fit1 <- update(mdi3.fit0, ~ . + depth*burn.sev, control=list(msMaxIter=100))
# Fails to converge; tweak convergence criteria

# Drop non-significant terms
mdi3.fit1     <-     update(mdi3.fit0,     log(meanvol2)     ~     daynum     +     depth,
control=list(msMaxIter=100))
anova(mdi3.fit1)
            numDF denDF   F-value p-value
(Intercept)     1   774 234.98725  <.0001
daynum          1   774  38.48625  <.0001
depth           1   774   4.98721  0.0258

# Add soil terms
mdi3.fit2 <- update(mdi3.fit1, ~ . + daynum*s3 + depth*s3)

anova(mdi3.fit2, type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   770 3.493310  0.0620
daynum          1   770 4.148717  0.0420
depth           1   770 0.090714  0.7634
s3              2    20 0.719081  0.4994
daynum:s3       2   770 0.638151  0.5285
depth:s3        2   770 1.185258  0.3062
# None of the new terms are significant

# Re-test without depth
mdi3.fit3 <- update(mdi3.fit2, log(meanvol2) ~ daynum*s3)
anova(mdi3.fit3,type="marginal")
anova(mdi3.fit3,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   773 5.614660  0.0181
daynum          1   773 7.059411  0.0080
s3              2    20 4.538904  0.0237
daynum:s3       2   773 4.477970  0.0117
# Without depth in the model, soil type looks significant

# Which soil types are different
Fixed effects: log(meanvol2) ~ daynum + s3 + daynum:s3
                    Value Std.Error  DF    t-value p-value
(Intercept)    -12.470676  5.262938 773 -2.3695273  0.0181
```

```
daynum           0.000913  0.000344 773  2.6569552  0.0080
s3MS            -5.730192  6.051917  20 -0.9468392  0.3550
s3SS/MS         14.337619  7.972325  20  1.7984239  0.0872
daynum:s3MS      0.000356  0.000396 773  0.8998853  0.3685
daynum:s3SS/MS  -0.000949  0.000521 773 -1.8227743  0.0687
# Granitic is the "baseline"; SS/MS might be different but not MS
# Looks like it has a higher intercept and lower slope
# But none of the individual p-values is less than 0.05

# See if this result holds up if we drop the random effect of site on depth
# This matches the random effects reported in October 2013.
mdi3.fit3a <- update(mdi3.fit3, random= ~ daynum)
anova(mdi3.fit3,mdi3.fit3a)
           Model df      AIC      BIC    logLik   Test  L.Ratio p-value
mdi3.fit3      1 14 2713.608 2780.904 -1342.804
mdi3.fit3a     2 13 2731.478 2793.967 -1352.739 1 vs 2 19.86985  <.0001
# The first model has the lower AIC so is supposedly better

anova(mdi3.fit3a,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   773 3.500152  0.0617
daynum          1   773 4.278019  0.0389
s3              2    20 0.694240  0.5111
daynum:s3       2   773 0.669122  0.5125
# The simpler model doesn't support the effect of soil nor its interaction with daynum
# That's a surprise because usually dropping important random effects makes the fixed
# effects look more significant.

# Compare residuals distributions of these two models
par(mfrow=c(1,2))
qqresid(mdi3.fit3)
qqresid(mdi3.fit3a)
```

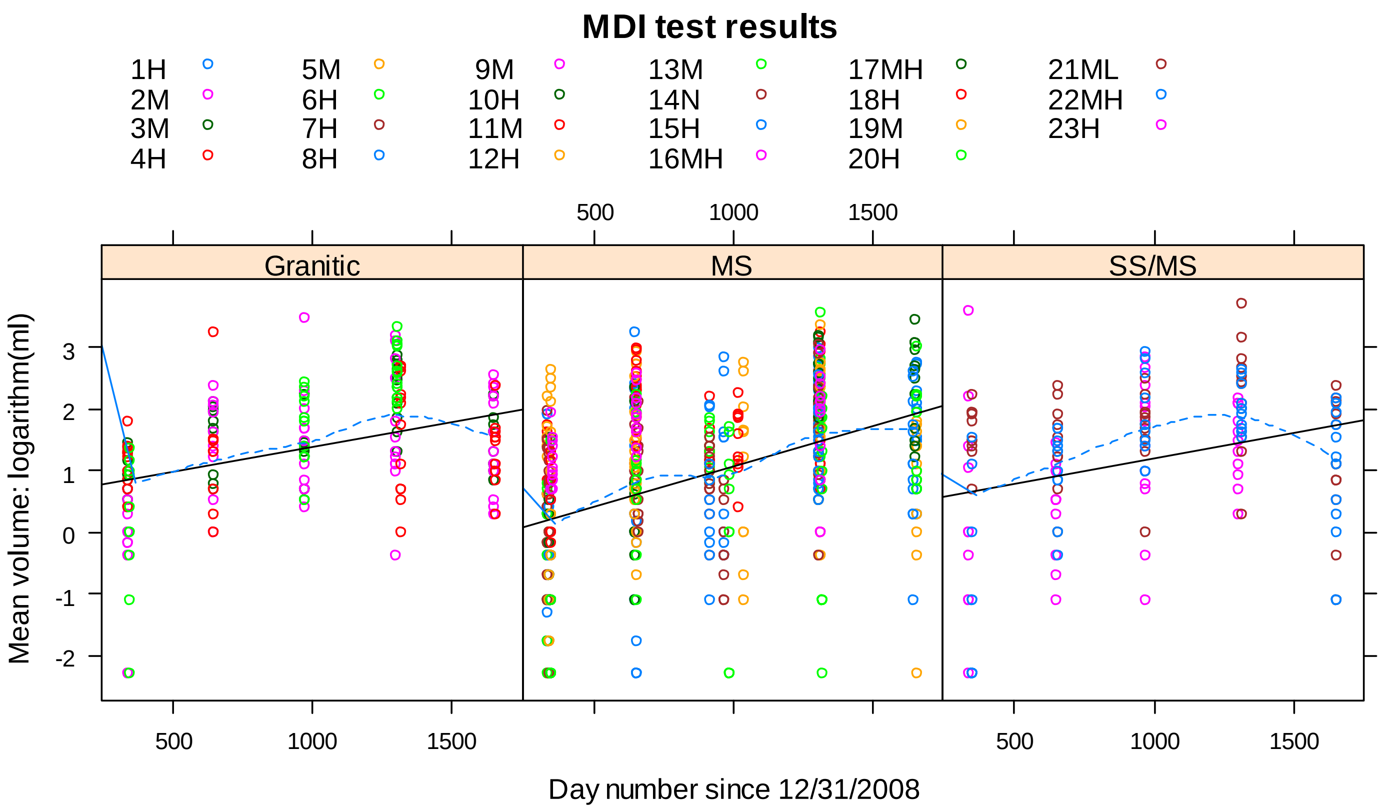





```
# The second model has a slightly smaller departure from normality

# Try testing soils and its interaction with day number in the October 2013 model
# (i.e. with one less random effect, but with depth and burn severity included)
mdi.logfit2c <- update(mdi.logfit2a, ~ . + s3*daynum)
# This is equivalent to
mdi3.fit3c <- update(mdi3.fit3a, ~ . + depth + burn.sev + daynum:burn.sev)
> AIC(mdi.logfit2c)
[1] 2810.794
> AIC(mdi3.fit3c)
[1] 2810.795

anova(mdi.logfit2c, type="marginal")
                numDF denDF   F-value p-value
(Intercept)         1   768 13.371609  0.0003
daynum              1   768 15.186221  0.0001
burn.sev            4    16  7.517636  0.0013
depth               1   768  8.311845  0.0040
s3                  2    16  3.731824  0.0468
daynum:burn.sev     4   768  7.363396  <.0001
daynum:s3           2   768  3.805177  0.0227
# Weird: Now everything appears to be at least somewhat significant.
# Compare this model directly with mdi3.fit3a above.

# Must fit using maximum likelihood for a valid comparison
mdi3.fit3aML <- update(mdi3.fit3a, method="ML")
mdi3.fit3cML <- update(mdi3.fit3c, method="ML")
anova(mdi3.fit3aML, mdi3.fit3cML)
             Model df      AIC      BIC    logLik   Test  L.Ratio p-value
```

```
mdi3.fit3aML     1 13 2684.244 2746.818 -1329.122
mdi3.fit3cML     2 22 2698.677 2804.573 -1327.339 1 vs 2 3.566119  0.9376
```
Suggests that the bigger model is no better, in fact has a higher AIC, but Pinheiro and Bates say (pg 91) that the conditional F-tests (in the anova tables showing p-values for each term) are more "realistic"; but these 2 results are radically different

```
# Compare with the simple fixed effects model: log(meanvol2) ~ daynum
AIC(update(mdi3.fit3a, log(meanvol2) ~ daynum, method="ML"))
[1] 2680.564
# this has the lowest AIC of all, suggesting all those terms are useless

# Try a model that treats year as a categorical variable
# There is a loss of information in the categorization of time, but
# we don't have to assume the effect of time is linear
mdi3.fit4 <- update(mdi3.fit3, log(meanvol2) ~ s3*year, control=list(msMaxIter=150))
# Fails to converge (I tried a variety of convergence criteria)

# Summary plot of fixed effects in model mdi3.fit3
xyplot(log(meanvol2) ~ daynum08 | s3, data=mdi.gd, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
            panel.loess(x,y,lty=2,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results", layout=c(3,1),
xlab="Day number since 12/31/2008", ylab="Mean volume: logarithm(ml)",
auto.key=list(columns=7)
)
```



The lines are not the lines fitted by the model, they are independent linear fits for each frame. The higher intercept and lower slope suggested by mdi3.fit3 for SS/MS relative to Granitic is not apparent; the MS curve is the steepest and the SS/MS curve is shifted lower (than Granitic). I'm skeptical of the soils effect since it only was significant in one of the three models I fitted, $0.01 < p < 0.05$, the individual soil coefficients were not significant ($p > 0.05$), and the model without the depth random effect had a slightly more normal residuals distribution. There seems to be some sort of confounding of depth and soil type.

```
# Look at the mean volumes by year and soil type
tapply(mdi$meanvol,list(mdi$year,mdi$s3),mean)
      Granitic       MS     SS/MS
2009  2.372326 1.899882 3.960667
2010  5.422500 5.190593 3.322667
2011  5.438611 3.446809 6.802812
2012 10.236458 8.247174 8.532222
2013  5.032778 6.743667 4.097500

# Look at log(mean volume) by year and soil
tapply(log(mdi$meanvol2),list(mdi$year,mdi$s3),mean)
      Granitic          MS     SS/MS
2009 0.5930171 -0.03844497 0.2773883
2010 1.4263308  1.11251027 0.9025328
```

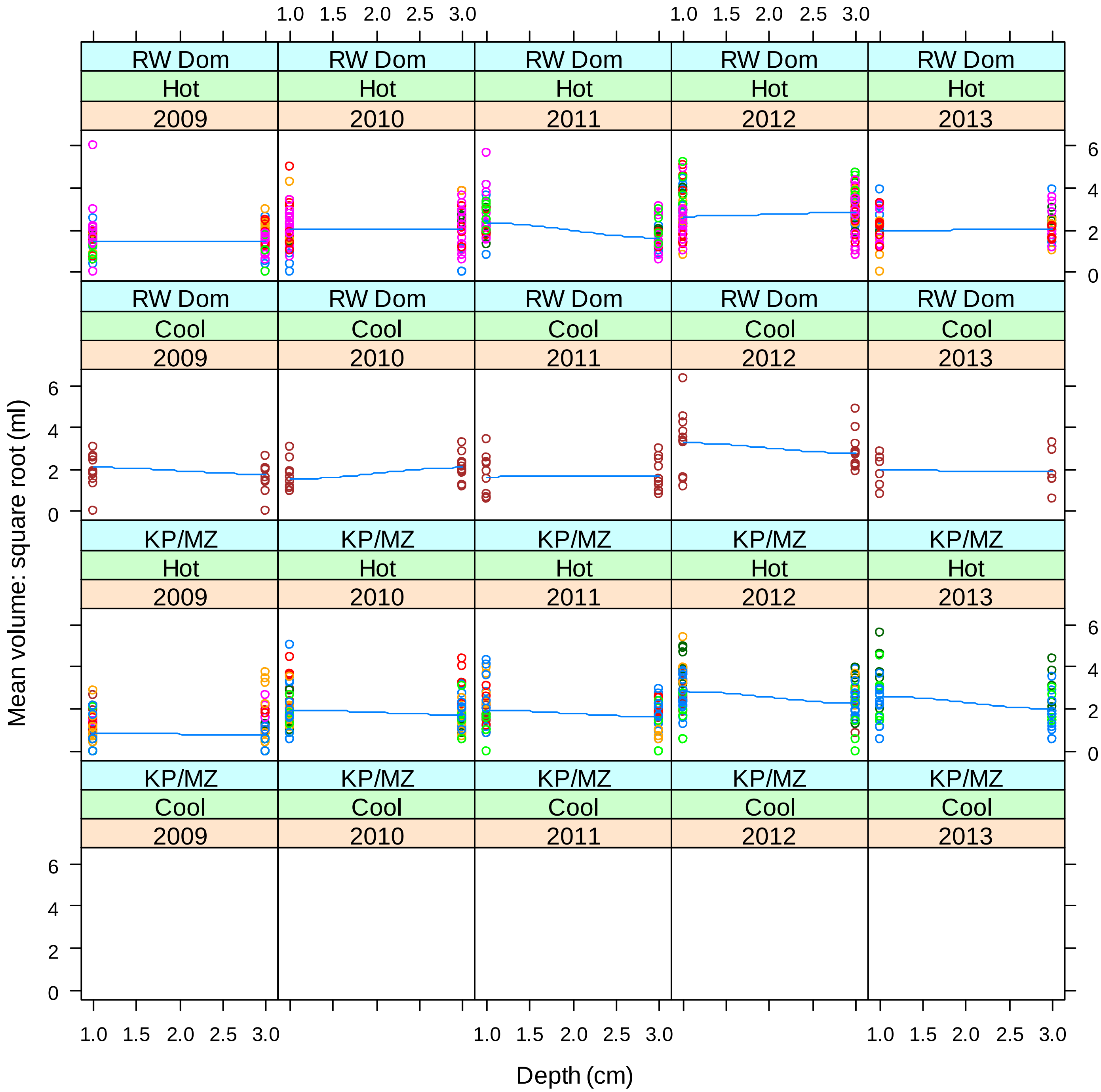
```
2011 1.4400703  0.80136226 1.6026973
2012 2.0398118  1.74099493 1.8919387
2013 1.4400097  1.44975520 0.9798522
```

```
In summary, there is very inconsistent evidence for a soils effect
```

Effects of Vegetation Type

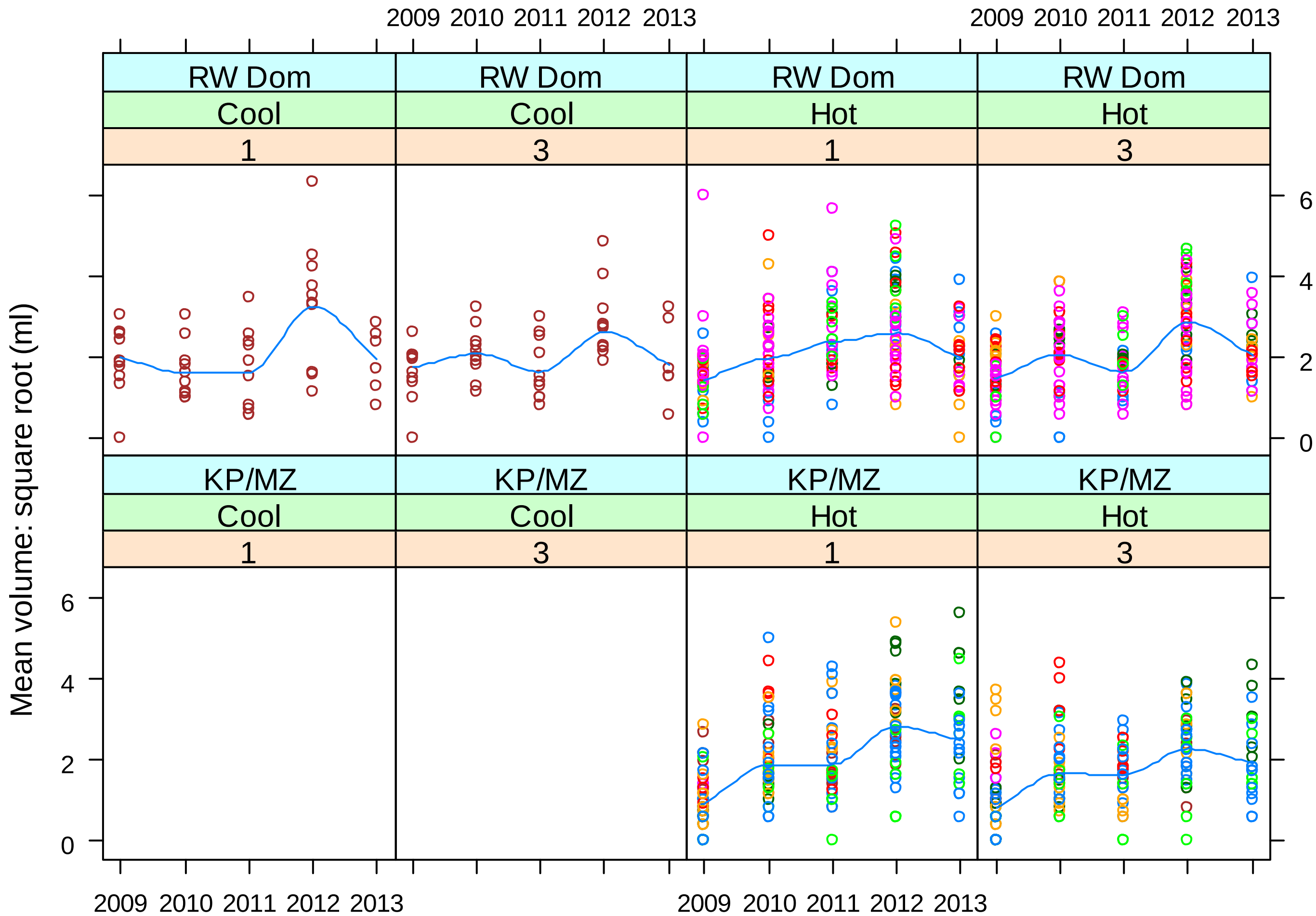
```
library(nlme)
library(lattice)

# READ in the Veg and Soil types
soilveg <- read.csv("Update Jun 2014/MDI WDPT soil veg.csv")
     veg     v3     soil
1      RW RW Dom       MS
2   RW/DF RW Dom    MS/SS
3      RW RW Dom Granitic
4   RW/TO RW Dom       MS
5   RW/TO RW Dom       MS
6      TO     To       MS
7   KP/MZ  KP/MZ       MS
8   KP/MZ  KP/MZ       MS
9   RW/TO RW Dom Granitic
10  KP/MZ  KP/MZ       MS
11  RW/TO RW Dom Granitic
12  KP/MZ  KP/MZ       MS
13     RW RW Dom Granitic
14     RW RW Dom       MS
15  KP/MZ  KP/MZ       MS
16  KP/MZ  KP/MZ       MS
17  KP/MZ  KP/MZ       MS
18  KP/MZ  KP/MZ       MS
19  KP/MZ  KP/MZ       MS
20  KP/MZ  KP/MZ       MS
21  RW/TO RW Dom    MS/SS
22  KP/MZ  KP/MZ       SS
23  RW/TP RW Dom       MS
# The row names coincide with the site numbers
# The veg types can be accessed by using site number as the subscript

mdi$v3 <- soilveg$v3[mdi$sitenum]
mdi$soil <- soilveg$soil[mdi$sitenum]
wdpt$v3 <- soilveg$v3[wdpt$sitenum]
wdpt$soil <- soilveg$soil[wdpt$sitenum]

save.image()

superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(23)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
trellis.par.set("superpose.line",superpose.line)
# Collapse over transect distance
xyplot(sqrt(meanvol) ~ depth | factor(year)*burn.sev2*v3, data=mdi, groups=site,
   panel=function(x,y, subscripts, groups) {
       panel.superpose(x,y, subscripts, groups, "panel.xyplot")
```

```
        panel.loess(x,y,xpan=1)
    }, subset=depth %in% c(1,3) & v3!="To", xlab="Depth (cm)", ylab="Mean volume: square root (ml)",layout=c(5,4))
```

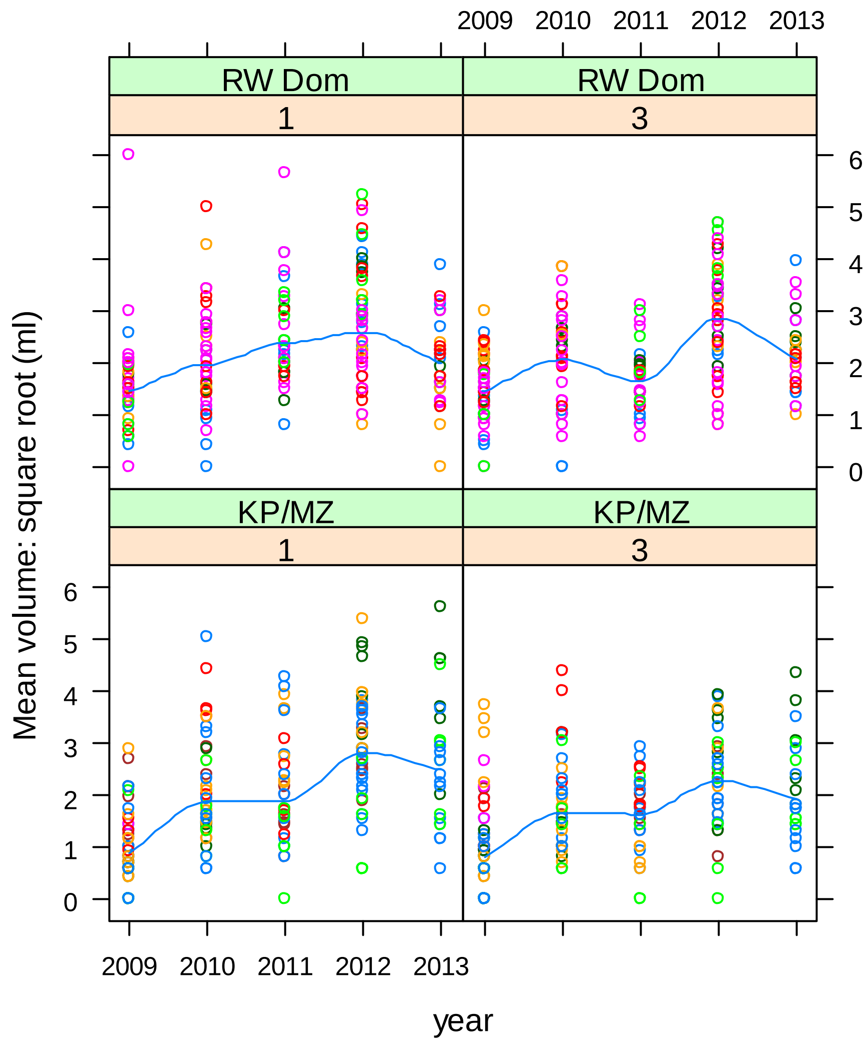



```
# Look at the effect of time by depth
xyplot(sqrt(meanvol) ~ year | factor(depth)*burn.sev2*v3, data=mdi, groups=site, aspect=1,
```

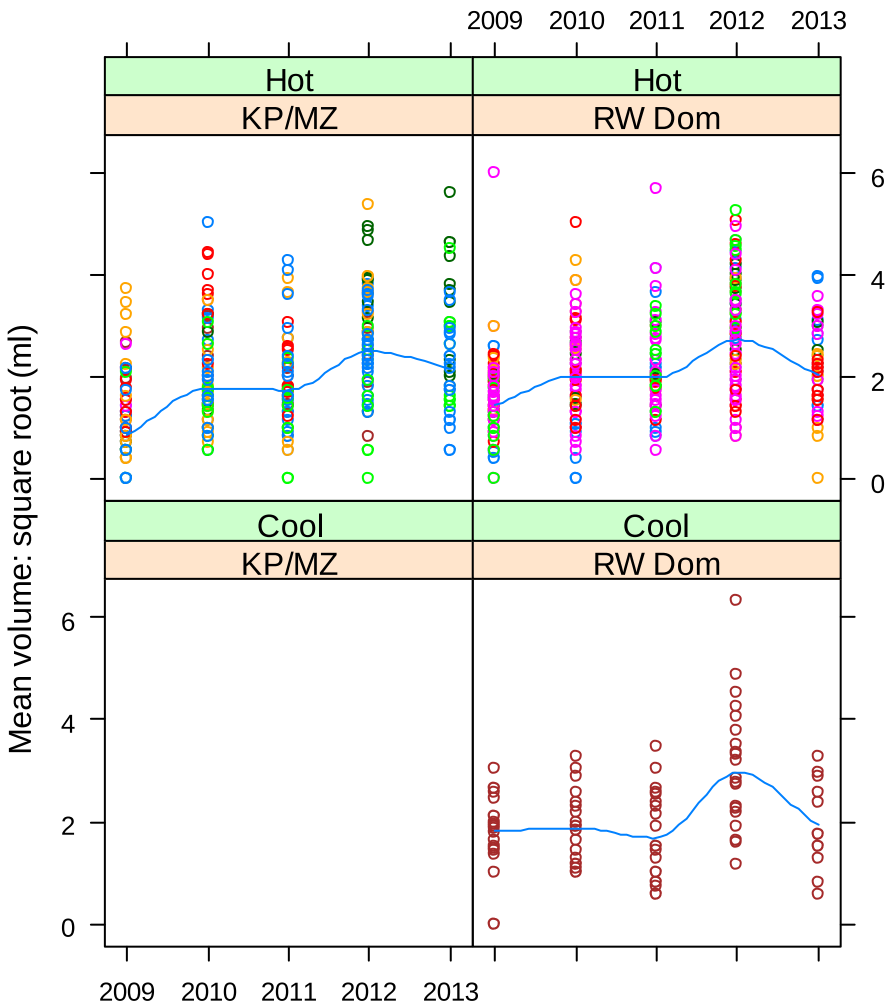
```
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
      panel.superpose(x,y,subscripts,groups, "panel.xyplot")
      panel.loess(x,y,span=0.5)
   },   subset=depth   %in%   c(1,3)   &   v3!="To",ylab="Mean   volume:   square   root
(ml)",layout=c(4,2),xlab="")
```



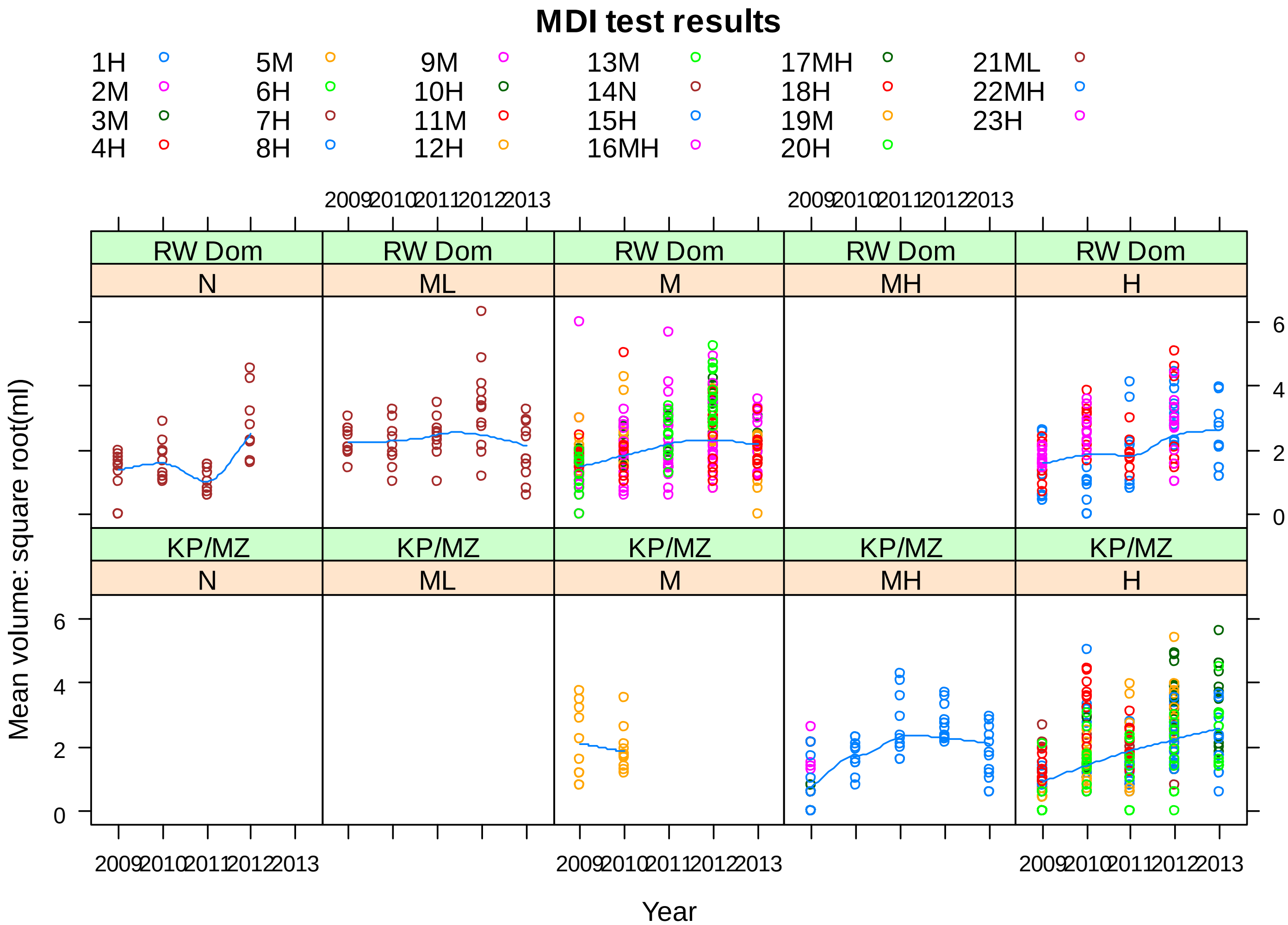

```
# Look closer at the "Hot" frames above

xyplot(sqrt(meanvol) ~ year | factor(depth) * v3, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
     # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
     panel.superpose(x,y,subscripts,groups, "panel.xyplot")
     panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3) & burn.sev2=="Hot" & v3!="To", ylab="Mean volume: square
root (ml)")
```



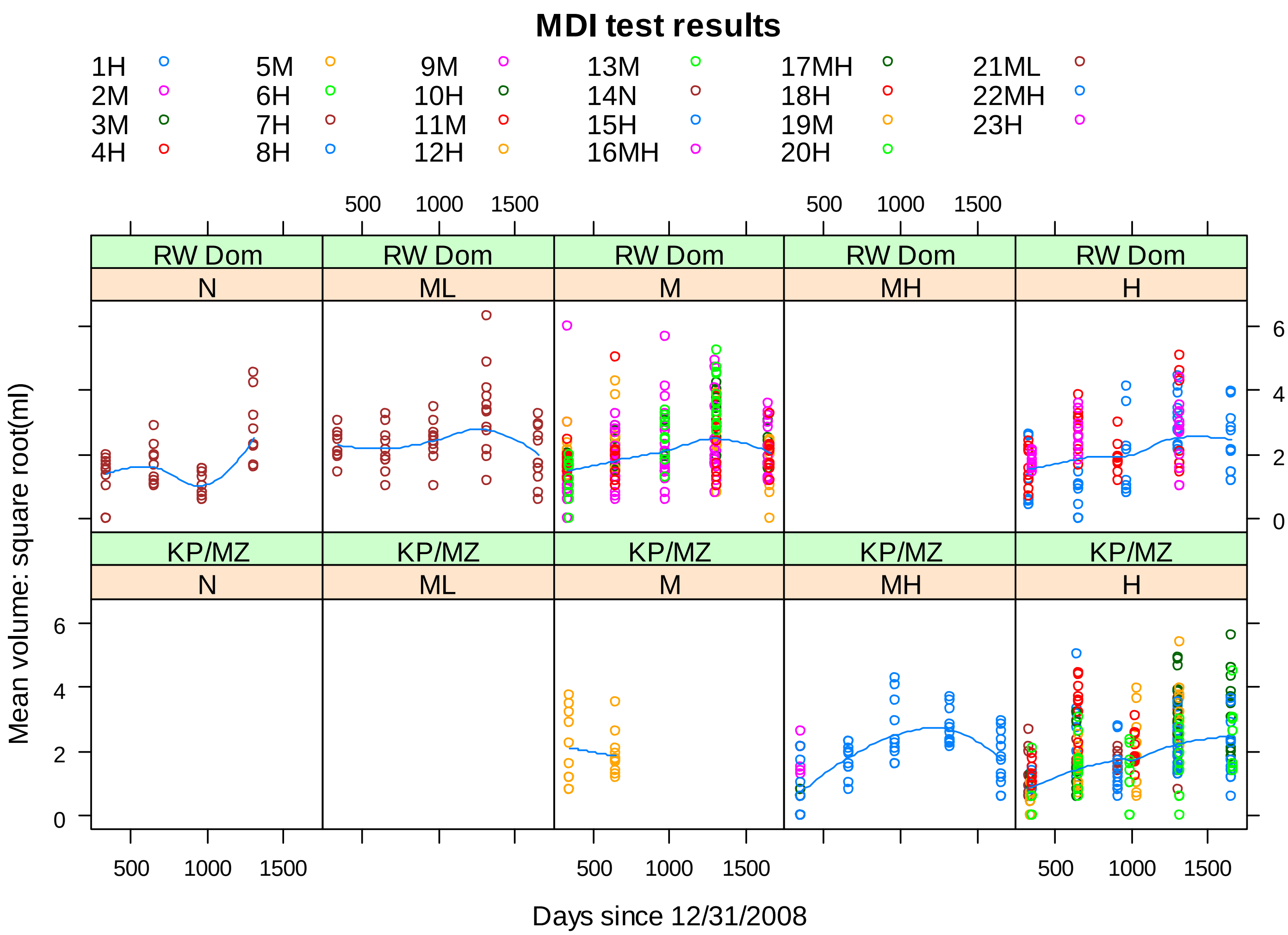

```
# Collapse over both transect distance and depth
xyplot(sqrt(meanvol) ~ year | v3*burn.sev2, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
         # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.33)
         panel.superpose(x,y,subscripts,groups, "panel.xyplot")
         panel.loess(x,y,span=0.5)
   }, subset=depth %in% c(1,3) & v3!="To", xlab="", ylab="Mean volume: square root (ml)")
```



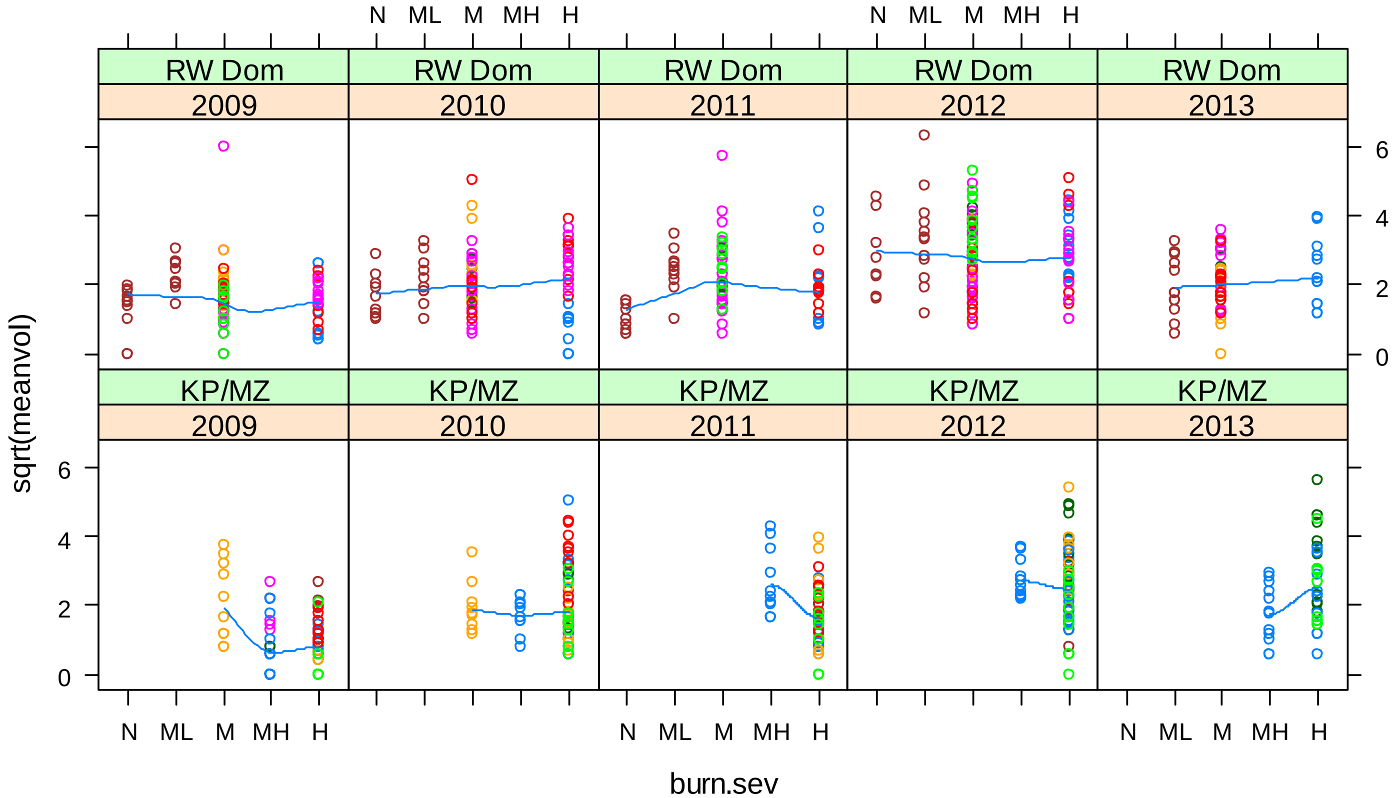

```
# Repeat with original burn categories, loess line, and sqrt(meanvol)
xyplot(sqrt(meanvol) ~ factor(year) | burn.sev * v3, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,span=0.67)
   }, subset=depth %in% c(1,3) & v3 !="To", main="MDI test results",
xlab="", ylab="Mean volume: square root(ml)", auto.key=list(columns=7)
)
```



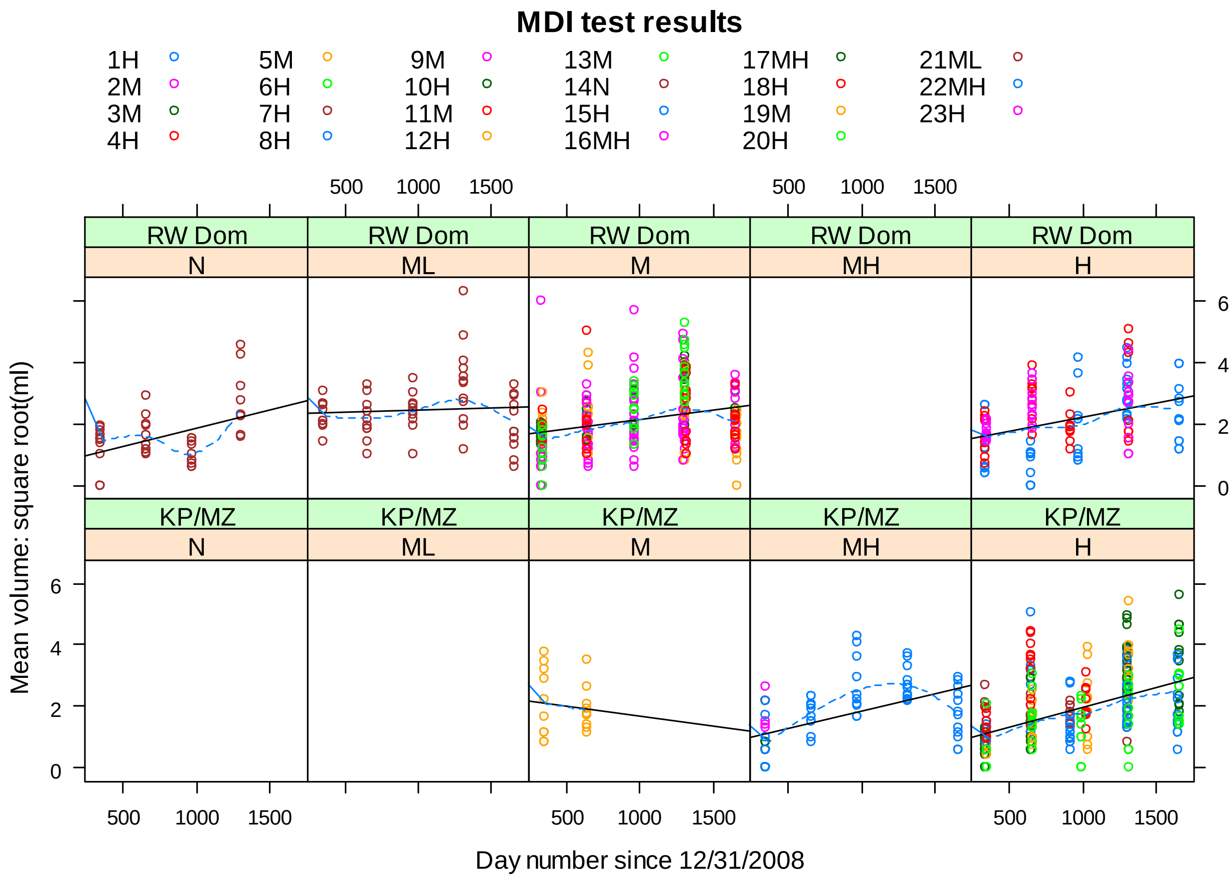

```
# Plot against day number instead of year for a bit more resolution
xyplot(sqrt(meanvol) ~ daynum08 | burn.sev * v3, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,degree=2,span=1)
   }, subset=depth %in% c(1,3) & v3 != "To", main="MDI test results",
xlab="Days     since     12/31/2008",     ylab="Mean     volume:     square     root(ml)",
auto.key=list(columns=7)
)
```



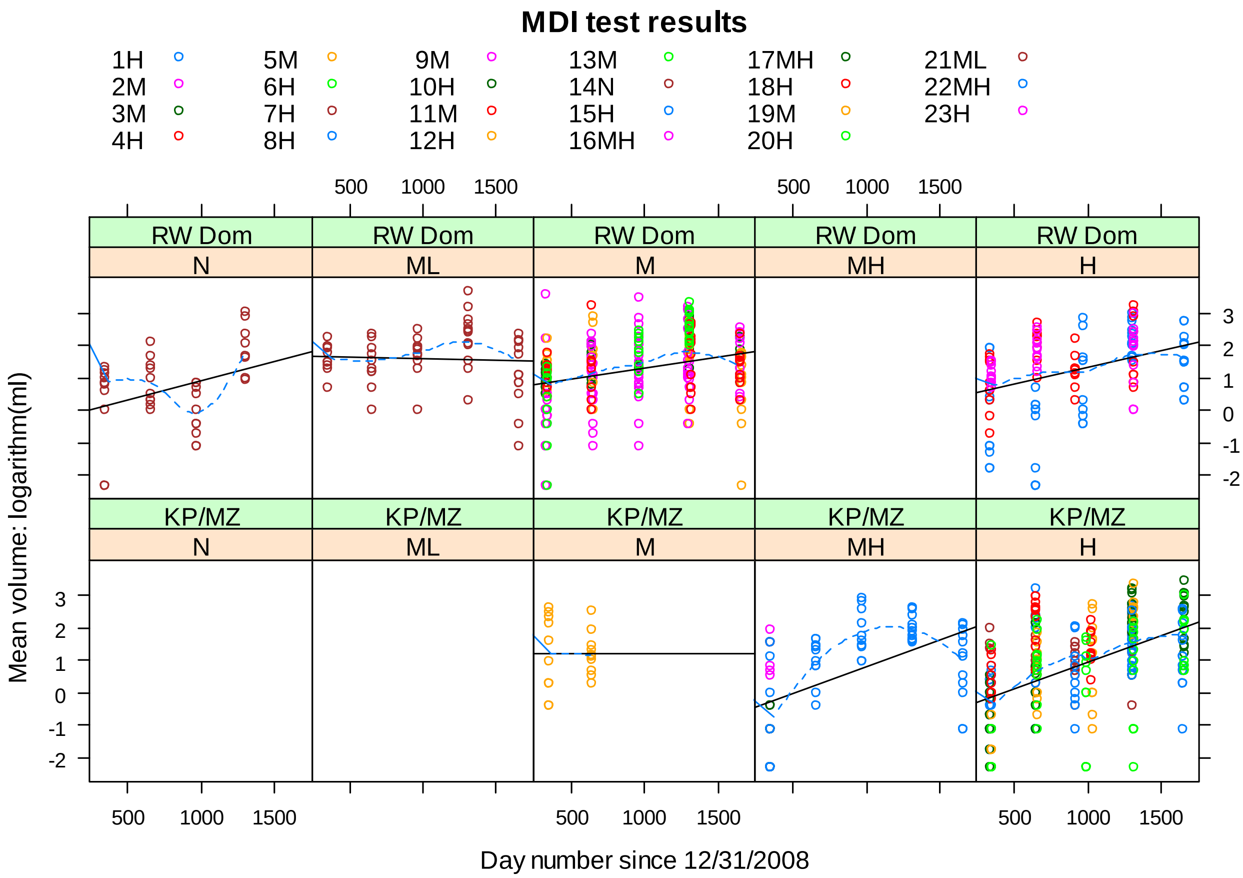

```
# Compare original burn categories for each year
# I had to increase the smoothing parameter to get sensible curves in frames that include
only 2 burn classes
xyplot(sqrt(meanvol) ~ burn.sev | factor(year) * v3, data=mdi, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.xyplot")
      panel.loess(x,y,span=0.9)
   }, subset=depth %in% c(1,3) & v3 != "To"
)
```




```
xyplot(sqrt(meanvol) ~ daynum08 | burn.sev*v3, data=mdi2.gd, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
            panel.loess(x,y,lty=2,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Day    number    since    12/31/2008",    ylab="Mean    volume:    square    root(ml)",
auto.key=list(columns=7)
)
```



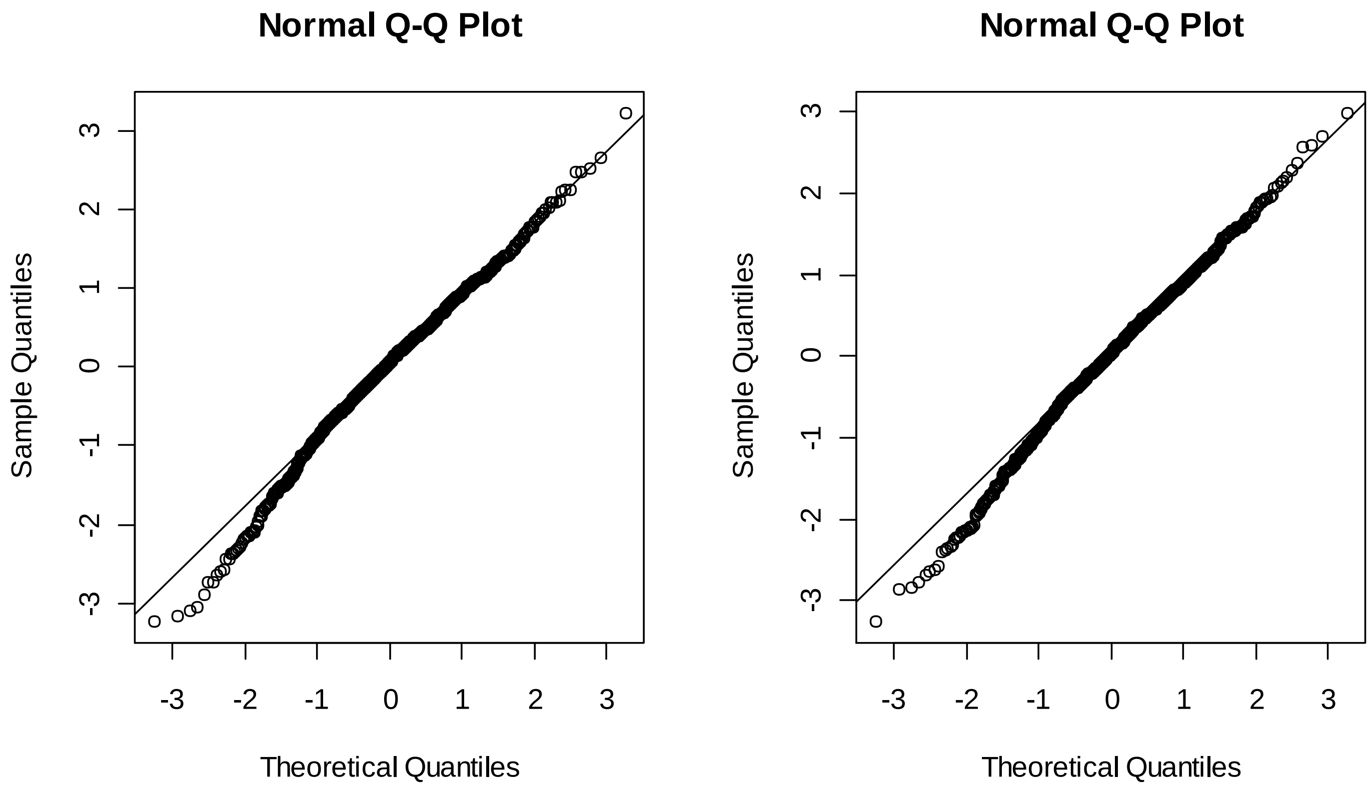

```
# Replot last one with log transformed response

xyplot(log(meanvol2) ~ daynum08 | burn.sev * v3, data=mdi2.gd, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
            panel.loess(x,y,lty=2,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Day    number    since    12/31/2008",    ylab="Mean    volume:    logarithm(ml)",
auto.key=list(columns=7)
)
```



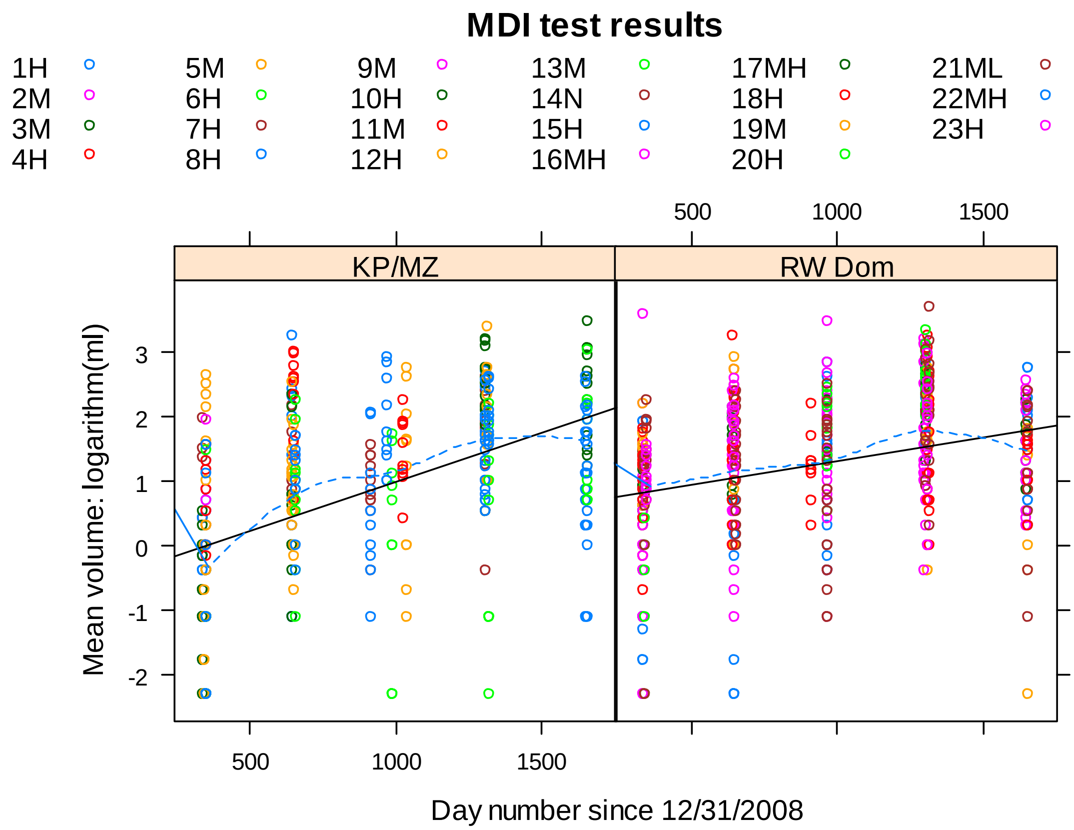

```
==================================================================
# Mixed effects models
mdi2.gd  <-  groupedData(meanvol  ~  daynum  |  site/dist,  outer  =  ~  burn.sev,
data=mdi[mdi$depth %in% c(1,3) & mdi$v3 != "To",])
options(contrasts=c("contr.treatment","contr.treatment"))

# Try modeling the logarithm, which was successful before
# Must first deal with zeroes
sum(mdi2.gd$meanvol==0)
[1] 32
# Set the zeroes to 0.10
mdi2.gd$meanvol2 <- mdi2.gd$meanvol
mdi2.gd$meanvol2[mdi2.gd$meanvol==0] <- 0.10

# Fit the random effects model that we had for the full data set
mdi2.fit0  <-  lme(log(meanvol2)  ~  daynum  +  burn.sev  +  depth  +  daynum:burn.sev,
random=list(site=~daynum+depth, dist=~-1+daynum), data=mdi2.gd)

anova(mdi2.fit0) # Sequential
                numDF denDF   F-value p-value
(Intercept)         1   742 181.63490  <.0001
daynum              1   742  45.53880  <.0001
burn.sev            4    17   1.37084  0.2855
depth               1   742   3.96905  0.0467
daynum:burn.sev     4   742   1.94609  0.1010

anova(mdi2.fit0,type="marginal")
```

```
                numDF denDF  F-value p-value
(Intercept)         1   742 5.833535  0.0160
daynum              1   742 6.249084  0.0126
burn.sev            4    17 2.036819  0.1346
depth               1   742 3.688263  0.0552
daynum:burn.sev     4   742 1.946088  0.1010
# The burn severity and its interaction are not significant
# and depth is only marginally significant.

# Retest the interaction between depth and burn severity
mdi2.fit1 <- update(mdi2.fit0, ~ . + depth*burn.sev)
# Fails to converge; tweak convergence criteria
mdi2.fit1 <- update(mdi2.fit0, ~ . + depth*burn.sev, control=list(msMaxIter=100))
                numDF denDF   F-value p-value
(Intercept)         1   738 183.11431  <.0001
daynum              1   738  45.84900  <.0001
burn.sev            4    17   1.37974  0.2826
depth               1   738   3.75919  0.0529
daynum:burn.sev     4   738   1.98320  0.0953
burn.sev:depth      4   738   0.81187  0.5177
# Only daynum is significant; drop non-significant interactions

mdi2.fit2   <-   update(mdi2.fit0,   log(meanvol2)   ~   daynum   +   depth   +   burn.sev,
control=list(msMaxIter=100))
            numDF denDF   F-value p-value
(Intercept)     1   746 192.05012  <.0001
daynum          1   746  36.90740  <.0001
depth           1   746   4.57336  0.0328
burn.sev        4    17   1.27987  0.3167

mdi2.fit3 <- update(mdi2.fit2, ~ . + daynum*v3 + depth*v3)

anova(mdi2.fit3,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   744 32.25164  <.0001
daynum          1   744 33.72224  <.0001
depth           1   744  4.88438  0.0274
burn.sev        4    16  0.70420  0.6005
v3              1    16  4.77972  0.0440
daynum:v3       1   744  4.60861  0.0321
depth:v3        1   744  1.35124  0.2454

# See if the veg terms hold up after dropping insignificant terms
mdi2.fit4   <-   update(mdi2.fit0,   log(meanvol2)   ~   daynum   +   depth   +   v3*daynum,
control=list(msMaxIter=100))
anova(mdi2.fit4,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   745 32.49554  <.0001
daynum          1   745 35.34894  <.0001
depth           1   745  4.05725  0.0443
v3              1    20  3.39243  0.0804
daynum:v3       1   745  3.16658  0.0756
# Vegetation is not significant at the 0.05 level

                     Value Std.Error  DF   t-value p-value
(Intercept)     -21.955297  3.851478 745 -5.700486  0.0000
daynum            0.001520  0.000256 745  5.945497  0.0000
```

```
depth            -0.093670  0.046504 745 -2.014261  0.0443
v3RW Dom          8.517127  4.624208  20  1.841856  0.0804
daynum:v3RW Dom  -0.000540  0.000303 745 -1.779487  0.0756
# Although not significant the coefficients suggest higher MDI volumes in the RW dominant
veg type, with slightly lower slopes

# Compare models with different fixed effects using maximum likelihood
tmp1 <- update(mdi2.fit4, method="ML")
tmp0 <- update(tmp1, ~ . - depth - v3*daynum)
anova(tmp0,tmp1)
     Model df      AIC      BIC    logLik   Test  L.Ratio p-value
tmp0     1  9 2599.086 2642.064 -1290.543
tmp1     2 13 2577.335 2639.415 -1275.667 1 vs 2 29.75073  <.0001
# This suggests keeping depth and the v3:daynum interaction
# Pinheiro and Bates recommend going by the conditional F and t-tests,
# i.e. the 0.0804 and 0.0756, but can 2 nearly significant terms considered
# together can constitute an improvement?  Thats' probably pushing things too far.

# What happens if we go to a slightly simpler random effects model
# This is probably not wise either because then the residuals might not be
# fully independent.  So the following is just to satisfy curiosity.
# Drop the effect of site on depth

mdi2.fit4a <- update(mdi2.fit4, random= ~daynum)
anova(mdi2.fit4, mdi2.fit4a)
           Model df      AIC      BIC    logLik   Test  L.Ratio p-value
mdi2.fit4      1 13 2616.869 2678.874 -1295.434
mdi2.fit4a     2 12 2629.596 2686.832 -1302.798 1 vs 2 14.72751   1e-04
# The original model is better by AIC

anova(mdi2.fit4a,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   745 33.90165  <.0001
daynum          1   745 37.01091  <.0001
depth           1   745  8.18450  0.0043
v3              1    20  5.64492  0.0276
daynum:v3       1   745  5.39863  0.0204
# All fixed effects are more significant in this model than in mdi2.fit4
# That is as expected.

Fixed effects: log(meanvol2) ~ daynum + depth + v3 + daynum:v3
                     Value Std.Error  DF   t-value p-value
(Intercept)     -25.088569  4.308891 745 -5.822512  0.0000
daynum            0.001727  0.000284 745  6.083660  0.0000
depth            -0.093025  0.032516 745 -2.860857  0.0043
v3RW Dom         13.884383  5.843830  20  2.375905  0.0276
daynum:v3RW Dom  -0.000892  0.000384 745 -2.323496  0.0204

# Compare residuals distributions
par(mfrow=c(1,2))
qqresid(mdi2.fit4)
qqresid(mdi2.fit4a)
```




```
# Very similar; the latter is perhaps slightly more normal

xyplot(log(meanvol2) ~ daynum08 | v3, data=mdi2.gd, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.lmline(x,y)
            panel.loess(x,y,lty=2,degree=2,span=1)
   }, subset=depth %in% c(1,3), main="MDI test results",
xlab="Day    number    since    12/31/2008",    ylab="Mean    volume:    logarithm(ml)",
auto.key=list(columns=7)
)
```



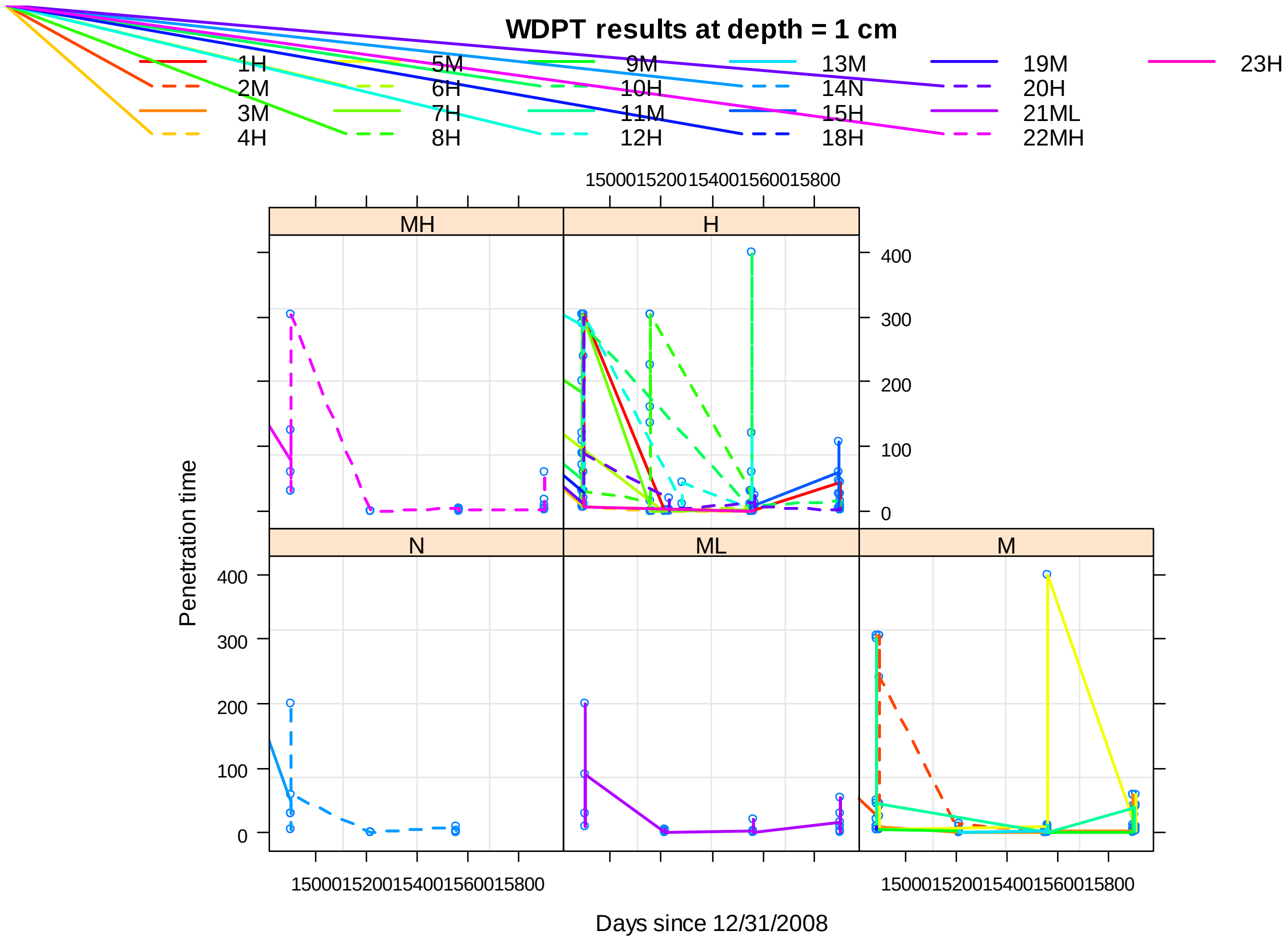

```
# The statistical significance of vegetation depends on the random effects

# Try a model that treats year as a categorical variable
mdi2.fit5   <-   update(mdi2.fit0,   log(meanvol2)   ~   daynum   +   depth   +   v3*year,
control=list(msMaxIter=100))

anova(mdi2.fit5,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1   744 13.991677  0.0002
daynum          1   744  8.971751  0.0028
depth           1   744  3.902272  0.0486
v3              1    20  3.176608  0.0899
year            1   744 13.873266  0.0002
v3:year         1   744  3.171963  0.0753
# Essentially the same result

# Look at mean volumes by year and veg type
tapply(mdi$meanvol,list(mdi$year,mdi$v3),mean)
        KP/MZ   RW Dom        To
2009 1.537250 3.095929  0.950000
2010 4.814250 4.988125        NA
2011 4.196290 4.901250  3.833333
2012 7.559405 9.227381 11.581667
2013 7.040833 4.808056        NA

# Same thing: logarithms
tapply(log(mdi$meanvol2),list(mdi$year,mdi$v3),mean)
          KP/MZ     RW Dom         To
2009 -0.3696405 0.6705739 -0.4132257
```

```
2010  1.0859993 1.1605157        NA
2011  0.9335343 1.1957786  1.2791047
2012  1.6532094 1.9073606  2.2567524
2013  1.4720946 1.2733552        NA

# RW Dom appears to have had higher volumes than KP/MZ except in 2013
```

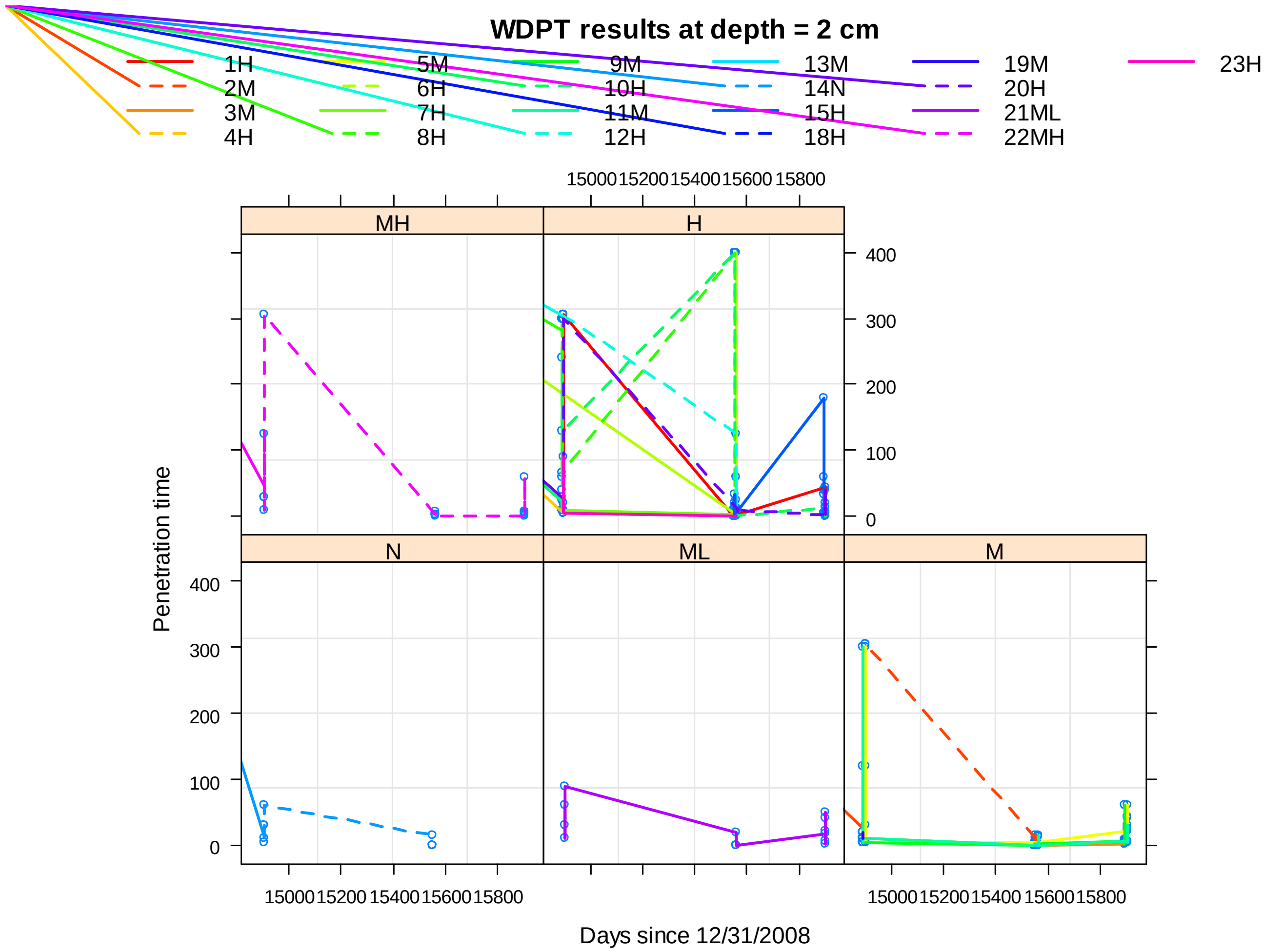
Appendix L. R Code and Output for the WDPT Dataset

Effects of Burn Severity

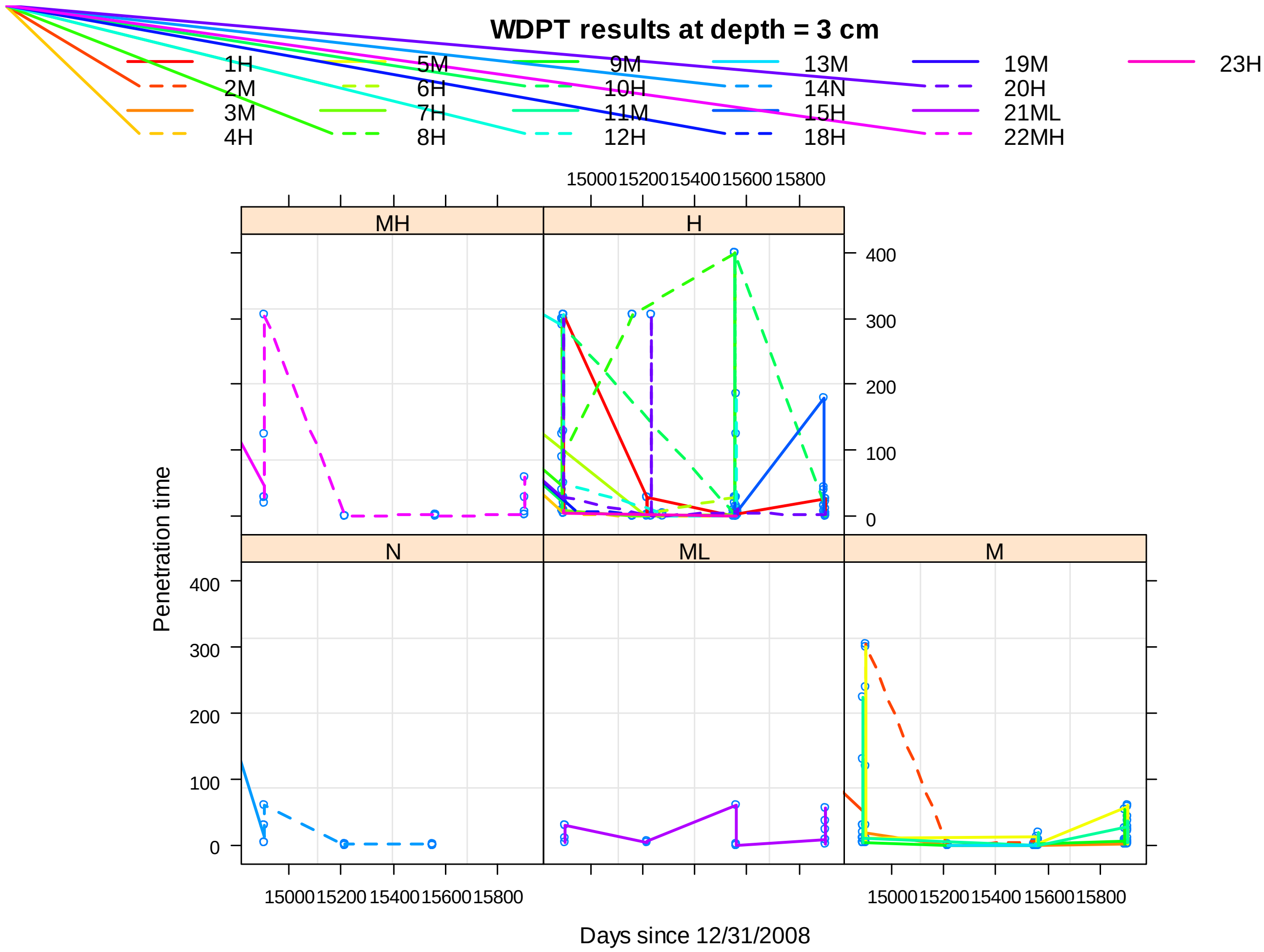
```
library("chron")
library("lattice")
library(nlme)

# Correct the depths

table(wdpt$depth)

0.393700787           1 1.181102362           2           3
         72         261          65         261         261

sum(wdpt$depth < 1)
[1] 72
wdpt$depth[wdpt$depth < 1] <- 1
sum(wdpt$depth > 1 & wdpt$dept < 2)
[1] 65
wdpt$depth[wdpt$depth > 1 & wdpt$dept < 2] <- 3
table(wdpt$depth)
  1   2   3
333                                  261                                     326

save.image()

superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(23)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
trellis.par.set("superpose.line",superpose.line)

wdpt.gd <- groupedData(time2 ~ daynum | site, outer = ~ burn.sev, data=wdpt)
save.image()

tmp <- wdpt.gd[wdpt.gd$depth==1, ]
plot(tmp,  aspect=1,  outer=T  ,xlab="Days  since  12/31/2008",ylab="Penetration
time",main="WDPT results at depth = 1 cm")
```



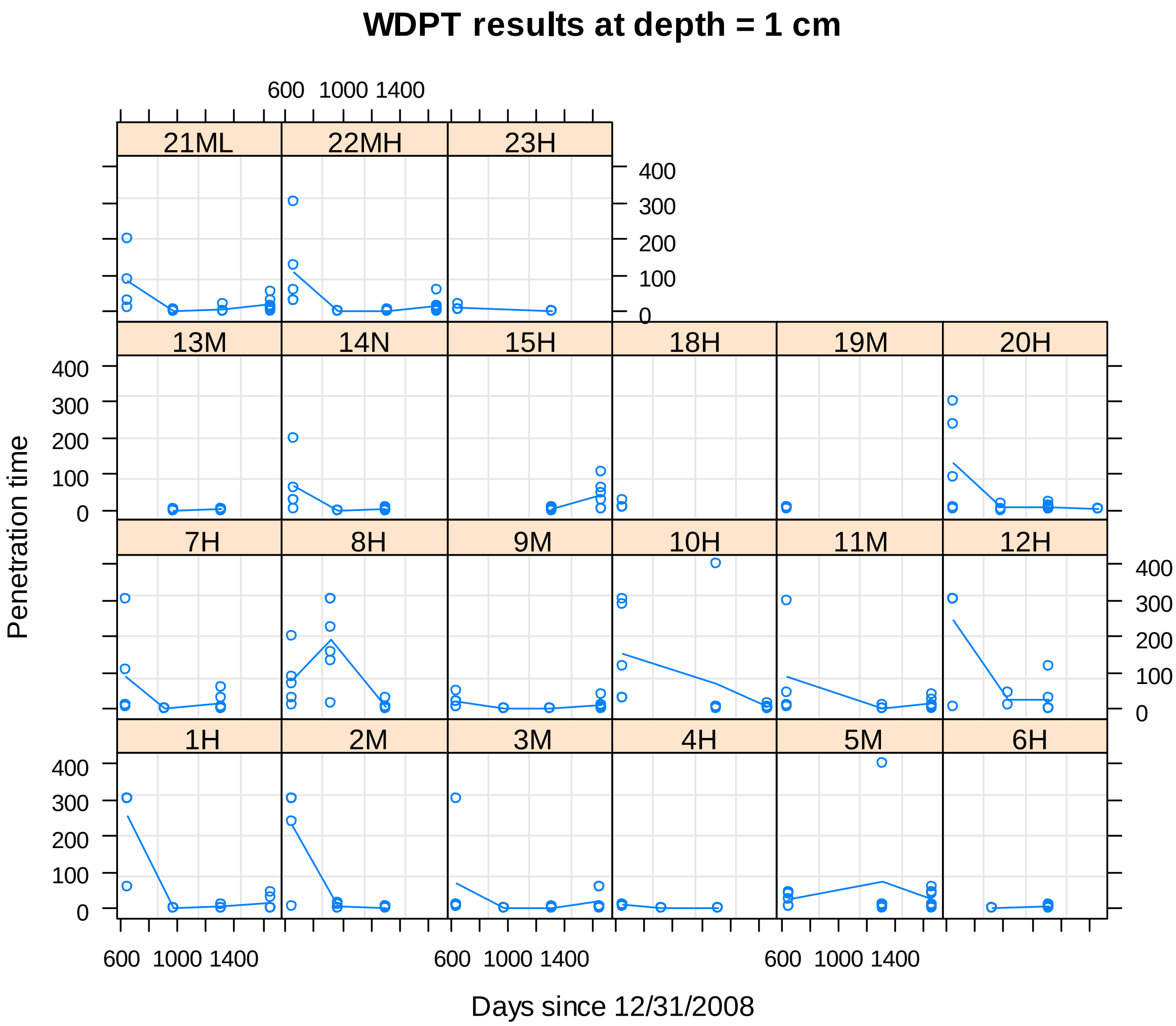

```
tmp <- wdpt.gd[wdpt.gd$depth==2, ]
plot(tmp, aspect=1, outer=T ,xlab="Days since 12/31/2008",ylab="Penetration
time",main="WDPT results at depth = 2 cm")
```



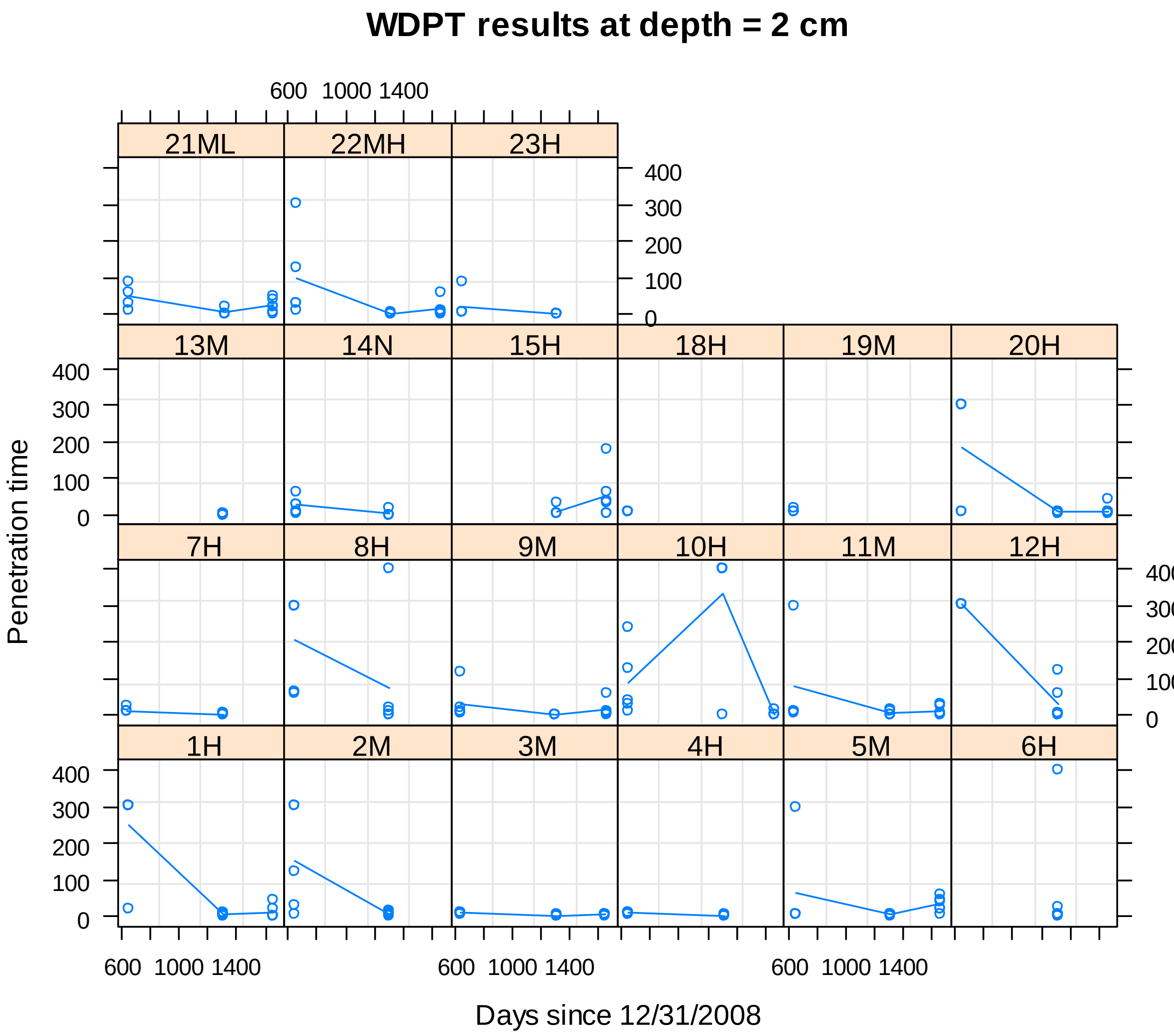

```
tmp <- wdpt.gd[wdpt.gd$depth==3, ]
plot(tmp, aspect=1, outer=T ,xlab="Days since 12/31/2008",ylab="Penetration
time",main="WDPT results at depth = 3 cm")
```



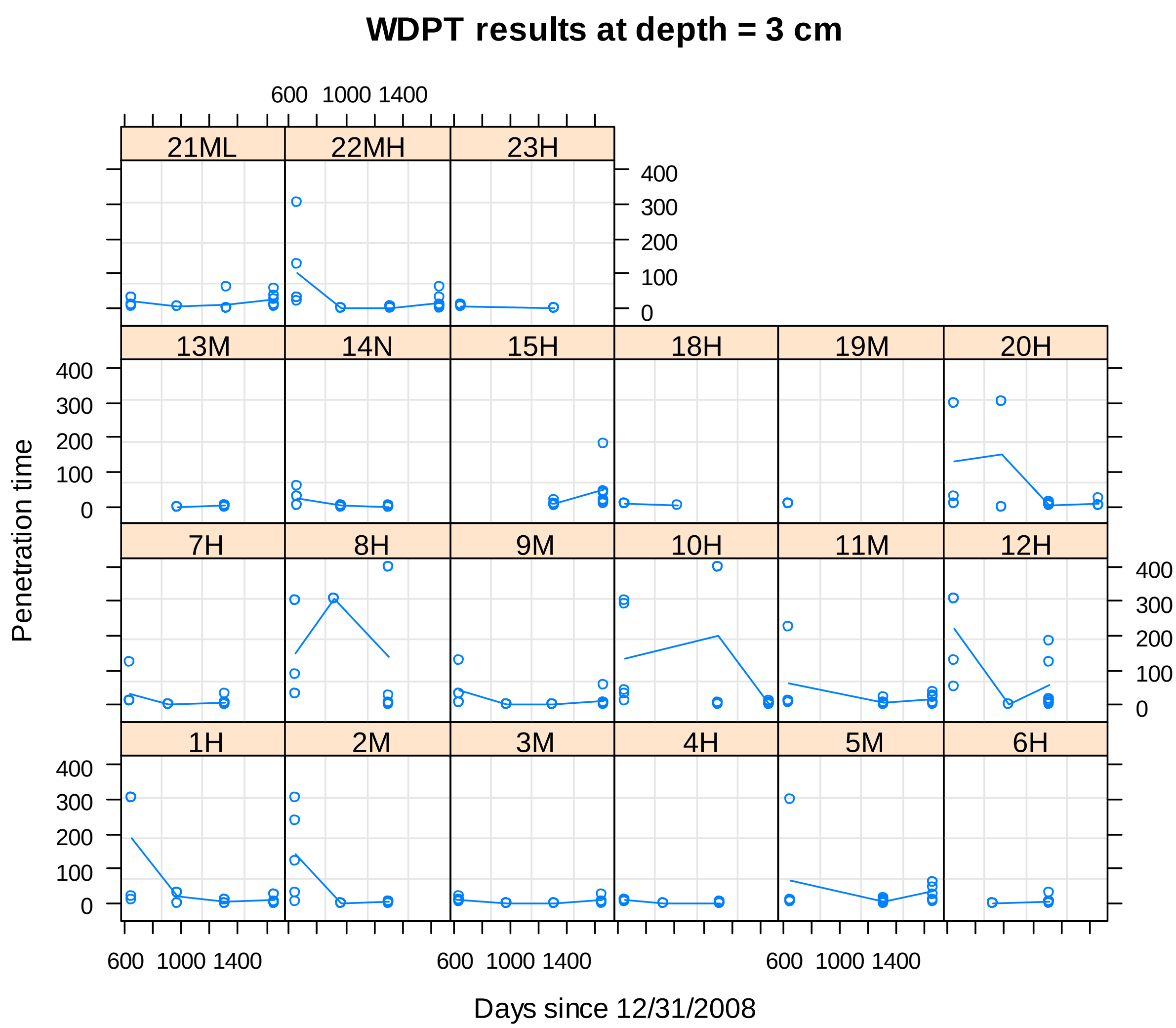

```
tmp    <-    wdpt.gd[wdpt.gd$depth    ==1,    ];    tmp$daynum    <-    tmp$daynum    -
as.numeric(dates("1/1/2009"))
plot(tmp,         aspect=1,         layout=c(6,4),         xlab="Days         since
12/31/2008",ylab="Penetration time",main="WDPT results at depth = 1 cm")
```



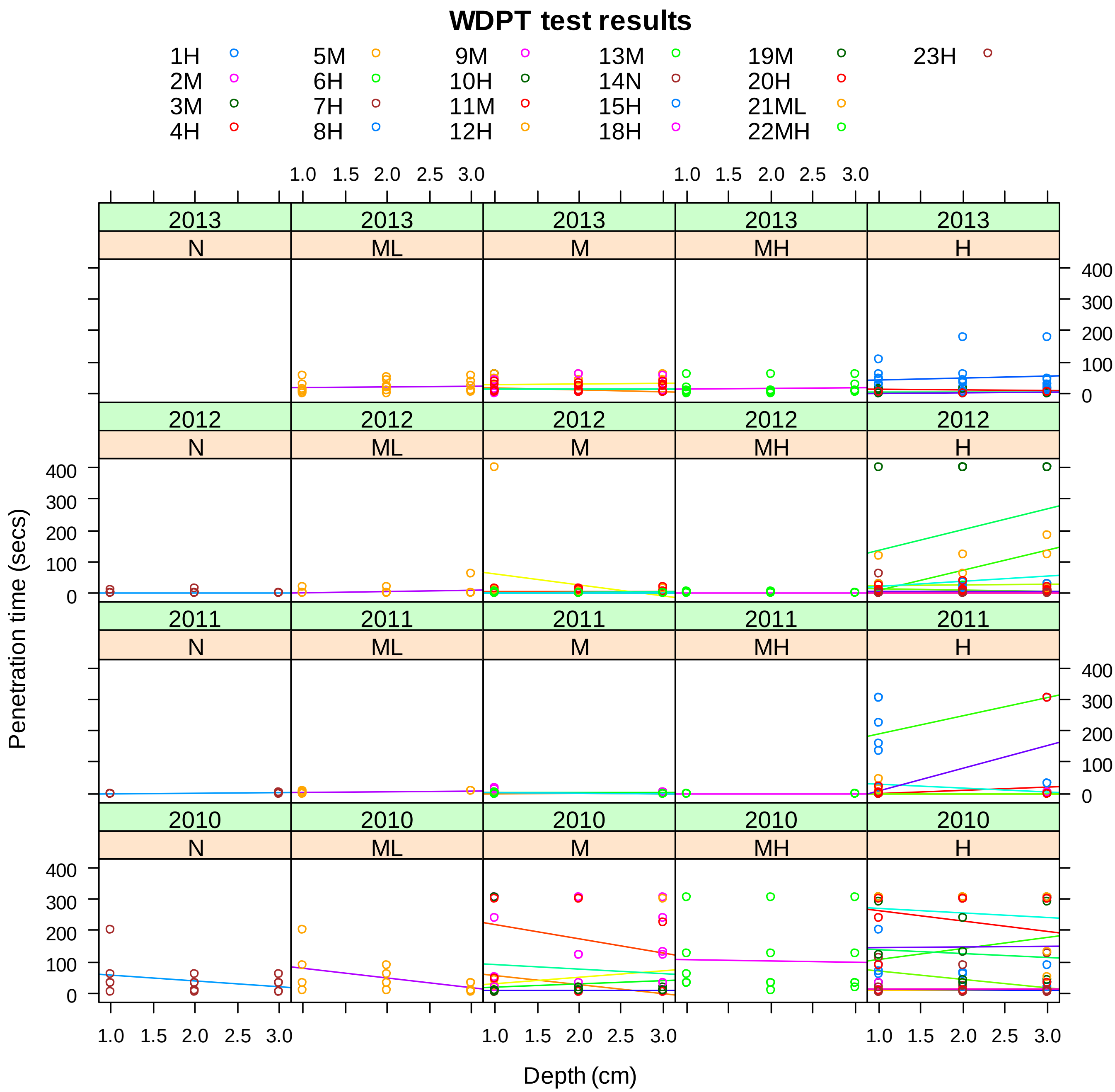

```
tmp <- wdpt.gd[wdpt.gd$depth==2, ]; tmp$daynum <- tmp$daynum - as.numeric(dates("1/1/2009"))
plot(tmp, aspect=1, layout=c(6,4), xlab="Days since 12/31/2008",ylab="Penetration time",main="WDPT results at depth = 2 cm")
```



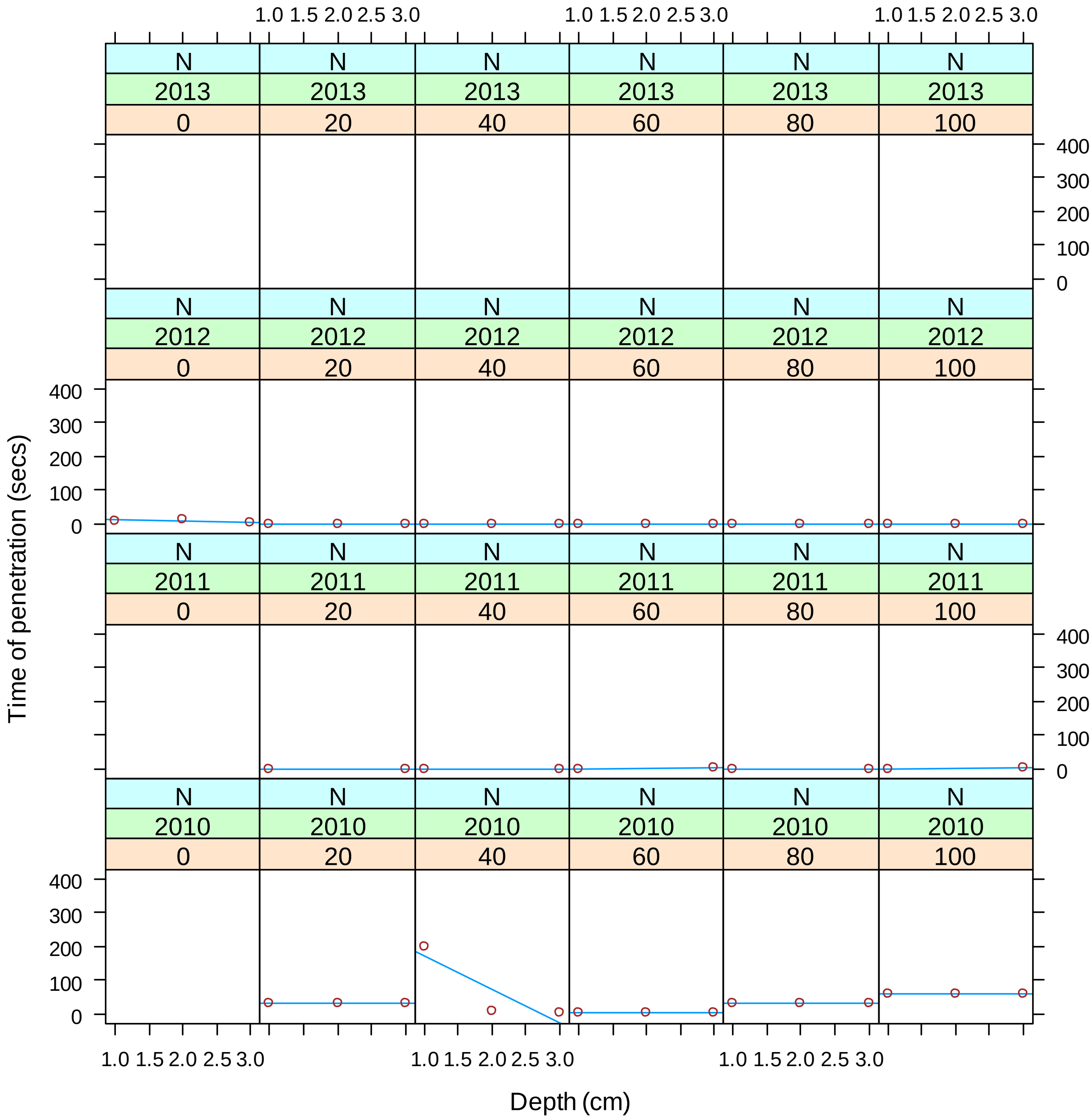

```
tmp <- wdpt.gd[wdpt.gd$depth==3, ]; tmp$daynum <- tmp$daynum -
as.numeric(dates("1/1/2009"))
plot(tmp, aspect=1, layout=c(6,4), xlab="Days since
12/31/2008",ylab="Penetration time",main="WDPT results at depth = 3
cm",ylim=c(-50,425))
```

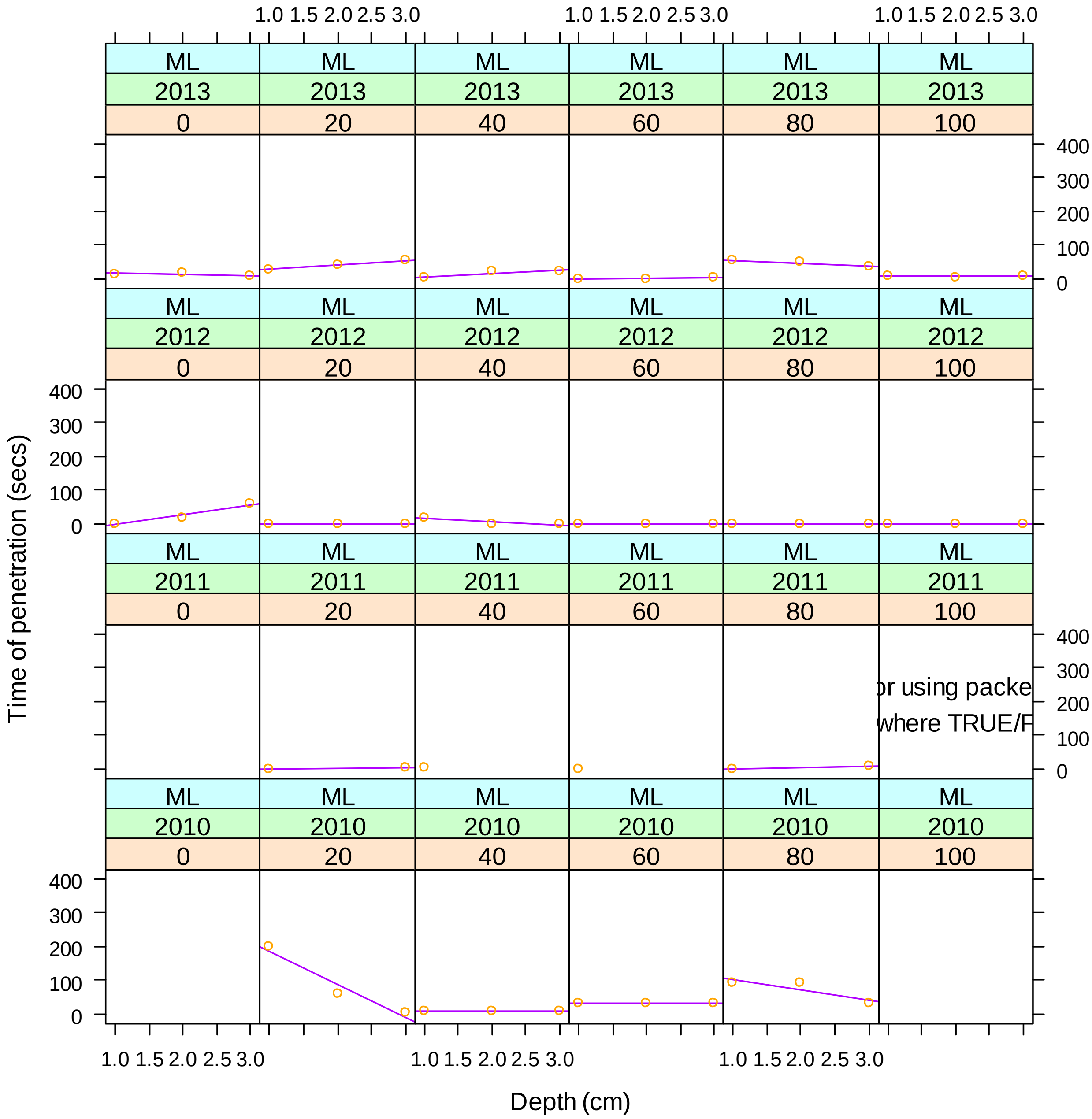


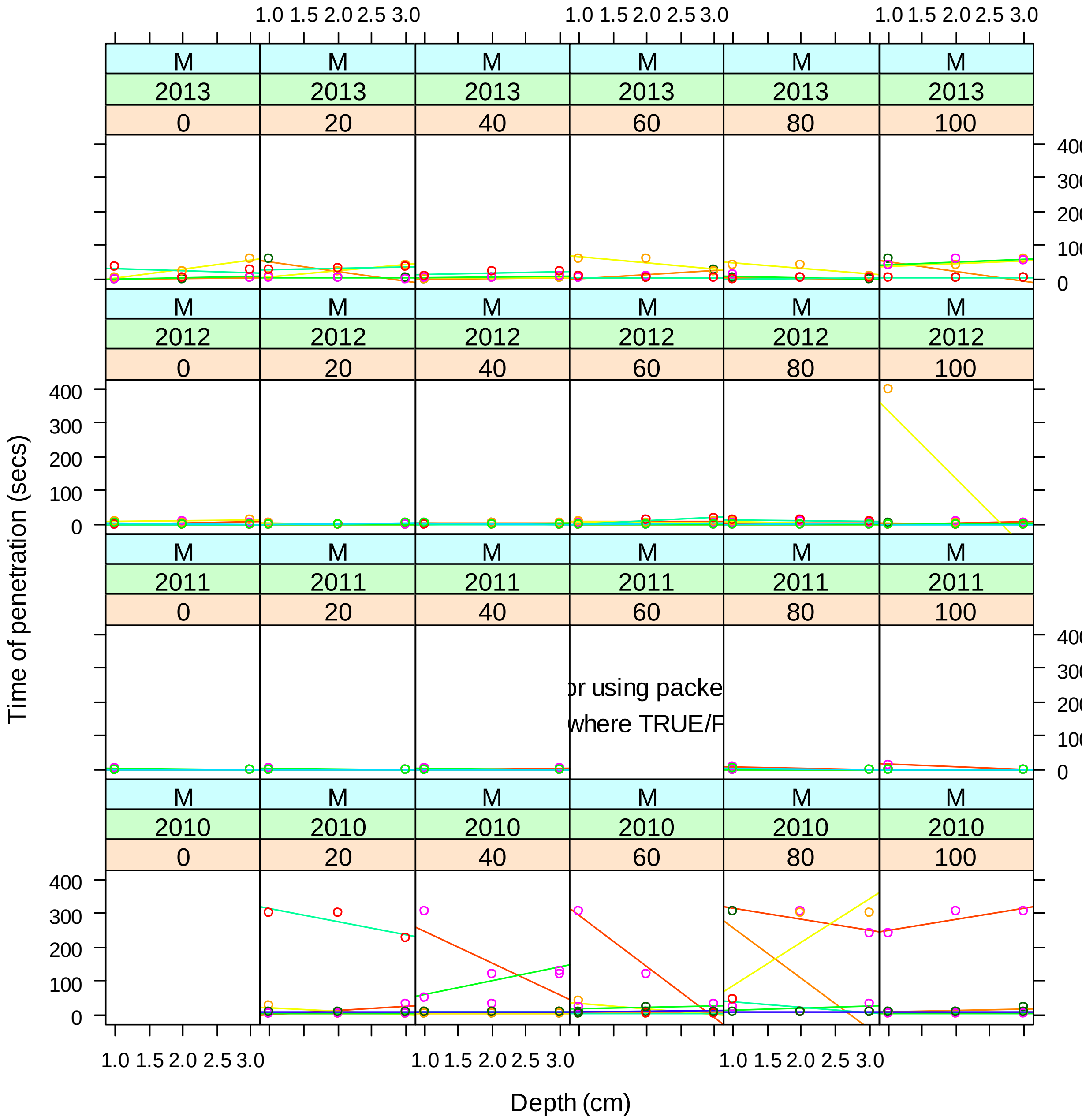

```
xyplot(time ~ depth | burn.sev*year, data=wdpt, group=site,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
   }
)

# Recode time=1000 to 400

superpose.line$lwd <- 1
superpose.line$lty <- 1
trellis.par.set("superpose.line",superpose.line)

xyplot(time2 ~ depth | burn.sev*year, data=wdpt, groups=site,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.lmline")
      panel.superpose(x,y,subscripts,groups, "panel.xyplot")
   }, xlab = "Depth (cm)", ylab="Penetration time (secs)",
main="WDPT test results", auto.key=list(columns=6))
```

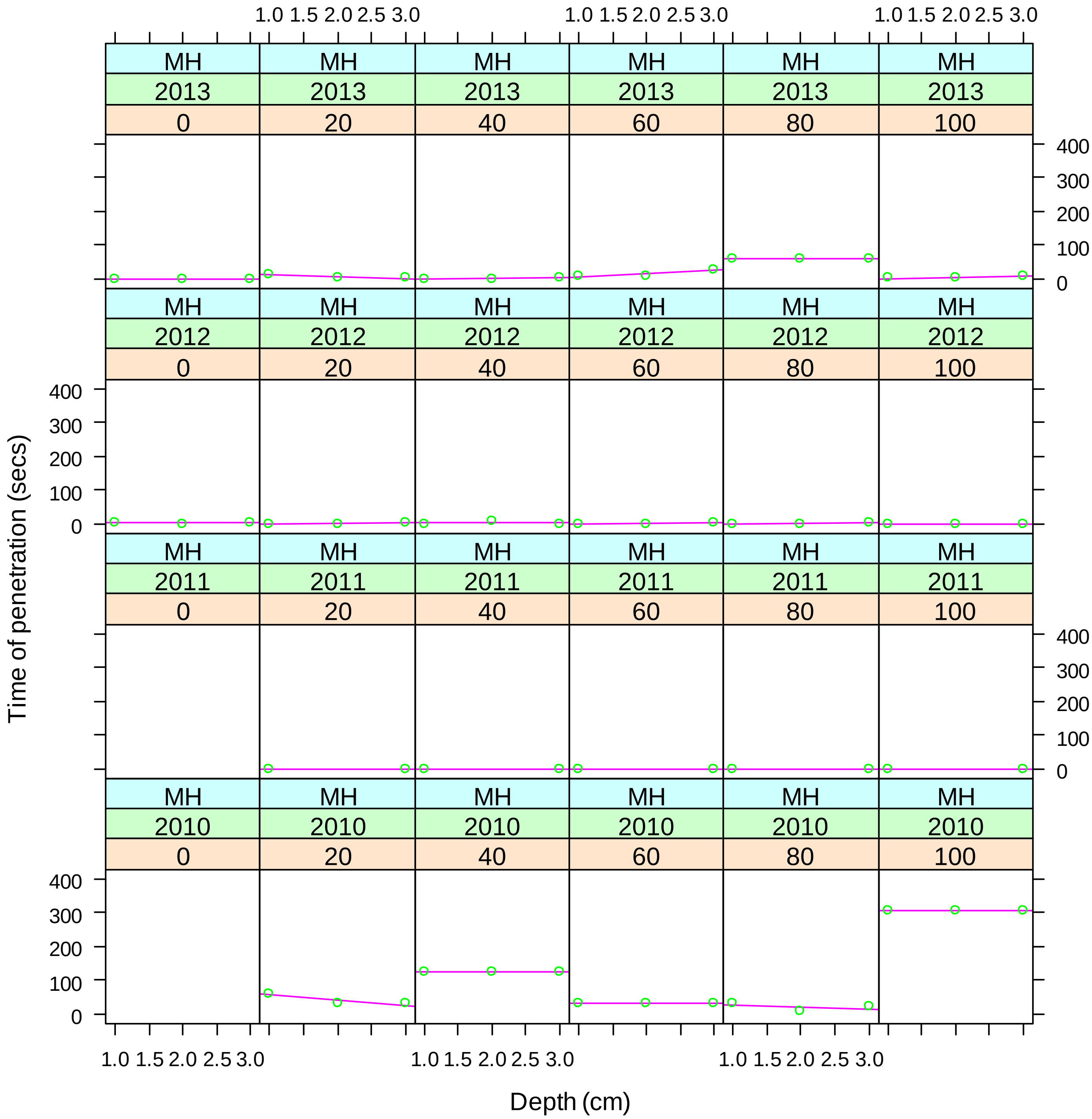


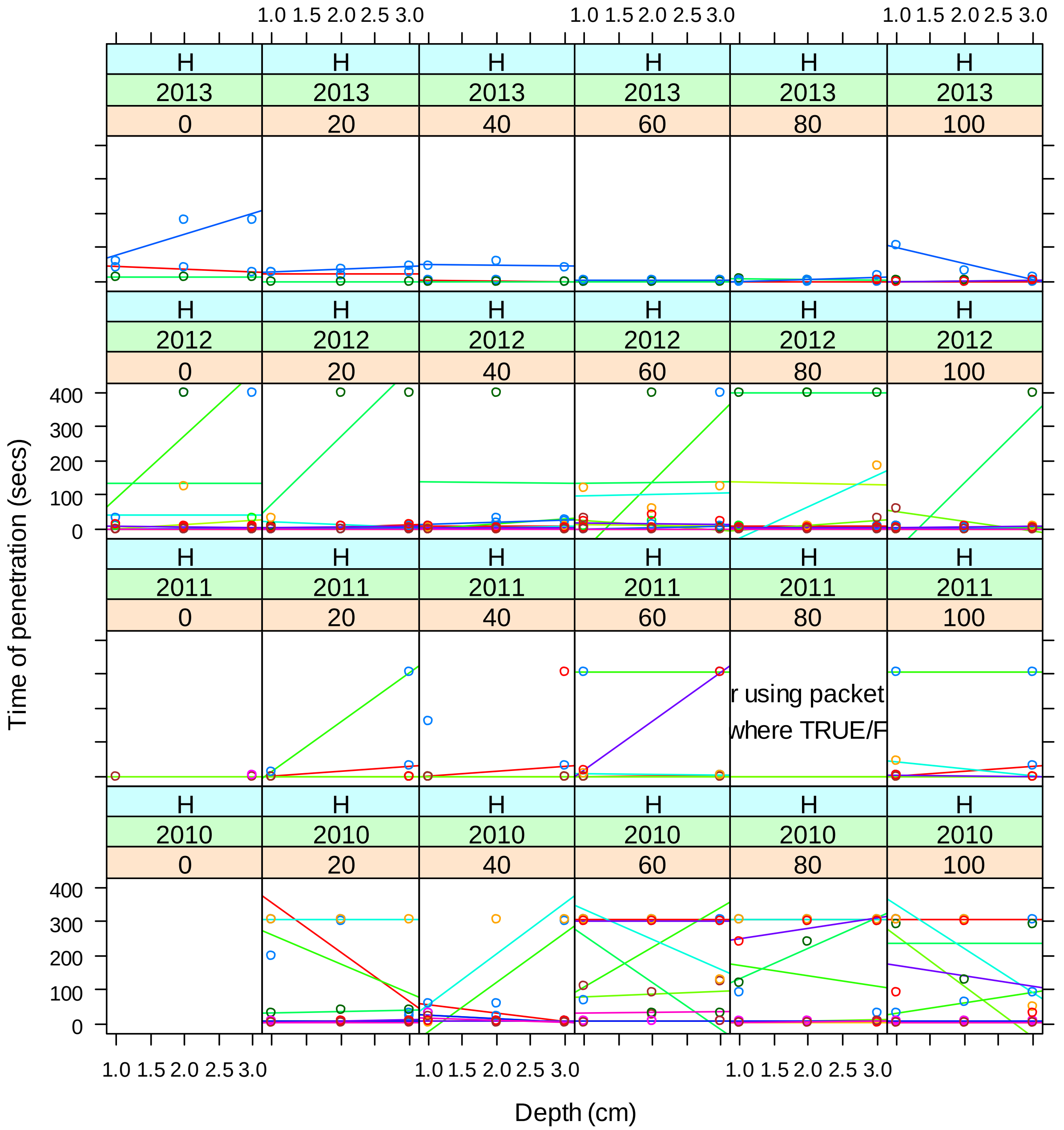

```
# 3-way plot layout
par(ask=T)
xyplot(time2 ~ depth | factor(dist)*year*burn.sev, data=wdpt, groups=site,
aspect=1, xlab="Depth (cm)", ylab="Time of penetration (secs)",
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.lmline")
      panel.superpose(x,y, subscripts, groups, "panel.xyplot")
   }
)
```


N
2013
0
20
40
60
80
100
2012
2011
2010
400
300
200
100
0
1.0 1.5 2.0 2.5 3.0
Time of penetration (secs)
Depth (cm)

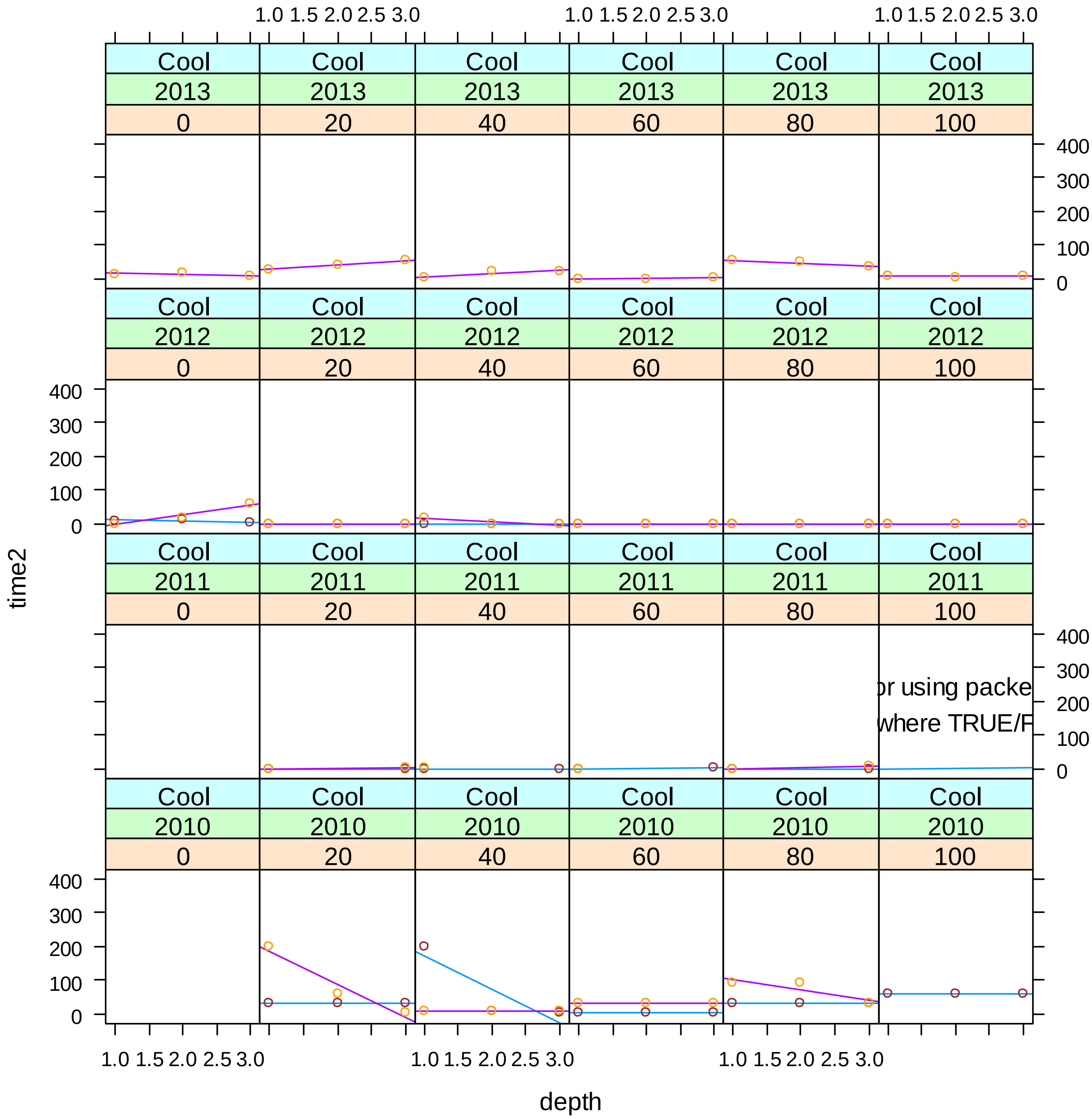

1.0 1.5 2.0 2.5 3.0
ML
2013
2012
2011
2010
0
20
40
60
80
100
0
100
200
300
400
Time of penetration (secs)
Depth (cm)
or using packe
where TRUE/F

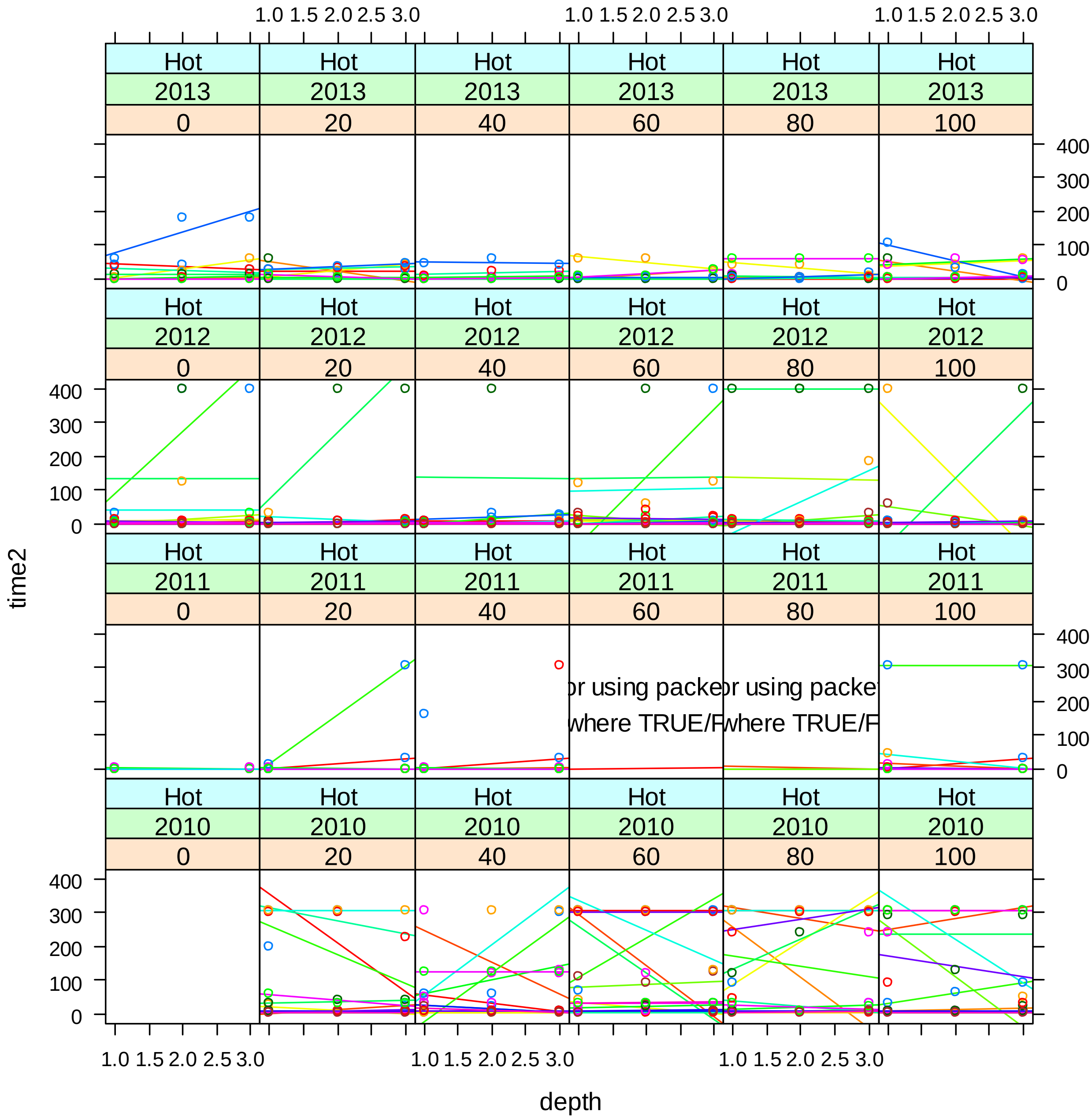

M
2013
0
20
40
60
80
100
M
2012
M
2011
M
2010
400
300
200
100
0
1.0 1.5 2.0 2.5 3.0
Time of penetration (secs)
Depth (cm)
or using packe
where TRUE/F


MH
2013
2012
2011
2010
0
20
40
60
80
100
Time of penetration (secs)
Depth (cm)
1.0 1.5 2.0 2.5 3.0
0
100
200
300
400

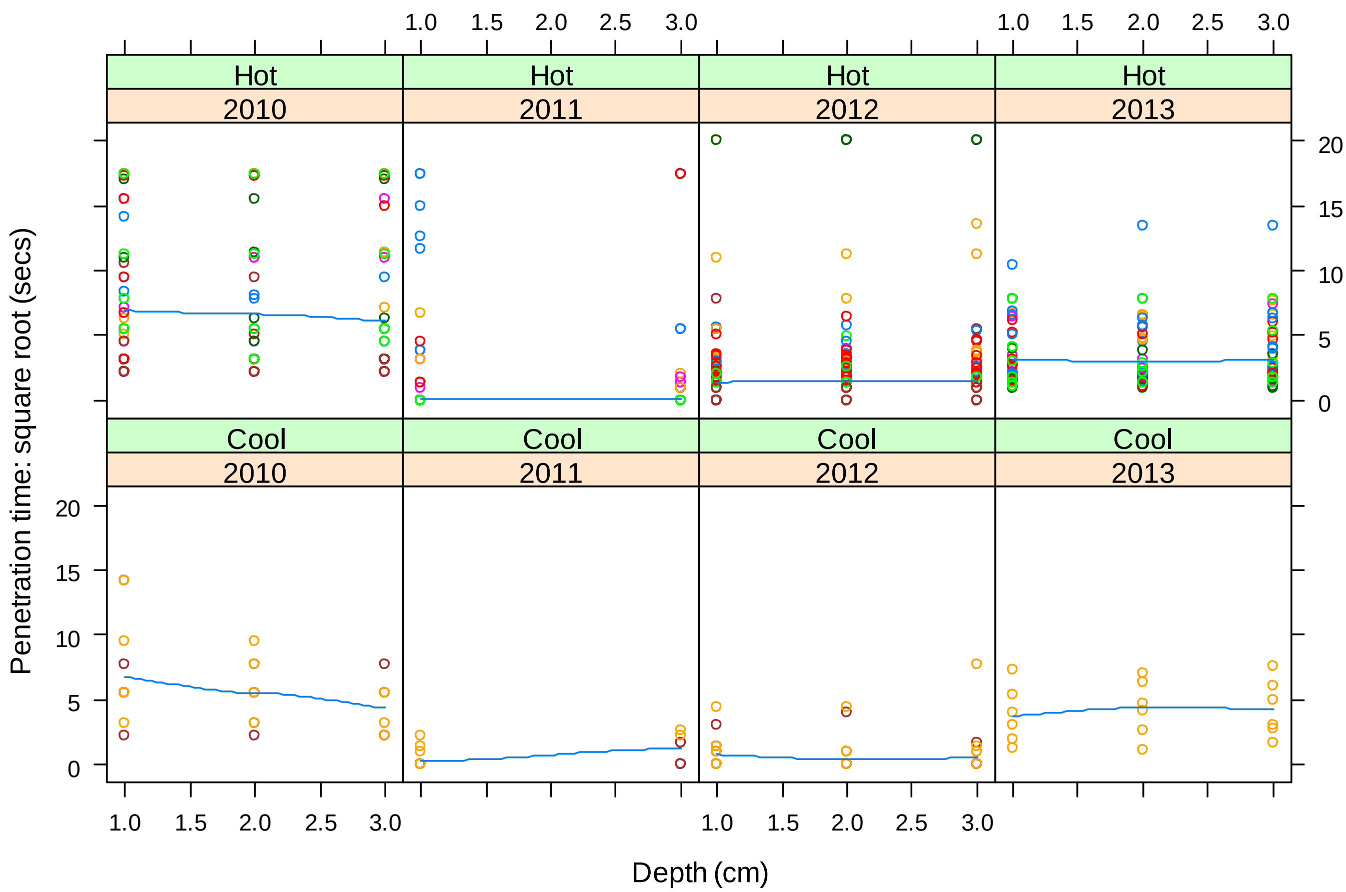



```
# 3-way plot layout, combine burn groups into cool=N,ML and hot=M,MH,H
wdpt$burn.sev2 <- wdpt$burn %in% c("M","MH","H")
wdpt$burn.sev2 <- factor(wdpt$burn.sev2,labels=c("Cool","Hot"))
xyplot(time2 ~ depth | factor(dist)*year*burn.sev2, data=wdpt, groups=site,
aspect=1,
   panel=function(x,y, subscripts, groups) {
      panel.superpose(x,y, subscripts, groups, "panel.lmline")
      panel.superpose(x,y,subscripts,groups, "panel.xyplot")
   }
)
```

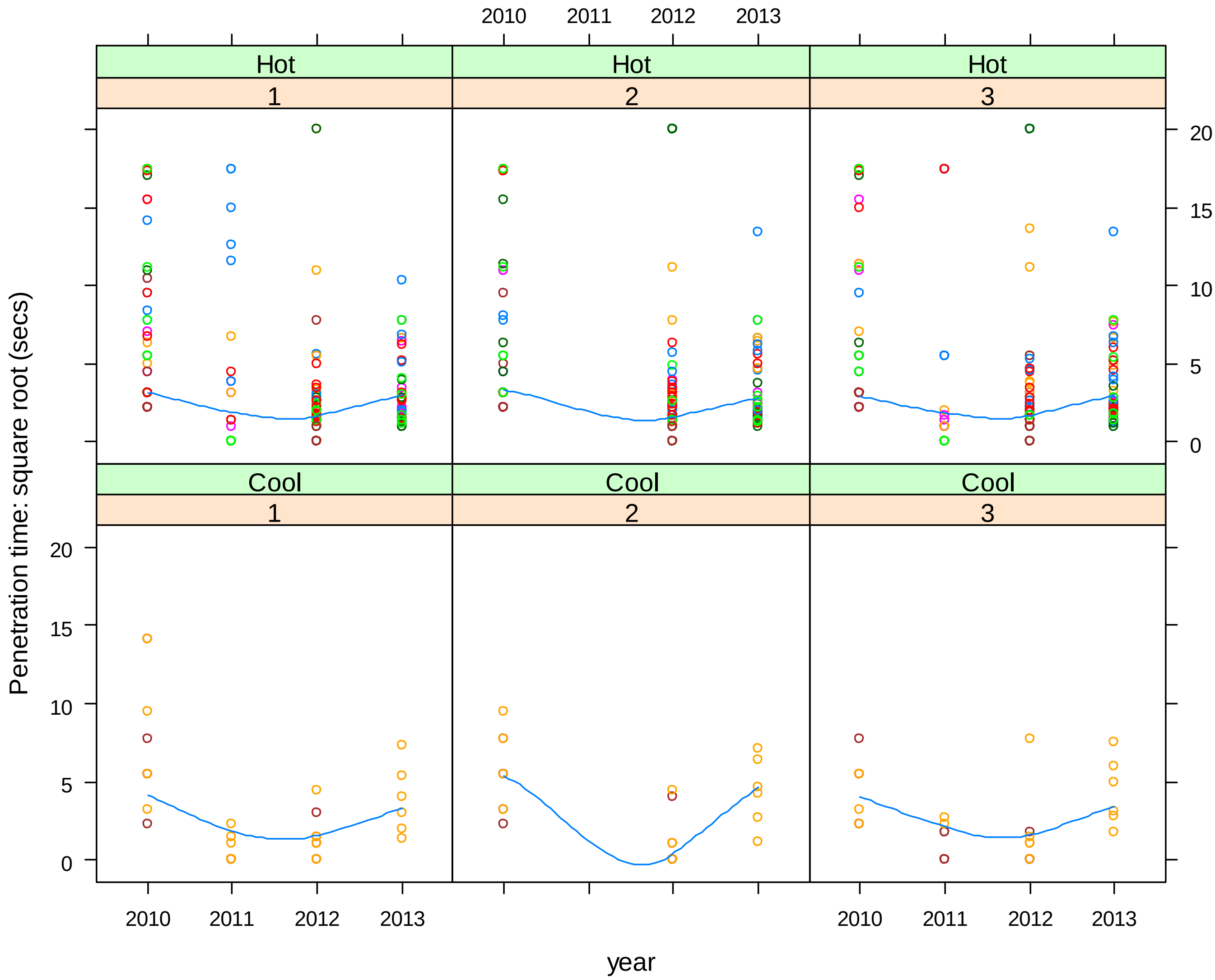

Cool
2013
0
20
40
60
80
100
2012
2011
2010
or using packe
where TRUE/F
time2
depth
1.0 1.5 2.0 2.5 3.0
0
100
200
300
400



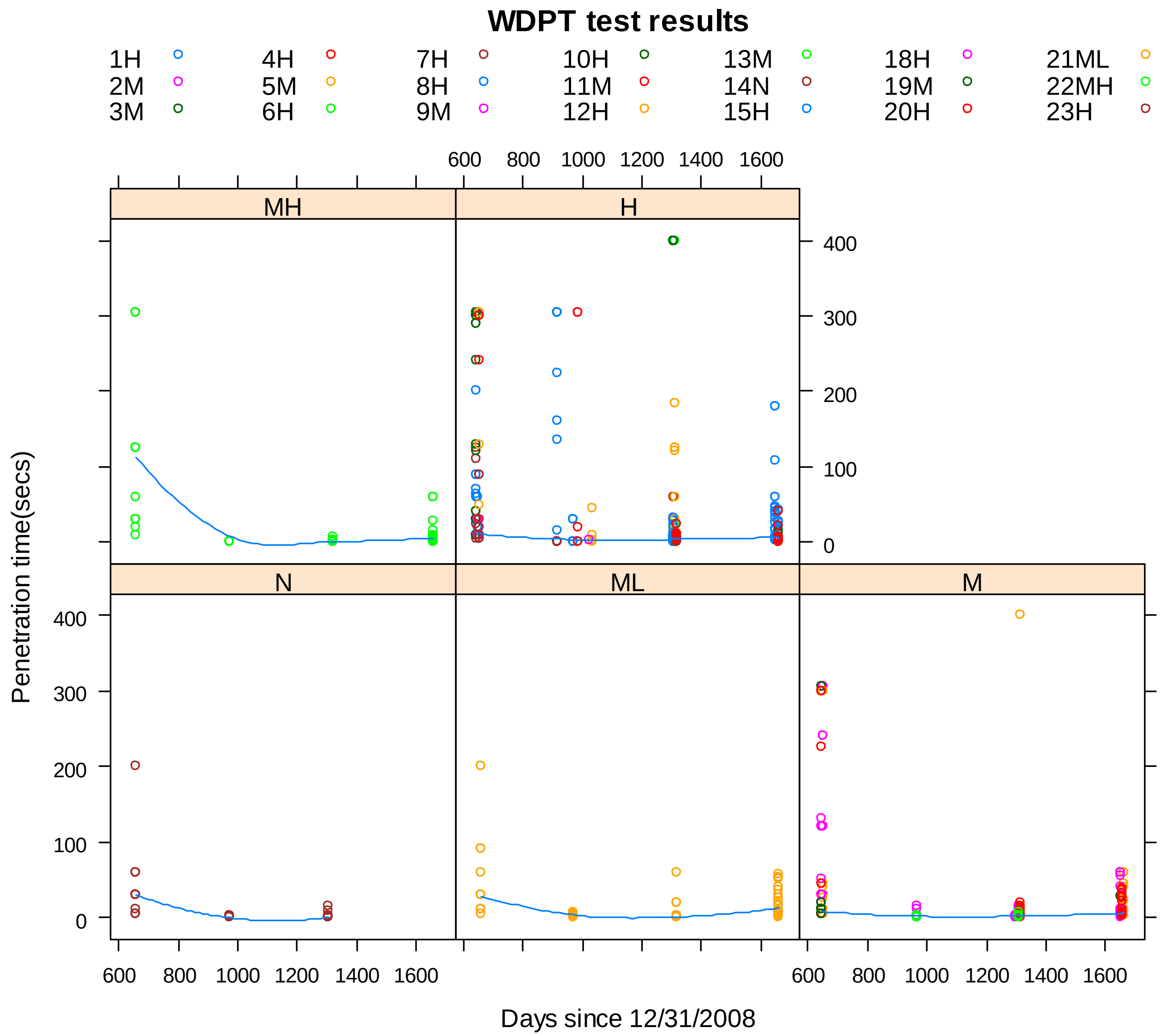

```
# Collapse over transect distance
xyplot(sqrt(time2)  ~  depth  |  year*burn.sev2,  data=wdpt,  groups=site,
aspect=1,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,span=1)
   }, ylab="Penetration time: square root (secs)", xlab="Depth (cm)"
)
```




```
# This makes it clear that hot burns had longer penetration times in all
years
# AND depth doesn't seem to have a consistent effect if any

xyplot(sqrt(time2) ~ year | factor(depth)*burn.sev2, data=wdpt, groups=site,
aspect=1,
   panel=function(x,y, subscripts, groups) {
       # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
       panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       panel.loess(x,y,degree=1, span=1)
   }, ylab="Penetration time: square root (secs)")
```

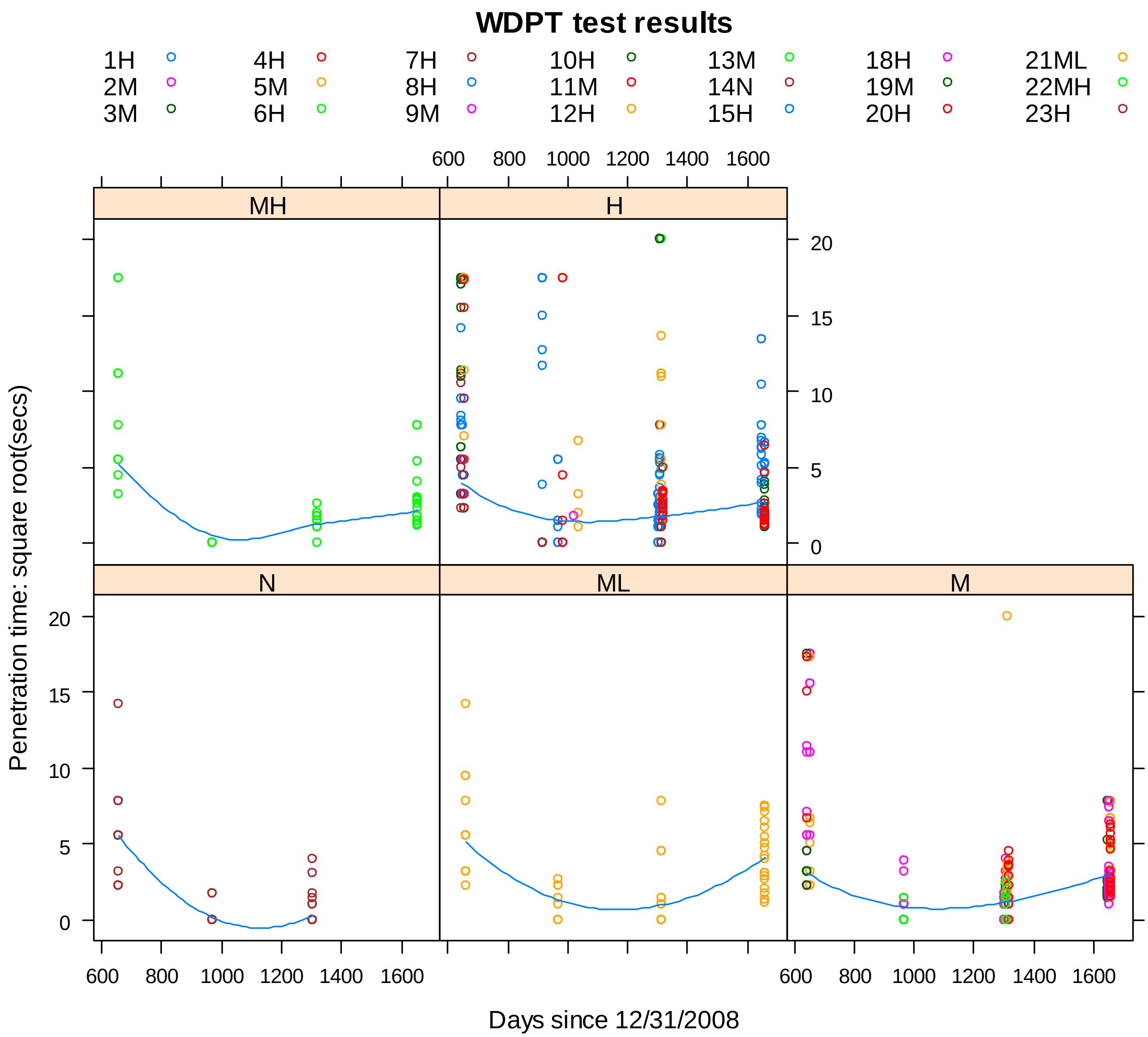



```
# Collapse over both transect distance AND depth;
xyplot(time2 ~ daynum08 | burn.sev, data=wdpt, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1.25,degree=2)
       #    had to increase span to eliminate warnings
   }, ylab="Penetration time(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```



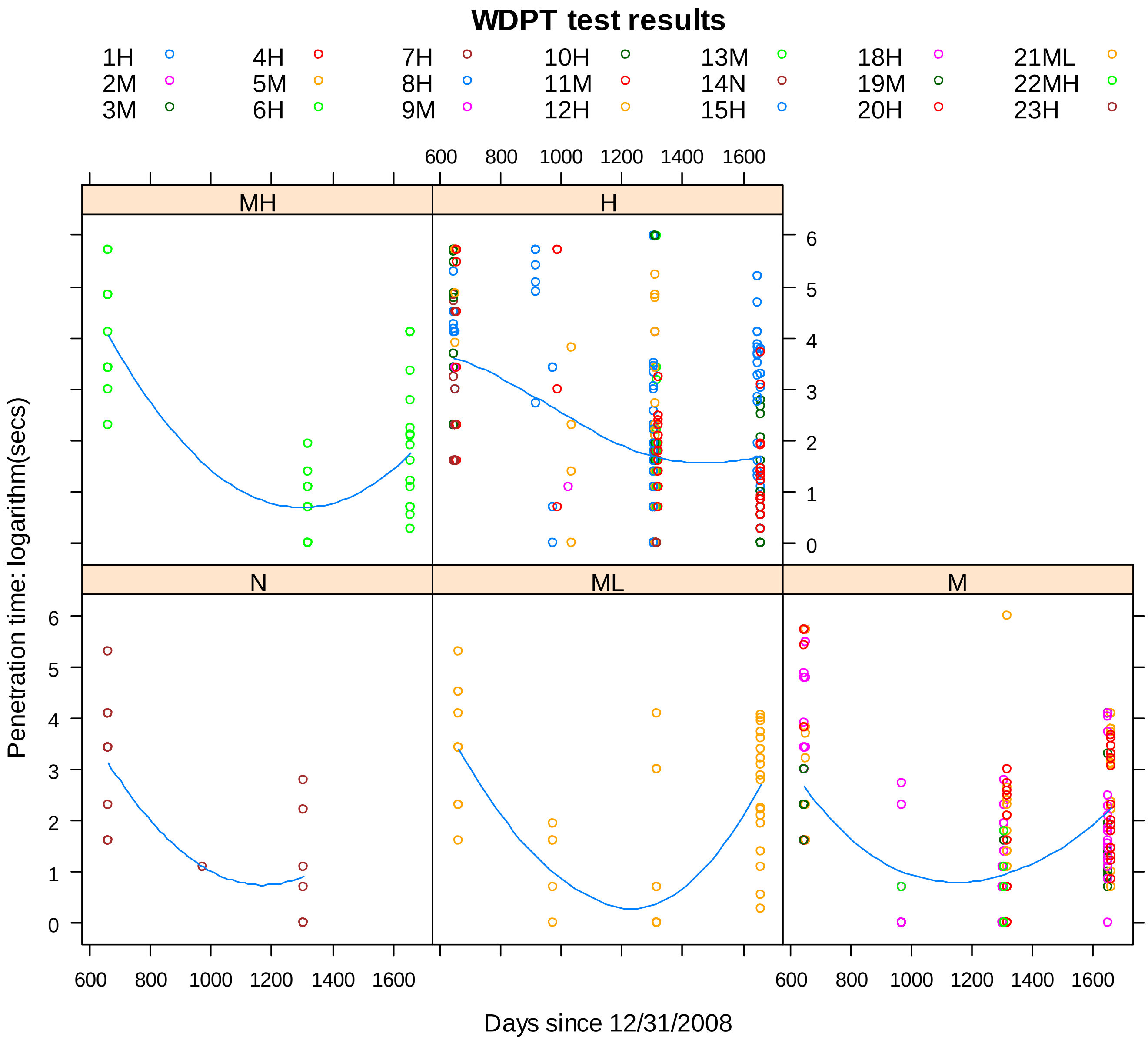

```
# Use square root transformation
xyplot(sqrt(time2) ~ daynum08 | burn.sev, data=wdpt, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1.25,degree=2)
            # had to increase span to avoid warnings
   },   ylab="Penetration   time:   square   root(secs)",   xlab="Days   since
12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
```

```
)
```



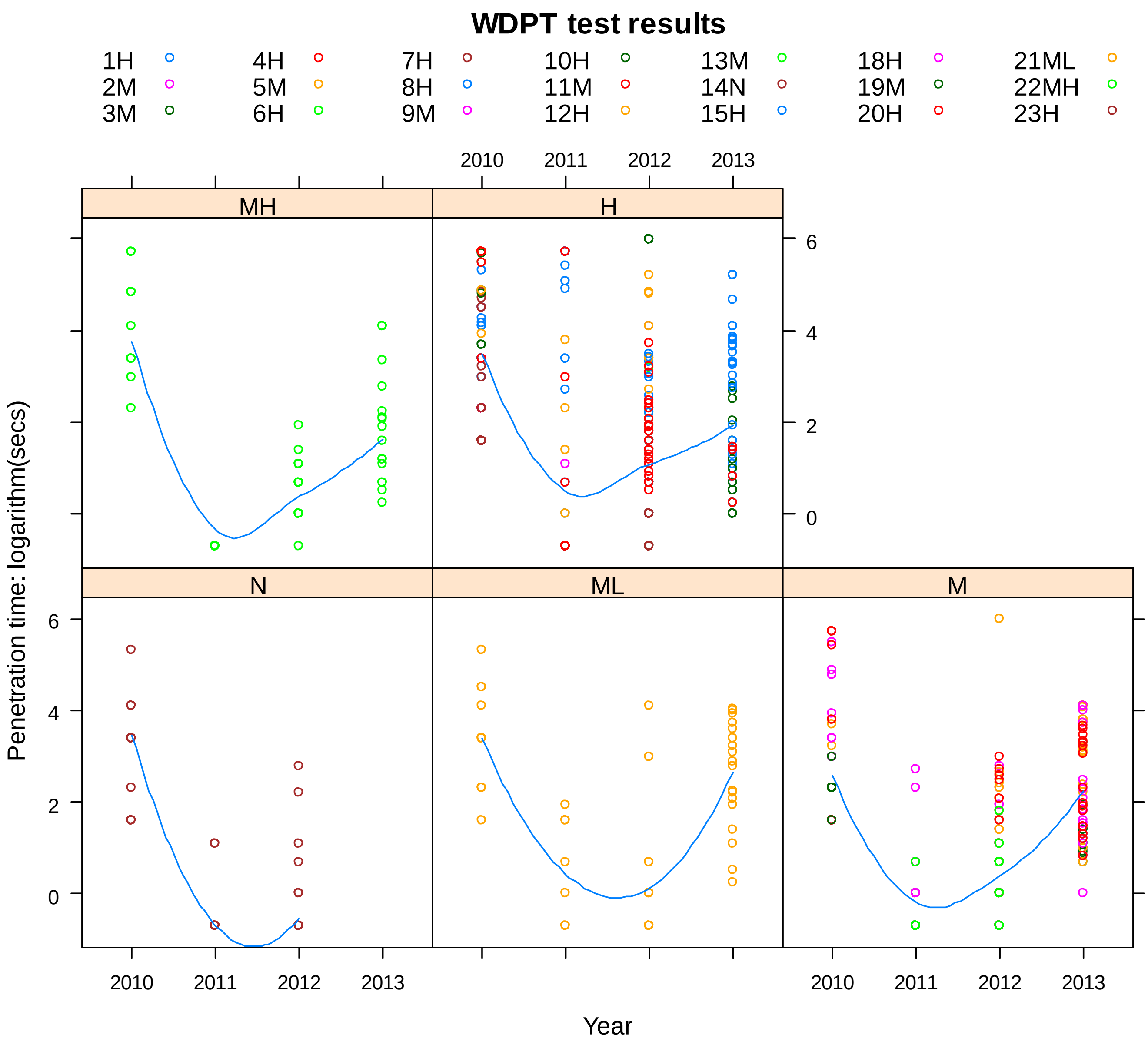

```
# The decline in times seems to have reversed in 2013

# Use log transformation
xyplot(log(time2) ~ daynum08 | burn.sev, data=wdpt, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1.25,degree=2)   # had to increase span to
avoid warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="Days since 12/31/2008",
```

```
main="WDPT test results", auto.key=list(columns=7)
)
```



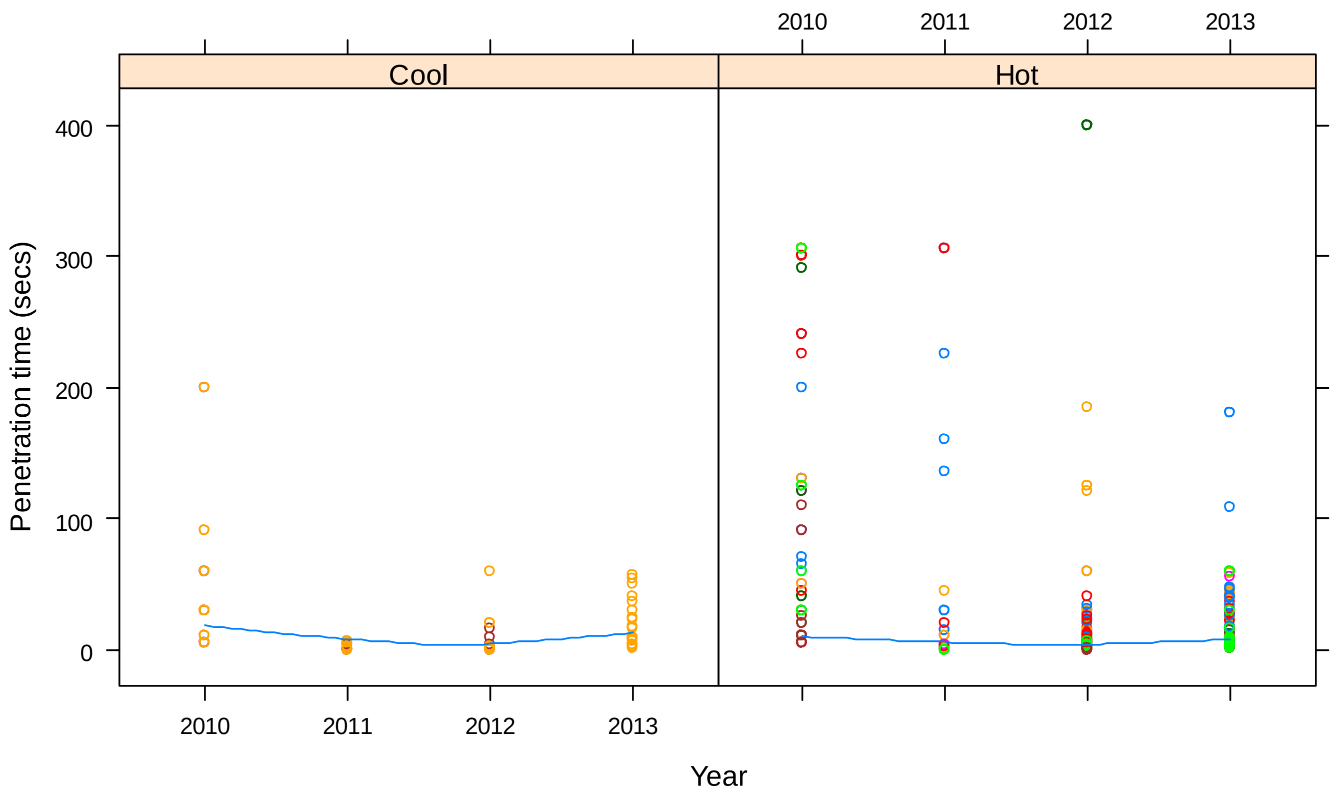

```
# But we cannot ignore 164 values of penetration time that are 0
# Use log transformation with 0's recoded to 0.5
wdpt$time3 <- wdpt$time2
wdpt$time3[wdpt$time2==0] <- 0.5

xyplot(log(time3) ~ year | burn.sev, data=wdpt, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
```

```
            panel.loess(x,y,span=1.25, degree=2)   # had to increase span to
avoid warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="Year",
main="WDPT test results", auto.key=list(columns=7)
)
```



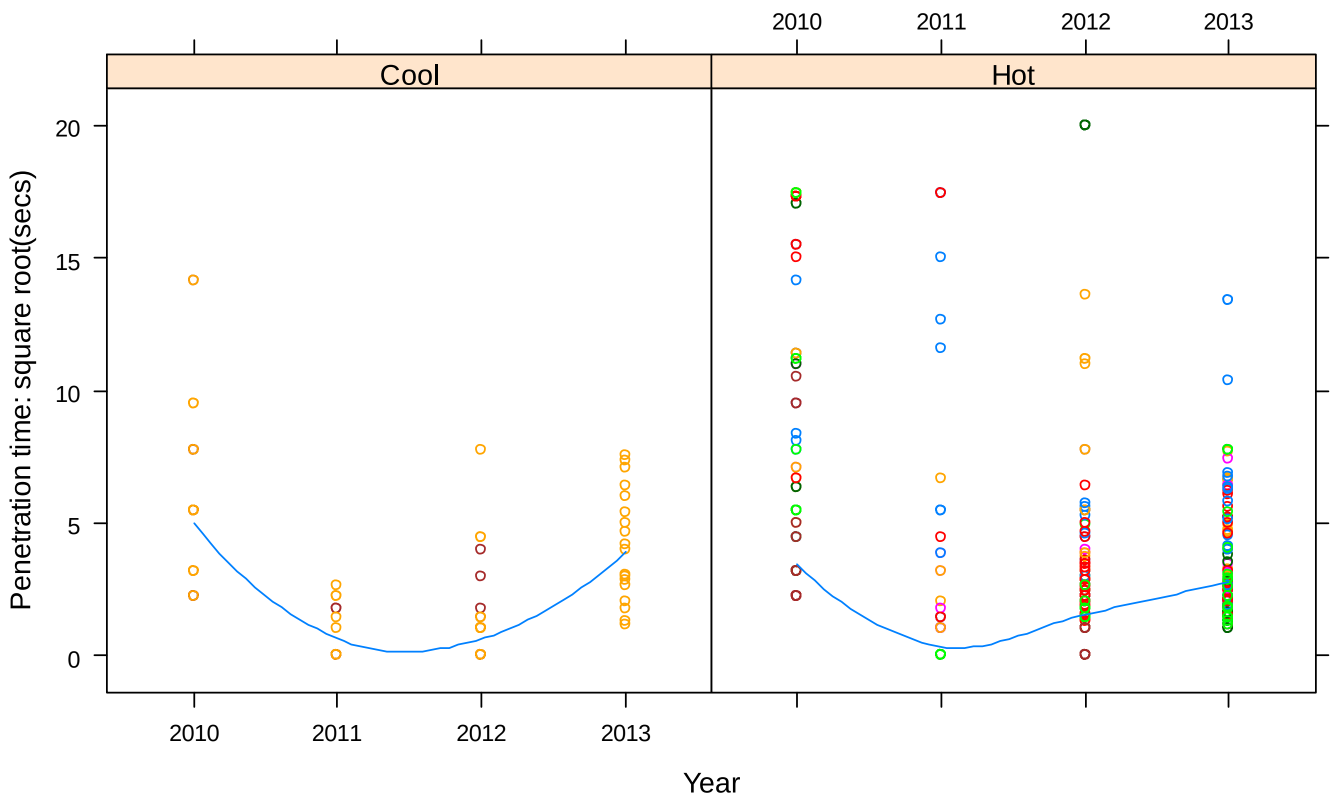

```
# OK it's pretty clear that 2010 had higher penetration times than 2011 and
2012.  And 2013 is intermediate.

# Combining N and ML severity levels
xyplot(time2 ~ year | burn.sev2, data=wdpt, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
```

```
        panel.superpose(x,y,subscripts,groups, "panel.xyplot")
    #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
        panel.loess(x,y,span=1)
  }, ylab="Penetration time (secs)", xlab="Year"
)
```

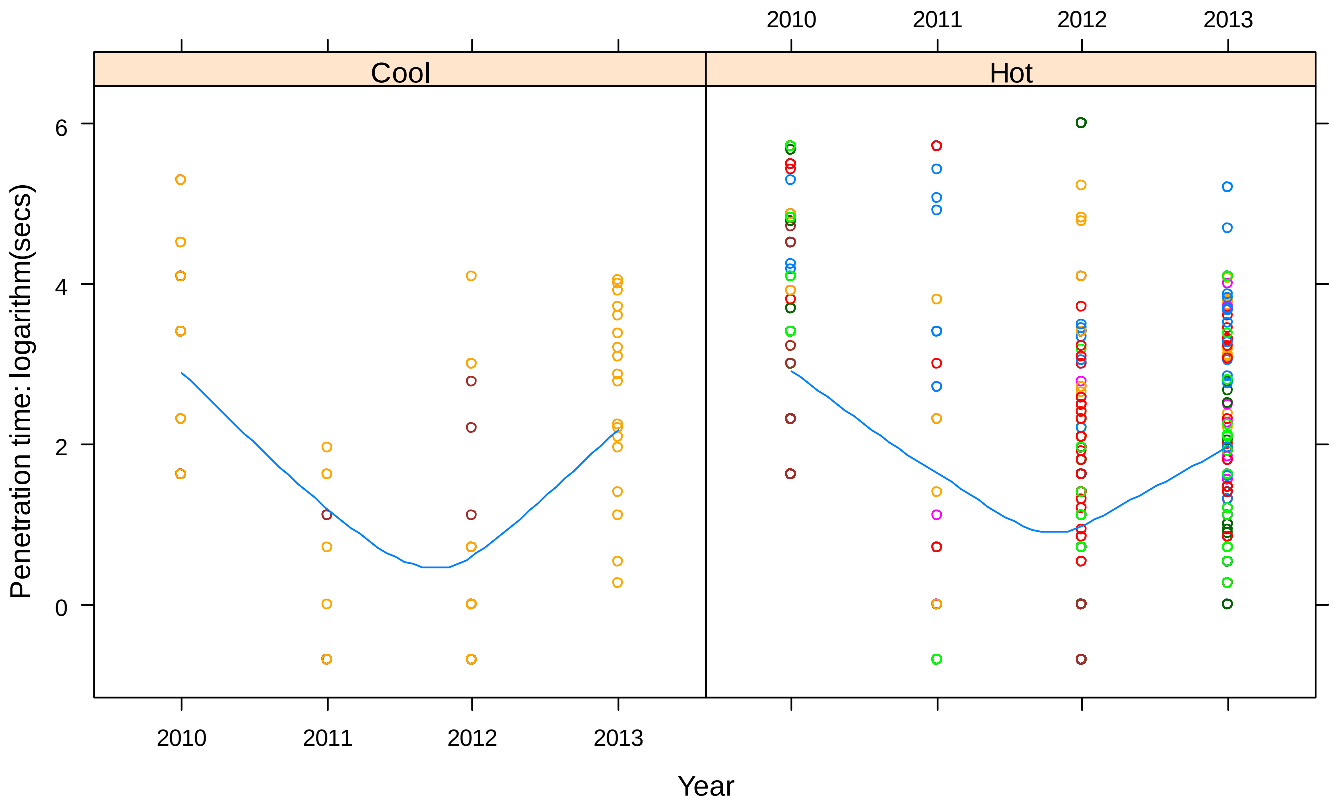



```
xyplot(sqrt(time2) ~ year | burn.sev2, data=wdpt, groups=site, aspect=1,
  panel=function(x,y, subscripts, groups) {
        panel.superpose(x,y,subscripts,groups, "panel.xyplot")
    #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
        panel.loess(x,y,span=1,degree=2)
  }, ylab="Penetration time: square root(secs)", xlab="Year"
```

)




```
xyplot(log(time3) ~ year | burn.sev2, data=wdpt, groups=site, aspect=1,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1,degree=1)
   }, ylab="Penetration time: logarithm(secs)", xlab="Year"
)
```

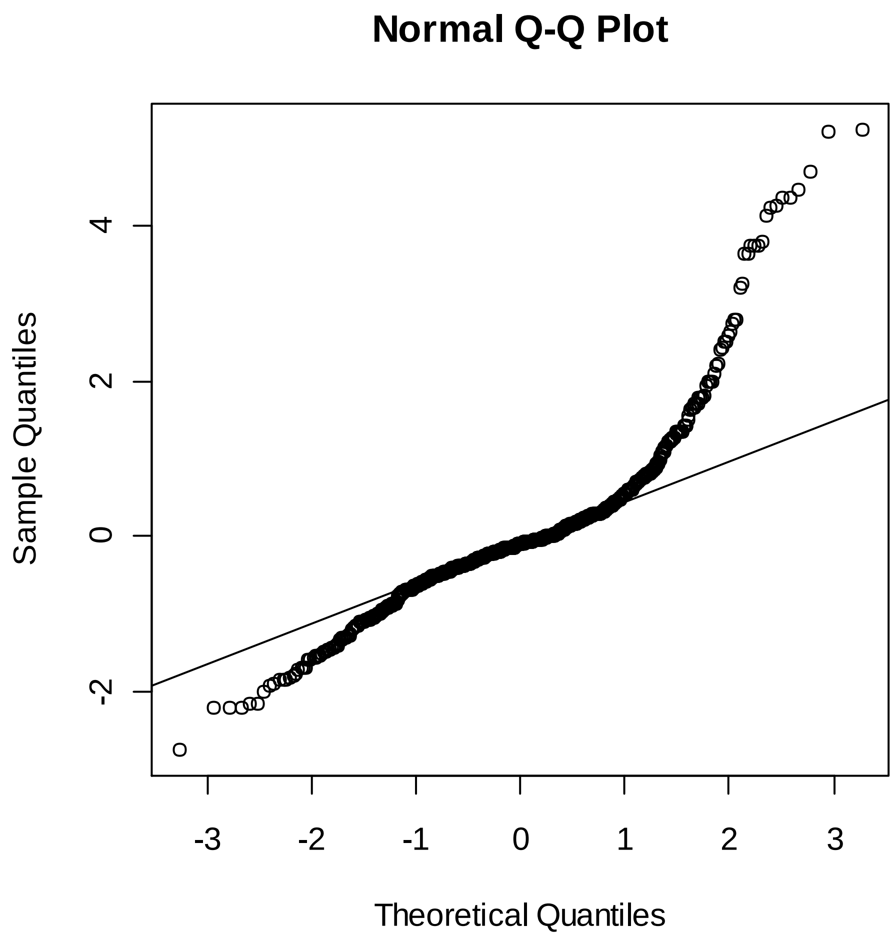


==

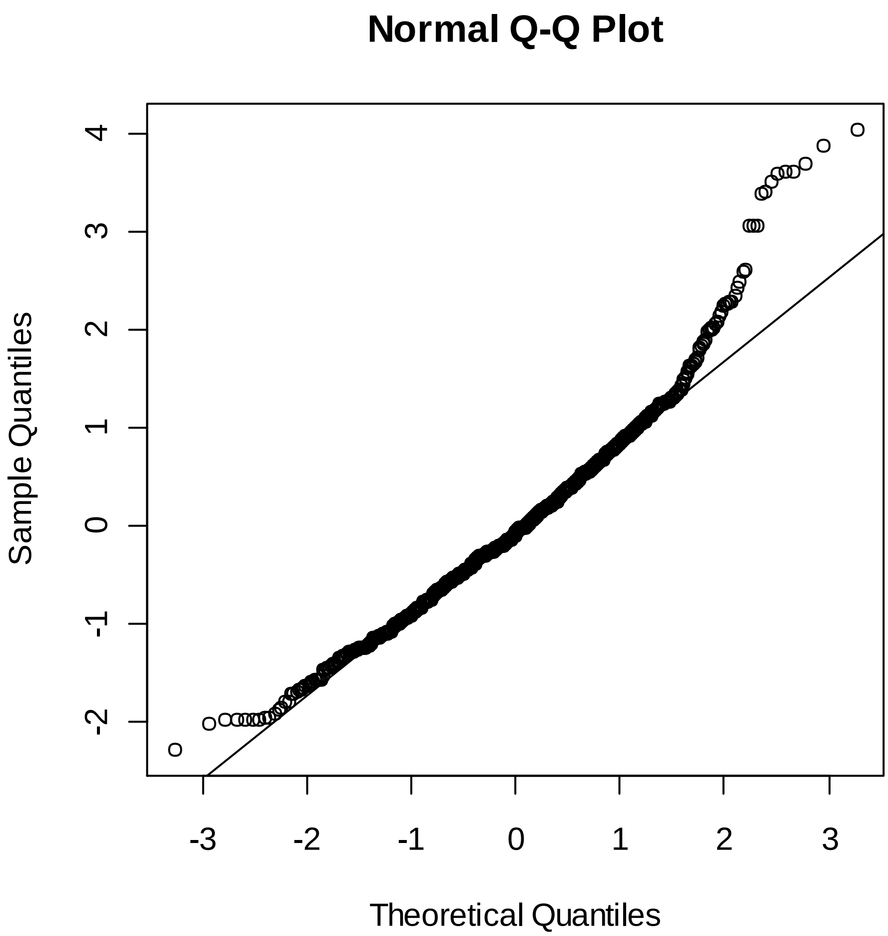
```
table(wdpt$depth)

  1   2   3
333 261 326

wdpt.gd <- groupedData(sqrt(time2) ~ year | site/dist, outer = ~ burn.sev,
data=wdpt)
options(contrasts=c("contr.treatment","contr.treatment"))
```

```
# Test a random effect of transect within site on the coefficient of daynum
wdpt.fit0 <- lme(sqrt(time2) ~ daynum*burn.sev, data=wdpt.gd, random=~1)
wdpt.fit1 <- lme(sqrt(time2) ~ daynum*burn.sev, data=wdpt.gd, random=~daynum)
anova(wdpt.fit0,wdpt.fit1)
          Model df      AIC      BIC    logLik   Test  L.Ratio p-value
wdpt.fit0     1 13 5314.497 5377.072 -2644.249
wdpt.fit1     2 17 5244.759 5326.588 -2605.380 1 vs 2 77.73851  <.0001
# Keep the random effects on daynum

# Are nested random effects (transects within site) really needed?
wdpt.fit11    <-    lme(sqrt(time2)    ~    daynum*burn.sev,    data=wdpt.gd,
random=list(site=~daynum))
anova(wdpt.fit11,wdpt.fit1)
           Model df      AIC      BIC    logLik   Test  L.Ratio p-value
wdpt.fit11     1 14 5326.191 5393.580 -2649.096
wdpt.fit1      2 17 5244.759 5326.588 -2605.380 1 vs 2 87.43242  <.0001
# Yes the nested random effect is needed

anova(wdpt.fit1,type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   790 6.216169  0.0129
daynum              1   790 6.139258  0.0134
burn.sev            4    16 1.953027  0.1506
daynum:burn.sev     4   790 1.928779  0.1037
# Burn severity and its interaction with daynum are not significant

wdpt.fit2 <- update(wdpt.fit1, ~ . + depth)
anova(wdpt.fit2,type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   789 6.198319  0.0130
daynum              1   789 6.138708  0.0134
burn.sev            4    16 1.949458  0.1512
depth               1   789 0.329874  0.5659
daynum:burn.sev     4   789 1.925247  0.1043
# Depth was highly significant when miscoded, now it is unimportant

anova(wdpt.fit2,type="sequential")
                numDF denDF  F-value p-value
(Intercept)         1   789 41.78695  <.0001
daynum              1   789 44.86518  <.0001
burn.sev            4    16  0.66365  0.6263
depth               1   789  0.34783  0.5555
daynum:burn.sev     4   789  1.92525  0.1043
# Burn severity and its interaction with day number are not significant
# Only day number is significant

wdpt.fit2a <- update(wdpt.fit2, ~ . + depth*daynum)
anova(wdpt.fit2a)
                numDF denDF  F-value p-value
(Intercept)         1   788 41.83086  <.0001
daynum              1   788 44.82616  <.0001
burn.sev            4    16  0.66478  0.6255
depth               1   788  0.34832  0.5552
daynum:burn.sev     4   788  1.92373  0.1046
daynum:depth        1   788  2.23640  0.1352
# Depth interaction is not significant either
```

```
# Best model so far is wdpt.fit1.  But is the trend linear?  No.  A quadratic
would be a much better fit.  Here goes:

wdpt.fit3 <- update(wdpt.fit1, ~ . + I(daynum^2)*burn.sev)
anova(wdpt.fit3)
                     numDF denDF   F-value p-value
(Intercept)              1   785  49.56129  <.0001
daynum                   1   785  49.77195  <.0001
burn.sev                 4    16   0.79771  0.5440
I(daynum^2)              1   785 117.54848  <.0001
daynum:burn.sev          4   785   0.83308  0.5043
burn.sev:I(daynum^2)     4   785   4.39200  0.0016

anova(wdpt.fit3, type="marginal")
                     numDF denDF  F-value p-value
(Intercept)              1   785 5.599882  0.0182
daynum                   1   785 5.496387  0.0193
burn.sev                 4    16 4.358494  0.0142
I(daynum^2)              1   785 5.397587  0.0204
daynum:burn.sev          4   785 4.378426  0.0017
burn.sev:I(daynum^2)     4   785 4.392002  0.0016

# OK so keep the quadratic term. Note that burn severity has significant
interactions with both the linear and quadratic trend terms.

wdpt.fit3a <- update(wdpt.fit3, ~ . + depth*burn.sev)
anova(wdpt.fit3a, type="marginal")
                     numDF denDF  F-value p-value
(Intercept)              1   780 5.596618  0.0182
daynum                   1   780 5.491764  0.0194
burn.sev                 4    16 4.363992  0.0142
I(daynum^2)              1   780 5.393047  0.0205
depth                    1   780 0.483869  0.4869
daynum:burn.sev          4   780 4.381489  0.0016
burn.sev:I(daynum^2)     4   780 4.395265  0.0016
burn.sev:depth           4   780 1.001095  0.4061
# Depth is not significant nor is its interaction with burn severity.

# The best model remains wdpt.fit3.

qqresid(wdpt.fit3)
```

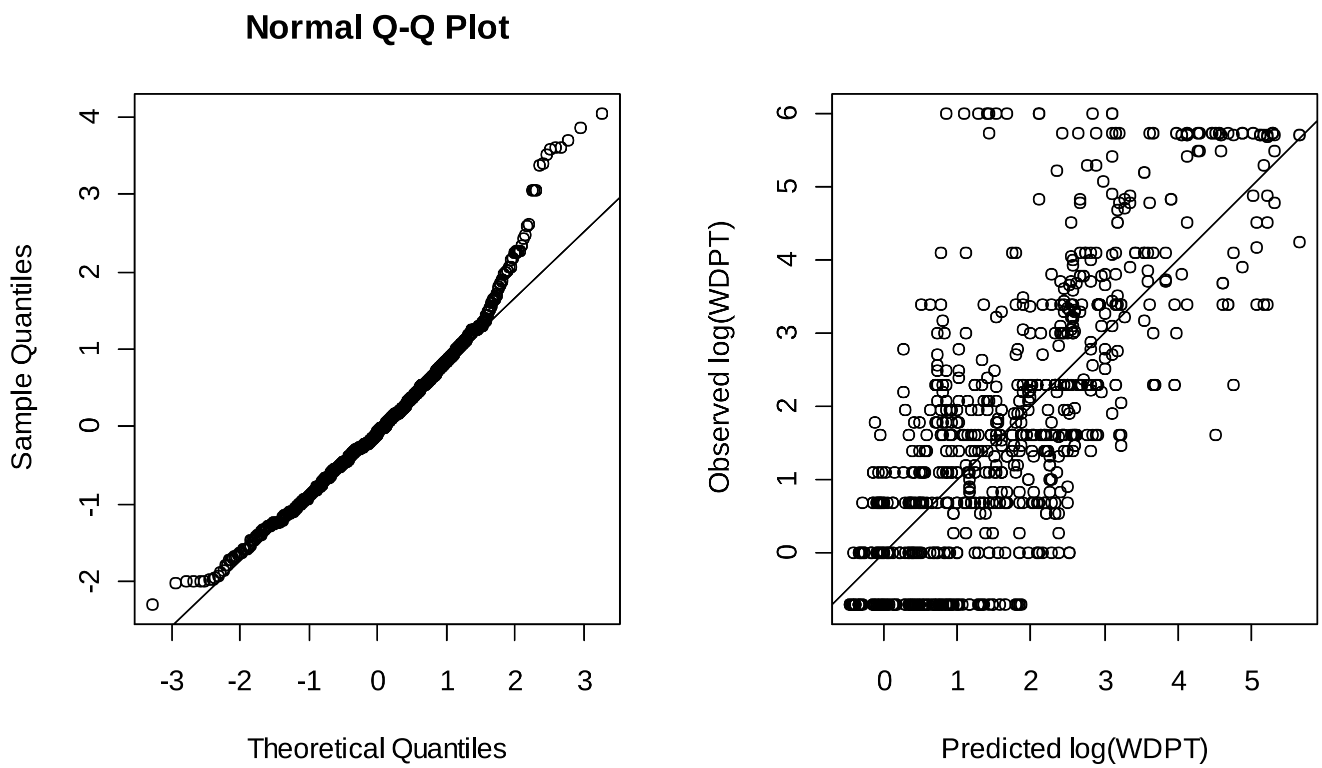



```
# Very bad.  We really cannot trust the significance tests above.
# Try a model with log(response)
wdpt.fit4    <-    update(wdpt.fit3,log(time3)    ~    burn.sev*daynum    +
burn.sev*I(daynum^2))

Error in lme.formula(fixed = log(time3) ~ burn.sev + daynum + I(daynum^2) +
:
  nlminb problem, convergence error code = 1
  message = iteration limit reached without convergence (9)

# Can get convergence by removing the quadratic term interaction with burn
severity
# Probably not as important to test as the linear term interaction
wdpt.fit4 <- update(wdpt.fit3,log(time3) ~ daynum * burn.sev + I(daynum^2))
anova(wdpt.fit4,type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   789 334.5511  <.0001
daynum              1   789 326.0395  <.0001
burn.sev            4    16   1.7680  0.1847
I(daynum^2)         1   789 315.0162  <.0001
daynum:burn.sev     4   789   1.7186  0.1438
# Neither burn severity term is significant but the residuals distribution
still doesn't look great
```

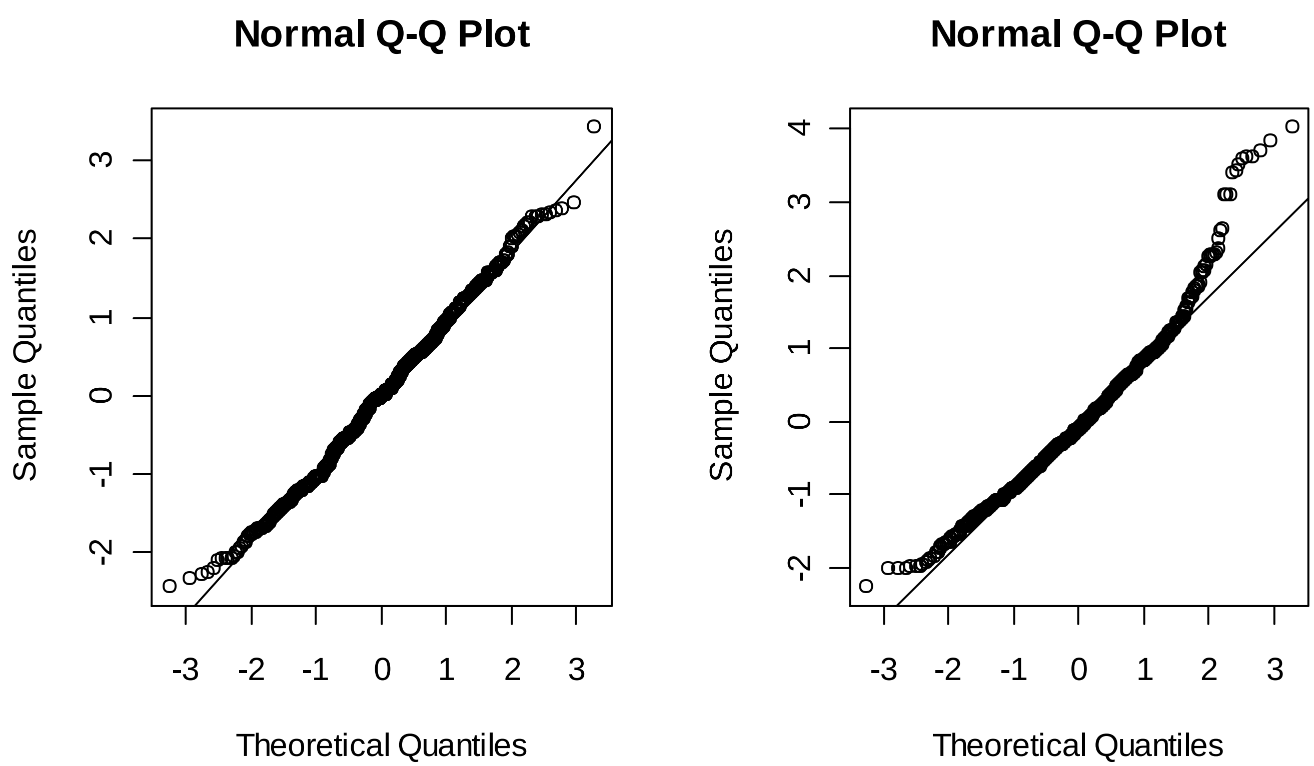



```
# Figure 13 for report
par(mfrow=c(1,2))
qqresid(wdpt.fit3,main="a")
qqresid(wdpt.fit4,main="b")

# Take a look at the coefficients
as.data.frame(fixef(wdpt.fit4))
                  fixef(wdpt.fit4)
(Intercept)           1.918641e+03
daynum               -2.471129e-01
burn.sevML           -2.088823e+01
burn.sevM            -2.620042e+01
burn.sevMH           -4.340682e+00
burn.sevH            -1.336605e+01
I(daynum^2)           7.955678e-06
daynum:burn.sevML     1.406284e-03
daynum:burn.sevM      1.729130e-03
daynum:burn.sevMH     3.272330e-04
daynum:burn.sevH      9.358705e-04
# If recovery were faster for higher burn severities the daynum:burn.sev
coefficients would all be negative and increasingly so from ML to H.  They
are not.
```

```
# Some diagnostics
par(mfrow=c(1,2))
qqresid(wdpt.fit4)
plot(fitted(wdpt.fit4),log(wdpt$time3),xlab="Predicted
log(WDPT)",ylab="Observed log(WDPT)")
abline(0,1)
cor(fitted(wdpt.fit4),log(wdpt$time3))^2
[1] 0.6267522     # This is the proportion of variance explained by the model
```



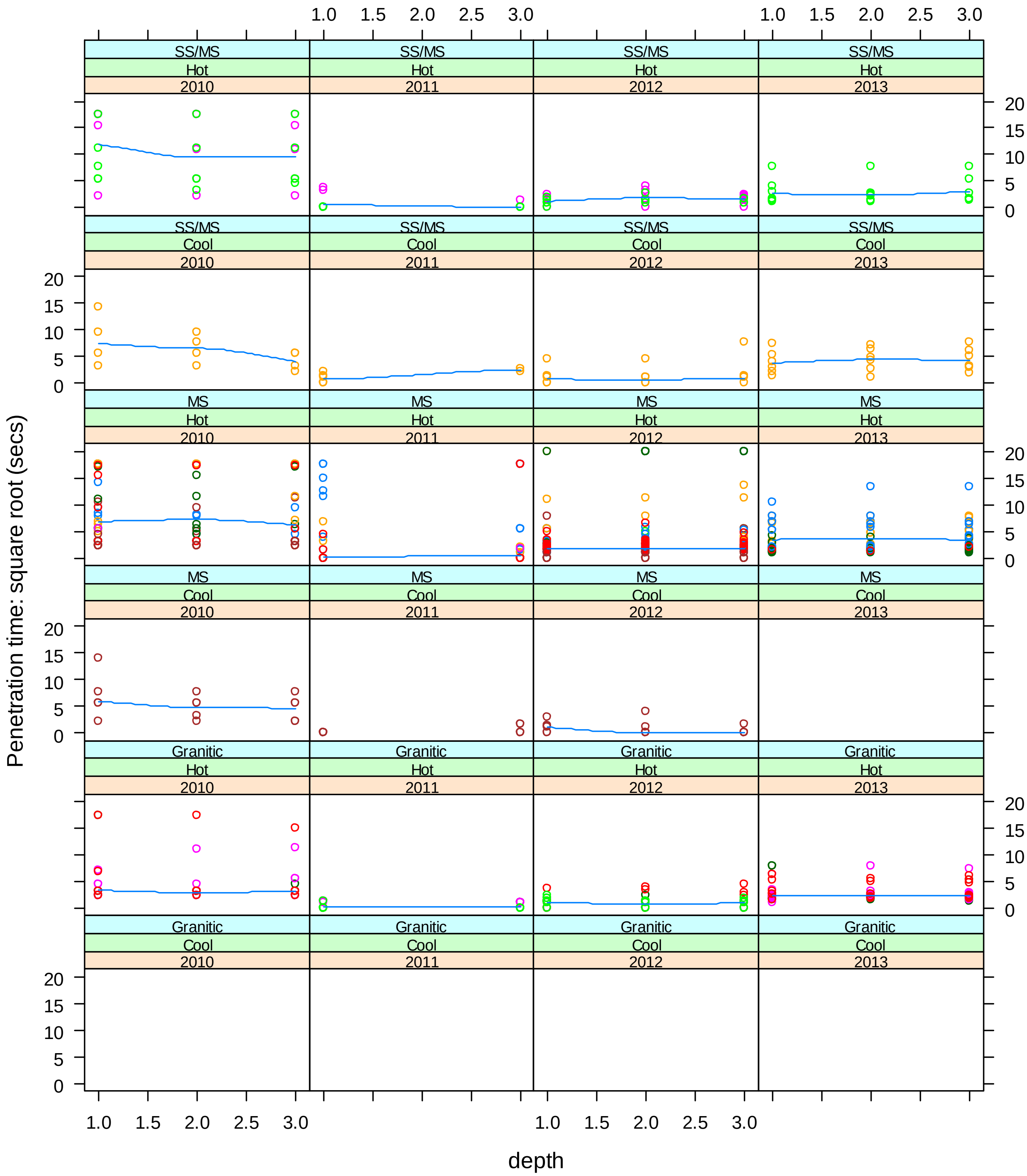

```
# It is possible to find a model with fewer fixed effects that has Gaussian
(normal) residuals but as we add more fixed effects to the model (esp the
squared day number) the distribution gets more and more skewed.  For example:

qqresid(update(wdpt.fit4, log(time3) ~ burn.sev + daynum))
qqresid(update(wdpt.fit4, log(time3) ~ daynum + I(daynum^2))
```




```
We wound up with the same model as before (when depth was miscoded),
but now depth is no longer a significant predictor.

===================================================================

# Try a simple regression model

f0  <-  lm(log(time3)  ~  burn.sev*daynum  +  burn.sev*I(daynum^2)  +  depth,
data=wdpt)
anova(f0)
Analysis of Variance Table

Response: log(time3)
                      Df  Sum Sq Mean Sq  F value    Pr(>F)    
burn.sev               4  104.02   26.01  10.7350 1.670e-08 ***
daynum                 1  272.62  272.62 112.5320 < 2.2e-16 ***
I(daynum^2)            1  754.37  754.37 311.3916 < 2.2e-16 ***
depth                  1    0.96    0.96   0.3971   0.52876    
burn.sev:daynum        4   24.55    6.14   2.5337   0.03895 *  
burn.sev:I(daynum^2)   4   71.07   17.77   7.3341 8.182e-06 ***
Residuals            904 2190.00    2.42                       

Residual standard error: 1.556 on 904 degrees of freedom
Multiple R-squared: 0.3592,     Adjusted R-squared: 0.3486 
F-statistic: 33.78 on 15 and 904 DF,  p-value: < 2.2e-16 

# Most terms highly significant, but depth is not
and the linear interaction with burn.sev is barely significant, certainly not
reliable since the model ignores the dependencies created by the groupings.
```

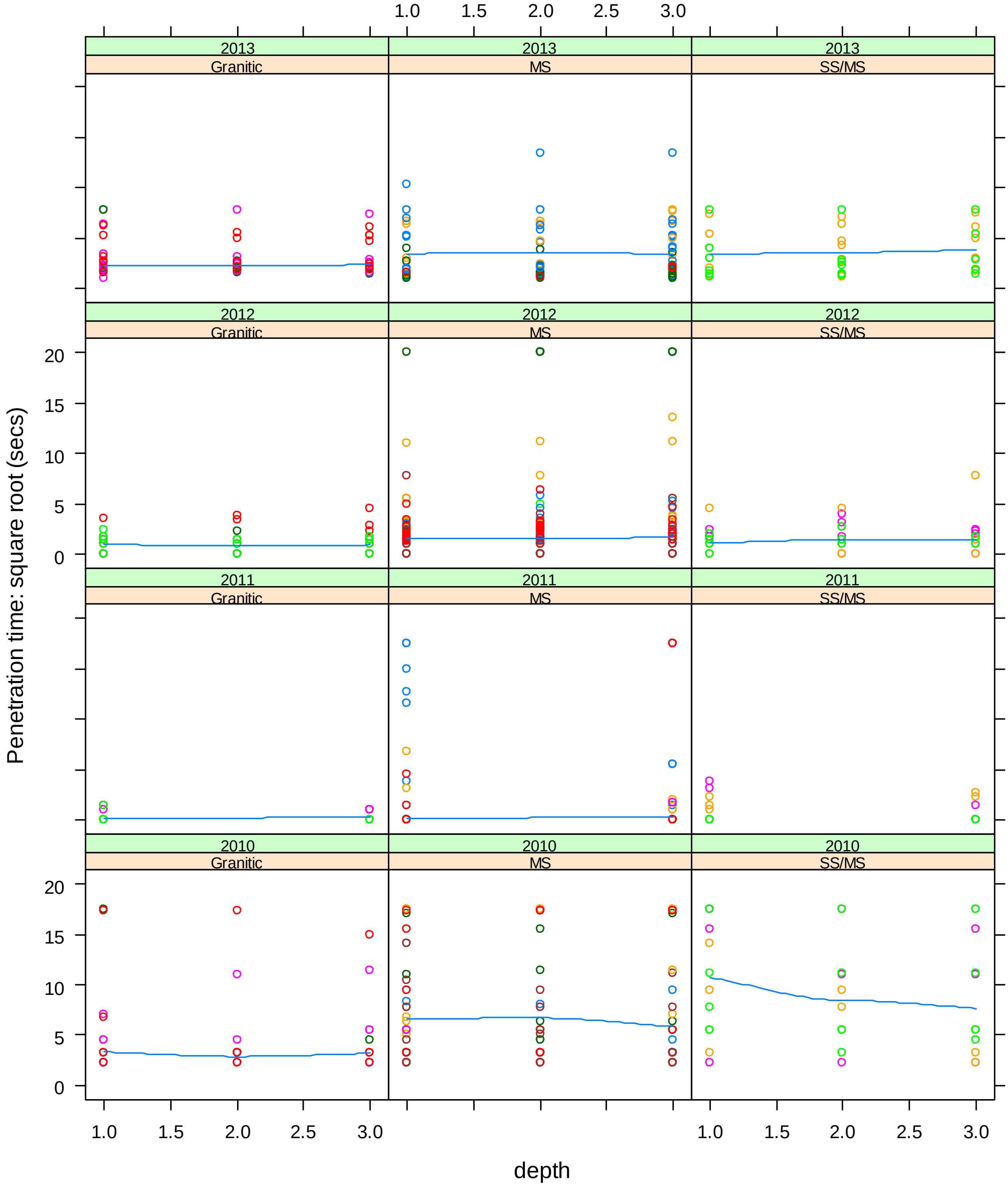
Effects of Soil Parent Material

```
library("chron")
library("lattice")
library(nlme)

table(wdpt$soil)
Granitic       MS    MS/SS       SS
     204      554      101       61
# Combine MS/SS and SS into "SS/MS" in new variable: s3

wdpt$s3 <- as.character(wdpt$soil)
wdpt$s3[wdpt$soil %in% c("MS/SS","SS")] <- "SS/MS"
wdpt$s3 <- factor(wdpt$s3)

table(wdpt$s3)
Granitic       MS    SS/MS
     204      554      162

superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(23)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
trellis.par.set("superpose.line",superpose.line)


# Collapse over transect distance
xyplot(sqrt(time2) ~ depth | year*burn.sev2*s3, data=wdpt, groups=site,
   lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,span=1)
   },   ylab="Penetration   time:   square   root   (secs)",   layout=c(4,6),   strip   =
strip.custom(par.strip.text     =     list(cex     =     0.66)),     par.settings     =
list(layout.heights=list(strip=0.66)))
```



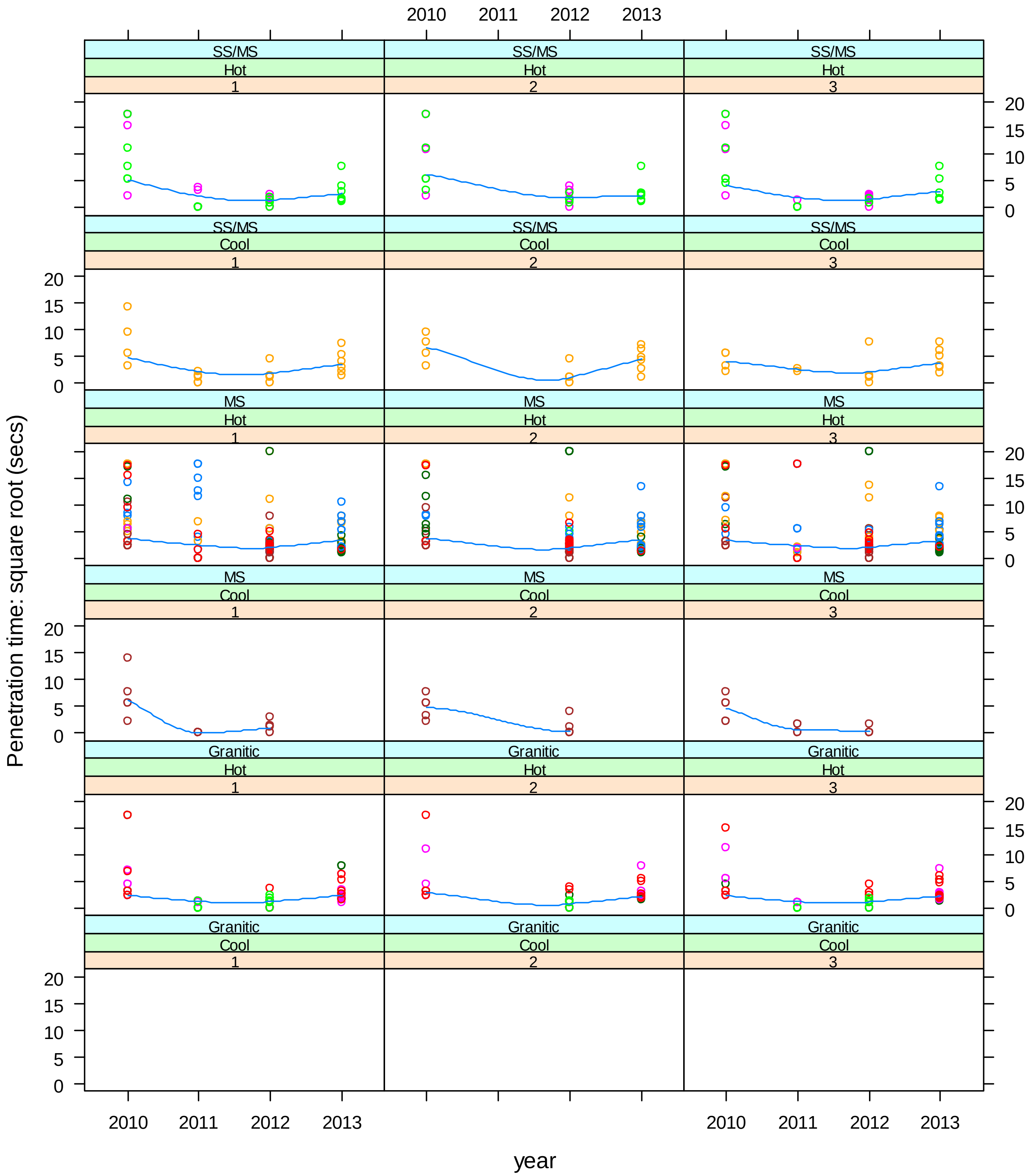

```
 # Collapse over transect distance and burn severity
xyplot(sqrt(time2) ~ depth | s3*year, data=wdpt, groups=site,
```

```
   lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
           panel.superpose(x,y,subscripts,groups, "panel.xyplot")
           panel.loess(x,y,span=1)
   },   ylab="Penetration   time:   square   root   (secs)",   layout=c(3,4),   strip   =
strip.custom(par.strip.text    =    list(cex    =    0.66)),    par.settings    =
list(layout.heights=list(strip=0.66)))
```



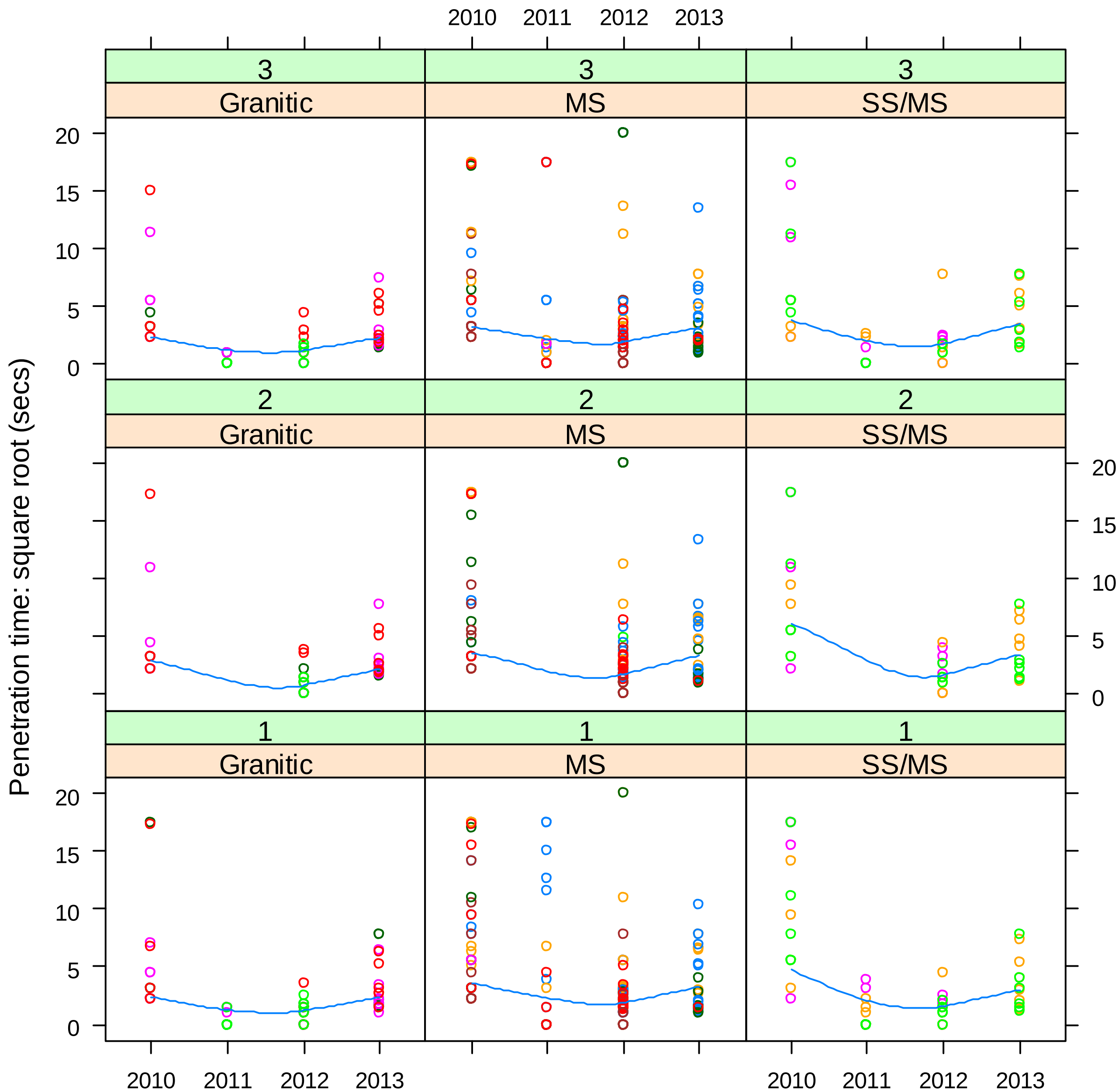

```
# Soil type seems to have been important only in 2010
```

```
xyplot(sqrt(time2) ~ year | factor(depth)*burn.sev2*s3, data=wdpt, groups=site,
layout=c(3,6), panel=function(x,y, subscripts, groups) {
       # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
       panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       panel.loess(x,y,degree=1, span=1)
   },subset=depth %in% c(1,2,3), ylab="Penetration time: square root (secs)", strip =
strip.custom(par.strip.text = list(cex = 0.66)), par.settings =
list(layout.heights=list(strip=0.66)))
```



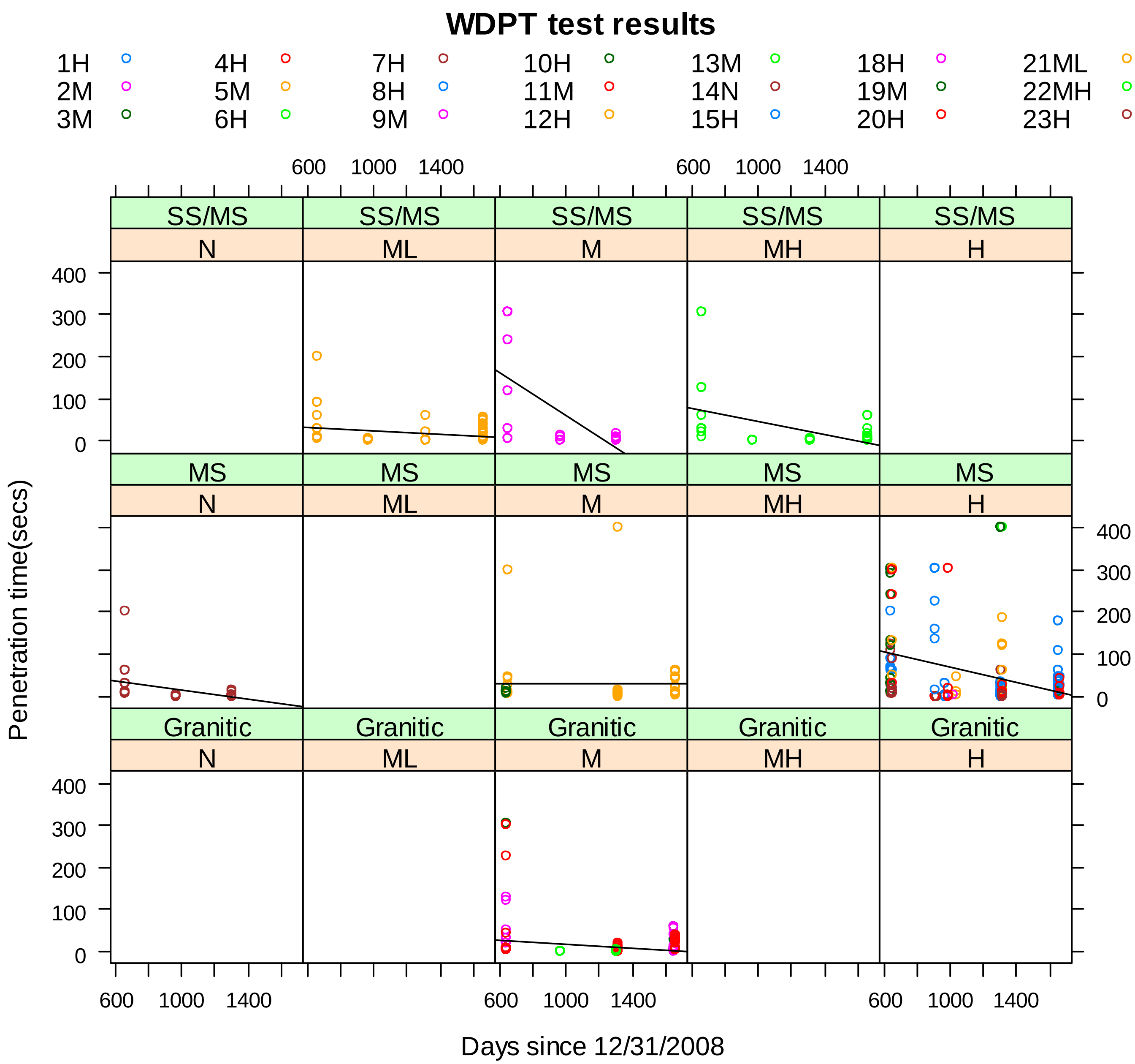

```
# Collapse over transect distance and burn severity
```

```
xyplot(sqrt(time2)  ~  year  |  s3*factor(depth),  data=wdpt,  groups=site,  layout=c(3,3),
panel=function(x,y, subscripts, groups) {
       # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
       panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       panel.loess(x,y,degree=1, span=1)
   },subset=depth %in% c(1,2,3), xlab="", ylab="Penetration time: square root (secs)")
```

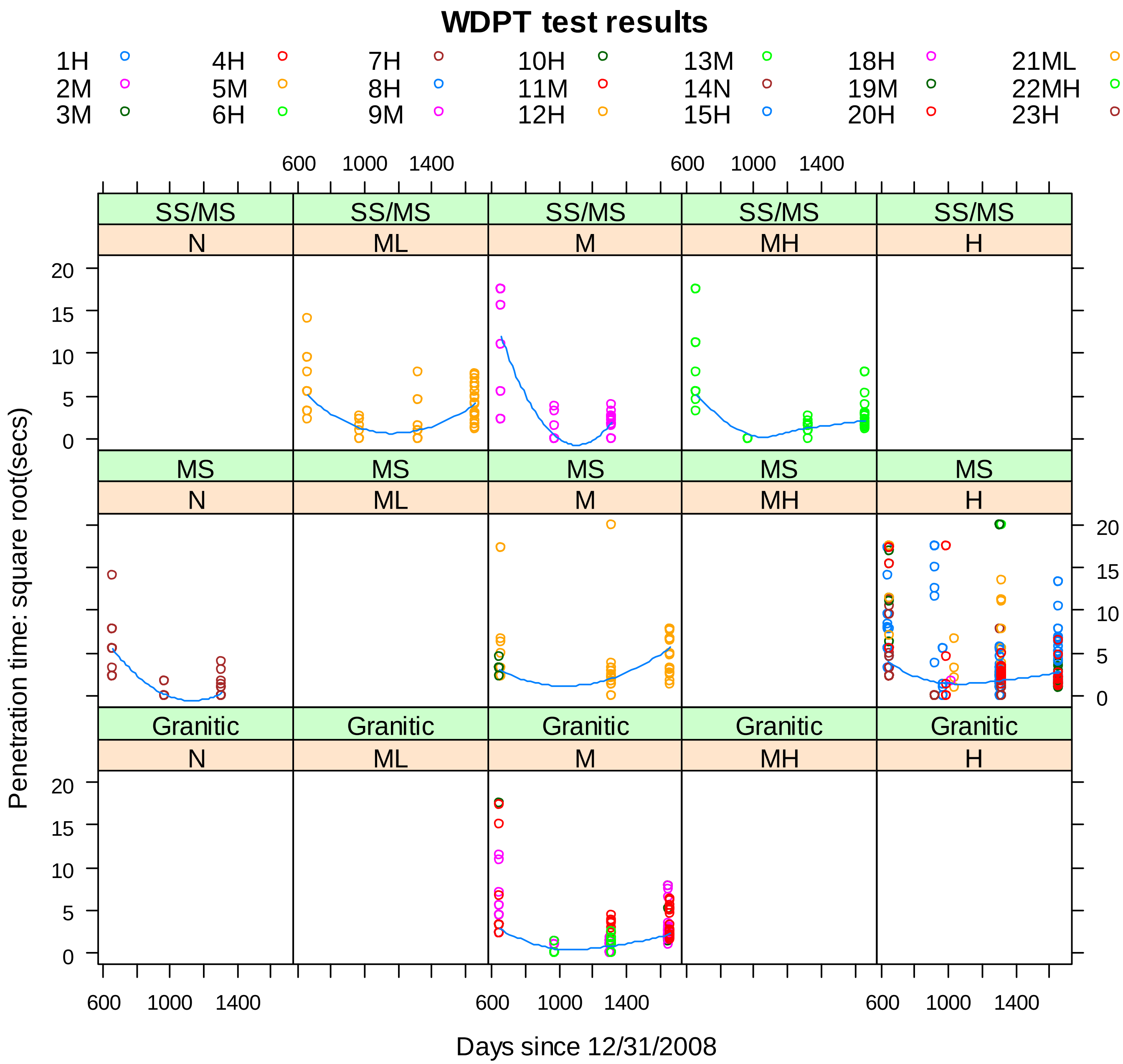



```
# Collapse over transect distance and depth
xyplot(time2 ~ daynum08 | burn.sev*s3, data=wdpt, groups=site, aspect=1, layout=c(5,3),
lattice.options = list(panel.error = "warning"),
 panel=function(x,y, subscripts, groups) {
           panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
```

```
#   panel.loess(x,y,span=1.25,degree=2)
        panel.lmline(x,y)
  }, ylab="Penetration time(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```

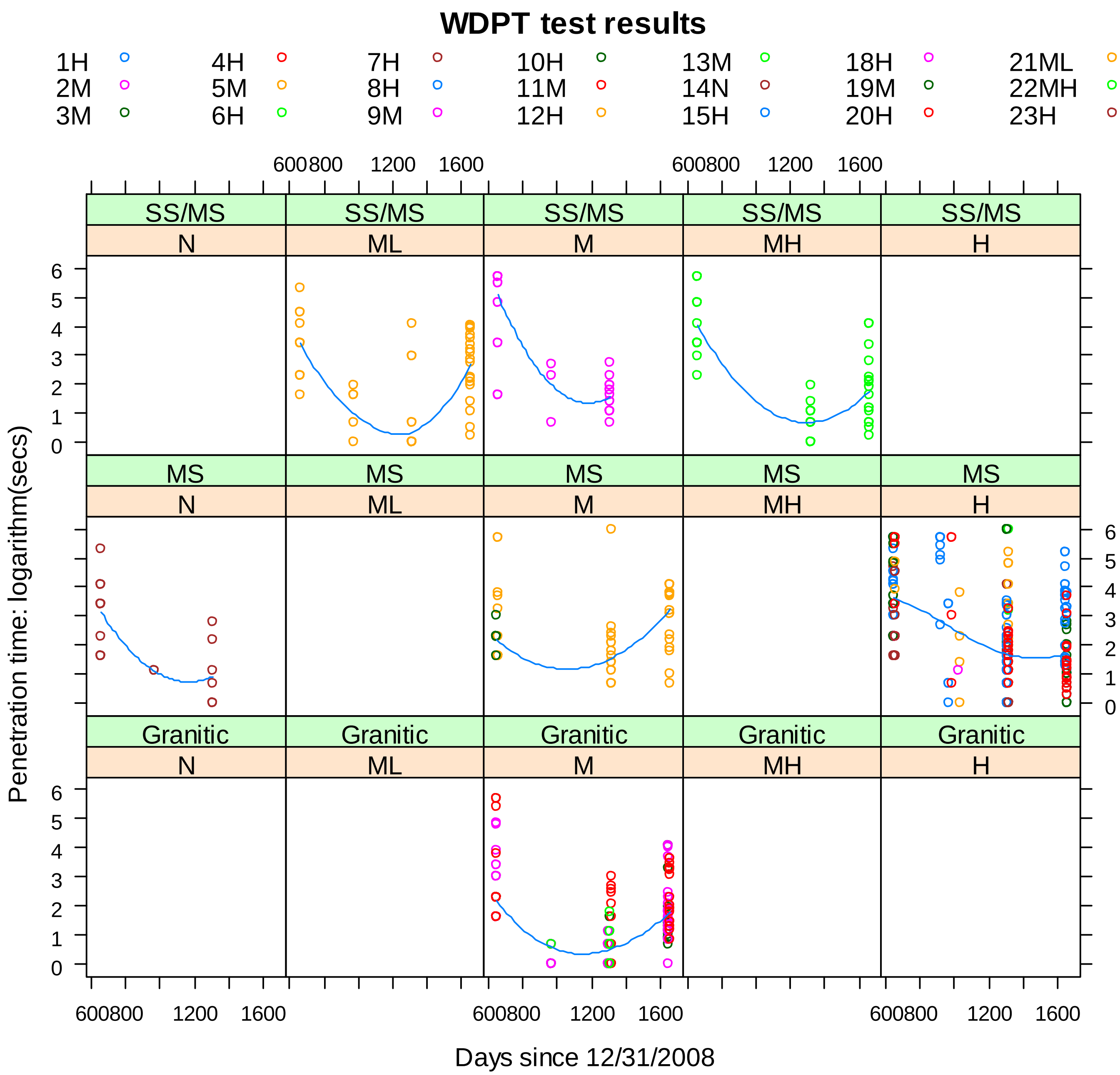


```
# Use square root transformation
xyplot(sqrt(time2) ~ daynum08 | burn.sev*s3, data=wdpt, groups=site, aspect=1,
layout=c(5,3), lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
        #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1.25,degree=2)
            # had to increase span to avoid warnings
   }, ylab="Penetration time: square root(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```



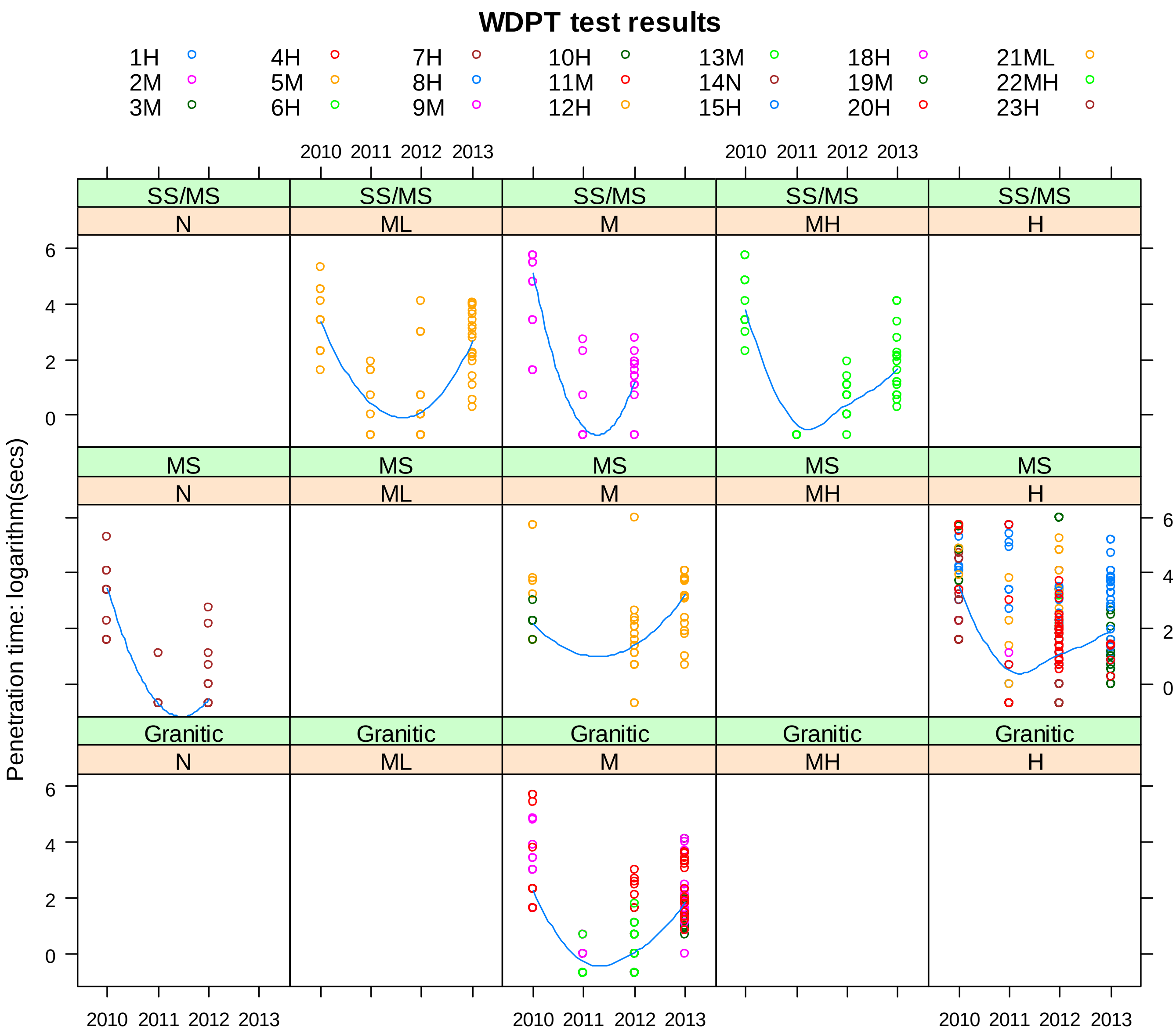

```
# As noted before, the decline in times seems to have reversed in 2013

# Use log transformation
xyplot(log(time2) ~ daynum08 | burn.sev*s3, data=wdpt, groups=site, aspect=1,
layout=c(5,3), lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
```

```
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1.25,degree=2)
            # had to increase span to avoid warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```



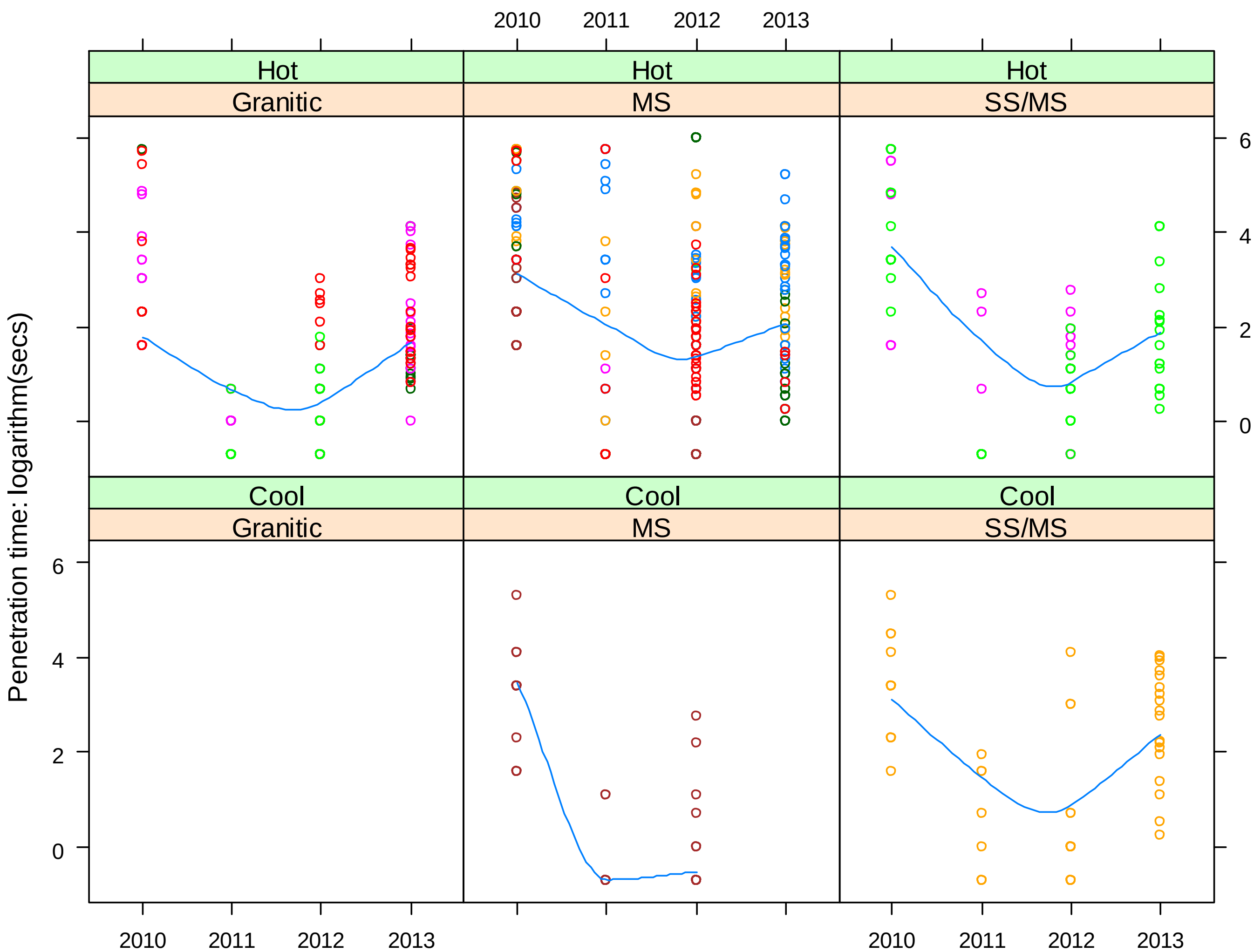

```
# But we should not ignore 164 values of penetration time that are 0
# Use log transformation with 0's recoded to 0.5
xyplot(log(time3) ~ year | burn.sev*s3, data=wdpt, groups=site, aspect=1,
layout=c(5,3), lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
          panel.superpose(x,y,subscripts,groups, "panel.xyplot")
```

```
    #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
          panel.loess(x,y,span=1.25,degree=2)
          # had to increase span to avoid warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="",
main="WDPT test results", auto.key=list(columns=7)
)
```



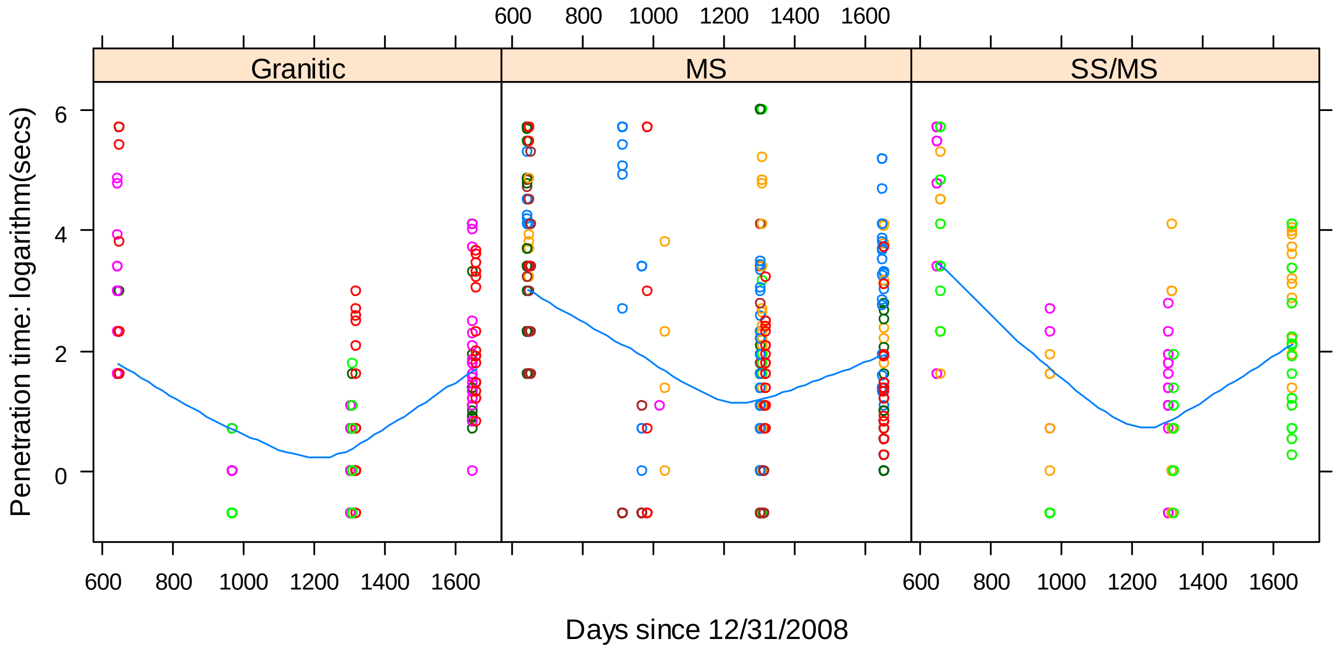

```
# as noted before, 2010 had higher penetration times, 2011 and 2012 are lower.  And 2013
is intermediate.  If there is a soils effect, it's not obvious so far

# Go back to the Hot/Cool dichotomy
xyplot(log(time3) ~ year | s3*burn.sev2, data=wdpt, groups=site,
   panel=function(x,y, subscripts, groups) {
          panel.superpose(x,y,subscripts,groups, "panel.xyplot")
    #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
```

```
            panel.loess(x,y,span=1)
   }, ylab="Penetration time: logarithm(secs)", xlab=""
)
```




```
# It looks like the granitic soils had lower penetration times than the other soils
# in the hot burns.  Actually all the granitic burns were of moderate severity.

xyplot(log(time3) ~ year | s3, data=wdpt, groups=site, layout=c(3,1),
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1)
   }, xlab="",ylab="Penetration time: logarithm(secs)")
```

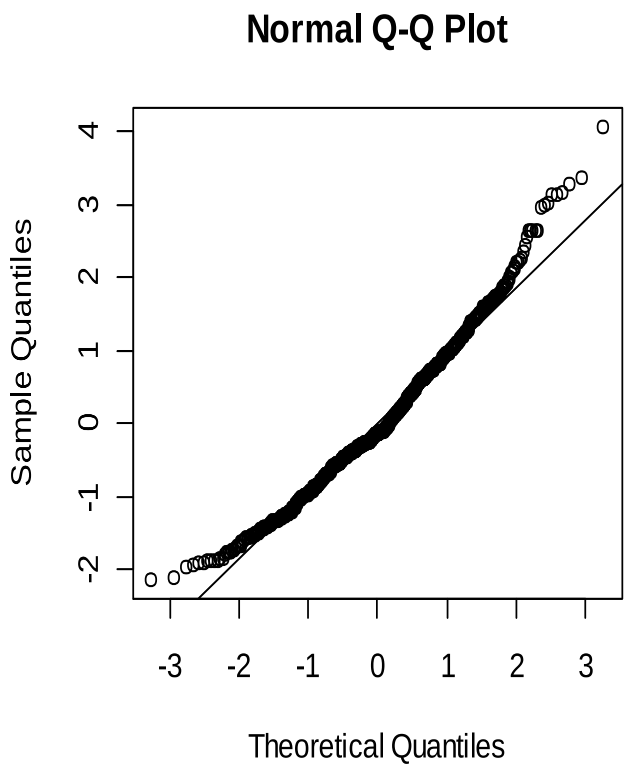

```
# Do granitic soils have lower penetration times in general?
# Look at means by soil and year
tapply(wdpt$time2, list(wdpt$s3,wdpt$year),mean)
              2010       2011      2012     2013
Granitic  43.33333  0.4166667  2.055556 13.01667
MS        90.27778 40.2253521 32.197797 22.89737
SS/MS    113.80952  1.5666667  4.277778 18.68056

# Logarithms
tapply(log(wdpt$time3),list(wdpt$s3,wdpt$year),mean)
             2010       2011      2012     2013
Granitic 2.685195 -0.4043359 0.2318470 1.954713
MS       3.363894  0.7468353 1.3625989 2.154982
SS/MS    4.010686 -0.1229174 0.7119686 2.251108

# Replot using day number in place of year
xyplot(log(time3) ~ daynum08 | s3, data=wdpt, groups=site, layout=c(3,1),
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1)
   }, ylab="Penetration time: logarithm(secs)", xlab="Days since 12/31/2008"
)
```

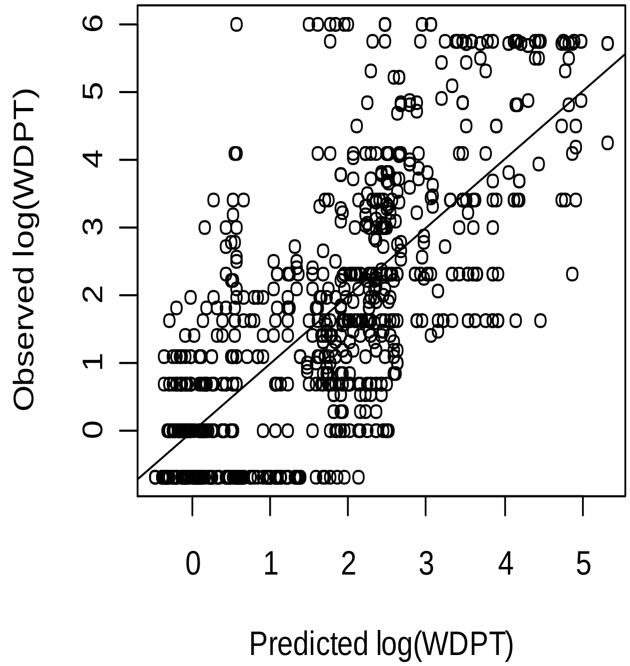



```
==============================================================================

> dim(wdpt)
[1] 920  19
> dim(wdpt.gd)
[1] 920  18

# Add s3 to wdpt.gd
wdpt.gd$s3 <- wdpt$s3

options(contrasts=c("contr.treatment","contr.treatment"))
wdpt3.fit0 <- lme(sqrt(time2) ~ daynum*burn.sev, data=wdpt.gd, random=~1)
wdpt3.fit1 <- lme(sqrt(time2) ~ daynum*burn.sev, data=wdpt.gd, random=~daynum)

anova(wdpt3.fit0,wdpt3.fit1)
           Model df      AIC      BIC    logLik   Test  L.Ratio p-value
wdpt3.fit0     1 13 5314.497 5377.072 -2644.249
wdpt3.fit1     2 17 5244.759 5326.588 -2605.380 1 vs 2 77.73851  <.0001
# Keep the random effects of site (and transect within site) on daynum

> anova(wdpt3.fit1,type="marginal")
                numDF denDF  F-value p-value
(Intercept)         1   790 6.216169  0.0129
daynum              1   790 6.139258  0.0134
burn.sev            4    16 1.953027  0.1506
daynum:burn.sev     4   790 1.928779  0.1037

> anova(wdpt3.fit0,type="marginal")
                numDF denDF   F-value p-value
(Intercept)         1   790 11.482839   7e-04
```

```
daynum              1   790 11.092459   9e-04
burn.sev            4    16  8.910057   6e-04
daynum:burn.sev     4   790  8.732744  <.0001
# It makes a big difference which random effects are included
# The better model says daynum is the only significant fixed effect (so far)

#  Let's  not  mess  with  these  models.   We  know  the  fit  is  poor  and  the  residuals
distribution is terrible.  Go straight to the quadratic trend model for log(WDPT)

wdpt3.fit2 <- update(wdpt3.fit1, log(time3) ~ daynum + I(daynum^2))
Error in logLik.lmeStructInt(lmeSt, lmePars) :
  NA/NaN/Inf in foreign function call (arg 3)
# Cannot fit the complete random effects model (with site effects on depth)

wdpt3.fit2 <- update(wdpt3.fit0, log(time3) ~ daynum + I(daynum^2))
anova(wdpt3.fit2)
            numDF denDF  F-value p-value
(Intercept)     1   793  82.2013  <.0001
daynum          1   793 170.3924  <.0001
I(daynum^2)     1   793 321.5489  <.0001

# Test depth in this model
anova(wdpt3.fit3)
wdpt3.fit3 <- update(wdpt3.fit2, ~ . + depth)
            numDF denDF  F-value p-value
(Intercept)     1   792  82.1000  <.0001
daynum          1   792 170.3500  <.0001
I(daynum^2)     1   792 321.4372  <.0001
depth           1   792   0.8004  0.3712
# Depth not significant

# Test burn severity
wdpt3.fit4 <- update(wdpt3.fit2, ~ . + burn.sev)
anova(wdpt3.fit4)
            numDF denDF  F-value p-value
(Intercept)     1   793  74.8750  <.0001
daynum          1   793 170.5697  <.0001
I(daynum^2)     1   793 321.1177  <.0001
burn.sev        4    16   0.5651  0.6915
# Burn severity not significant

# Test soil and its influences on trend
wdpt3.fit5 <- update(wdpt3.fit2, ~ . + s3*daynum + s3*I(daynum^2))

anova(wdpt3.fit5,type="marginal")
               numDF denDF   F-value p-value
(Intercept)        1   789 110.94626  <.0001
daynum             1   789 110.51750  <.0001
I(daynum^2)        1   789 110.16765  <.0001
s3                 2    18  20.71270  <.0001
daynum:s3          2   789  20.77988  <.0001
I(daynum^2):s3     2   789  20.83631  <.0001
# All terms very significant

# Take another look at burn severity
wdpt3.fit5a <- update(wdpt3.fit5, ~ . + burn.sev)
anova(wdpt3.fit5a)
```

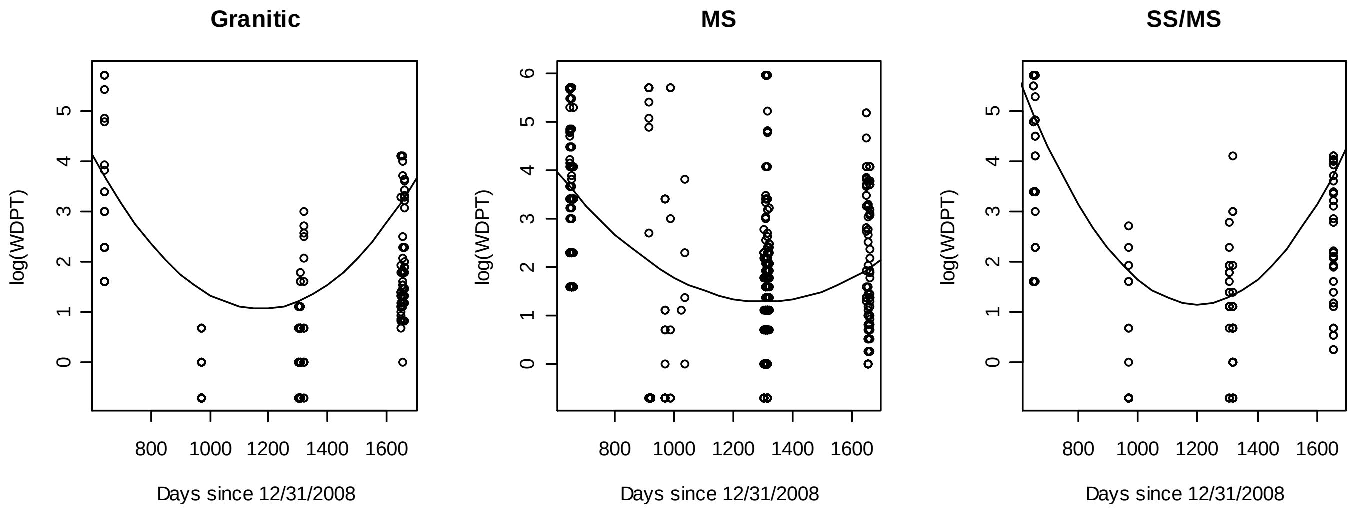
```
anova(wdpt3.fit5a,type="marginal")
               numDF denDF   F-value p-value
(Intercept)        1   789 110.54535  <.0001
daynum             1   789 110.18363  <.0001
I(daynum^2)        1   789 109.83342  <.0001
s3                 2    14  20.81898  0.0001
burn.sev           4    14   0.28764  0.8811
daynum:s3          2   789  20.87597  <.0001
I(daynum^2):s3     2   789  20.93541  <.0001
# NOT
# Also cannot test interaction of s3 and burn severity at this point
# Had same issue with testing interaction of v3 and burn severity
"Error in MEEM: Singularity in backsolve at level 0, block 1"

# Take a look at the coefficients of wdpt3.fit5
as.data.frame(fixef(wdpt3.fit5))
                    fixef(wdpt3.fit5)
(Intercept)              2.244511e+03
daynum                  -2.911469e-01
I(daynum^2)              9.440852e-06
s3MS                    -9.287770e+02
s3SS/MS                  7.110801e+02
daynum:s3MS              1.220433e-01
daynum:s3SS/MS          -9.150133e-02
I(daynum^2):s3MS        -4.003423e-06
I(daynum^2):s3SS/MS      2.944469e-06
# linear interaction is negative, the quadratic is positive
Granitic     2245 -0.2911d + 9.4409e-06d^2
MS delta     -929 +0.1220d - 4.0034e-06d^2
MS curve     1316 -0.1691d + 5.4375e-06d^2
SS/MS delta   711 -0.0915d + 2.9445e-06d^2
SS/MS curve  2956 -0.3826d + 1.2385e-05d^2

# Some diagnostics
par(mfrow=c(1,2))
qqresid(wdpt3.fit5)
plot(fitted(wdpt3.fit5),log(wdpt.gd$time3),xlab="Predicted       log(WDPT)",ylab="Observed
log(WDPT)")
abline(0,1)
cor(fitted(wdpt3.fit5),log(wdpt.gd$time3))^2
[1] 0.5564504  # This is the proportion of variance explained by the model
```






```
# Plot the quadratic curves determined from the model coefficients
Granitic     2245 -0.2911d + 9.4409e-06d^2
MS delta     -929 +0.1220d - 4.0034e-06d^2
MS curve     1316 -0.1691d + 5.4375e-06d^2
SS/MS delta   711 -0.0915d + 2.9445e-06d^2
SS/MS curve  2956 -0.3826d + 1.2385e-05d^2

x0 <- seq(600,1700,50)
x1 <- x0 + 14245  # Day numbers used for model fitting used R's origin 1/1/70
y1 <- 2245 -0.2911*x1 + 9.4409e-06*x1^2
y2 <- 1316 -0.1691*x1 + 5.4375e-06*x1^2
y3 <- 2956 -0.3826*x1 + 1.2385e-05*x1^2
par(mfrow=c(1,3))
attach(wdpt.gd[wdpt.gd$s3=="Granitic",])
plot(daynum08,log(time3),xlab="Days since 12/31/2008",ylab="log(WDPT)",main="Granitic")
lines(x0,y1)
detach(2)
attach(wdpt.gd[wdpt.gd$s3=="MS",])
plot(daynum08,log(time3),xlab="Days since 12/31/2008",ylab="log(WDPT)",main="MS")
lines(x0,y2)
detach(2)
attach(wdpt.gd[wdpt.gd$s3=="SS/MS",])
```

```
plot(daynum08,log(time3),xlab="Days since 12/31/2008",ylab="log(WDPT)",main="SS/MS")
lines(x0,y3)
detach(2)
```



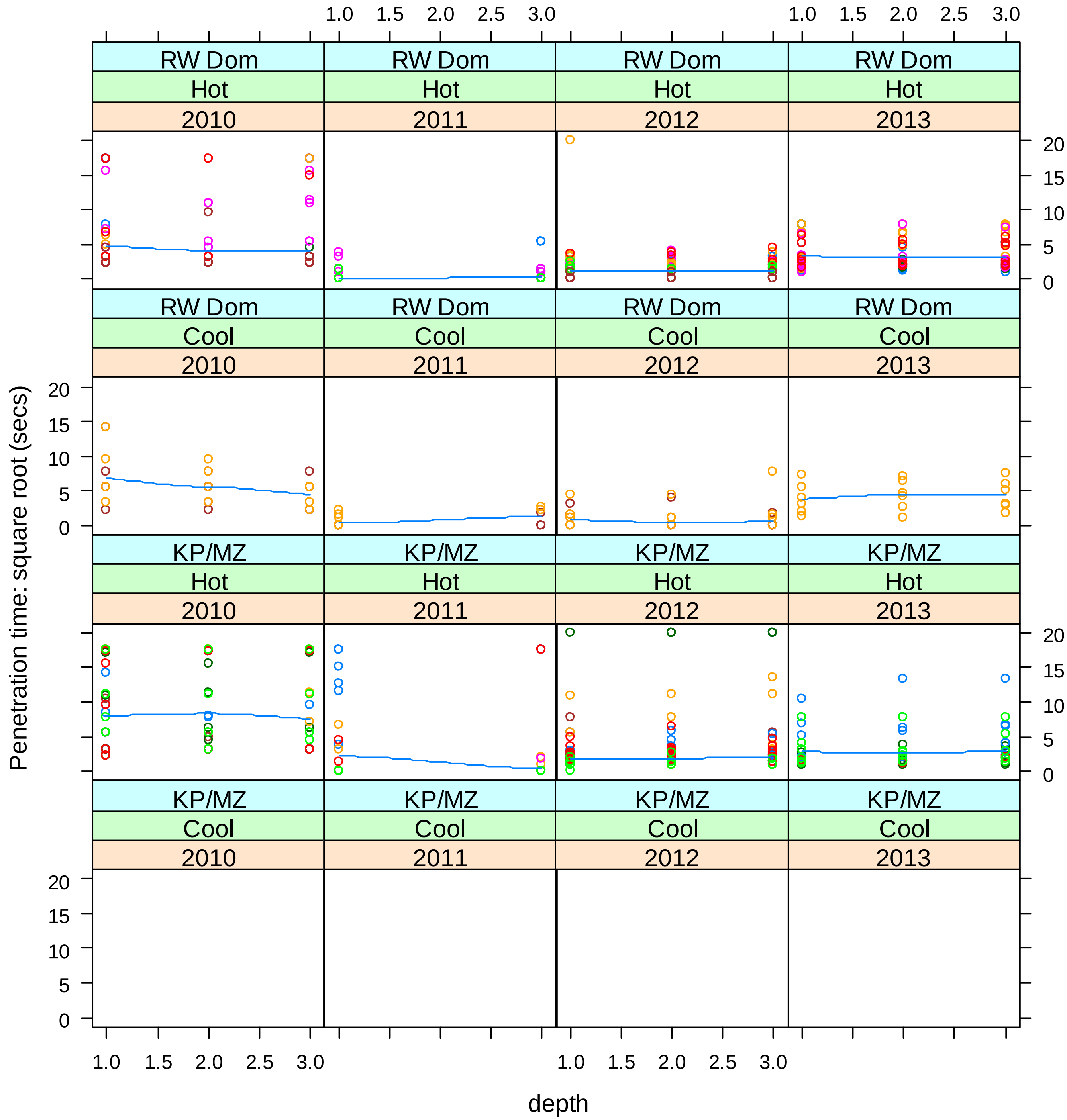

```
# These curves aren't really very good fits to the data

# We could also have treated year as a categorical variable
# And this is probably the most informative for identifying systematic differences
wdpt3.fit6 <- update(wdpt3.fit2, log(time3) ~ year*s3)
anova(wdpt3.fit6,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   786 28.36376  <.0001
year            3   786 43.97105  <.0001
s3              2    18  1.78542  0.1962
year:s3         6   786  7.23915  <.0001
# There's an interaction but not a soil effect by itself

# Drop the solo soil effect
wdpt3.fit6a <- update(wdpt3.fit6, log(time3) ~ year + year:s3)
anova(wdpt3.fit6a,type="marginal")
            numDF denDF  F-value p-value
(Intercept)     1   784 28.36376  <.0001
year            3   784 43.97105  <.0001
year:s3         8   784  5.62921  <.0001

# Look at individual effects
fixef(wdpt3.fit6a)
     (Intercept)          year2011          year2012          year2013
       2.6318994        -2.8890936        -2.4000523        -0.7191309
   year2010:s3MS     year2011:s3MS     year2012:s3MS     year2013:s3MS
       0.7932075         1.0034920         0.9375594        -0.3667029
year2010:s3SS/MS year2011:s3SS/MS year2012:s3SS/MS year2013:s3SS/MS
       1.3684331         0.1094009         0.4801216         0.4860827
# this model says that WDPT decreased in 2011 and subsequently increased
# Compared to the Granitic sites:
# MS sites had higher penetration times in all years but 2013
# SS/MS sites had higher penetration times in all years
```

```
# But the individual contrasts are not necessarily significant
# The model only says there are soil related differences
summary(wdpt3.fit6a)
Fixed effects: log(time3) ~ year + year:s3
                      Value Std.Error  DF   t-value p-value
(Intercept)       2.6318994 0.4941825 784  5.325764  0.0000
year2011         -2.8890936 0.3075695 784 -9.393304  0.0000
year2012         -2.4000523 0.2583136 784 -9.291235  0.0000
year2013         -0.7191309 0.2644411 784 -2.719437  0.0067
year2010:s3MS     0.7932075 0.5579008 784  1.421772  0.1555
year2011:s3MS     1.0034920 0.5756446 784  1.743249  0.0817
year2012:s3MS     0.9375594 0.5366143 784  1.747176  0.0810
year2013:s3MS    -0.3667029 0.5666280 784 -0.647167  0.5177
year2010:s3SS/MS  1.3684331 0.7422006 784  1.843751  0.0656
year2011:s3SS/MS  0.1094009 0.7546092 784  0.144977  0.8848
year2012:s3SS/MS  0.4801216 0.7203763 784  0.666487  0.5053
year2013:s3SS/MS  0.4860827 0.7428891 784  0.654314  0.5131
# In fact none of the soil-related coefficients individually pass at 0.05

Look back at mean WDPT by year and veg type

# Look at means by soil and year
tapply(wdpt$time2, list(wdpt$s3,wdpt$year),mean)
              2010       2011      2012     2013
Granitic  43.33333  0.4166667  2.055556 13.01667
MS        90.27778 40.2253521 32.197797 22.89737
SS/MS    113.80952  1.5666667  4.277778 18.68056

# Logarithms
tapply(log(wdpt$time3),list(wdpt$s3,wdpt$year),mean)
             2010       2011      2012     2013
Granitic 2.685195 -0.4043359 0.2318470 1.954713
MS       3.363894  0.7468353 1.3625989 2.154982
SS/MS    4.010686 -0.1229174 0.7119686 2.251108

===================================================================

# Try simple regression models

f1 <- lm(log(time3) ~ s3*daynum + s3*I(daynum^2), data=wdpt.gd)
summary(f1)

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)          2.374e+03  2.293e+02  10.355  < 2e-16 ***
s3MS                -8.269e+02  2.728e+02  -3.031  0.00251 **
s3SS/MS              4.935e+02  3.489e+02   1.415  0.15752
daynum              -3.081e-01  2.980e-02 -10.340  < 2e-16 ***
I(daynum^2)          9.993e-06  9.676e-07  10.327  < 2e-16 ***
s3MS:daynum          1.082e-01  3.549e-02   3.049  0.00236 **
s3SS/MS:daynum      -6.302e-02  4.536e-02  -1.389  0.16504
s3MS:I(daynum^2)    -3.535e-06  1.154e-06  -3.064  0.00225 **
s3SS/MS:I(daynum^2)  2.013e-06  1.473e-06   1.366  0.17227

Residual standard error: 1.558 on 911 degrees of freedom
Multiple R-squared: 0.3525,     Adjusted R-squared: 0.3469
F-statistic: 62.01 on 8 and 911 DF,  p-value: < 2.2e-16
```

```
# The contrasts of MS with Granitic are significant
# The contrasts of SS/MS with Granitic are not
# Of course we can't accept these tests because the observations are not independent,
which is why we had to use mixed-effects models in the first place.
```

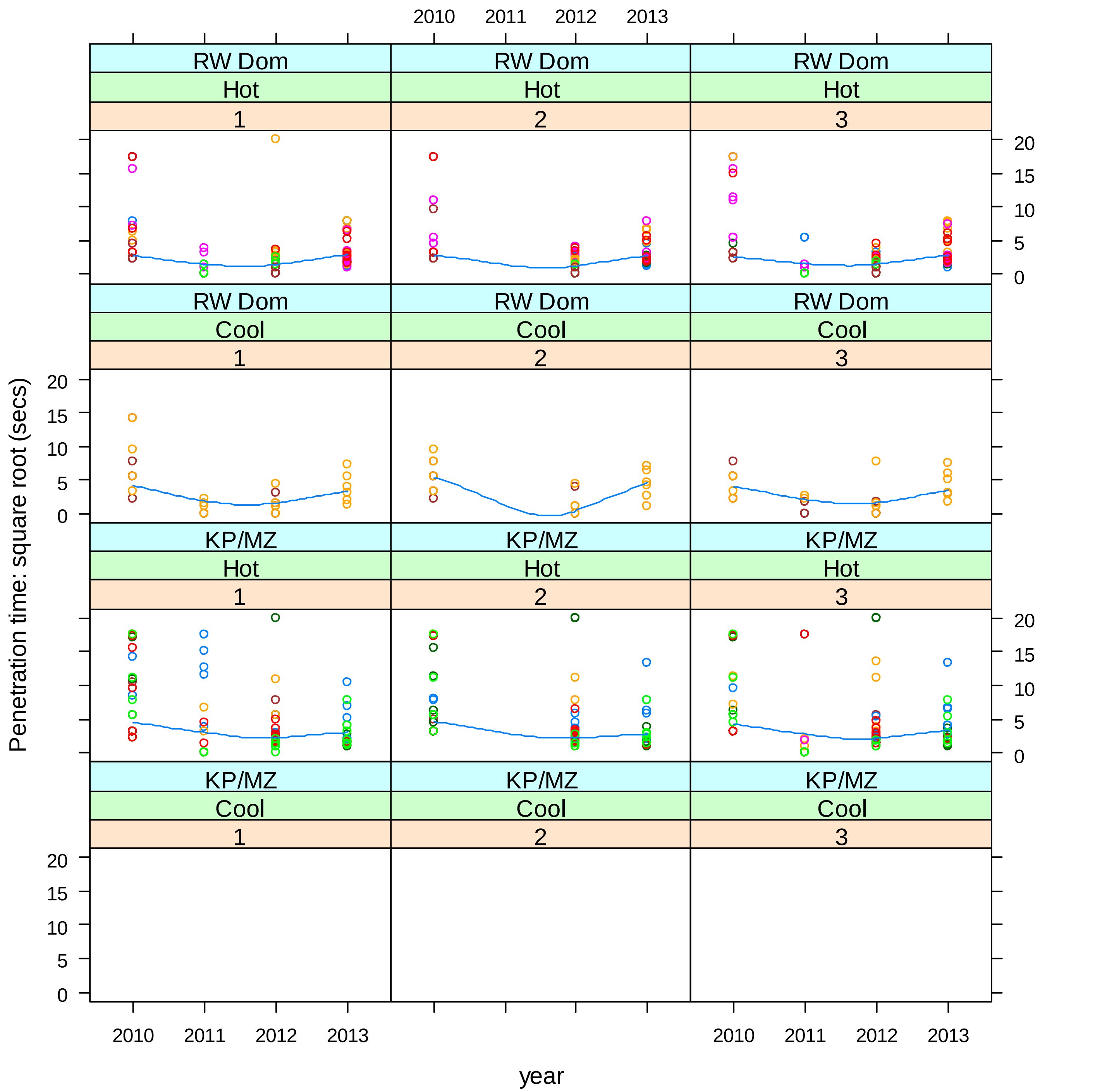
Effects of Vegetation Type

```
library("chron")
library("lattice")
library(nlme)

wdpt$v3 <- soilveg$v3[wdpt$sitenum]
wdpt$soil <- soilveg$soil[wdpt$sitenum]
save.image()

superpose.line <- trellis.par.get("superpose.line")
superpose.line$col <- rainbow(23)
superpose.line$lwd <- 2
superpose.line$lty <- 1:2
trellis.par.set("superpose.line",superpose.line)

wdpt2.gd <- groupedData(sqrt(time2) ~ year | site/dist, outer = ~ burn.sev, data=
wdpt[wdpt$v3 != "To",])

# Collapse over transect distance
xyplot(sqrt(time2) ~ depth | year*burn.sev2*v3, data=wdpt2.gd, groups=site,
   panel=function(x,y, subscripts, groups) {
      # panel.superpose(x,y, subscripts, groups, "panel.lmline")
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
            panel.loess(x,y,span=1)
   }, ylab="Penetration time: square root (secs)", layout=c(4,4)
)
```

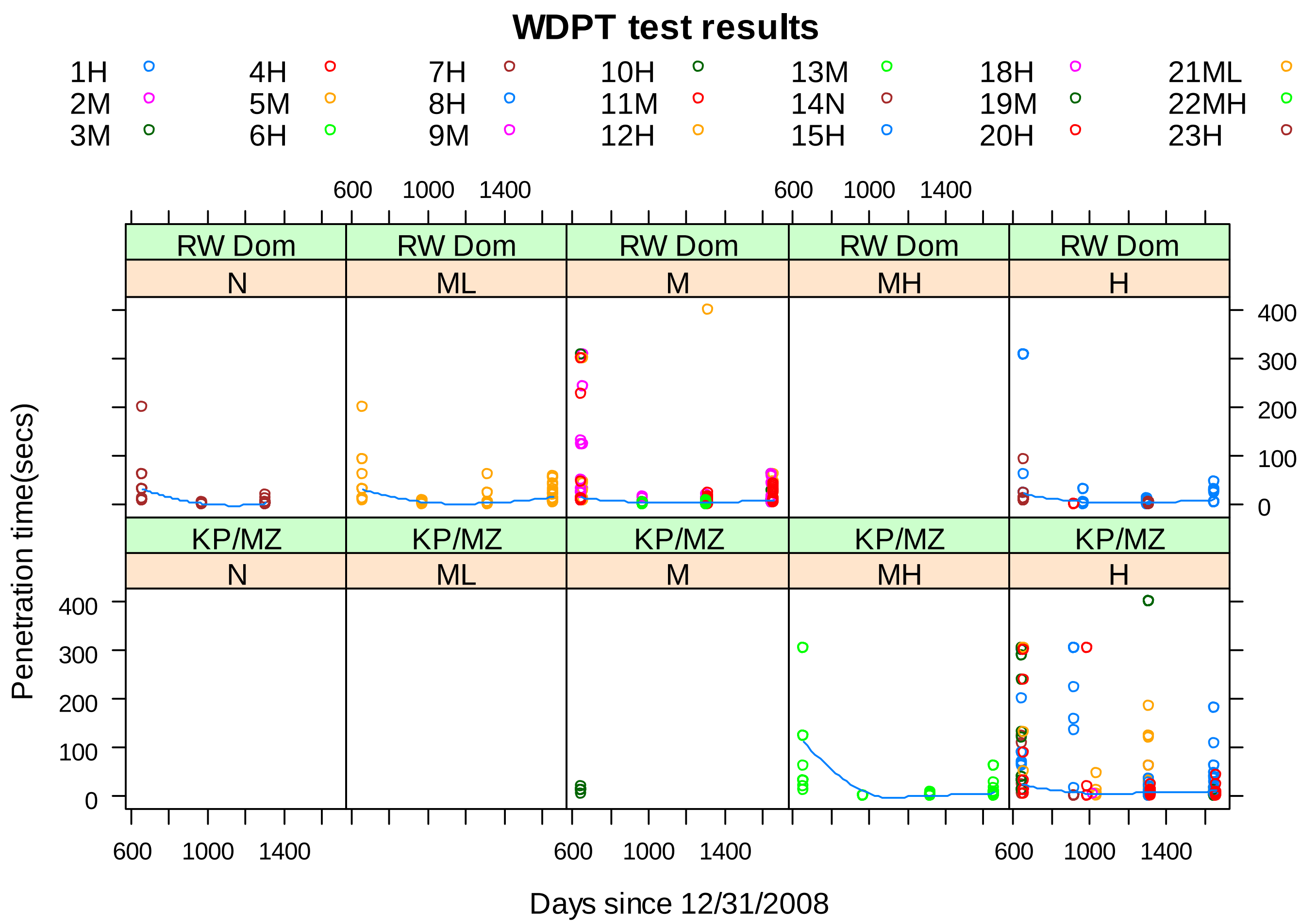



```
# Previous observation that hot burns have longer penetration times may not have been correct.  We see that in the RW Dom vegetation, there's not much difference in penetration time between Hot and Cool burns.  Most of the long penetration times were on the KP/MZ vegetations, which were all Hot, but there are no Cool burns on KP/MZ to compare with.
# Depth doesn't seem to have a consistent effect
```

```
xyplot(sqrt(time2)  ~  year  |  factor(depth)*burn.sev2*v3,  data=wdpt2.gd,  groups=site,
layout=c(3,4), panel=function(x,y, subscripts, groups) {
       # panel.superpose(x,y, subscripts, groups, "panel.loess",span=0.333)
       panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       panel.loess(x,y,degree=1, span=1)
   },subset=depth %in% c(1,2,3), ylab="Penetration time: square root (secs)")
```

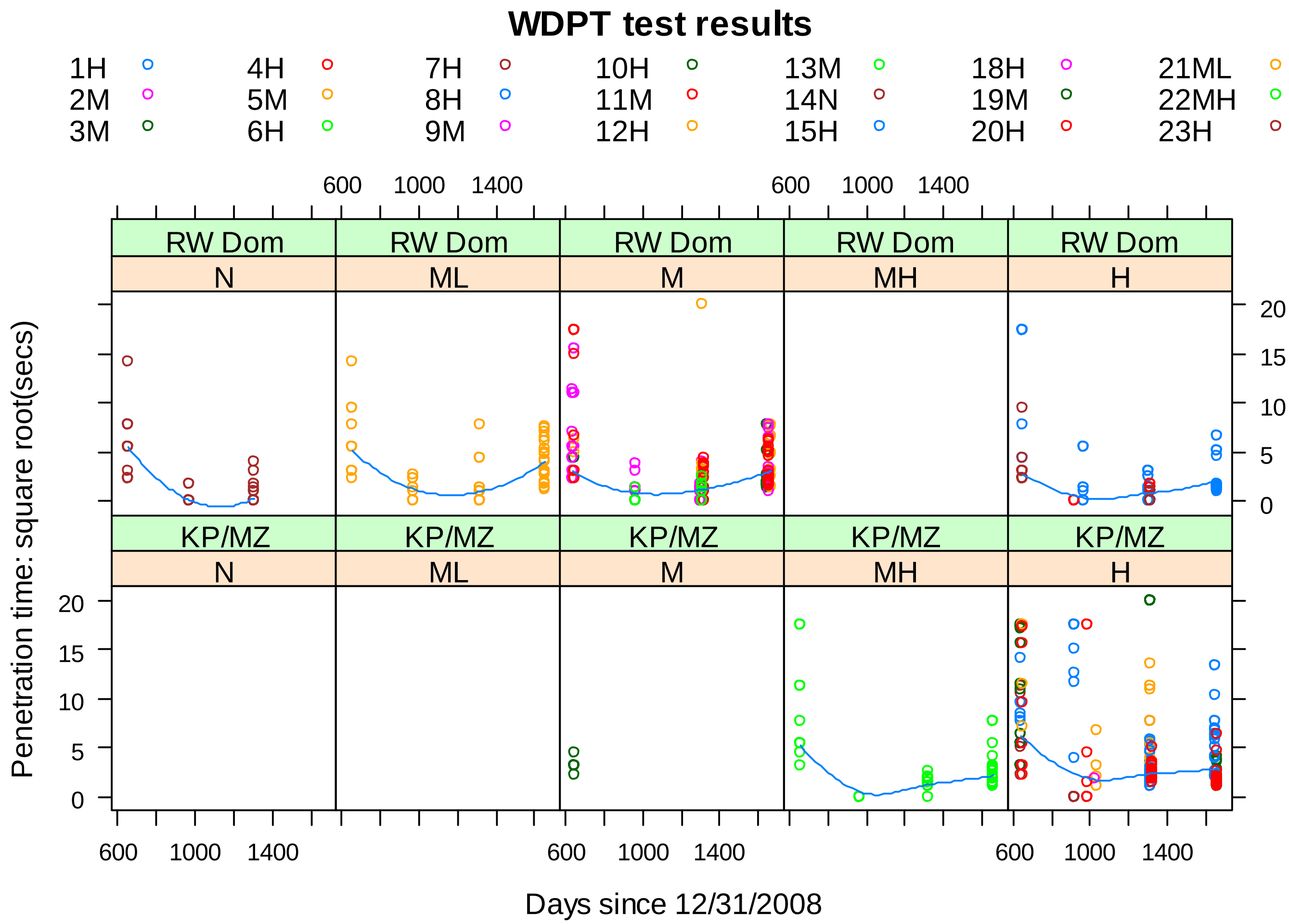


```
# Collapse over both transect distance AND depth;
xyplot(time2   ~   daynum08   |   burn.sev*v3,   data=wdpt2.gd,   groups=site,   aspect=1,
layout=c(5,2), lattice.options = list(panel.error = "warning"),
 panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1.25,degree=2)
       #    had to increase span to eliminate warnings
   }, ylab="Penetration time(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```



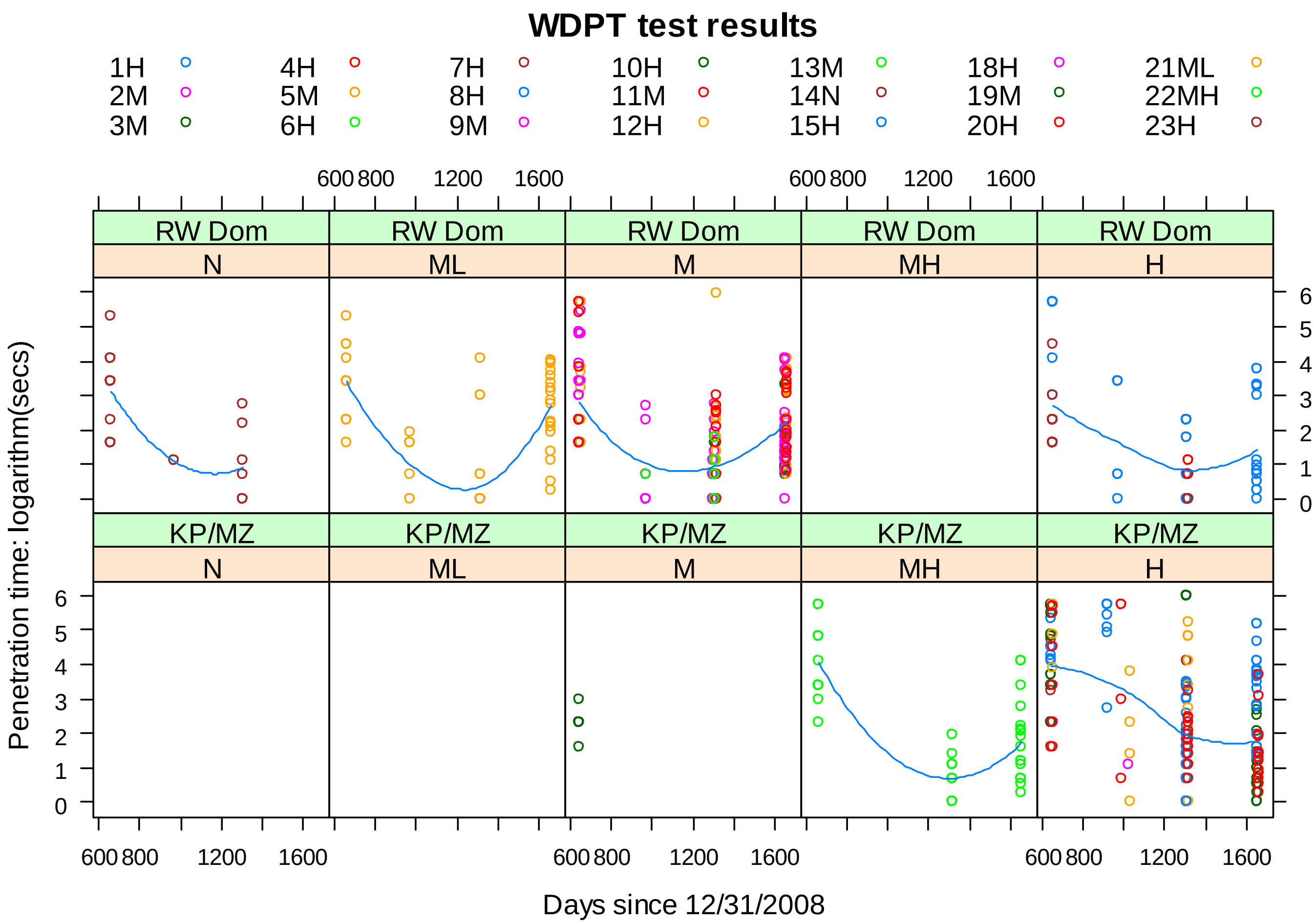

```
# Use square root transformation
xyplot(sqrt(time2) ~ daynum08 | burn.sev*v3, data=wdpt2.gd, groups=site, aspect=1,
layout=c(5,2), lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
         panel.superpose(x,y,subscripts,groups, "panel.xyplot")
      #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
         panel.loess(x,y,span=1.25,degree=2)
```

```
            # had to increase span to avoid warnings
   }, ylab="Penetration time: square root(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```



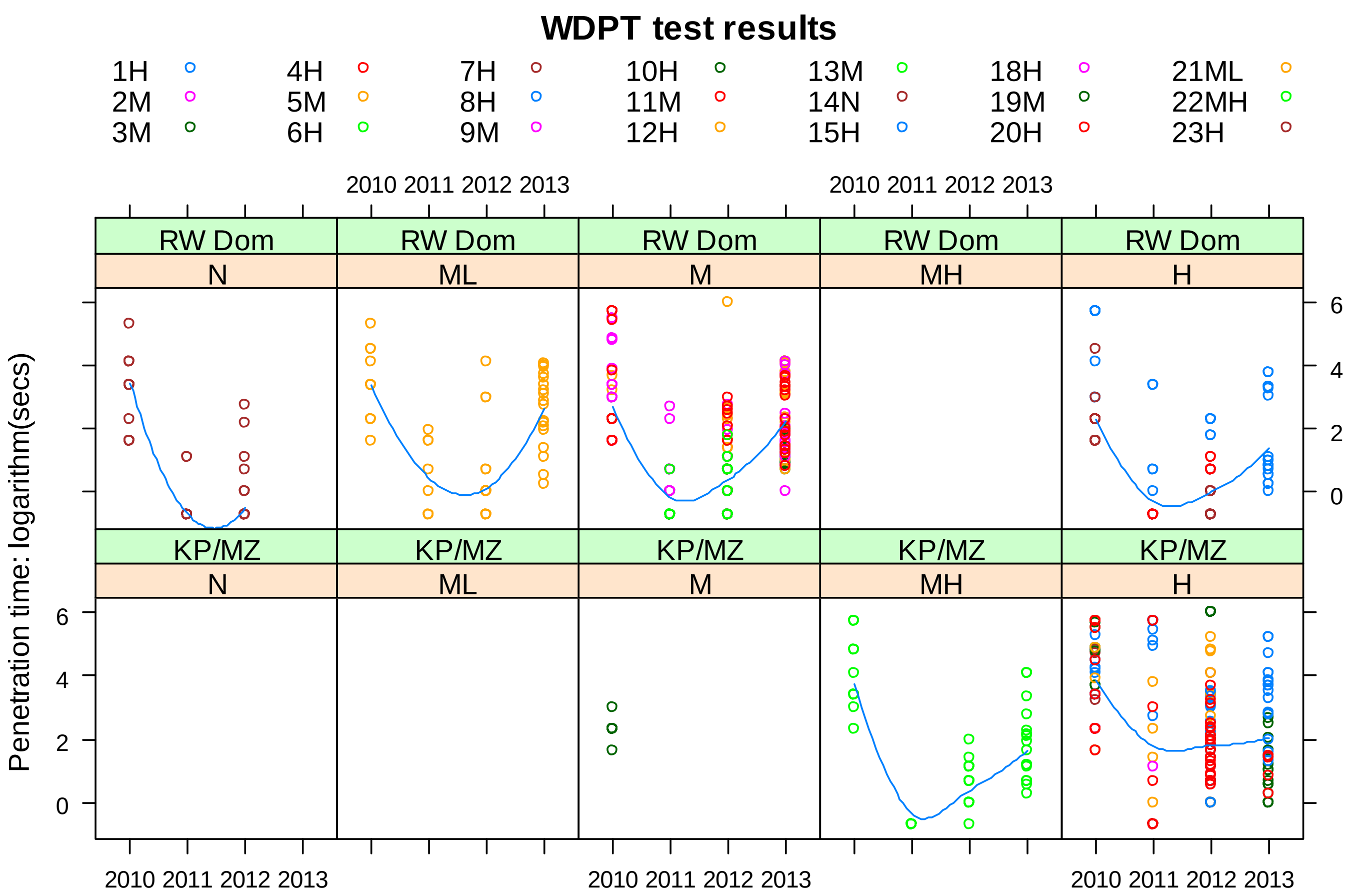

```
# The decline in times seems to have reversed in 2013
# The big contrast is between RW Dom and KP/MZ in the Hot burns
# There are many more long penetration times in the KP/MZ hot burns
```

```
# Use log transformation
xyplot(log(time2) ~ daynum08 | burn.sev*v3, data=wdpt2.gd, groups=site, aspect=1,
layout=c(5,2), lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=1.25,degree=2)
            # had to increase span to avoid warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```



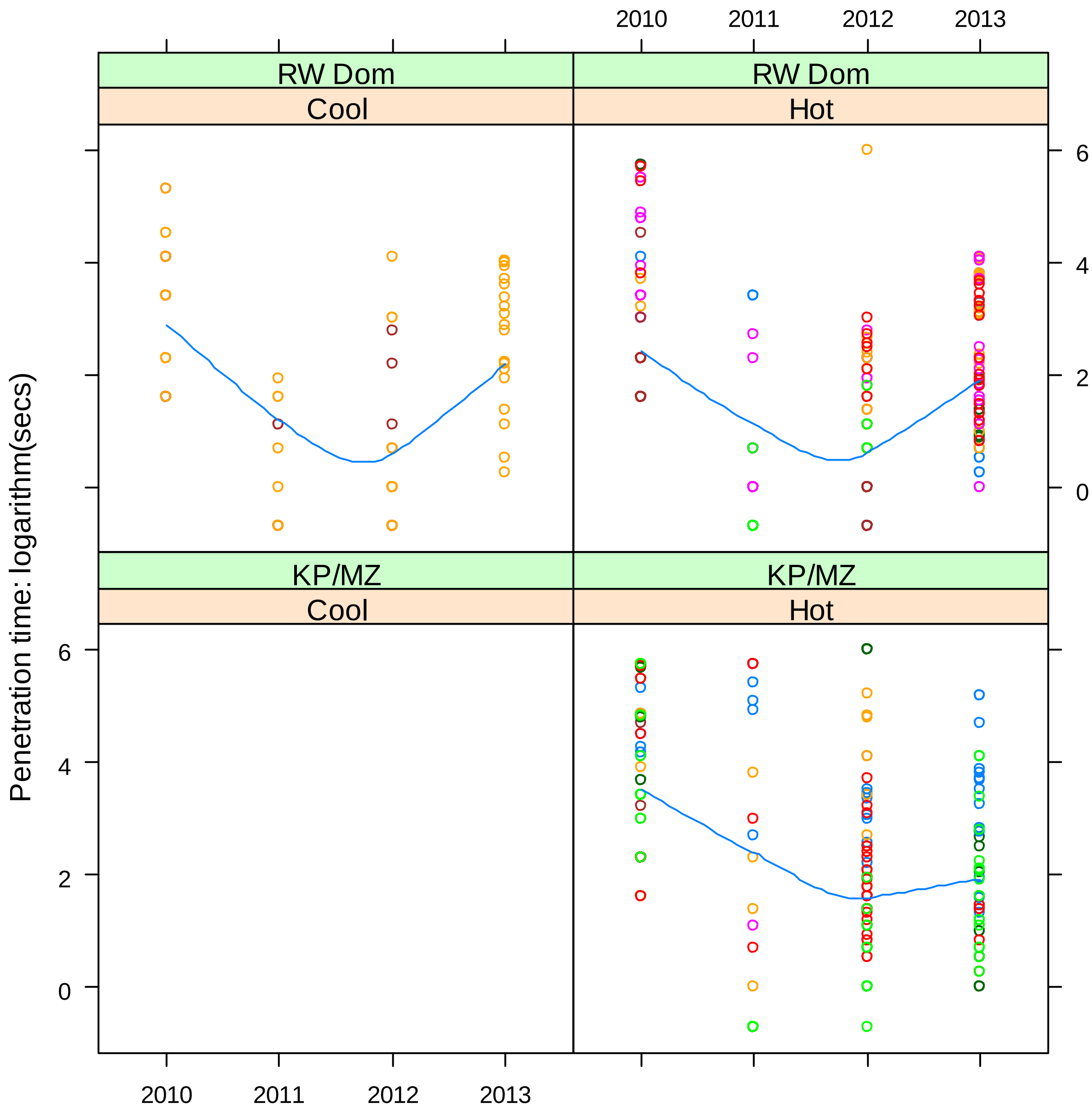

```
# But we cannot ignore 164 values of penetration time that are 0
# Use log transformation with 0's recoded to 0.5
xyplot(log(time3) ~ year | burn.sev*v3, data=wdpt2.gd, groups=site, aspect=1,
layout=c(5,2), lattice.options = list(panel.error = "warning"),
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
```

```
            panel.loess(x,y,span=1.25,degree=2)
            # had to increase span to avoid warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="",
main="WDPT test results", auto.key=list(columns=7)
)
```



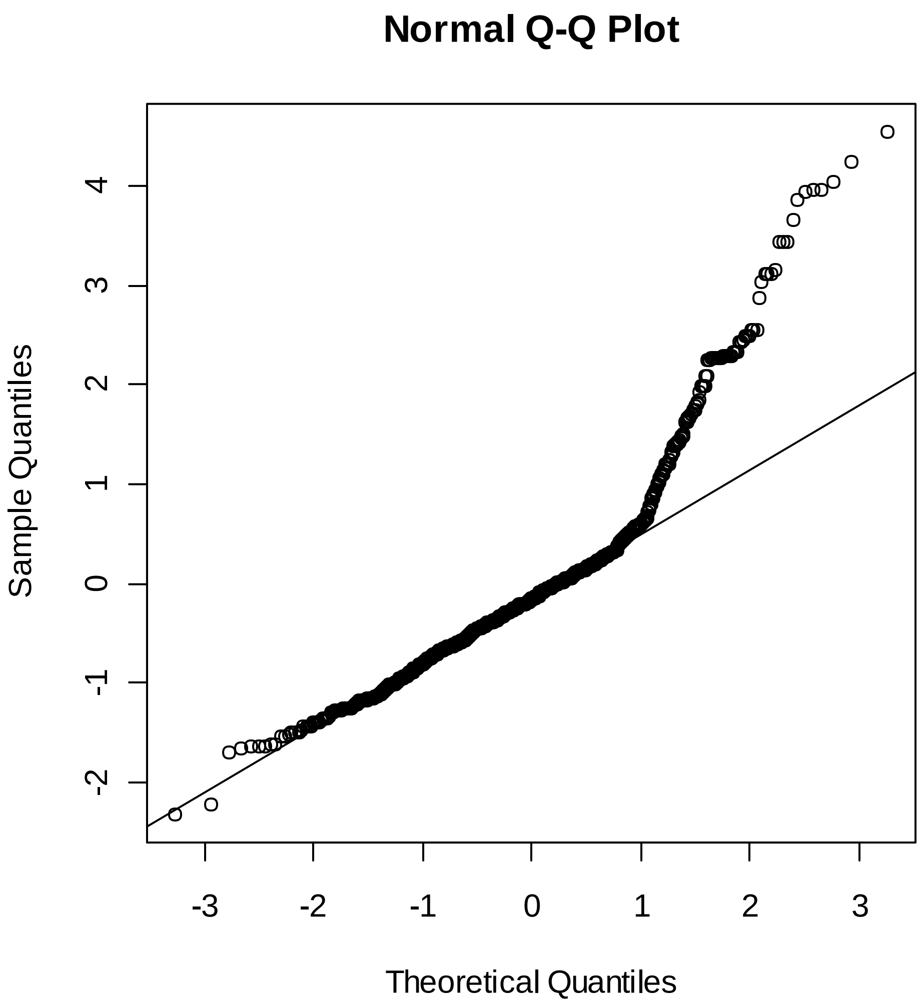

```
# OK it's pretty clear that KP/MZ had higher penetration times than RW Dom in the hot
burns.  And as noted before, 2010 had higher penetration times, 2011 and 2012 are lower.
And 2013 is intermediate.
# It looks like burn severity is unimportant in the RW types, but might be important in
KP/MZ.

# Go back to the Hot/Cool dichotomy



xyplot(log(time3) ~ year | burn.sev2*v3, data=wdpt2.gd, groups=site,
   panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
```

```
        #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
             panel.loess(x,y,span=1)
    }, ylab="Penetration time: logarithm(secs)", xlab=""
)
```

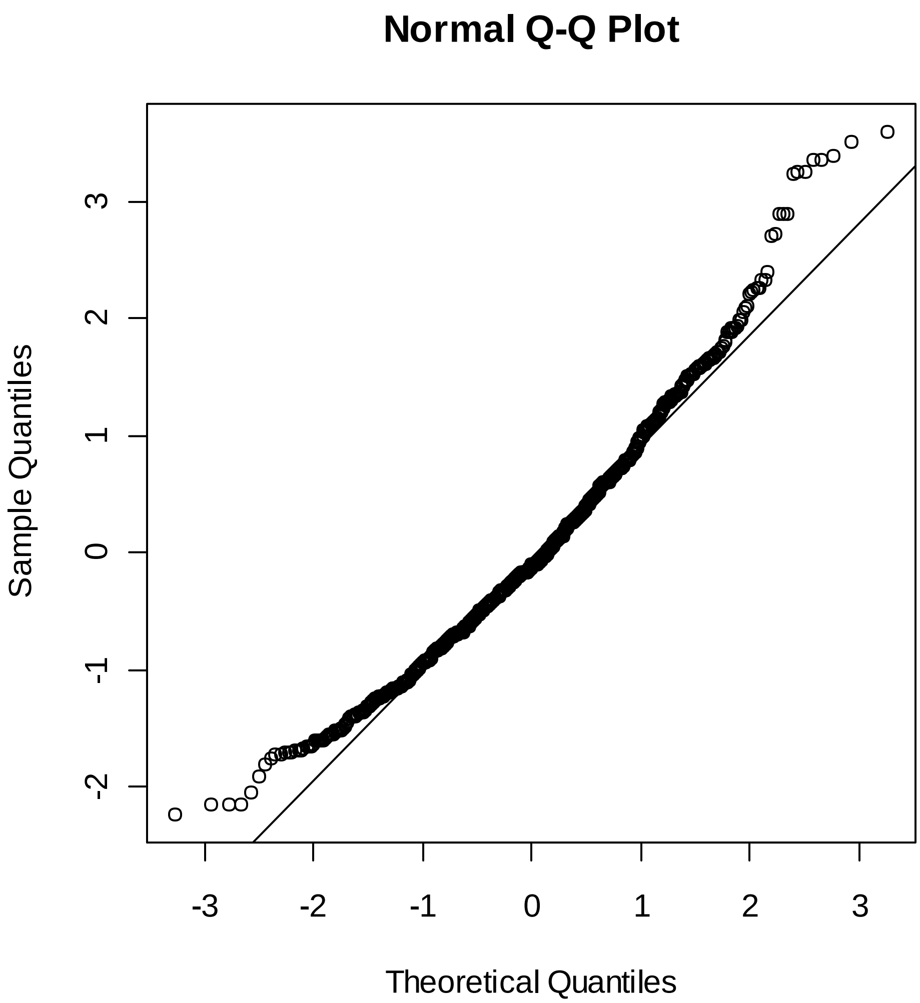



```
================================================================================

table(wdpt2.gd$depth)

  1   2   3
322 255 315

options(contrasts=c("contr.treatment","contr.treatment"))
wdpt2.fit0 <- lme(sqrt(time2) ~ daynum*burn.sev, data=wdpt2.gd, random=~1)
```

```
wdpt2.fit1 <- lme(sqrt(time2) ~ daynum*burn.sev, data=wdpt2.gd, random=~daynum)
Error in logLik.lmeStructInt(lmeSt, lmePars) :
  NA/NaN/Inf in foreign function call (arg 3)
Warning messages:
1: In logLik.lmeStructInt(lmeSt, lmePars) :
  Singular precision matrix in level -1, block 1
# I cannot get a solution with random=~daynum, although that was the best random effects
model in the full data set.  I'm not sure what's causing the error.

anova(wdpt2.fit0,type="marginal")
                numDF denDF   F-value p-value
(Intercept)         1   768 11.635045   7e-04
daynum              1   768 11.244478   8e-04
burn.sev            4    15 10.103408   4e-04
daynum:burn.sev     4   768  9.873789  <.0001
# Everything is significant

wdpt2.fit1 <- update(wdpt2.fit0, ~ . + depth)
                numDF denDF   F-value p-value
(Intercept)         1   767 11.589360  0.0007
daynum              1   767 11.232393  0.0008
burn.sev            4    15 10.083881  0.0004
depth               1   767  0.244772  0.6209
daynum:burn.sev     4   767  9.854759  <.0001
# Depth is not significant

# Best model so far is wdpt2.fit0.

But is the trend linear?  No.  A quadratic would be a much better fit.  Here goes:

wdpt2.fit2 <- update(wdpt2.fit0, ~ . + I(daynum^2))
anova(wdpt2.fit2)
                numDF denDF   F-value p-value
(Intercept)         1   767  39.62613  <.0001
daynum              1   767 172.78062  <.0001
burn.sev            4    15   0.56442  0.6922
I(daynum^2)         1   767 110.69500  <.0001
daynum:burn.sev     4   767   6.67173  <.0001
# Burn severity drops out.

wdpt2.fit2a <- update(wdpt2.fit2, ~ . - burn.sev)
anova(wdpt2.fit2a, type="marginal")
                numDF denDF   F-value p-value
(Intercept)         1   767 112.57020  <.0001
daynum              1   767 109.72151  <.0001
I(daynum^2)         1   767 107.00285  <.0001
daynum:burn.sev     4   767   0.26569     0.9
# And the burn.sev interaction drops out too

wdpt2.fit2b <- update(wdpt2.fit2a, sqrt(time2) ~ daynum + I(daynum^2))
anova(wdpt2.fit2b)
            numDF denDF   F-value p-value
(Intercept)     1   771  47.27846  <.0001
daynum          1   771 167.15880  <.0001
I(daynum^2)     1   771 107.44988  <.0001

qqresid(wdpt2.fit2b)
```



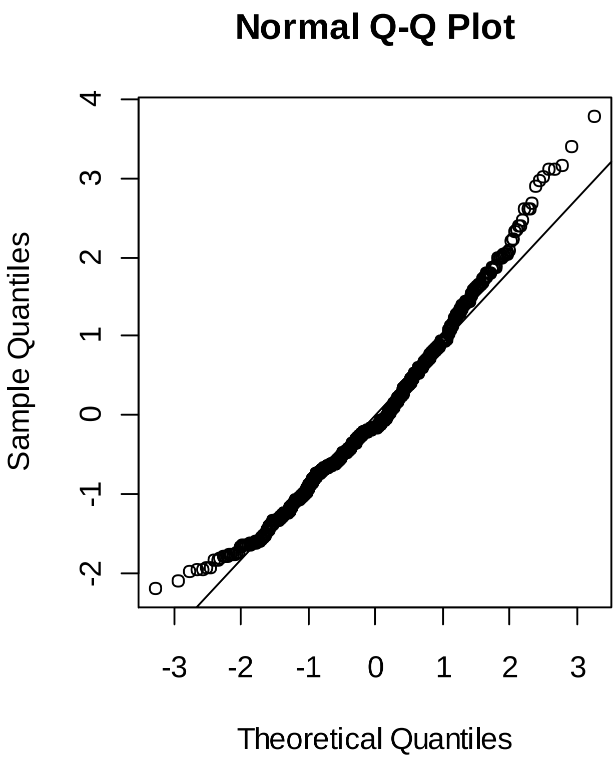

```
# Very bad.  We really cannot trust the significance tests above.
# Try a model with log(response)
wdpt2.fit3 <- update(wdpt2.fit2b, log(time3) ~ daynum + I(daynum^2))
anova(wdpt.fit3)
            numDF denDF  F-value p-value
(Intercept)     1   771  78.2666  <.0001
daynum          1   771 188.0971  <.0001
I(daynum^2)     1   771 331.0722  <.0001
```

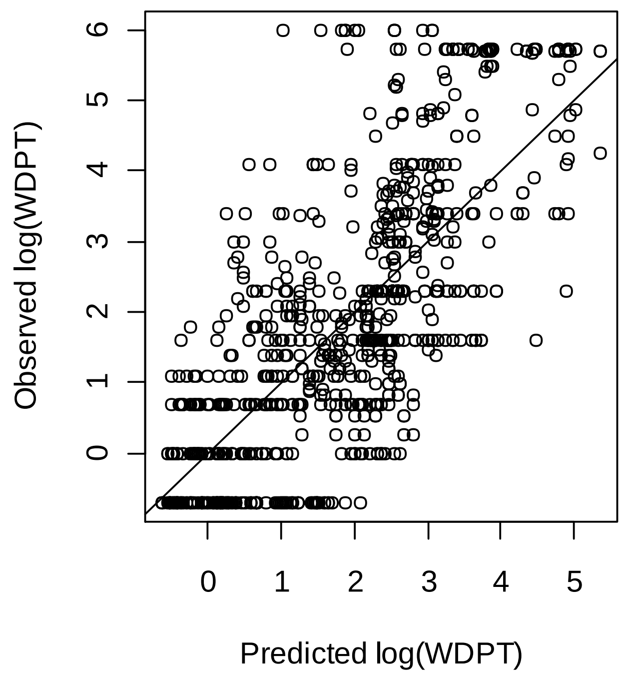



```
# A little better

# See if we can use the same random-effects models we used in the full data set
wdpt2.fit3a <- update(wdpt2.fit3, random= ~daynum)
# Yes, got a solution this time!
anova(wdpt2.fit3,wdpt2.fit3a)
            Model df      AIC      BIC    logLik   Test L.Ratio p-value
wdpt2.fit3      1  6 3218.143 3246.883 -1603.071
wdpt2.fit3a     2 10 3184.253 3232.154 -1582.127 1 vs 2 41.8896  <.0001
# We're good

anova(wdpt2.fit3a)
            numDF denDF  F-value p-value
(Intercept)     1   771  71.5654  <.0001
daynum          1   771  93.4679  <.0001
I(daynum^2)     1   771 342.7361  <.0001

# NOW, look at vegetation
wdpt2.fit4 <- update(wdpt2.fit3a, ~ . + v3*daynum + v3*I(daynum^2))
Error in logLik.lmeStructInt(lmeSt, lmePars) :
  NA/NaN/Inf in foreign function call (arg 3)
```

```
In addition: There were 28 warnings (use warnings() to see them)

# Back to the simpler random effects model
wdpt2.fit4 <- update(wdpt2.fit3, ~ . + v3*daynum + v3*I(daynum^2))

anova(wdpt2.fit4)
               numDF denDF  F-value p-value
(Intercept)        1   769  99.0394  <.0001
daynum             1   769 195.6808  <.0001
I(daynum^2)        1   769 346.7013  <.0001
v3                 1    18   4.8363  0.0412
daynum:v3          1   769   7.7373  0.0055
I(daynum^2):v3     1   769  31.3615  <.0001
# All terms signficant

anova(wdpt2.fit4,type="marginal")
               numDF denDF  F-value p-value
(Intercept)        1   769 56.69346  <.0001
daynum             1   769 54.82295  <.0001
I(daynum^2)        1   769 53.18647  <.0001
v3                 1    18 30.69145  <.0001
daynum:v3          1   769 31.05014  <.0001
I(daynum^2):v3     1   769 31.36150  <.0001
# All terms very significant

# Take another look at burn severity
wdpt2.fit4a <- update(wdpt2.fit4, ~ . + burn.sev)
anova(wdpt2.fit4a)
               numDF denDF  F-value p-value
(Intercept)        1   769  79.7968  <.0001
daynum             1   769 196.2969  <.0001
I(daynum^2)        1   769 345.9304  <.0001
v3                 1    14   3.8549  0.0698
burn.sev           4    14   0.2245  0.9202
daynum:v3          1   769   7.9898  0.0048
I(daynum^2):v3     1   769  30.7475  <.0001
# NOT
# Also cannot test interaction of v3 and burn severity at this point
"Error in MEEM: Singularity in backsolve at level 0, block 1"

# Take a look at the coefficients of wdpt2.fit4
as.data.frame(fixef(wdpt2.fit4))
                     fixef(wdpt2.fit4)
(Intercept)               1.208317e+03
daynum                   -1.548418e-01
I(daynum^2)               4.965975e-06
v3RW Dom                  1.145296e+03
daynum:v3RW Dom          -1.500842e-01
I(daynum^2):v3RW Dom      4.910395e-06
# linear interaction is negative, the quadratic is positive
KP/MZ  1208 - 0.1548d + 4.966e-06d^2
diff   1145 - 0.1501d + 4.910e-06d^2
RWDom  2353 - 0.3049d + 9.876e-06d^2

# Some diagnostics
par(mfrow=c(1,2))
qqresid(wdpt2.fit4)
```

```
plot(fitted(wdpt2.fit4),log(wdpt2.gd$time3),xlab="Predicted      log(WDPT)",ylab="Observed
log(WDPT)")
abline(0,1)
cor(fitted(wdpt2.fit4),log(wdpt2.gd$time3))^2
[1] 0.5631743  # This is the proportion of variance explained by the model
```

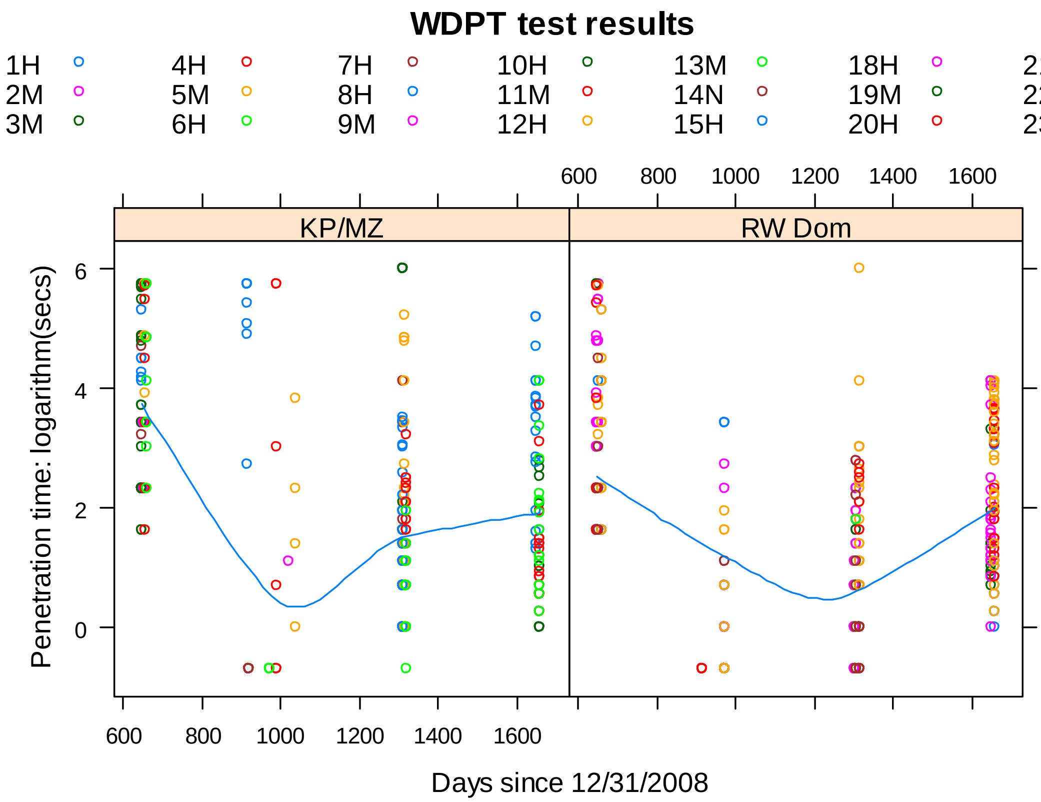




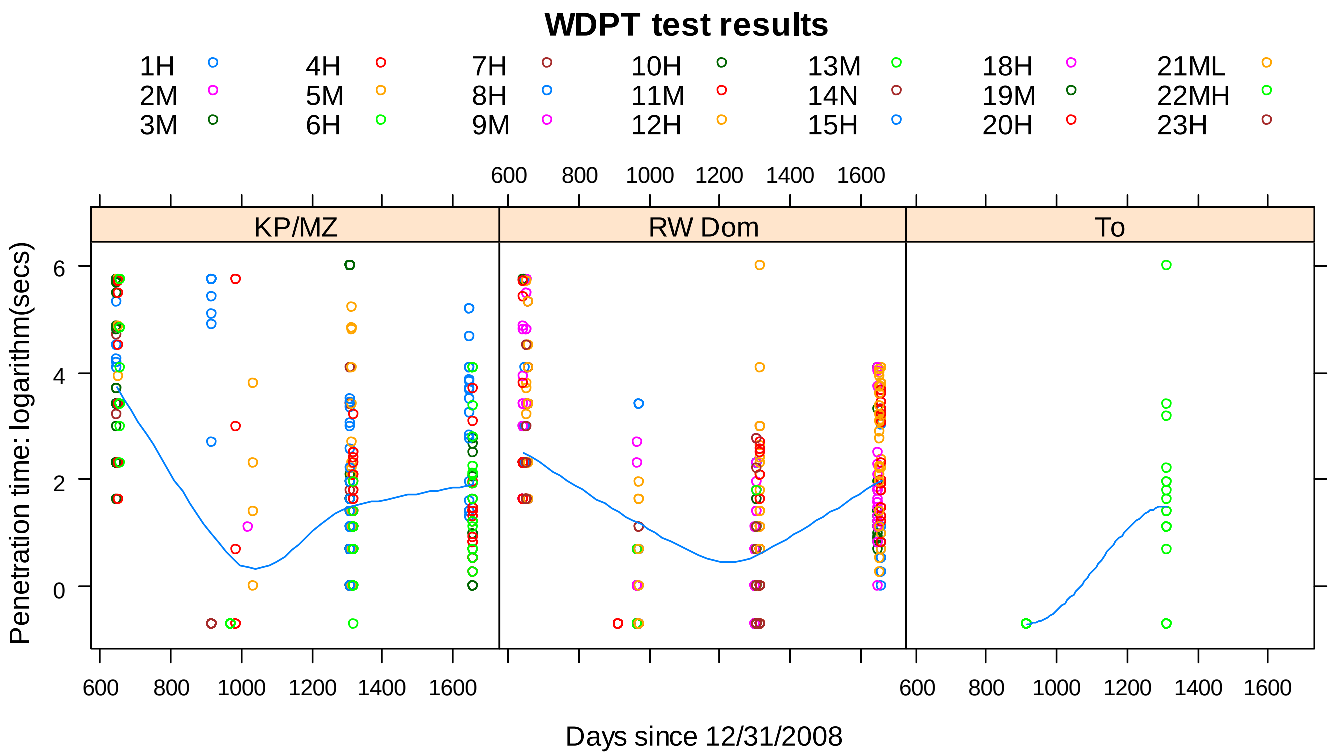

```
# Display the fixed effects in this model
xyplot(log(time3) ~ daynum | v3, data=wdpt2.gd, groups=site, aspect=1, lattice.options =
list(panel.error = "warning"),
 panel=function(x,y, subscripts, groups) {
           panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
           panel.loess(x,y,span=0.8)
       #    had to increase span to eliminate warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```

```
xyplot(log(time3) ~ daynum08 | v3, data=wdpt2.gd, groups=site, aspect=1, lattice.options
= list(panel.error = "warning"),
 panel=function(x,y, subscripts, groups) {
           panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
           panel.loess(x,y,span=0.8)
       #    had to increase span to eliminate warnings
```

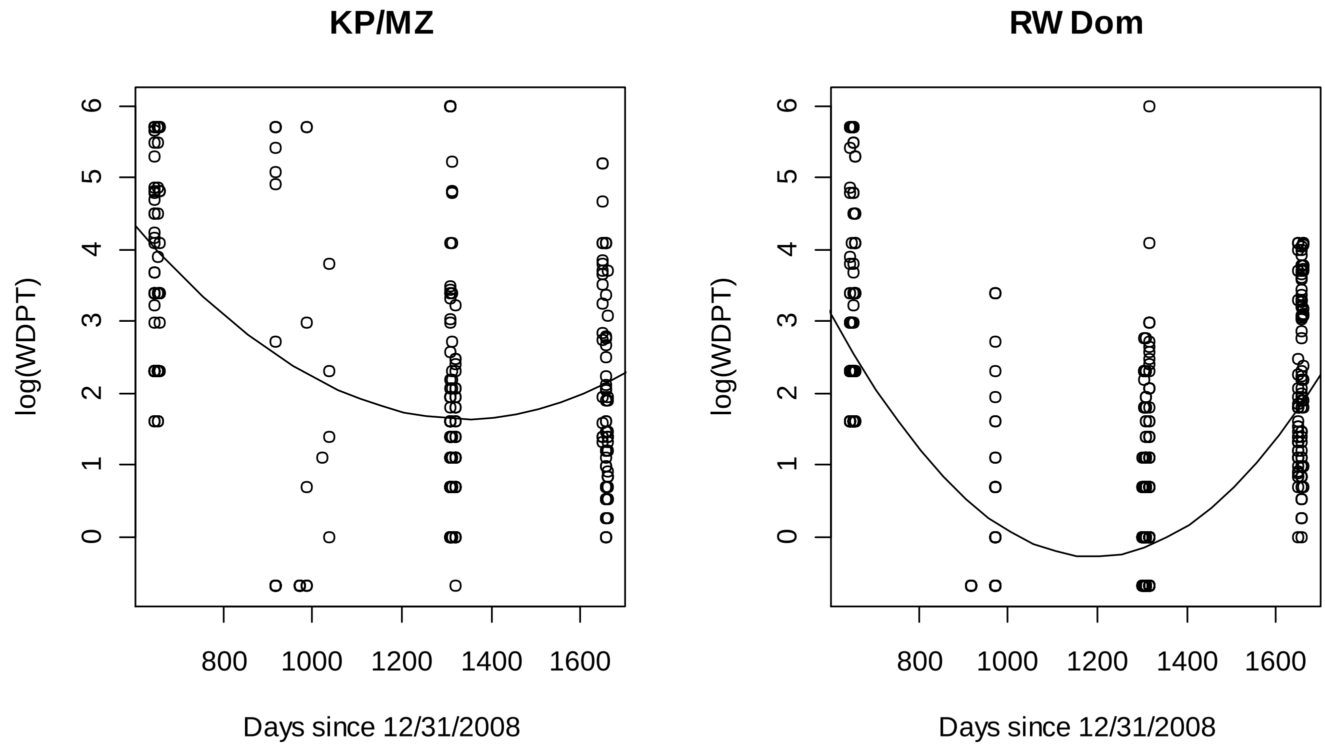
```
   }, ylab="Penetration time: logarithm(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```




```
# For the heck of it include the TO site
xyplot(log(time3) ~ daynum08 | v3, data=wdpt.gd, groups=site, aspect=1, lattice.options =
list(panel.error = "warning"),layout=c(3,1),
 panel=function(x,y, subscripts, groups) {
            panel.superpose(x,y,subscripts,groups, "panel.xyplot")
       #   panel.superpose(x,y,subscripts,groups, "panel.lmline")   fails
            panel.loess(x,y,span=0.8)
       #    had to increase span to eliminate warnings
   }, ylab="Penetration time: logarithm(secs)", xlab="Days since 12/31/2008",
main="WDPT test results", auto.key=list(columns=7)
)
```




```
# That wasn't very helpful.  It looks like the tanoak site is similar to the others in
2012 (third column of points).  Look at the mean WDPT by year and veg type

tapply(log(wdpt.gd$time3),list(wdpt.gd$v3,wdpt.gd$year),mean)[,"2012"]
    KP/MZ    RW Dom        To
1.8391637 0.4149558 1.4472190

# Plot the quadratic curves determined from the model coefficients
KP/MZ  1208 - 0.1548d + 4.966d^2
RWDom  2353 - 0.3049d + 9.876d^2

x0 <- seq(14800,16000,50)
y1 <- 1208 - 0.1548*x0 + 4.966e-06*x0^2
y2 <- 2353 - 0.3049*x0 + 9.876e-06*x0^2
par(mfrow=c(1,2))
attach(wdpt2.gd[wdpt2.gd$v3=="KP/MZ",])
plot(daynum08,log(time3),xlab="Days since 12/31/2008",ylab="log(WDPT)",main="KP/MZ")
lines(x0-14245,y1)
detach(2)
attach(wdpt2.gd[wdpt2.gd$v3=="RW Dom",])
plot(daynum08,log(time3),xlab="Days since 12/31/2008",ylab="log(WDPT)",main="RW Dom")
lines(x0-14245,y2)
detach(2)
```




```
# compute mean of log penetration time by year
tapply(log(wdpt2.gd$time3),list(wdpt2.gd$v3,wdpt2.gd$year),mean)
           2010       2011      2012     2013
KP/MZ  3.715101  1.2349101 1.8391637 1.995007
RW Dom 3.061916 -0.1355711 0.4149558 2.172802
# So penetration times were higher in KP/MZ except in 2013

# Same for untransformed times (truncated at 400 secs)
tapply(wdpt2.gd$time2,list(wdpt2.gd$v3,wdpt2.gd$year),mean)
            2010      2011      2012     2013
KP/MZ  105.70833 64.069767 44.413571 21.53966
RW Dom  70.59028  1.940476  4.938462 17.28056

# We could also have treated year as a categorical variable
wdpt2.fit5 <- update(wdpt2.fit4, log(time3) ~ year*v3)
anova(wdpt2.fit5,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1   767 172.92632  <.0001
year            3   767  71.20616  <.0001
v3              1    18   3.75018  0.0687
year:v3         3   767   9.08867  <.0001

fixef(wdpt2.fit5)
      (Intercept)          year2011          year2012          year2013
        3.7985722        -2.6146990        -2.2867710        -2.0387909
         v3RW Dom year2011:v3RW Dom year2012:v3RW Dom year2013:v3RW Dom
       -0.7545649        -0.5568813        -0.3515950         0.9687823

wdpt2.fit5a <- update(wdpt2.fit4, log(time3) ~ year + year:v3)
```

```
anova(wdpt2.fit5a,type="marginal")
            numDF denDF   F-value p-value
(Intercept)     1   766 172.92632  <.0001
year            3   766  71.20616  <.0001
year:v3         4   766   8.03158  <.0001

fixef(wdpt2.fit5a)
      (Intercept)          year2011          year2012          year2013
        3.7985722        -2.6146990        -2.2867710        -2.0387909
year2010:v3RW Dom year2011:v3RW Dom year2012:v3RW Dom year2013:v3RW Dom
       -0.7545649        -1.3114463        -1.1061599         0.2142174
# this model says the WDPT difference varies by year; WDPT was significantly higher at
the KP/MZ sites every year except 2013.
===================================================================

# Try simple regression models

f0 <- lm(log(time3) ~ v3*daynum + v3*I(daynum^2), data=wdpt2.gd)
anova(f0)
Analysis of Variance Table

Coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)           1.055e+03  1.742e+02   6.056 2.06e-09 ***
v3RW Dom              1.427e+03  2.239e+02   6.371 3.02e-10 ***
daynum               -1.352e-01  2.269e-02  -5.961 3.62e-09 ***
I(daynum^2)           4.342e-06  7.386e-07   5.879 5.84e-09 ***
v3RW Dom:daynum      -1.864e-01  2.916e-02  -6.393 2.63e-10 ***
v3RW Dom:I(daynum^2)  6.084e-06  9.490e-07   6.410 2.36e-10 ***

Residual standard error: 1.512 on 886 degrees of freedom
Multiple R-squared: 0.3874,     Adjusted R-squared: 0.3839
F-statistic: 112.1 on 5 and 886 DF,  p-value: < 2.2e-16
# All terms highly significant despite the low R-squared, which is because the random
effects of site and transect within site are not accounted for.
```