REVISED Final Draft

ODA Fertilizer Research Program Grant

Lower Umatilla Basin (LUB) Soil Moisture Monitoring Project

Prepared for

Oregon Department of Agriculture Fertilizer Research Program

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1 Introduction

The Oregon Groundwater Protection Act of 1989 required the Oregon Department of Environmental Quality (DEQ) to declare a Groundwater Management Area (GWMA) if area wide groundwater contamination, caused primarily by nonpoint source pollution, exceeded certain trigger levels. Because nitrate levels exceeded the Oregon drinking water standard of 7 mg/L in many wells within a 352,000-acre portion of northern Morrow and Umatilla counties, DEQ declared the Lower Umatilla Basin Groundwater Management Area (LUBGWMA) in 1990. Once the LUBGWMA was established, the Groundwater Protection Act required the formation of a local Groundwater Management Committee comprised of affected and interested parties. The Irrigated Ag Sub Committee (IAS) was formed to represent the interests of the agricultural community in the LUBGWMA.

To better understand the impact that general agriculture was having in the LUBGWMA, the IAS applied for and received an Oregon Department of Agriculture (ODA) fertilizer research grant to complete a two-part project. Phase 1 was to complete an independent review of DEQ's statistical interpretation of the data from their groundwater monitoring program. The results of the independent review of the regional monitoring program was presented in the June 2013 *Independent Review of the LUB GWMA Monitoring Program* Report. Phase 2 was to assess water and nitrogen fertilizer migration below the root zone on an irrigated field and attempt to determine to what extent the physical variability of the field affected the rate and level of potential migration.

Phase 2 of the grant included a 2-year soil monitoring program to begin to refine the understanding of the relationship between irrigated agriculture, nitrogen application, and its potential to contribute to groundwater contamination. The monitoring program consisted of instrumentation in three distinctly different locations (dry, average, and wet areas) within an actively managed field that was farmed utilizing a high level of best management practices (BMPs). Monitoring included weather monitoring, soil moisture measurement up to 8 feet below ground surface and nitrogen monitoring via soil samples at different crop stage intervals to evaluate nitrate as nitrogen (NO_3-N) concentrations. This report summarizes Phase 2 of the project.

2 Field Selection

The Lower Umatilla Basin consists of over 180,000 acres of irrigated cropland with a variety of crops grown. The selection of a field for the 2-year soil monitoring program was led by the IAS and required voluntary grower participation in the project. With several potential locations identified, the IAS used the following criteria to assess and ultimately come to consensus on a field to conduct the 2-year soil moisture measurement study. The criteria included:

a) Location, Farm Size, and Irrigation Method
b) Best Management Practices (BMP's)
c) Crop Rotation
d) Soil Type and Elevation
e) Source water and Groundwater Nitrate Concentrations

The field that fit all criteria was a 128-acre, irrigated circle located in the central part of the LUBGWMA. The chosen field was labeled "Field R". Figure 1 shows a map of the Lower Umatilla Basin and the location of Field R.

Location and Farm Size. Field R is part of a large-acreage commercial farming operation. The IAS recruited a large-acreage landowner to better represent the farming demographic in the LUBGWMA. Water is supplied to this field via a commercial irrigation system and is supplemented by groundwater irrigation wells. Irrigation water is applied to Field R by a center pivot that is on a telemetry system and can be monitored remotely for pressure issues.

BMP's. When designing this study, the IAS believed that this investigation would be the most effective if completed on a test site that was actively managed using a high level of best management practices (BMP's). Those BMP's included:

> a) Scientific Irrigation Scheduling (SIS) - Scientific Irrigation Scheduling can allow growers to make irrigation decisions by using soil moisture monitoring, weather station data and crop-specific evapotranspiration. (Energy Trust of Oregon, year unknown)
>
> b) Soil Sampling - Collecting soil and having it analyzed to determine nutrient content, composition, and other characteristics. (Wikipedia, 2017)
>
> c) Nutrient Management Programs - Field and crop-specific plans that specify how much commercial fertilizer or other nutrient sources can be safely applied to achieve yields and prevent excess nutrients from leaching. (Maryland Department of Agriculture, year unknown)
>
> d) Integrated pest management (IPM) – The carefully managed use of an array of pest control tactics – including biological, cultural, and chemical methods – to achieve the best results with the least disruption of the environment. (EPA, 1993).

These BMP's are commonly practiced by growers in the LUBGWMA already. Making this a condition of the study should provide the highest probability of developing meaningful results for future use by the IAS and DEQ.

Crop production scheme for field selected for the research.

There were two cash crops grown on Field R during the two years of this study. Onions were the cash crop in 2015 and carrots in 2016. Ground preparation for both cash crops was similar and included:

- deep ripping to break up soil compaction layers

- tilling or disking to form a good seed bed and incorporate nutrients into the soil

- applying pesticides, herbicides or fungicides as needed to control pest populations.

- utilization of a non-growing season cover-crop to prevent soil erosion by wind or rain. Irrigation and nitrogen fertilizer was applied as-needed to the cover crop for crop health.

- Prior to planting the cash crop, portions of the cover crop were killed by selectively spraying the area to be seeded and tilling the sprayed portion approximately two to four inches deep to make the final seed bed. The remainder of the cover crop then continued to grow for erosion protection until the cash crop was large enough to provide the protection itself.

Main cash crops were planted during a time that was appropriate for the selected variety and anticipated harvest date. Planting was also timed on availability of water from the irrigation source. The Columbia River water source is regulated so that water is not generally available until March. Onion planting generally starts about this time while carrot planting begins later in the growing season.

Nitrogen fertilizer was applied to onions through the irrigation system (fertigation) as needed to maintain adequate nitrogen levels in the rooting zone. Onion fertigation needs were based on weekly soil sample results. Soil sampling for carrots may be more or less frequent than onions and chemigation could vary depending on grower experience. All nitrogen applications generally continued until the crop was mature enough to finish development without added nutrients. It is important to note that the fertilizer nitrogen applied during the early part of the cash crop growing season also accounts for the nutrient needs of the remaining cover crop. Onion and carrot crops cannot be effectively grown on sandy soils without an effective cover crop.

The irrigation system was also used to convey insect and disease control measures (chemigation) to the field for both cash crops. Because of this, irrigation could occur at a time when ET or other factors indicated water was not needed for optimum crop growth. Pest control measures through chemigation are generally applied using small amounts of water and do not contribute to excessive water applications. These applications are considered in the overall irrigation scheme and growers usually monitor the soil moisture in the root zone so as not to drive water below this level.

For onions, irrigation was reduced during maturation of the crop and stopped two weeks to as much as one month prior to harvest depending on the variety and use of the crop. Soil moisture was maintained at a higher level late in the season for carrots to keep them from drying out and losing moisture prior to harvest. The optimum soil moisture level for these crops during the primary growth phase is between 85% and 95%. It is difficult to maintain these soil moisture levels with center pivot systems on sandy soils like Field R. Therefore, soil moisture levels often fluctuated from field capacity as the system passed over a monitoring site to below 75% prior to the next irrigation.

Crop Rotation. A typical crop rotation in the LUBGWMA consists of a high value row crop (potatoes, onions etc.) followed by a few of years of rotational crops (corn, wheat, alfalfa, peas, etc.). Crop rotation data for the past 10 years for Field R was:

2005	Field Corn
2006	Potato
2007	Onion
2008	Peas/ Sweet Corn
2009	Peas/ Sweet Corn
2010	Potato
2011	Onion
2012	Field Corn
2013	Potato
2014	Grass / Beans

2015	Onion
2016	Carrots

Highlighted years part of soil moisture monitoring program

Cropping decisions are based on market conditions, the availability of resources such as seed, fertilizers and/or water and other factors. Additionally, agricultural land ownership is consolidating within the LUBGWMA. Large landowners frequently lease their field to other growers. The owner of Field R leased it to other growers for both years of the study.

Soil Type and Elevation. The Lower Umatilla Basin consists of varying soil types ranging from course sand to silt loams. When deciding on the field, the IAS wanted it to represent the major soil types in the area. After reviewing the USDA NRCS Soil Survey Data, the dominant soil type in the LUBGWMA is Quincy Loamy Fine Sand. Field R is classified in the survey to be 100% Quincy Loamy Fine Sand (Figure 2).

Field R is relatively flat with only a 30-foot elevation change across the 128-acre circle. Figure 3 shows the Contour Map of Field R. The elevations range from 480 feet at the northern most corner of the field to about 510 at the southern part of the field.

Source Water and Groundwater Nitrate Concentrations. Field R is irrigated primarily with Columbia River Water which is very low in nitrogen. The irrigation system is a center pivot with drop sprinklers that apply approximately 8 gallons per minute per acre. The 1995 LUBGWMA Report showed that nitrate concentrations in groundwater wells near Field R were 25 to 30 mg/L. In 2014, the concentrations were approaching 50 mg/L

3 Monitoring Program

The monitoring program approved by the IAS and ODA included:

- Soil Moisture
- Irrigation and Weather Data
- Fertilizer Application Timing and Amounts
- Soil Nitrate Sampling

Soil Moisture Monitoring

Sentek™ Technologies EnviroSCAN™ Screw Cap capacitance soil moisture probes were installed in the three designated locations within Field R as shown on Figure 3. The three locations selected were intended to represent a dry area, an average area, and a wet area within the field and were labeled:

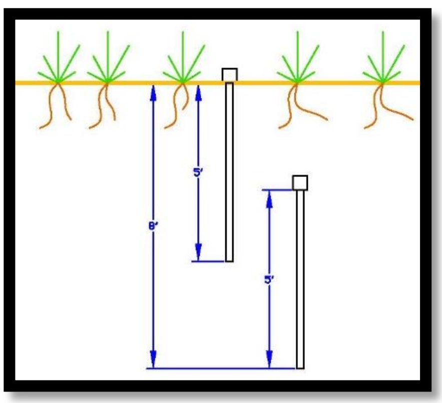
- R-1 – Dry
- R-2 – Wet
- R-3 – Average

Topography was utilized to determine the location of the three sites. The "Dry Area" was installed at a high elevation point in the field. The "Average Area" is relatively flat and represents an average (or mid-slope) elevation in the field. The "Wet Area" is a small depression in the field that runs generally north and south and is a topographic low spot.

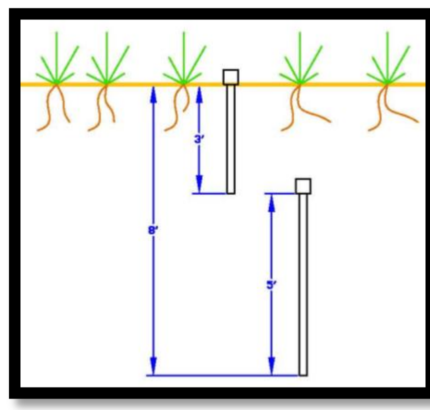
Monitoring site R-1 consisted of a shallow probe that measured from ground level to five feet deep and monitoring sites R-2 and R-3 shallow probes were ground level to three feet deep. All three sites had a sub-surface deep probe installed to monitor the lower depths in the soil profile (four feet to eight feet). All probe boreholes were dug using AMS, Inc. non-powered soil augers with a 1 -7/8 inch outside diameter soil bucket and 6-foot extension. The location of each probe site (shallow and deep) was recorded with a Javad GNSS Triumph-1 Base Rover Set using the real time kinematic technique (RTK) for high accuracy.

To install the deep probes, the top three feet of the soil profile was mechanically removed and the probe boreholes were dug using the non-powered soil auger. Once each probe was installed, the soil was replaced. The deep probes were below the tillage layer and remained installed for the entire 2-year monitoring period. Because of concerns due to the soil disturbance and the possibility of preferential pathways being created during installation of the deep probes, a longer shallow probe was installed at site R-1 and overlapped the deep probe by two feet. Data from the overlapped portion of the soil profile was compared to assess soil probe installation techniques. The probe configuration at each of the 3 sites is illustrated below:

Probes installation at R-1.



Probe installation at R-2 and R-3.



The GPS coordinates for each site are listed in Table 1. The specific depths of the soil moisture sensors used at each location are presented in Table 2. Soil moisture data was recorded every 30 minutes and sent wirelessly to IRZ servers.

The shallow probes (zero to five feet at R-1 and zero to three feet at R-2 and R-3) were removed prior to planting or harvesting of a crop and reinstalled following establishment of the new crop. The 2015 shallow probe installation and removal timeline is as follows:

2015 Growing Season – Shallow Probe Installation/Removal	
Initial installation in cover crop	December 12, 2014
Removal in spring prior to planting onions	March 17, 2015
Onions Planted	March 25, 2015
Probes installed into onions	May 22, 2015
Removal prior to onion harvest	July 22, 2015

Onion harvest	July-August 2015
Install after onion harvest, field tillage and winter cover grain crop was planted.	October 16, 2015

There are gaps in the shallow probe data. During the winter of 2014/2015, freezing weather caused sensors to malfunction until soils thawed out. On March 17, 2015, the shallow sites were pulled so onions could be planted. The onions were planted on March 25, 2015 and the grower did not want the shallow sites re-installed until the crop was dammer-diked and chemical applications were completed. The shallow probes were re-installed on May 22,2015.

The shallow probes were pulled prior to onion harvest on July 22, 2015. The onions were harvested and a cover-grain crop was planted. Probes were installed on October 16, 2015. When the probes were installed, the technician returned to the same GPS coordinates and installed the shallow probes in the same boreholes from the previous installation. This is not a recommended practice as the probes require a snug fit to accurately measure soil moisture and need to be installed in a new borehole every time. The shallow probes were reinstalled approximately a foot away into new boreholes.

For 2016, the shallow probe timeline is as follows:

2016 Growing Season – Shallow Probe Installation/Removal	
Probes installed into 2015/2016 winter cover-grain crop	October 16, 2015
Removal prior to planting carrot crop	April 25, 2016
Carrot crop planted	May 25, 2016
Installed probes into carrot crop	June 21, 2016
Removal prior to harvesting carrot	August 30, 2016
Carrot harvest	September 2016
Install after carrot harvest, field tillage and cover crop planting	October 21, 2016
End of Project - removed shallow and deep probes	December 5, 2016

In Spring 2016, there was an unanticipated delay in planting the carrot crop. Once the crop was planted and established, growers utilized an inter-row ripper to open the soil and create tillage reservoirs. This improves each plant's access to moisture, nutrients, temperature and air. The carrot grower requested that the shallow probes not be installed until ripping was completed. The probes were re-installed into the carrot crop June 21, 2016.

The deep probes were installed 3 feet below grade in December 2014. Since they were below the tillage line and unaffected by surface activities, they remained in place throughout the entire 2-year data collection period. Appendix C contains high resolution soil moisture graphs that are divided into four-month time periods for easier viewing.

Irrigation and Weather Data

Irrigation data was collected at each site (R-1, R-2 and R-3) using in-field electronic rain gauge sensors. The total amounts applied differed due to the variation in water application and timing of when water was applied. The irrigation and precipitation data annual totals are summarized in Table 3 and the daily precipitation and irrigation totals are shown on the graphs in Figures 4, 5, and 6.

Weather data for Phase 2 was collected from an existing IRZ weather station that is located approximately 150 yards northeast of Field R. This real-time weather station continuously monitors weather data and transmits the data wirelessly to IRZ servers every half hour. The United States Bureau of Reclamation has an AgriMet Weather Station (HERO) located approximately 4.7 map-distance miles from Field R. The decision was made to utilize the IRZ weather station due to its proximity to Field R and ability to represent the micro-climate. For the purposes of this study daily maximum temperature, minimum temperature, dew point, precipitation, wind speed and solar radiation were collected and used.

Temperature is an important metric for agriculture. Many organisms such as plants, insects and plant pathogens do not have a complex thermoregulatory system. For them to continue to develop physiologically, upper and lower temperature thresholds must not be exceeded. Growers monitor the ambient air temperature and make crop management decisions based on that data (for example, using irrigation to cool a crop if upper threshold limits may be exceeded). Also, minimum and maximum air temperature are used to calculate growing degree days (GDD). GDD is used to estimate crop growth stage and pest/pathogen development rates.

Humidity affects the ability of both plants and animals to cool themselves through evaporation and is also an important factor in precipitation formation. Humidity measures the amount of water vapor in the atmosphere and a high-water vapor content is necessary to produce clouds and precipitation. Relative humidity and dew point are the two main ways to describe humidity. Dew point measurements are taken at the IRZ weather stations as it is a more reliable indicator because it doesn't fluctuate with changes in air temperature and doesn't change much through the course of a day. It is an important metric for growers for predicting condensation on leaf surfaces and subsequent disease progression.

Precipitation amounts from the weather station were used to determine how much irrigation was applied. Each site (R1-Dry, R2-Wet and R3-Average) had in-field, real-time rain gauges installed to record the total amount of water that was received by the crop in that zone. To determine irrigation amounts, the precipitation values from the IRZ weather station were subtracted from the total amounts recorded by the in-field rain gauges, giving a more complete picture of the hydraulic loading at each site in Field R.

Growers are dependent on wind speed and direction data for many crop management decisions. Wind speed and direction data is utilized when deciding to apply fertilizers or pesticides to a crop. High wind speeds during application could cause these products to 'drift' off the field, wasting resources or potentially damaging adjacent crops. Wind can also influence irrigation decisions. If a crop is immature or has just been planted and wind speeds increase, irrigation might be required to keep soils in place. Excessive wind also dries soil out and needs to be considered when formulating an irrigation plan.

Solar radiation provides energy for the metabolic processes of the plants. It primarily aids in photosynthesis but also affects evapotranspiration processes of the plant. The productivity and yield of a crop depends on the ability of plants to intercept solar radiation so most production strategies are directed at optimizing healthy plant canopy development.

2015 was a year with above average temperatures and dry conditions. When compared with the AgriMet HERO historical 10- year averages, the 2015 average maximum temperatures between February and June were above historical averages and there were 23 days during the year that the temperature exceeded 100F. High temperatures can affect the crop by increasing disease and pest pressure as well as driving up evapotranspiration rates resulting in increased irrigation demand.

The average rainfall from March to October was below normal, except for the month of May, where there was a one-day precipitation event of 1.2 inches. Precipitation for the year was 6.82 inches, 1.36 inches less than the 10-year average of 8.18 inches. Some irrigators had to shut down earlier than normal or ration water in 2015. The system that supplied most of the irrigation water to Field R was operational for the duration of the growing season.
2016 was cooler and had more precipitation than 2015. Only five days exceeded 100F in 2016. The carrot crop was planted at the end of May and ambient air temperatures were high enough to protect the carrots from freezing.

Precipitation occurred mostly in the winter and spring months with very little rain during the growing season. October 2016 was the wettest month of the year with 1.76 inches of precipitation. Total annual precipitation was approximately 7.54 inches compared to the 10-year average of 8.18 inches.

Fertilizer Applications

The quantity, type and date of fertilizer applications was recorded by the respective growers and voluntarily provided to the project team at the end of each season. Fertilizer applications are summarized in Table 4 and the growers' datasheets are provided in Appendix A.

Nitrate Sampling

Soil samples at each of the three sites in Field R were collected using a non-powered hand auger and tested for nitrate at various times during the 2-year period. Baseline soil samples were collected during the installation of the probes in December 2014 and were collected at one-foot intervals to a depth of eight feet. These samples were analyzed for Nitrate-Nitrogen, TKN and pH. Additional soil samples from the first, third and fifth foot were collected at each of the three sites during the crop growing seasons and analyzed for Nitrate. A final set of soil samples were collected from each site at one-foot intervals down to eight feet at the end of the project in December 2016. The soil samples for each site were collected from one specific horizontal location and vertical interval (discrete sampling).

The onion grower collected nitrate soil samples during the growing season. These sample results are provided for reference but were not utilized in the analysis because they were not at the depths defined in the scope of the study. All soil sample results are summarized in Tables 5, 6, 7, and 8 and copies of the original laboratory reports are in Appendix B.

Irrigation Water. During the study, one irrigation water sample was collected from the irrigation system for Field R and tested for nitrate. The result was 4.4 milligrams per liter of nitrate as nitrogen in the irrigation water. This sample was utilized to estimate the amount of nitrogen that was supplied to the crop from fresh water irrigation for both years of the study. The laboratory report is presented in Appendix B.

4 Results & Analysis

Nitrogen and Hydraulic Loading

IRZ engineering staff determined the percentage of Field R that fit either the R1-Dry, R2-Wet or R3-Average categories. Using these percentages, acres were estimated:

Site	Percentage of Field	Approximate Acres
R1-Dry	43%	55.04
R2-Wet	15%	19.20
R3-Average	42%	53.76
Total Field R	100%	128.00

In field rain gauge data was used to determine total hydraulic loading to each site. Precipitation amounts from the IRZ weather station was subtracted from the in-field rain gauge data to determine net irrigation values. Crop water use (also known as crop specific ET) was calculated using data from the IRZ weather station.

Nitrogen and hydraulic summaries were developed to present the data collected in this study (Tables 9-23). These reports summarize irrigation and precipitation amounts, estimate nitrogen loading from fresh water, summarize commercial nitrogen fertilizer applications and show crop specific evapotranspiration (ET) rates. Data is displayed monthly and totals at the bottom of the columns are for the crop cycle. The results of the soil samples are also included.

The nitrogen and hydraulic loading summary reports do not include data from the real-time soil moisture probes. The soil moisture probe data for R1-Dry is in Figure 4, R2-Wet is Figure 5 and R-3 Dry is Figure 6. High resolution moisture graphs can be found in Appendix C.

2014/2015 Cover Crop

Cover crops are planted to reduce or eliminate soil erosion during the non-cropping time of year. The cover crops are not harvested but instead incorporated into the field to help improve soil organic matter and add nutrients that would later be available to the next crop. Although cover crops do grow and utilize water and nutrients during the winter months, crop specific ET's were not calculated.

In-field rain gauges and soil moisture monitoring equipment was installed on December 12, 2014 at all three sites. The 2014/2015 cover crop was planted in the fall of 2014 and had been established prior to the start of this study. Baseline soil samples were taken at all three sites on December 12, 2014 and results are in Table 5. Between December 12, 2014 and March 24, 2015, 4.24 inches of precipitation were collected at the IRZ Weather Station. A 60 pound per acre commercial fertilizer application was applied to Field R in February prior to the planting of the main cash crop. Fresh water irrigation was not available until March 10, 2015. Also in

March, a portion of the cover crop was killed with an herbicide and the remainder left in strips to protect the soil and upcoming onion crop from wind erosion.

Site specific data for R1- Dry (Table 9), had 64 pounds of nitrogen available for the cover crop in the top three feet of soil based on the soil sample collected at the start of the study. From March 10, 2015 to March 24, 2015, the ground was irrigated to prepare it for the next crop. 0.03 pounds of nitrogen was added from fresh water irrigation. Site R2- Wet (Table 10) had 72 pounds of crop available nitrogen per acre and 0.08 pounds of nitrogen from fresh water. R3-Average had 65 pounds of nitrogen in the root zone and 0.03 pounds of nitrogen from fresh water.

2015 Onions

Onions are a high value crop in the LUBGWMA. Field R was leased to a large corporate farm that only grows onions. The crop was planted on March 25, 2015 and harvest was completed by July 31, 2015. The study scope did not include a pre-plant soil sample for the onion crop. The IAS felt that a pre-plant soil sample was not relevant because the cover crop was not completely terminated. Portions of it are left in place to protect the soil and onion crop from wind erosion. The grower, as part of their BMP's, collected their own pre-planting soil samples and soil sampled the field weekly throughout the season. They used the results of these samples for fertilizer application decisions. The grower nitrogen soil sample results are summarized in Tables 6, 7 and 8. They were not utilized in the data analysis but do illustrate a BMP that growers in the LUBGWMA generally utilize for crop management.

According to *Nutrient Management Guide for Onions in the Pacific Northwest*, onion crop nitrogen uptake ranges from 0.14 to 0.24 pounds per cwt fresh bulb yield. The root zone for onions is the top two feet of the soil profile. Fertilizer records show that 82 pounds per acre of commercial nitrogen fertilizer was applied to all of Field R for the onion crop. The formulation of the commercial fertilizer product is CN9 and contains approximately 9.0% total nitrogen (8.42% nitrate nitrogen and 0.58% ammonia nitrogen).

The scope of the study required the shallow soil moisture probes to be removed prior to planting the crop. Once the crop was established, the probes would be re-installed. The shallow probes were removed March 17, 2015 and re-installed on May 22, 2015. The shallow soil moisture probes were removed July 22, 2015 for harvest. The in-field rain gauges and the deep soil moisture probes remained in the field through the study and were never removed.

From March 25, 2015 to July 31, 2015, the onions in Field R utilized 24.89 inches of water for growth and evapotranspiration (ET). Field R received 1.64 inches of precipitation. A significant precipitation event occurred on May 13, 2015 when 1.2 inches of precipitation was recorded at the IRZ weather station.

Irrigation amounts varied for each site. R1- Dry totaled 24.52 inches of water applied as irrigation from March 25, 2015 to July 31, 2015. Site R2-Wet totaled 25.00 inches of irrigation and R3-Average totaled 23.83 inches of irrigation. Nitrogen that was added from irrigation water was minimal with approximately 0.44 pounds per acre at sites R1-Dry and R3-Average and 1.3 pounds per acre at R2-Wet.

Post-harvest soil samples were collected from all three sites on August 31, 2015 and analyzed for nitrate-nitrogen in the first, third and fifth foot. R1-Dry nitrate-nitrogen was 22 pounds per acre in the first foot, 10 pounds per acre in the third foot and 25 pounds per acre in the fifth foot. R2-Wet had 55 pounds per acre nitrogen in the first foot, 37 pounds per acre nitrogen in the third foot and 30 pounds per acre nitrogen in the fifth foot. R3-Average first foot nitrogen was 37 pounds per acre, third foot nitrogen was 19 pounds per acre and fifth foot nitrogen was 9 pounds per acre.

The nitrogen and hydraulic summaries for the 2015 onion crop are in Table 12 for R1-Dry, Table 13 for R2-Wet and Table 14 for R3-Average.

2015/2016 Cover Crop

For the 2015/2016 cover crop, irrigation was used for cover crop establishment, chemigation and field prep for the 2016 carrot crop. Irrigation was applied August 1, 2015 through October 21, 2015 for cover crop establishment. The fresh water irrigation system was shut-down for the season and was not available until March 5, 2016. Pre-plant soil fumigation for the carrot crop occurred in March 2016. Fumigation is an important practice for the suppression and control of soil parasites, soil-borne diseases, insects, weeds and germinating weed seeds. The fumigation chemical was injected into the irrigation water and applied to Field R using the center pivot irrigation system. Irrigation applied from May 1, 2016 through May 24, 2016 was to prepare the ground for planting the carrot crop on May 25, 2016. For Site R1-Dry, 10.49 inches of irrigation was applied August 1, 2015 through May 24, 2016, site R2-Wet received 12.14 inches of irrigation and R3-Average totaled 9.49 inches of irrigation. Total precipitation from August 1, 2015 to May 24, 2016 was 6.88 inches for Field R. No crop specific ET was recorded for the 2015/2016 cover crop.

The shallow soil moisture probes were installed on October 16, 2015 after the cover crop was established. The 4-inch soil moisture sensor at Site R1-Dry malfunctioned due to freezing weather from November 28, 2015 to December 2, 2015 and January 2, 2016 through January 7, 2016. Site R2-Wet and R3-Average soil moisture sensors remained functional during the freezing weather. All shallow probes were removed April 25, 2016 at the request of the carrot grower. In-field rain gauges and deep soil moisture probes remained in place.

The post-harvest soil samples for onions taken August 31, 2015 at sites R1-Dry, R2-Wet and R3-Average were used as the pre-plant soil samples for the 2015/2016 cover crop. Winter soil samples were taken on December 11, 2015 at each site and R-1 Dry first foot nitrate-nitrogen was 5 pounds per acre, third foot 9 pounds per acre and fifth foot 28 pounds per acre. R2-Wet had 3 pounds per acre nitrate-nitrogen in the top foot, 7 pounds per acre nitrogen in the third foot and 39 pounds per acre nitrogen in the fifth foot. R3-Average had 3 pounds of nitrate-nitrogen in the first foot, 14 pounds of nitrogen in the third foot and 26 pounds of nitrogen in the fifth foot.

Commercial nitrogen was applied to Field R in the form of compost in preparation for the carrot crop. As an already-stabilized material, compost is more useful for improving long-term soil quality and nutrient supply than as an immediate source of nutrients. A certified fertilizer report was provided from the grower that showed 135.43 pounds per acre of nitrogen was applied to Field R via compost. There is approximately 10% of the nitrogen readily available from the compost and the remainder is slowly released during the season. Most reports suggest approximately 40% of the organic nitrogen from compost may be released over the course of the first growing season after application. The compost was applied on May 7, 2016 and the carrot crop was planted May 25, 2016. The net amount of available nitrogen to the cover crop would be minimal due to the timing of the application.

Nitrogen applied to the crop from fresh water continued to be low. From August 1, 2015 to May 24, 2016 site R1-Dry had an estimated 0.19 pounds of nitrogen per acre from irrigation water, R2-Wet had 0.63 pounds of nitrogen from irrigation and R3-Average had 0.55 pounds per acre of nitrogen from irrigation.

The cover crop was incorporated into the soil and not harvested. The nitrogen and hydraulic summaries for the 2015/2016 cover crop are in Table 15 for R1-Dry, Table 16 for R2-Wet and Table 17 for R3-Average.

2016 Carrots

For the 2016 growing season, Field R was leased to a carrot grower. Data that was provided by this grower included crop plant and harvest dates and commercial fertilizer applied. No other data about crop management practices, additional sampling or yields was volunteered. A guidance document written by Delbert Hemphill and published by Oregon State University for growing carrots in Eastern Oregon was relied upon for this crop analysis.

According to Hemphill, the Quincy Loamy Fine Sand soil type in Field R combined with the long growing season and a harvest period relatively free from rain is likely to produce high carrot yields and quality. The soil type does not affect the amount of total water needed for the crop but does dictate the frequency of water application. Soil types like Field R need more frequent water applications, but less water applied per application.

Hemphill further recommends that nitrogen loading for carrots in Eastern Oregon be between 80 to 150 pounds per acre. The grower applied approximately 135 pounds of commercial nitrogen in the form of compost and incorporated it into the soil on May 7, 2016, prior to planting the carrots on May 25, 2016. There is approximately 10% of the nitrogen readily available from the compost at the time of application and the remainder is slowly released during the season. Most reports suggest approximately 40% of the organic nitrogen may be released at some time during the first growing season after compost application. Therefore, the net amount of available nitrogen to the carrot crop was about 67.5 pounds from compost. In addition to the compost, commercial nitrogen fertilizer was applied to the carrots in the form of a urea and ammonium nitrate solution that was applied in June, July and August of 2016 for a total of 87.67 pounds.

Carrots were a short season crop that was planted on May 25, 2016 and harvested August 30, 2016. The carrots in Field R utilized 23.66 inches of water for growth and evapotranspiration (ET) and received 0.84 inches of precipitation during this time. The shallow soil moisture probes were installed June 21, 2016 after crop establishment and inter-row ripping was completed. The shallow probes were removed August 30, 2016 for crop harvest.

Irrigation amounts varied for each site. R1- Dry totaled 23.70 inches of water applied as irrigation from May 25, 2016 to August 1, 2016. Site R2-Wet totaled 20.79 inches of irrigation and R3-Average totaled 19.77 inches of irrigation. Nitrogen that was added from irrigation water was minimal with approximately 0.43 pounds per acre at site R1-Dry, 1.08 pounds per acre at R2-Wet and 0.37 pounds per acre at R3-Average.

The pre-planting soil samples were taken April 26, 2016. Crop establishment soil samples were taken June 22, 2016 and peak growth samples were taken August 22, 2016 just before the carrot harvest. All samples were analyzed for nitrate-nitrogen in the first, third and fifth foot. The results are:

Date	4/26/2016	6/22/2016	8/22/2016
Site R1-Dry			
Depth	**Pre-planting**	**Establishment**	**Peak Crop Growth**
NO3-N in ft 1 (lbs/ac)	24	183	16
NO3-N in ft 3 (lbs/ac)	2	18	22
NO3-N in ft 5 (lbs/ac)	13	28	11
Site R2-Wet			
Depth	**Pre-planting**	**Establishment**	**Peak Crop Growth**
NO3-N in ft 1 (lbs/ac)	25	89	9
NO3-N in ft 3 (lbs/ac)	3	7	9
NO3-N in ft 5 (lbs/ac)	5	0.4	8
Site R3-Average			
Depth	**Pre-planting**	**Establishment**	**Peak Crop Growth**
NO3-N in ft 1 (lbs/ac)	13	53	22
NO3-N in ft 3 (lbs/ac)	2	12	18
NO3-N in ft 5 (lbs/ac)	13	1	18

The analytical laboratory was asked to verify the fifth foot nitrogen results for the crop establishment soil sample taken on June 22, 2016 because the values were low. These results were confirmed. This was the only time during the study where a peak crop growth soil sample was obtained. The peak crop growth soil results are also used as the post-harvest soil sample results.

The nitrogen and hydraulic summaries for the 2016 carrot crop are in Table 18 for R1-Dry, Table 19 for R2-Wet and Table 20 for R3-Average.

2016 Cover Crop

Field R was planted to cover crop in September of 2016. The study concluded on December 1, 2016. From September 1, 2016 to December 1, 2016, 2.62 inches of precipitation was recorded from the IRZ weather station near Field R. No crop specific ET was recorded for the 2016 cover crop.

Site specific irrigation amounts varied. Between September 1, 2016 and December 1, 2016, Site R1-Dry had 3.59 inches of irrigation, R2- Wet had 3.88 inches of irrigation and R3-Average had 3.90 inches of irrigation. The shallow soil moisture probes were installed October 21, 2016 after the cover crop was established and all in-field monitoring equipment was removed after the study concluded.

Between September 1, 2016 and December 1, 2016, no commercial nitrogen fertilizer was applied to this crop and only minimal amounts of nitrogen were added from the fresh water irrigation. Sites R1-Dry and R3-Average had 0.07 pounds of nitrogen per acre from irrigation and R2-Wet was 0.20 pounds of nitrogen per acre.

The results of the peak crop growth soil samples taken during the carrot crop were used as the post-harvest soil samples for the carrot crop and the pre-planting soil samples for the 2016 cover crop. The final soil samples for the study were taken December 1, 2016 and all eight feet were analyzed for nitrate nitrogen. The final soil sample results are:

December 1, 2016 Soil Samples	R1-Dry	R2-Wet	R3-Average
NO3-N in ft 1 (lbs/ac)	2	3	2
NO3-N in ft 2 (lbs/ac)	7	5	2
NO3-N in ft 3 (lbs/ac)	6	4	3
NO3-N in ft 4 (lbs/ac)	10	6	7
NO3-N in ft 5 (lbs/ac)	4	10	7
NO3-N in ft 6 (lbs/ac)	2	9	5
NO3-N in ft 7 (lbs/ac)	4	12	12
NO3-N in ft 8 (lbs/ac)	11	10	22

The nitrogen and hydraulic summaries for the 2016 carrot crop are in Table 21 for R1-Dry, Table 22 for R2-Wet and Table 23 for R3-Average.

5 Conclusions and Recommendations

Conclusions

The purpose of this study was to measure the hydraulic loading and nitrogen migration within a center-pivot irrigated field that was being managed with a high level of best management practices (BMPs). Field R was chosen by the IAS because it had a representative soil type and irrigation system, was controlled by one land owner that was willing to participate in the study, uses a high level of BMP's in managing their acreage and leases to other growers that utilize similar practices.

Farm land ownership is consolidating in the LUBGWMA. Small family farms are phasing out and either being developed into commercial or residential properties or being purchased by large corporate farming operations. Leasing ground to other growers, especially for the higher value and more specialized commodities, is a long-standing practice. The rotation of a variety of crops on these farms is also used to prevent the buildup of crop specific diseases and pests that may result in a non-sustainable management situation. It allows the land owner to keep land in production and minimizes financial risks as rental is guaranteed income.

Per the USDA Department of Natural Resources National Cooperative Soil Survey, Field R contains Quincy Loamy Fine Sand as its only soil type to the depth of 60 inches (the deepest the USDA soil survey goes). Quincy Loamy Fine Sand is one of the primary soil types for the LUBGWMA. This soil texture was verified when the soil moisture monitoring equipment was installed at each site. The USDA describes the drainage and permeability of Quincy Loamy Fine Sand as excessively drained with very slow to moderate runoff and rapid water permeability.

When the soil moisture sites were installed, the project team estimated soil moisture using the method described in USDA NRCS Program Aid Number 1619 *Estimating Soil Moisture by Feel and Appearance.* (USDA, 1998) This is the primary soil moisture estimation method used in the LUBGWMA when installing soil moisture monitoring equipment. On December 12, 2014, the soil moisture for the shallow probe for Site R1-Dry was estimated to be 90-95% of field capacity at all depths in the top five feet of the profile. The Site R1-Dry deep moisture probe was estimated at 75-80% of field capacity for soil moisture for the 6-foot depth and 70-75% of field capacity for 7-foot and 8-foot depths. The soil type in the 7-foot and 8-foot depths changed to a coarse sand that has a lower soil moisture holding capacity. Site R2-Wet soil moisture was estimated at 80-85% of field capacity for one-foot through three- foot depths, 80-85% of field capacity for the 4-foot, 5-foot and 6-foot depths and between 75-80% for the 7-foot and 8-foot depths. The soil type changed to coarse sand at the 7-foot and 8-foot depths at this site as well. Site R-3 Average was 90-95% of field capacity for the top eight inches, 85-90% of field capacity at the 1-foot depth and was 80-85% of field capacity for the 2- foot and 3-foot. The fourth and fifth foot were 75-80% of field capacity and the 6-foot, 7-foot and 8-foot were estimated at 70-75% of field capacity for soil moisture. No change in soil type was noted on the installation sheets for R3-Average.

The soil moisture levels for the deep probes remained stable until a significant precipitation event on May 13, 2015 when 1.2 inches of precipitation fell in a twenty-four-hour period. The rapid infiltration caused deep soil water percolation that registered on the deep sensors at sites R1- Dry (Figure 4), R2- Wet (Figure 5) and R3-Average (Figure 6). During the two-year study period, this was the only event that caused the deep probes to register a substantial change in the soil moisture. All other increases that registered on the deep probes were more gradual but also appear to be due to precipitation and not irrigation.

The shallow probes (4-inch, 8-inch, 1-foot, 2-foot, 3-foot) were reactive to both irrigation and precipitation events. There are gaps in the shallow probe dataset due to freezing weather conditions, removal to accommodate farming activities and delays in reinstallation due to reentry interval's after pesticide applications.

For site R-1, the shallow probe overlapped the deep installation for the fourth and fifth foot. As seen in Figure 4, the values are different between the 4th and 5th foot shallow probe and the 4th and 5th foot of the deep probe. Capacitance probes are intended to show trends in soil moisture and not exact values. The trends in Figure 4 are following a similar pattern between the two probes. The difference in numerical values can be attributed to variation in soil structure between the two probe sites. Soil structure changes when a field is cultivated and can be altered slightly when installing a capacitance probe. The deep probes were below the zone of influence for cultivation activities and the undisturbed soil structure would change very little.

Crop specific ET data was utilized in this study to compare irrigation applied to crop water usage for onions and carrots. The use of crop specific ET data in this report is in no way intended to establish hydraulic loading limits for these crops nor suggest that precipitation totaling more than the stated crop specific ET values was due to excessive or unwarranted irrigation.

When comparing the irrigation plus precipitation to crop specific ET for Onions, it was 105% of ET at site R1, 107% of ET at Site R2 and 102% of ET at site R3. Irrigation alone was 99% of crop specific ET at site R1, 100% at R2 and 95.7% at R3. The shallow soil moisture probe data supports the efficient irrigation. At sites R1 and R2, irrigation events register in the top two feet of the soil profile with little movement in the third foot. For site R3, there is a decreasing soil moisture trend in the second foot but no data for the third foot due to a faulty sensor.

Based on measurements taken by the IRZ weather station, ET for the 2016 carrot crop was 23.66 inches. Irrigation plus precipitation was 104% at site R1, 91% at R2 and 87% at R3. Irrigation alone was 100% of crop specific ET at R1, 88% at R2 and 84% at R3. The shallow soil moisture probes show that irrigation amounts stayed within the top two feet of the soil profile except for Site R1, which showed movement into the third foot.

Precipitation events such as the one that occurred in May 2015 resulted in deep water movement in these soils. Cover crops will extract some of the nutrients and utilize the soil moisture deeper than three feet but this is limited to their root depth. The cash crops grown during this study are considered shallow rooting crops and typically cannot utilize water and nutrients beyond a two-foot depth.

Nitrogen is supplied to crops from several sources:

- Soil nitrogen in the root zone of the crop.
- Nitrogen mineralized from previous crop residues and soil organic matter.
- Nitrogen that is supplied in irrigation water.
- Commercial nitrogen fertilizer applications.

Fresh water nitrogen levels are not a significant source of nitrogen for Field R. Columbia River water, the primary irrigation source water for Field R, is low in nitrates. Columbia River water is supplemented seasonally by ground water irrigation wells for Field R. One fresh water sample was obtained during the study at a point in the distribution system where all fresh water sources would be comingled. The sample result was 4.4 mg/L of nitrate-nitrogen, higher than other Columbia River water samples. The closest public water system to the intake for the irrigation system that supplies Field R is the City of Hermiston. Their Columbia River nitrate nitrogen samples from May 2002 until May 2016 range from 0.1 mg/L to 1.0 mg/L with an average of 0.22 mg/L nitrate. The nitrogen in the ground water wells that supplement the Columbia River water is the likely contributor to the higher nitrate nitrogen levels in the irrigation water sample but, still contributed very little to the nitrogen loading on Field R.

Based only on the data that was collected in this study, a definitive determination of nitrogen migration cannot be made at this time. Academic literature review, nitrogen modeling tools, and review of the data by university or extension personnel could help to explain nitrogen movement during this study and should be considered.

Efficient nitrogen management is essential to profitable and sustainable agricultural production (Roberston & Vitousek, 2009) Shallow rooted crops like carrots and onions should be rotated with a deep rooting crop (such as winter wheat, corn, alfalfa, triticale, canola, etc.) during the next growing season as a best management practice for nitrogen management.

The use of cover crops during the non-growing season is a best management practice that was utilized during this project. Cover crops, as compared to leaving a field fallow for the non-growing season, have been shown to reduce nitrogen leaching by approximately 50%. (Teixeira et al, 2016).

When this sampling plan was developed, it was assumed that the land owner that agreed to the study would be farming Field R and that the project team would be working with the land owner's field manager. Field R ended up being leased to two separate growers over the course of the study. These grower's, both corporate farming operations, were aware that a study was taking place but were not involved in the planning or execution of the study. Each grower specializes in the commodity that they produce and have their own specialized BMP's that are considered trade secrets.

Any time there was irrigation prior to or after a cash crop cycle, it was to either prep the field for planting of the cash crop or to establish the cover crop for the non-growing season. Section 4 Results and Analysis for the 2014/2015 cover crop and 2015/2016 cover crop, irrigation events are described in detail.

Recommendations

A. When this project was developed, it was assumed that the land owner would be farming Field R. There was no alternative plan for tenant farming. Field R was leased to two separate growers over the course of the study. The tenant growers were not involved with LUBGWMA or the Irrigated Ag Subcommittee. Future study proposals should include weekly field scouting and training sessions for all affected parties explaining the details of the study, roles, responsibilities and contact information.

B. The Phase II research study was an initial attempt to better understand the impact that general agriculture was having in the LUBGWMA. In the planning phase, some items were eliminated to meet available funding options that, in hindsight, made the overall evaluation of nitrogen movement difficult. Data from this study has identified areas where further research is needed. Future studies should include in-depth study design with greater assistance from land grant universities and/or extension service personnel. Once the study is designed, the adequate amount of funds to cover all portions of the plan should be pursued.

C. The shallow probes were removed at the request of the farmer to minimize disturbances during farming activities. For future studies, shallow probes could be removed but should be replaced after the farming activity is completed. This would show a more complete picture of hydraulic movement in the shallow soil profile over the life of the crop.

D. Soil sampling for the entire eight-foot profile at each determined sampling interval during the study could help to improve the analysis of nitrogen movement. Ammonia- nitrogen in the top foot and a measure of soil organic nitrogen should be included as well.

E. There are many credible resources to determine the correct amount of nitrogen to apply to crops and what nitrogen levels should be in soil in the crop's root zone. These crop specific manuals are available from most land-grant universities and are available online or in print. If a grower seeks guidance on the acceptable level of nitrogen below the root zone of the crop, they should consult with local land grant university or extension personnel.

F. Although the fresh water supplying Field R is low in nitrogen, future studies should include more fresh water sample points to better represent its contribution to nitrogen loading.

G. Future research should include more fields with different topographical features and/or with variable soil types within the LUBGWMA.

H. There is a lot of potential in the data collected during this study for further evaluation. It is rare for a study to collect data on several different aspects of a management area over multiple crops and growing seasons. Further evaluation could draw a more complete picture of nitrogen migration.

I. Many growers in the LUBGWMA have adopted best management practices for efficient resource utilization. BMP's that are being practiced more commonly are:
   - Scientific irrigation scheduling that incorporates weather, irrigation applied and soil moisture conditions.
   - Remote weather monitoring.
   - Infrared imaging of fields to determine crop health and water utilization.
   - Application of alternative fertilizers and soil amendments that increase soil health.
   - Using no-till farming practices when practical.
   - Alternating shallow rooted and deep-rooted crops for effective resource management.
   - Tracking irrigation water amounts applied to crops and utilizing more efficient sprinkler packages.
   - Tracking power usage on irrigation systems (pump stations, booster pumps, pivots, etc.) and replacing older equipment with more energy efficient options.

   Precision agriculture allows growers to better utilize their resources and manage wet areas, dry areas and undesirable irrigation areas (i.e. irrigation canals, pivot roads, rock outcroppings) within a field. Tools and equipment are becoming more cost-effective and readily available. Automated irrigation technology (AIT) is an effective tool in managing in-field variability and is currently available from most center pivot manufacturers. Two common AIT systems are GPS Positioning and Variable Rate Irrigation (VRI).

   GPS positioning systems use a controller module at the end of the pivot arm and use GPS to identify where the controller is in relation to the pivot point. Growers can program the controller to control end-gun areas, pivot shut downs and adjustment water application rates in undesirable irrigation areas. More advanced systems allow field and crop specific irrigation plans to be programmed for end-gun operation and sprinkler bank control. GPS positioning can be added to any new or existing center pivot.

   Variable Rate Irrigation (VRI) allows the application of different amounts of water over multiple crops, soil types and terrain. When the VRI system is installed, a field specific agronomic map is created. The grower can specify the application depths for each area of the field and generate an application plan. The plan is uploaded to the VRI controller and the controller sends signals to solenoids located on each individual sprinkler to turn on, off or pulsate according to the field position and the desired application depth. VRI is an expensive control option but is the most efficient way to irrigate wet, dry or undesirable irrigation zones within a field.

AIT is becoming more widespread. Growers and land owners in the LUBGWMA should consider AIT as an additional irrigation best management practice.

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Tables 1-23

Table 1

Soil Moisture Probe - GPS Locations

ODA - Fertilizer Research Program Grant

Location		feet bgs	GPS Location	
R-1	Shallow Probe	0' - 5'	45.8047931°	119.6205989°
	Deep Probe	3' - 8'	45.8048056°	119.6205740°
R-2	Shallow Probe	0' - 3'	45.8046345°	119.6188936°
	Deep Probe	3' - 8'	45.8046874°	119.6188860°
R-3	Shallow Probe	0' - 3'	45.8028100°	119.6135931°
	Deep Probe	3' - 8'	45.8028253°	119.6135430°

Table 2

LUB GWMA Field R - Test Site

Soil Moisture Probe Sensor Depths

ODA - Fertilizer Research Program Grant

3 Foot Long Shallow Probes		
	Depth *(from top of probe - Inches)*	Soil Moisture Plot Depth
Sensor 1	4	4 inch
Sensor 2	8	8 inch
Sensor 3	12	1 foot
Sensor 4	20	2 foot
Sensor 5	36	3 foot

5 Foot Long Shallow Probe		
	Depth *(from top of probe - Inches)*	Soil Moisture Plot Depth
Sensor 1	4	4 inch
Sensor 2	8	8 inch
Sensor 3	12	1 foot
Sensor 4	20	2 foot
Sensor 5	36	3 foot
Sensor 6	48	4 foot
Sensor 7	60	5 foot

5 Foot Long Deep Probe *(installed 3 feet bgs)*			
	Depth *(from top of probe - Inches)*	Depth *(bgs - Inches)*	Soil Moisture Plot Depth
Sensor 1	*not used*	*not used*	*not used*
Sensor 2	*not used*	*not used*	*not used*
Sensor 3	12	48	4 foot
Sensor 4	20	56	5 foot
Sensor 5	36	72	6 foot
Sensor 6	48	84	7 foot
Sensor 7	60	96	8 foot

Table 3

Irrigation and Rainfall Summary

LUB GWMA Field R - Test Site

ODA - Fertilizer Research Program Grant

	2015			
Sample Location	Irrigation Water *(inches/yr)*	Irrigation Water *(feet/yr)*	Rainfall *(inches/yr)*	Annual Total *(inches/yr)*
R-1 - Dry	32.49	2.71	8.45*	41.3
R-2 - Wet	34.04	2.84		42.9
R-3 - Average	30.76	2.56		39.6

	2016			
Sample Location	Irrigation Water *(inches/yr)*	Irrigation Water *(feet/yr)*	Rainfall *(inches/yr)*	Annual Total *(inches/yr)*
R-1 - Dry	31.41	2.62	7.24**	39.0
R-2 - Wet	29.37	2.45		36.9
R-3 - Average	27.83	2.32		35.4

*** Includes precipitation data starting December 12, 2014**

****Data ends December 1, 2016**

Table 4

Summary of Fertilizer Applied

LUB GWMA Field R - Test Site

ODA - Fertilizer Research Program Grant

2014/2015 - Cover Grain		
Date	**Product**	**lbs/acre**
2/20/2015	23-0-29-0	60
	Total N =	60

2015 - Onion Crop		
Date	**Product**	**lbs/acre**
4/29/2015	CN9*	11
5/6/2015	CN9*	9
5/13/2015	CN9*	20
5/27/2015	CN9*	22
6/3/2015	CN9*	20
7/22/2015	*Harvest Started*	
	Total N =	82

*CN9 = the exact manufacuture of product is unknown, approximate make up includes: Total Nitrogen = 9.0%; Nitrate Nitrogen = 8.42%; Ammoniacal N= 0.58%; Calcium = 11%

2016 - Carrot Crop		
Date	**Product**	**lbs/acre**
5/25/2016	*began planting Carrot Crop*	
5/30/2016	iNvigorate 0-0-0.5	0.00
5/30/2016	B Sure 0.5-0-0.5	0.01
6/13/2016	28-0-0-4s Hum	8.76
6/14/2016	28-0-0-4s Hum	8.47
7/2/2016	28-0-0-4s Hum	18.75
7/8/2016	28-0-0-4s Hum	19.35
7/22/2016	28-0-0-4s Hum	11.20
8/4/2016	28-0-0-4s Hum	10.57
8/18/2016	28-0-0-4s Hum	10.57
8/30/2016	*Harvest Started*	
	Total N =	87.68

2016/2015 - Cover Grain		
Date	**Product**	**lbs/acre**
5/4/2016	3.2-14.9-42.3 .6s	16.83
5/7/2016	Compost	118.6
	Total N =	135.43

Table 5

Baseline Conditions

Soil Sampling Results - December 2014

LUB GWMA Field R - Test Site

ODA - Fertilizer Research Program Grant

Sample Date: 12/11/14

Sample Depth	R-1 DRY				R-2 Wet				R-3 Average			
	NO_3-N	NO_3-N	TKN	pH	NO_3-N	NO_3-N	TKN	pH	NO_3-N	NO_3-N	TKN	pH
foot	#/Acre	ppm	%	pH units	#/Acre	ppm	%	pH units	#/Acre	ppm	%	pH units
1	51	12.8	0.079	6.0	56	14.0	0.082	5.7	51	12.8	0.045	6.2
2	13	3.3	0.045	8.0	16	4.0	0.057	5.9	14	3.5	0.040	6.7
3	7	1.8	0.016	8.2	4	1.0	0.034	6.7	9	2.3	0.019	7.7
4	4	1.0	0.031	8.3	3	0.8	0.038	6.9	7	1.8	0.028	8.3
5	4	1.0	0.020	8.2	5	1.3	0.017	8.0	8	2.0	0.020	8.4
6	7	1.8	0.041	8.4	6	1.5	0.024	8.3	4	1.0	0.026	8.4
7	6	1.5	0.023	8.5	7	1.8	0.020	8.3	4	1.0	0.023	8.3
8	7	1.8	0.035	8.4	8	2.0	0.013	8.4	8	2.0	0.033	8.4

Table 6

Site R-1 Dry Field Conditions
Nitrate Soil Sampling Results

LUB GWMA Field R - Test Site

ODA - Fertilizer Research Program Grant

Sample Depth	R-1 DRY *(Baseline - Dec 2014)* 12/11/2014			
foot	NO_3-N #/Acre	NO_3-N ppm	TKN %	pH pH units
1	51	12.8	0.079	6.0
2	13	3.3	0.045	8.0
3	7	1.8	0.016	8.2
4	4	1.0	0.031	8.3
5	4	1.0	0.020	8.2
6	7	1.8	0.041	8.4
7	6	1.5	0.023	8.5
8	7	1.8	0.035	8.4

Sample Depth	R-1 DRY *(Final - Dec 2016)* 12/1/2016	
foot	NO_3-N #/Acre	NO_3-N ppm
1	2	0.4
2	7	1.7
3	6	1.6
4	10	2.4
5	4	0.9
6	2	0.6
7	4	0.9
8	11	2.8

R-1 Dry Growing Season Nitrate Soil Results

Sample Depth	2015 Season			
	Peak Crop Growth * 8/31/2015		Start Winter Dormant 12/11/2015	
foot	#/Acre	ppm	#/Acre	ppm
1	22	5.5	5	1.3
3	10	2.5	9	2.3
5	25	6.3	28	7

Planted = onions March 25, 2015

Harvested = July - August 2015

** due to coordination issues soil samples were collected just after crop harvest*

2016 Season							
Prior to Planting 4/26/2016		Crop Establishment 6/22/2016		Peak Crop Growth 8/22/2016		Winter Dormancy 12/1/2016	
#/Acre	ppm	#/Acre	ppm	#/Acre	ppm	#/Acre	ppm
23.6	5.9	183.2	45.8	16	4.1	2	0.4
2.3	0.6	18.4	4.6	22	5.4	7	1.7
12.8	3.2	27.5	6.9	11	2.7	6	1.6

Planted = carrots May 25, 2016

Harvested = September 2016

Other Field R 2015 Nitrate Soil Results

by Farmer (unknown location)

Date	Depth	NO_3-N #/Acre
4/28/15	0-3"	15
	3-6"	17
5/5/15	0-3"	27
	3-6"	24
5/11/15	0-3"	32
	3-6"	20
5/19/15	6"	29
5/26/15	6"	34
6/1/15	12"	75
6/9/15	12"	67
6/17/2015	12"	64
7/1/2015	12"	43
Stopped applying fertilizer in early to mid July		

Table 7

Site R-2 Wet Field Conditions
Nitrate Soil Sampling Results

LUB GWMA Field R - Test Site

ODA - Fertilizer Research Program Grant

Sample Depth	R-2 WET *(Baseline - Dec 2014)*			
	12/11/2014			
	NO_3-N	NO_3-N	TKN	pH
foot	#/Acre	ppm	%	pH units
1	56	14.0	0.082	5.7
2	16	4.0	0.057	5.9
3	4	1.0	0.034	6.7
4	3	0.8	0.038	6.9
5	5	1.3	0.017	8.0
6	6	1.5	0.024	8.3
7	7	1.8	0.020	8.3
8	8	2.0	0.013	8.4

Sample Depth	R-2 WET *(Final - Dec 2016)*	
	12/1/2016	
	NO_3-N	NO_3-N
foot	#/Acre	ppm
1	3	0.8
2	5	1.2
3	4	0.9
4	6	1.4
5	10	2.6
6	9	2.1
7	12	3
8	10	2.5

R-2 Wet Growing Season Nitrate Soil Results

Sample Depth	2015 Season			
	Peak Crop Growth *		Start Winter Dormant	
	8/31/2015		12/11/2015	
foot	#/Acre	ppm	#/Acre	ppm
1	55	13.8	3	0.75
3	37	9.3	7	1.75
5	30	7.5	39	9.75

Planted = onions March 25, 2015

Harvested = July - August 2015

** due to coordination issues soil samples were collected just after crop harvest*

2016 Season							
Prior to Planting		Crop Establishment		Peak Crop Growth		Winter Dormancy	
4/26/2016		6/22/2016		8/22/2016		12/1/2016	
#/Acre	ppm	#/Acre	ppm	#/Acre	ppm	#/Acre	ppm
25.4	6.4	88.7	22.2	9	2.1	3	0.8
3.2	0.8	7.2	1.8	9	2.3	5	1.2
5.4	1.4	0.4	0.1	8	2.1	4	0.9

Planted = carrots May 25, 2016

Harvested = September 2016

Other Field R 2015 Nitrate Soil Results

by Farmer (unknown location)

Date	Depth	NO_3-N #/Acre
4/28/15	0-3"	15
	3-6"	17
5/5/15	0-3"	27
	3-6"	24
5/11/15	0-3"	32
	3-6"	20
5/19/15	6"	29
5/26/15	6"	34
6/1/15	12"	75
6/9/15	12"	67
6/17/2015	12"	64
7/1/2015	12"	43
Stopped applying fertilizer in early to mid July		

Table 8

Site R-3 Average Field Conditions
Nitrate Soil Sampling Results

LUB GWMA Field R - Test Site

ODA - Fertilizer Research Program Grant

Sample Depth	R-3 AVERAGE *(Baseline - Dec 2014)*			
	12/11/2014			
	NO_3-N	NO_3-N	TKN	pH
foot	#/Acre	ppm	%	pH units
1	51	12.8	0.045	6.2
2	14	3.5	0.040	6.7
3	9	2.3	0.019	7.7
4	7	1.8	0.028	8.3
5	8	2.0	0.020	8.4
6	4	1.0	0.026	8.4
7	4	1.0	0.023	8.3
8	8	2.0	0.033	8.4

Sample Depth	R-3 AVERAGE *(Final - Dec 2016)*	
	12/1/2016	
	NO_3-N	NO_3-N
foot	#/Acre	ppm
1	2	0.5
2	2	0.6
3	3	0.7
4	7	1.8
5	7	1.7
6	5	1.2
7	12	3.1
8	22	5.4

R-3 Average Growing Season Nitrate Soil Results

Sample Depth	2015 Season			
	Post Harvest		Start Winter Dormant	
	Peak Crop Growth *		12/11/2015	
foot	#/Acre	ppm	#/Acre	ppm
1	37	9.3	3	0.75
3	19	4.8	14	3.5
5	9	2.3	26	6.5

Planted = onions March 25, 2015

Harvested = July - August 2015

** due to coordination issues soil samples were collected just after crop harvest*

2016 Season							
Prior to Planting		Crop Establishment		Peak Crop Growth		Winter Dormancy	
4/26/2016		6/22/2016		8/22/2016		12/1/2016	
#/Acre	ppm	#/Acre	ppm	#/Acre	ppm	#/Acre	ppm
12.9	3.2	52.8	13.2	22	5.4	2	0.5
2.4	0.6	12.4	3.1	18	4.5	3	0.7
12.7	3.2	0.6	0.2	18	4.4	7	1.7

Planted = carrots May 25, 2016

Harvested = September 2016

Other 2015 Nitrate Soil Results

by Farmer (unknown location)

Date	Depth	NO_3-N #/Acre
4/28/15	0-3"	15
	3-6"	17
5/5/15	0-3"	27
	3-6"	24
5/11/15	0-3"	32
	3-6"	20
5/19/15	6"	29
5/26/15	6"	34
6/1/15	12"	75
6/9/15	12"	67
6/17/2015	12"	64
7/1/2015	12"	43
Stopped applying fertilizer in early to mid July		

ODA Nitrogen and Hydraulic Loading
Cover R1 Dry Site Summary 2014/2015

Table 9

General Information	
Field I.D.	**R1 - Dry**
Acres	55.04
Crop	Cover
Start Date of Study	12/12/2014
Crop End Date	3/24/2015
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	60.03

Next Crop Synopsis	
Crop	Onion
Root Depth (ft)	2

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
December 2014	0.00	0.00	1.63	0	**1.63**	0.00	---
January 2015	0.00	0.00	0.79	0	**0.79**	0.00	---
February 2015	0.00	0.00	0.94	60	**0.94**	60.00	---
March 1-24, 2015	1.60	0.03	0.88	0	**2.48**	0.03	---
Total	**1.60**	**0.03**	**4.24**	**60.00**	**5.84**	**60.03**	**0.00**

Soil Samples		
Depth	**Study Start**	**Post-Harvest**
Date	12/11/2014	
NO3-N in ft 1 (lbs/ac)	51	–
NO3-N in ft 2 (lbs/ac)	13	–
NO3-N in ft 3 (lbs/ac)	7	–
NO3-N in ft 4 (lbs/ac)	4	–
NO3-N in ft 5 (lbs/ac)	4	–
NO3-N in ft 6 (lbs/ac)	7	–
NO3-N in ft 7 (lbs/ac)	6	–
NO3-N in ft 8 (lbs/ac)	7	–

ODA Nitrogen and Hydraulic Loading
Cover R2 Wet Site Summary 2014/2015

Table 10

General Information	
Field I.D.	**R2 - Wet**
Acres	19.2
Crop	Cover
Crop Start Date	12/12/2014
Crop End Date	3/24/2015
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	60.08

Next Crop Synopsis	
Crop	Onion
Root Depth (ft)	2

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
December 2014	0.00	0.00	1.63	0	**1.63**	0.00	––
January 2015	0.00	0.00	0.79	0	**0.79**	0.00	––
February 2015	0.00	0.00	0.94	60	**0.94**	60.00	––
March 1-24, 2015	1.60	0.08	0.88	0	**2.48**	0.08	––
Total	**1.60**	**0.08**	**4.24**	**60.00**	**5.84**	**60.08**	**0.00**

Soil Samples		
Depth	**Study Start**	**Post-Harvest**
Date	12/11/2014	
NO3-N in ft 1 (lbs/ac)	56	–
NO3-N in ft 2 (lbs/ac)	16	–
NO3-N in ft 3 (lbs/ac)	4	–
NO3-N in ft 4 (lbs/ac)	3	–
NO3-N in ft 5 (lbs/ac)	5	–
NO3-N in ft 6 (lbs/ac)	6	–
NO3-N in ft 7 (lbs/ac)	7	–
NO3-N in ft 8 (lbs/ac)	8	–

ODA Nitrogen and Hydraulic Loading
Cover R3 Average Site Summary 2014/2015

Table 11

General Information	
Field I.D.	**R3 - Average**
Acres	53.76
Crop	Cover
Crop Start Date	12/12/2014
Crop End Date	3/24/2015
# of Cuttings	1
Root Depth (ft)	2
Total N Applied (lbs/ac)	60.03

Next Crop Synopsis	
Crop	Onion
Root Depth (ft)	2

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
December 2014	0.00	0.00	1.63	0	**1.63**	0.00	--
January 2015	0.00	0.00	0.79	0	**0.79**	0.00	--
February 2015	0.00	0.00	0.94	60	**0.94**	60.00	--
March 1-24, 2015	1.60	0.03	0.88	0	**2.48**	0.03	--
Total	**1.60**	**0.03**	**4.24**	**60.00**	**5.84**	**60.03**	**0.00**

Soil Samples		
Depth	**Study Start**	**Post-Harvest**
Date	12/11/2014	
NO3-N in ft 1 (lbs/ac)	51	–
NO3-N in ft 2 (lbs/ac)	14	–
NO3-N in ft 3 (lbs/ac)	9	–
NO3-N in ft 4 (lbs/ac)	7	–
NO3-N in ft 5 (lbs/ac)	8	–
NO3-N in ft 6 (lbs/ac)	4	–
NO3-N in ft 7 (lbs/ac)	4	–
NO3-N in ft 8 (lbs/ac)	8	–

ODA Nitrogen and Hydraulic Loading
Onion R1 Dry Site Summary 2015

Table 12

General Information	
Field I.D.	**R1 - Dry**
Acres	55.04
Crop	Onion
Crop Start Date	3/25/2015
Crop End Date	7/31/2015
# of Cuttings	1
Root Depth (ft)	2
Total N Applied (lbs/ac)	82.44

Next Crop Synopsis	
Crop	Cover
Root Depth (ft)	3

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
March 25-31, 2015	0.93	0.02	0	0	**0.93**	0.02	**0.32**
April 2015	2.78	0.05	0.16	11	**2.94**	11.05	**2.22**
May 2015	4.84	0.09	1.45	51	**6.29**	51.09	**5.46**
June 2015	9.26	0.17	0	20	**9.26**	20.17	**9.50**
July 2015	6.71	0.12	0.03	0	**6.74**	0.12	**7.39**
Total	**24.52**	**0.44**	**1.64**	**82.00**	**26.16**	**82.44**	**24.89**

Soil Samples		
Depth	**Pre-planting**	**Post-Harvest**
Date		8/31/2015
NO3-N in ft 1 (lbs/ac)	–	22
NO3-N in ft 2 (lbs/ac)	–	–
NO3-N in ft 3 (lbs/ac)	–	10
NO3-N in ft 4 (lbs/ac)	–	–
NO3-N in ft 5 (lbs/ac)	–	25
NO3-N in ft 6 (lbs/ac)	–	–
NO3-N in ft 7 (lbs/ac)	–	–
NO3-N in ft 8 (lbs/ac)	–	–

ODA Nitrogen and Hydraulic Loading
Onion R2 Wet Site Summary 2015

Table 13

General Information	
Field I.D.	**R2 - Wet**
Acres	19.2
Crop	Onion
Crop Start Date	3/25/2015
Crop End Date	7/31/2015
# of Cuttings	1
Root Depth (ft)	2
Total N Applied (lbs/ac)	83.30

Next Crop Synopsis	
Crop	Cover
Root Depth (ft)	3

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
March 25-31, 2015	0.93	0.05	0	0	**0.93**	0.05	**0.32**
April 2015	2.78	0.14	0.16	11	**2.94**	11.14	**2.22**
May 2015	4.84	0.25	1.45	51	**6.29**	51.25	**5.46**
June 2015	9.32	0.48	0	20	**9.32**	20.48	**9.50**
July 2015	7.13	0.37	0.03	0	**7.16**	0.37	**7.39**
Total	**25.00**	**1.30**	**1.64**	**82.00**	**26.64**	**83.30**	**24.89**

Soil Samples		
Depth	**Pre-planting**	**Post-Harvest**
Date		8/31/2015
NO3-N in ft 1 (lbs/ac)	–	55
NO3-N in ft 2 (lbs/ac)	–	–
NO3-N in ft 3 (lbs/ac)	–	37
NO3-N in ft 4 (lbs/ac)	–	–
NO3-N in ft 5 (lbs/ac)	–	30
NO3-N in ft 6 (lbs/ac)	–	–
NO3-N in ft 7 (lbs/ac)	–	–
NO3-N in ft 8 (lbs/ac)	–	–

ODA Nitrogen and Hydraulic Loading
Onion R3 Average Site Summary 2015

Table 14

General Information	
Field I.D.	**R3 - Average**
Acres	53.76
Crop	Onion
Crop Start Date	3/25/2015
Crop End Date	7/31/2015
# of Cuttings	1
Root Depth (ft)	2
Total N Applied (lbs/ac)	82.44

Next Crop Synopsis	
Crop	Cover
Root Depth (ft)	3

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
March 25-31, 2015	0.93	0.02	0	0	**0.93**	0.02	**0.32**
April 2015	2.78	0.05	0.16	11	**2.94**	11.05	**2.22**
May 2015	4.84	0.09	1.45	51	**6.29**	51.09	**5.46**
June 2015	8.50	0.16	0	20	**8.50**	20.16	**9.50**
July 2015	6.78	0.13	0.03	0	**6.81**	0.13	**7.39**
Total	**23.83**	**0.44**	**1.64**	**82.00**	**25.47**	**82.44**	**24.89**

Soil Samples		
Depth	**Pre-planting**	**Post-Harvest**
Date		8/31/2015
NO3-N in ft 1 (lbs/ac)	–	37
NO3-N in ft 2 (lbs/ac)	–	–
NO3-N in ft 3 (lbs/ac)	–	19
NO3-N in ft 4 (lbs/ac)	–	–
NO3-N in ft 5 (lbs/ac)	–	9
NO3-N in ft 6 (lbs/ac)	–	–
NO3-N in ft 7 (lbs/ac)	–	–
NO3-N in ft 8 (lbs/ac)	–	–

ODA Nitrogen and Hydraulic Loading
Cover R1 Dry Site Summary 2015/2016

Table 15

General Information	
Field I.D.	**R1 - Dry**
Acres	55.04
Crop	Cover
Crop Start Date	8/1/2015
Crop End Date	5/25/2016
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	135.62

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
August 2015	1.63	0.03	0.12	0	**1.75**	0.03	--
September 2015	2.38	0.04	0.06	0	**2.44**	0.04	--
October 2015	2.36	0.04	0.33	0	**2.69**	0.04	--
November 2015	0.00	0.00	0.84	0	**0.84**	0.00	--
December 2015	0.00	0.00	1.75	0	**1.75**	0.00	--
January 2016	0.00	0.00	1.56	0	**1.56**	0.00	--
February 2016	0.00	0.00	0.43	0	**0.43**	0.00	--
March 2016	2.25	0.04	0.88	0	**3.13**	0.04	--
April 2016	0.10	0.00	0.18	0	**0.28**	0.00	--
May 1-24, 2016	1.77	0.03	0.73	135.43*	**2.50**	135.46	--
Total	**10.49**	**0.19**	**6.88**	**135.43**	**17.37**	**135.62**	--

Next Crop Synopsis	
Crop	Carrot
Root Depth (ft)	2

Soil Samples			
Depth	**Pre-planting**	**Winter 2015**	**Post-Harvest**
Date	8/31/2015	12/11/2015	4/26/2016
NO3-N in ft 1 (lbs/ac)	22	5	24
NO3-N in ft 2 (lbs/ac)	–	–	–
NO3-N in ft 3 (lbs/ac)	10	9	2
NO3-N in ft 4 (lbs/ac)	–	–	–
NO3-N in ft 5 (lbs/ac)	25	28	13
NO3-N in ft 6 (lbs/ac)	–	–	–
NO3-N in ft 7 (lbs/ac)	–	–	–
NO3-N in ft 8 (lbs/ac)	–	–	–

***Notes**

Commercial nitrogen was applied as compost in preparation for the next crop. A certified fertilizer report was provided from the grower that showed 135.43 pounds of commercial nitrogen was applied via compost so that number was used. Approximately 10% of compost nitrogen is readily available and the remainder is slowly released during the season. The compost was applied on May 7, 2016 and the carrot crop was planted May 25, 2016. The net amount of available nitrogen to the cover crop would be minimal.

ODA Nitrogen and Hydraulic Loading
Cover R2 Wet Site Summary 2015/2016

Table 16

General Information	
Field I.D.	**R2 - Wet**
Acres	19.2
Crop	Cover
Crop Start Date	8/1/2015
Crop End Date	5/25/2016
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	136.06

Next Crop Synopsis	
Crop	Carrot
Root Depth (ft)	2

***Notes**

Commercial nitrogen was applied as compost in preparation for the next crop. A certified fertilizer report was provided from the grower that showed 135.43 pounds of commercial nitrogen was applied via compost so that number was used. Approximately 10% of compost nitrogen is readily available and the remainder is slowly released during the season. The compost was applied on May 7, 2016 and the carrot crop was planted May 25, 2016. The net amount of available nitrogen to the cover crop would be minimal.

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
August 2015	1.84	0.10	0.12	0	**1.96**	0.10	--
September 2015	2.51	0.13	0.06	0	**2.57**	0.13	--
October 2015	3.09	0.16	0.33	0	**3.42**	0.16	--
November 2015	0.00	0.00	0.84	0	**0.84**	0.00	--
December 2015	0.00	0.00	1.75	0	**1.75**	0.00	--
January 2016	0.00	0.00	1.56	0	**1.56**	0.00	--
February 2016	0.00	0.00	0.43	0	**0.43**	0.00	--
March 2016	2.40	0.12	0.88	0	**3.28**	0.12	--
April 2016	0.12	0.01	0.18	0	**0.30**	0.01	--
May 1-24, 2016	2.18	0.11	0.73	135.43*	**2.91**	135.54	--
Total	**12.14**	**0.63**	**6.88**	**135.43**	**19.02**	**136.06**	--

Soil Samples			
Depth	**Pre-planting**	**Winter 2015**	**Post-Harvest**
Date	8/31/2015	12/11/2015	4/26/2016
NO3-N in ft 1 (lbs/ac)	55	3	25
NO3-N in ft 2 (lbs/ac)	–	–	–
NO3-N in ft 3 (lbs/ac)	37	7	3
NO3-N in ft 4 (lbs/ac)	–	–	–
NO3-N in ft 5 (lbs/ac)	30	39	5
NO3-N in ft 6 (lbs/ac)	–	–	–
NO3-N in ft 7 (lbs/ac)	–	–	–
NO3-N in ft 8 (lbs/ac)	–	–	–

ODA Nitrogen and Hydraulic Loading
Cover R3 Average Site Summary 2015/2016

Table 17

General Information	
Field I.D.	**R3 - Average**
Acres	53.76
Crop	Cover
Crop Start Date	8/1/2015
Crop End Date	5/25/2016
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	135.98

Next Crop Synopsis	
Crop	Carrot
Root Depth (ft)	2

*Notes
Commercial nitrogen was applied as compost in preparation for the next crop. A certified fertilizer report was provided from the grower that showed 135.43 pounds of commercial nitrogen was applied via compost so that number was used. Approximately 10% of compost nitrogen is readily available and the remainder is slowly released during the season. The compost was applied on May 7, 2016 and the carrot crop was planted May 25, 2016. The net amount of available nitrogen to the cover crop would be minimal.

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
August 2015	0.95	0.02	0.12	0	**1.07**	0.02	–
September 2015	1.74	0.13	0.06	0	**1.80**	0.13	–
October 2015	2.64	0.16	0.33	0	**2.97**	0.16	–
November 2015	0.00	0.00	0.84	0	**0.84**	0.00	–
December 2015	0.00	0.00	1.75	0	**1.75**	0.00	–
January 2016	0.00	0.00	1.56	0	**1.56**	0.00	–
February 2016	0.00	0.00	0.43	0	**0.43**	0.00	–
March 2016	2.21	0.12	0.88	0	**3.09**	0.12	–
April 2016	0.08	0.01	0.18	0	**0.26**	0.01	–
May 1-24, 2016	1.87	0.11	0.73	135.43*	**2.60**	135.54	–
Total	**9.49**	**0.55**	**6.88**	**135.43**	**16.37**	**135.98**	–

Soil Samples			
Depth	**Pre-planting**	**Winter 2015**	**Post-Harvest**
Date	8/31/2015	12/11/2015	4/26/2016
NO3-N in ft 1 (lbs/ac)	37	3	13
NO3-N in ft 2 (lbs/ac)	–	–	–
NO3-N in ft 3 (lbs/ac)	19	14	2
NO3-N in ft 4 (lbs/ac)	–	–	–
NO3-N in ft 5 (lbs/ac)	9	26	13
NO3-N in ft 6 (lbs/ac)	–	–	–
NO3-N in ft 7 (lbs/ac)	–	–	–
NO3-N in ft 8 (lbs/ac)	–	–	–

Table 18

ODA Nitrogen and Hydraulic Loading
Carrot R1 Dry Site Summary 2016

General Information	
Field I.D.	**R1 - Dry**
Acres	55.04
Crop	Carrot
Crop Start Date	5/4/2016
Crop End Date	8/30/2016
# of Cuttings	1
Root Depth (ft)	2
Total N Applied (lbs/ac) {9}	88.11

Next Crop Synopsis	
Crop	Cover
Root Depth (ft)	3

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
May 25-31, 2016	1.89	0.03	0	0.01	**1.89**	0.04	**0.52**
June 2016	5.85	0.11	0.51	17.23	**6.36**	17.34	**5.11**
July 2016	8.12	0.15	0.16	49.3	**8.28**	49.45	**9.76**
August 2016	7.84	0.14	0.17	21.14	**8.01**	21.28	**8.27**
Total	**23.70**	**0.43**	**0.84**	**87.68**	**24.54**	**88.11**	**23.66**

Soil Samples			
Depth	**Pre-planting**	**Establishment**	**Peak/Post-Harvest**
Date	4/26/2016	6/22/2016	8/22/2016
NO3-N in ft 1 (lbs/ac)	24	183	16
NO3-N in ft 2 (lbs/ac)	–	–	–
NO3-N in ft 3 (lbs/ac)	2	18	22
NO3-N in ft 4 (lbs/ac)	–	–	–
NO3-N in ft 5 (lbs/ac)	13	28	11
NO3-N in ft 6 (lbs/ac)	–	–	–
NO3-N in ft 7 (lbs/ac)	–	–	–
NO3-N in ft 8 (lbs/ac)	–	–	–

ODA Nitrogen and Hydraulic Loading
Carrot R2 Wet Site Summary 2016

Table 19

General Information	
Field I.D.	**R2 - Wet**
Acres	19.2
Crop	Carrot
Crop Start Date	5/4/2016
Crop End Date	8/30/2016
# of Cuttings	1
Root Depth (ft)	2
Total N Applied (lbs/ac)	88.76

Next Crop Synopsis	
Crop	Cover
Root Depth (ft)	3

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
May 25-31, 2016	0.76	0.04	0	0.01	**0.76**	0.05	**0.52**
June 2016	2.97	0.15	0.51	17.23	**3.48**	17.38	**5.11**
July 2016	8.72	0.45	0.16	49.3	**8.88**	49.75	**9.76**
August 2016	8.34	0.43	0.17	21.14	**8.51**	21.57	**8.27**
Total	**20.79**	**1.08**	**0.84**	**87.68**	**21.63**	**88.76**	**23.66**

Soil Samples			
Depth	**Pre-planting**	**Establishment**	**Peak/Post-harvest**
Date	4/26/2016	6/22/2016	8/22/2016
NO3-N in ft 1 (lbs/ac)	25	89	9
NO3-N in ft 2 (lbs/ac)	–	–	–
NO3-N in ft 3 (lbs/ac)	3	7	9
NO3-N in ft 4 (lbs/ac)	–	–	–
NO3-N in ft 5 (lbs/ac)	5	0.4	8
NO3-N in ft 6 (lbs/ac)	–	–	–
NO3-N in ft 7 (lbs/ac)	–	–	–
NO3-N in ft 8 (lbs/ac)	–	–	–

ODA Nitrogen and Hydraulic Loading
Carrot R3 Average Site Summary 2016

Table 20

General Information	
Field I.D.	**R3 - Average**
Acres	53.76
Crop	Carrot
Crop Start Date	5/4/2016
Crop End Date	8/30/2016
# of Cuttings	1
Root Depth (ft)	2
Total N Applied (lbs/ac)	88.05

Next Crop Synopsis	
Crop	Cover
Root Depth (ft)	3

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
May 25-31, 2016	1.09	0.02	0	0.01	**1.09**	0.03	**0.52**
June 2016	3.84	0.07	0.51	17.23	**4.35**	17.30	**5.11**
July 2016	6.99	0.13	0.16	49.3	**7.15**	49.43	**9.76**
August 2016	7.85	0.15	0.17	21.14	**8.02**	21.29	**8.27**
Total	**19.77**	**0.37**	**0.84**	**87.68**	**20.61**	**88.05**	**23.66**

Soil Samples			
Depth	**Pre-planting**	**Establishment**	**Peak/Post-Harvest**
Date	4/26/2016	6/22/2016	8/22/2016
NO3-N in ft 1 (lbs/ac)	13	53	22
NO3-N in ft 2 (lbs/ac)	–	–	–
NO3-N in ft 3 (lbs/ac)	2	12	18
NO3-N in ft 4 (lbs/ac)	–	–	–
NO3-N in ft 5 (lbs/ac)	13	1	18
NO3-N in ft 6 (lbs/ac)	–	–	–
NO3-N in ft 7 (lbs/ac)	–	–	–
NO3-N in ft 8 (lbs/ac)	–	–	–

ODA Nitrogen and Hydraulic Loading
Cover R1 Dry Site Summary 2016

Table 21

General Information	
Field I.D.	**R1 - Dry**
Acres	55.04
Crop	Cover 2016
Crop Start Date	9/1/2016
Crop End Date	12/1/2016
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	0.07

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
September 2016	2.72	0.05	0.4	0	**3.12**	0.05	--
October 2016	0.87	0.02	1.76	0	**2.63**	0.02	--
November 2016	0.00	0.00	0.46	0	**0.46**	0.00	--
December 1, 2016	0.00	0.00	0	0	**0.00**	0.00	--
Total	**3.59**	**0.07**	**2.62**	**0.00**	**6.21**	**0.07**	--

Soil Samples		
Depth	**Pre-planting**	**End of Study**
Date	8/22/2016	12/1/2016
NO3-N in ft 1 (lbs/ac)	16	2
NO3-N in ft 2 (lbs/ac)	–	7
NO3-N in ft 3 (lbs/ac)	22	6
NO3-N in ft 4 (lbs/ac)	–	10
NO3-N in ft 5 (lbs/ac)	11	4
NO3-N in ft 6 (lbs/ac)	–	2
NO3-N in ft 7 (lbs/ac)	–	4
NO3-N in ft 8 (lbs/ac)	–	11

ODA Nitrogen and Hydraulic Loading
Cover R2 Wet Site Summary 2016

Table 22

General Information	
Field I.D.	**R2 - Wet**
Acres	19.2
Crop	Cover 2016
Crop Start Date	9/1/2016
Crop End Date	12/1/2016
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	0.20

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
September 2016	3.02	0.16	0.4	0	**3.42**	0.16	--
October 2016	0.86	0.04	1.76	0	**2.62**	0.04	--
November 2016	0.00	0.00	0.46	0	**0.46**	0.00	--
December 1, 2016	0.00	0.00	0	0	**0.00**	0.00	--
Total	**3.88**	**0.20**	**2.62**	**0.00**	**6.50**	**0.20**	--

Soil Samples		
Depth	**Pre-planting**	**End of Study**
Date	8/22/2016	12/1/2016
NO3-N in ft 1 (lbs/ac)	9	3
NO3-N in ft 2 (lbs/ac)	–	5
NO3-N in ft 3 (lbs/ac)	9	4
NO3-N in ft 4 (lbs/ac)	–	6
NO3-N in ft 5 (lbs/ac)	8	10
NO3-N in ft 6 (lbs/ac)	–	9
NO3-N in ft 7 (lbs/ac)	–	12
NO3-N in ft 8 (lbs/ac)	–	10

ODA Nitrogen and Hydraulic Loading
Cover R3 Average Site Summary 2016

Table 23

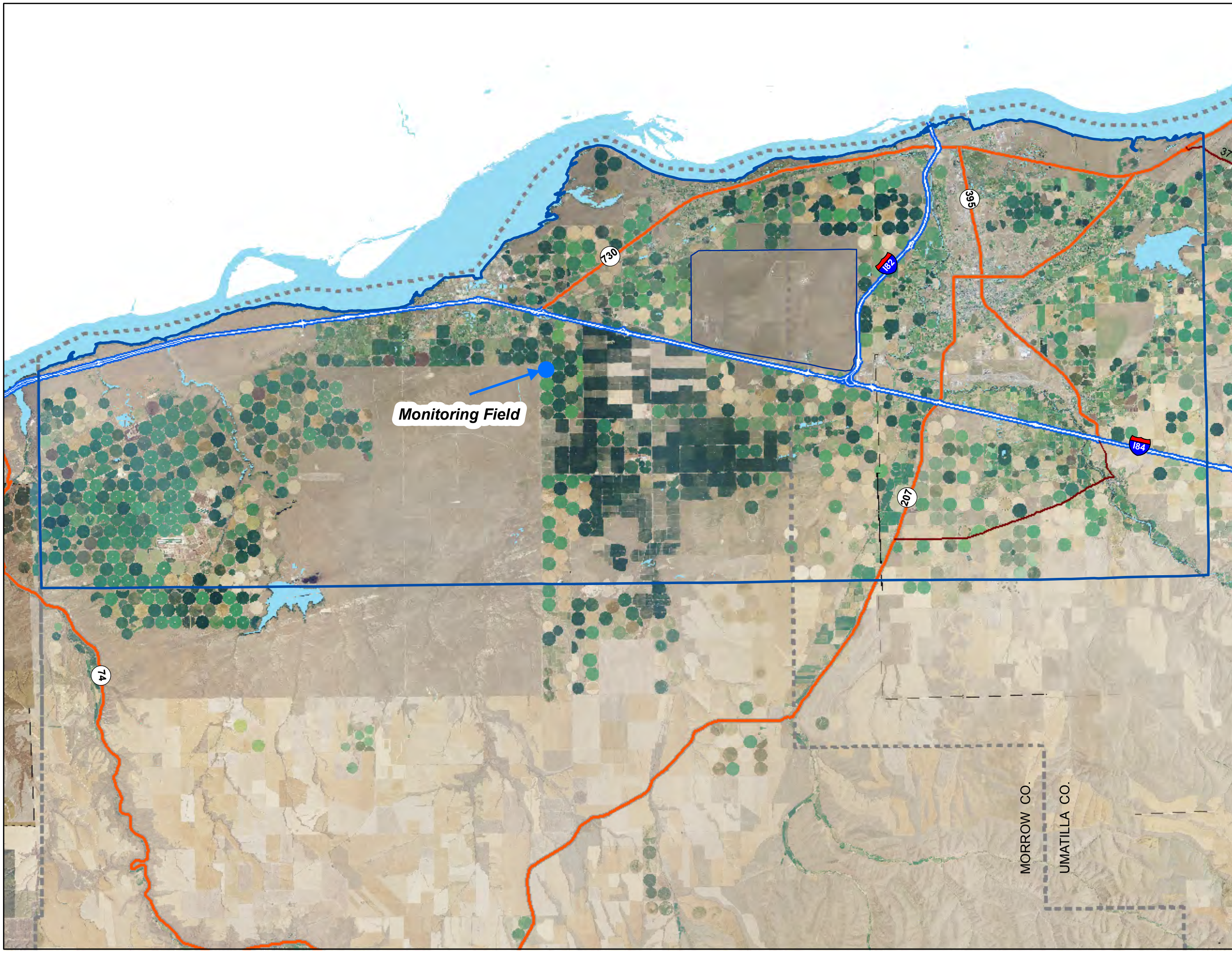
General Information	
Field I.D.	**R3 - Average**
Acres	53.76
Crop	Cover 2016
Crop Start Date	9/1/2016
Crop End Date	12/1/2016
# of Cuttings	0
Root Depth (ft)	3
Total N Applied (lbs/ac)	0.07

	Irrigation Water		Precip	Comm Fert	Totals		ET Rate
Month	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**	**lbs N/Ac**	**In/Ac**
September 2016	3.50	0.06	0.4	0	**3.90**	0.06	--
October 2016	0.40	0.01	1.76	0	**2.16**	0.01	--
November 2016	0.00	0.00	0.46	0	**0.46**	0.00	--
December 1, 2016	0.00	0.00	0	0	**0.00**	0.00	--
Total	**3.90**	**0.07**	**2.62**	**0.00**	**6.52**	**0.07**	--

Soil Samples		
Depth	**Pre-planting**	**End of Study**
Date	8/22/2016	12/1/2016
NO3-N in ft 1 (lbs/ac)	22	2
NO3-N in ft 2 (lbs/ac)	–	2
NO3-N in ft 3 (lbs/ac)	18	3
NO3-N in ft 4 (lbs/ac)	–	7
NO3-N in ft 5 (lbs/ac)	18	7
NO3-N in ft 6 (lbs/ac)	–	5
NO3-N in ft 7 (lbs/ac)	–	12
NO3-N in ft 8 (lbs/ac)	–	22

Figures 1-6

Figure 1
Monitoring Field Location



Legend

Lower Umatilla Basin Groundwater Management Area

Projection: Oregon Statewide Lambert
Datum: NAD 1983

Date: 2/3/2017

N
W E
S

0 0.5 1 2 3
Miles

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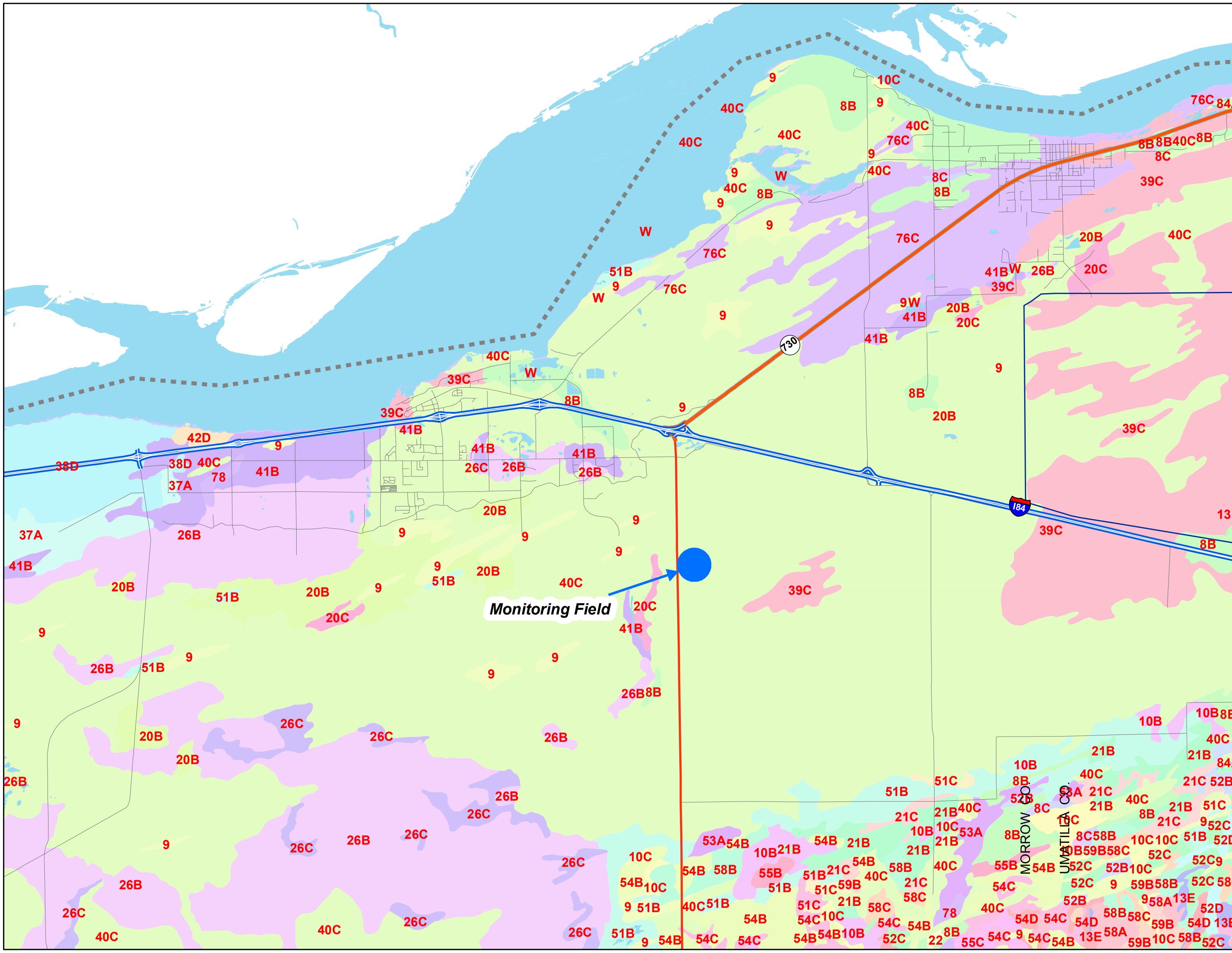
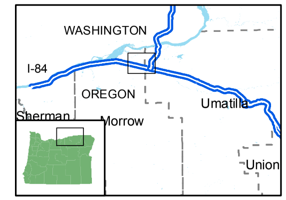
Figure 2
Morrow County Soil Type Map





Legend

- 39C-Quincy fine sand, 2 to 12 percent slopes
- 40C-Quincy loamy fine sand, 2 to 12 percent slopes
- 41B-Quinton loamy fine sand, 2 to 5 percent slopes
- 26B-Koehler loamy fine sand, 2 to 5 percent slopes
- 20C-Hezel loamy fine sand, 5 to 12 percent slopes
- 8B-Burbank loamy fine sand, 2 to 5 percent slopes

Data taken from United States Department of Agriculture

Projection: Oregon Statewide Lambert
Datum: NAD 1983

Date: 3/20/2017

0 0.5 1
Miles

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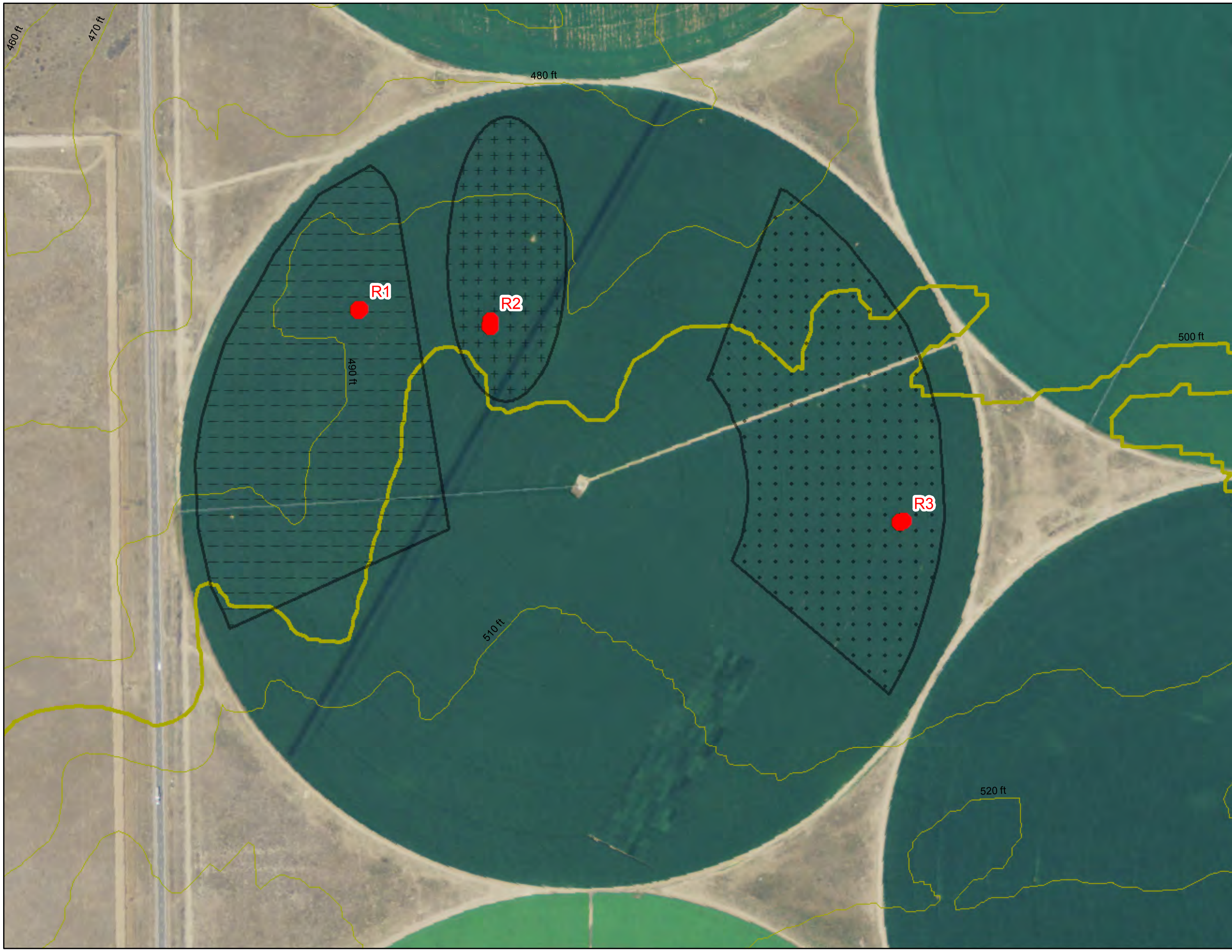
Figure 3
Countour Map and Sampling Locations



Legend

- Soil moisture sites locations
- Dry
- Wet
- Average
- Contour Line, Intermediate
- Contour Line, Major
- Contour Line, Minor

Projection: Oregon Statewide Lambert
Datum: NAD 1983

Date: 2/6/2017

N W E S

0 100 200 Feet

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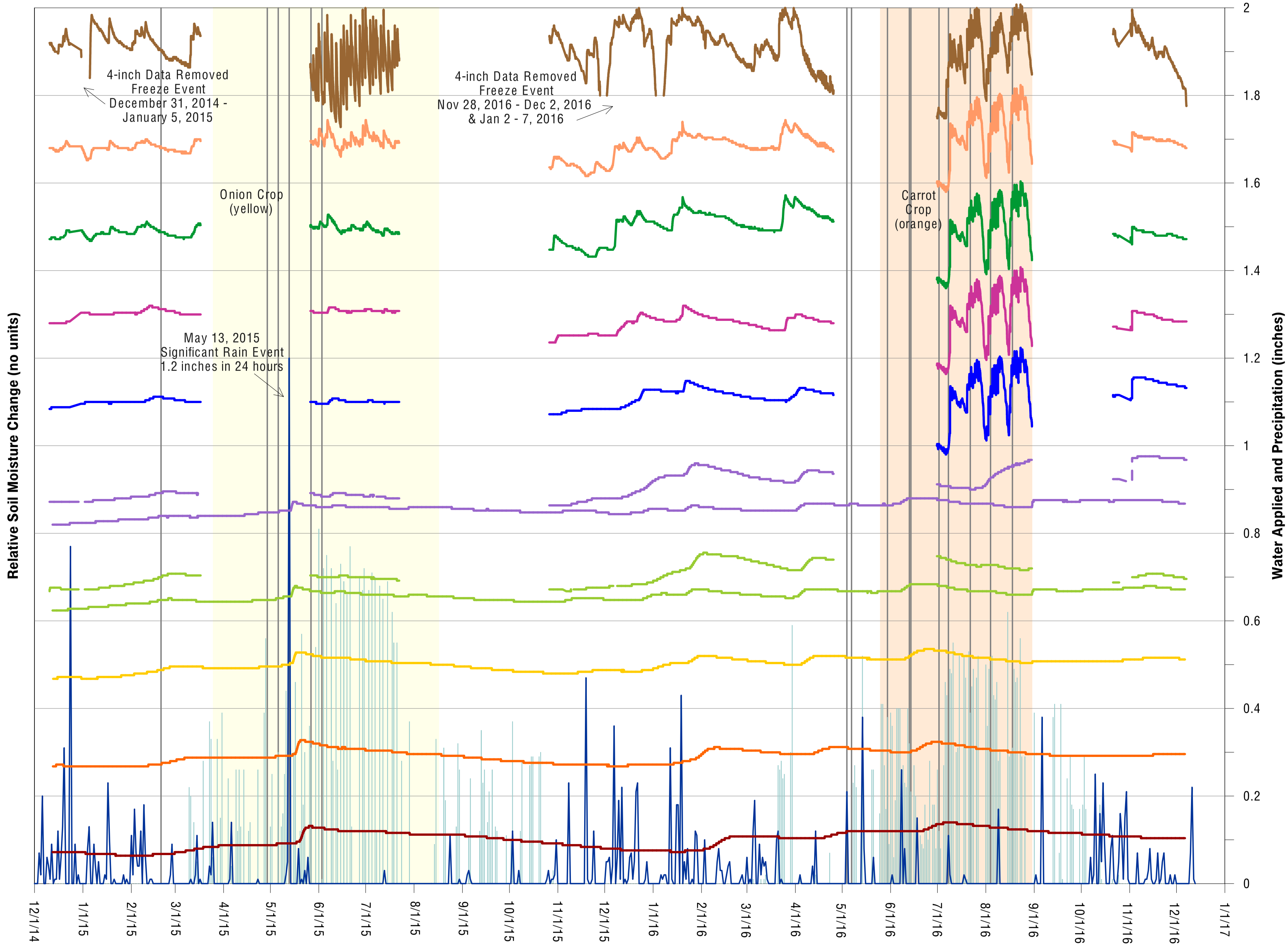

Figure 4
Soil Moisture, Water Gauge and Precipitation in 2015 & 2016: Site R-1 (Dry Area)

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet, shallow probe
- 4 feet, deep probe
- 5 feet, shallow probe
- 5 feet, deep probe
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. R-1 shallow probe extends to 5 feet, therefore 4 foot and 5 foot measurements are collected by both probes. The 2 foot probe is at 20 inches.

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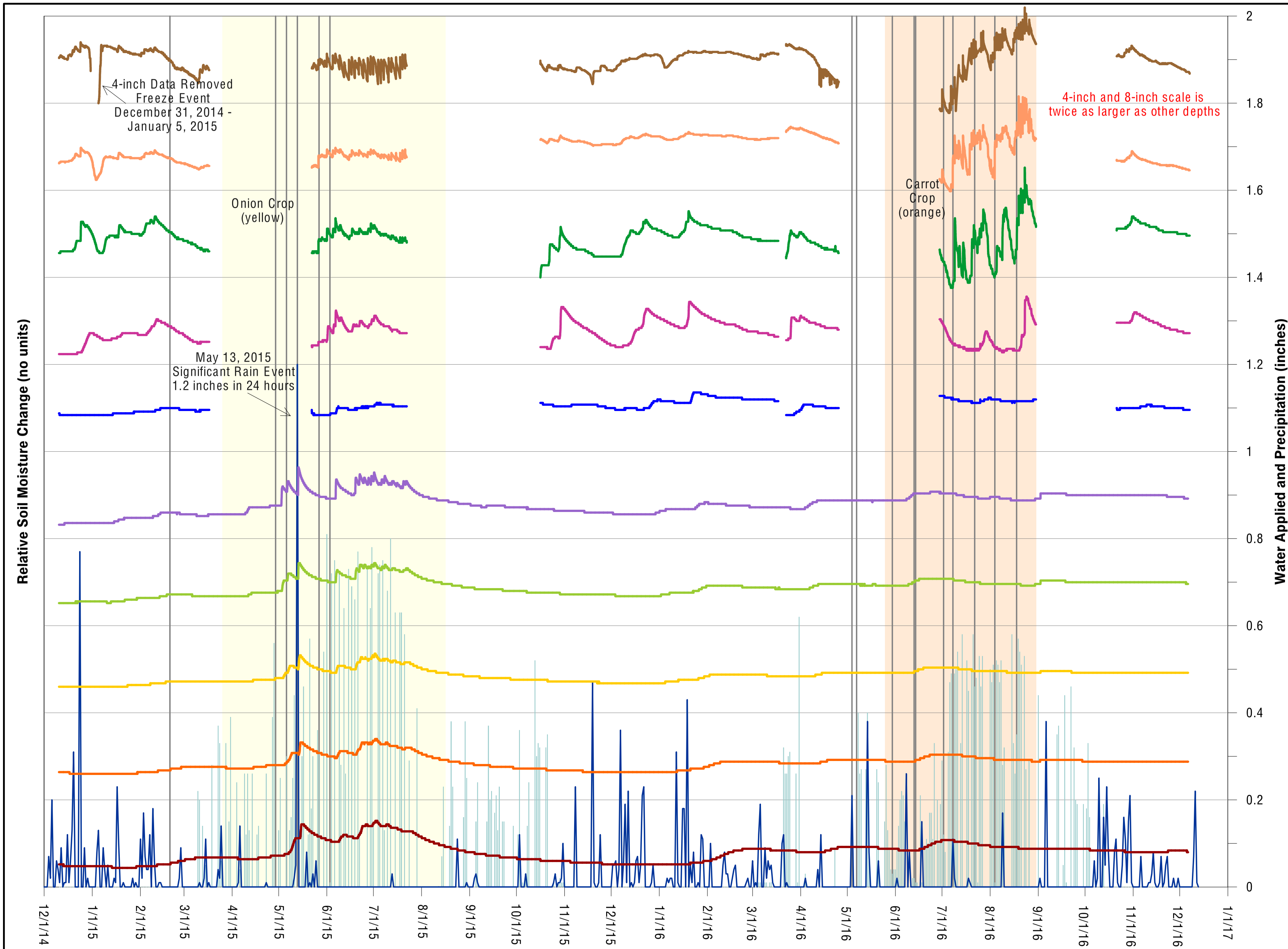

Figure 5
Soil Moisture, Water Gauge and Precipitation in 2015 & 2016:
Site R-2 (Wet Area)

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20.

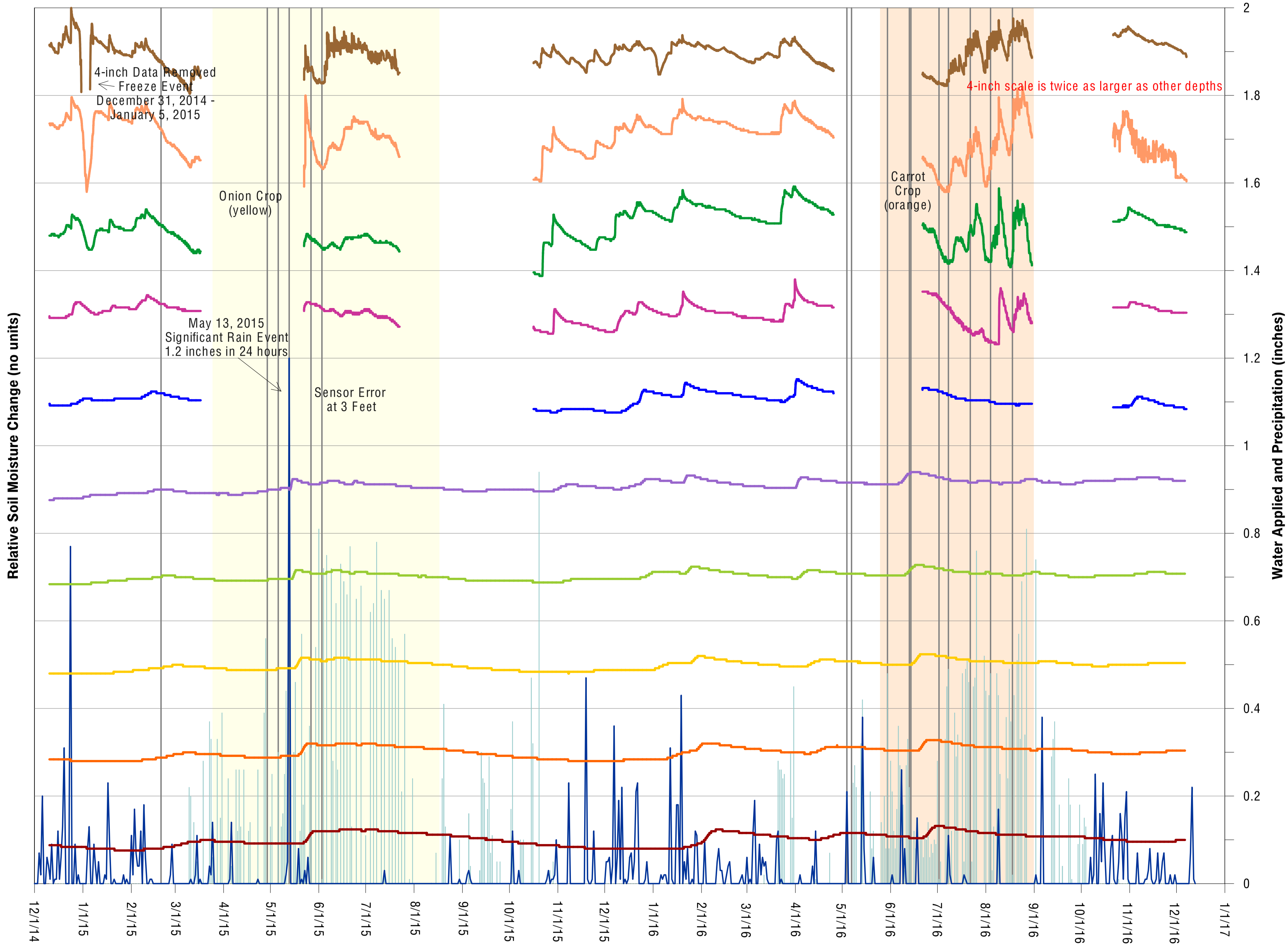

Figure 6
Soil Moisture, Water Gauge and Precipitation in 2015 & 2016: Site R-3 (Average Area)

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20 inches.

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APPENDIX A

Fertilizer Application Datasheets

Applied Product By Field Detail

128.00 acres

Sep 15, 2014 - Oct 1, 2015

Onions : Yellow Onions

fertilizer

DATE	APPLICATION CO	PRODUCT	LBS N/Acre	RATE	AREA	TOTAL	COST
2/20/2015		23-0-29-0	60 lbs	0.13 ton	128.00 acres	16.02 ton	$0.00
4/29/2015		CN9	11 lbs	0.06 ton	128.00 acres	7.62 ton	$0.00
5/6/2015		CN9	9 lbs	0.05 ton	128.00 acres	6.99 ton	$0.00
5/13/2015		CN9	20 lbs	0.11 ton	128.00 acres	14.29 ton	$0.00
5/27/2015		CN9	22 lbs	0.12 ton	128.00 acres	15.24 ton	$0.00
6/3/2015		CN9	20 lbs	0.11 ton	128.00 acres	14.29 ton	$0.00
		TOTAL N	142 lbs	**$ / Area:**	$0.00	**Total Cost:**	$0.00

$ / Area: $0.00 **Total Cost:** $0.00

Preplant.

Fertilizer Detail Report
128.00 acres

fertilizer

DATE	PRODUCT	RATE	AREA	TOTAL	Units / Area
May 4	3.2-14.9-42.3 .6S	0.26 ton	130.00 acres	68,380.00 lb	16.83N - 78.37P - 222.5K - 03.16S
May 7	Compost	3.01 ton	128.00 acres	384.89 ton	111.86N - 119.08P - 187.03K - 143.13Ca - 46.91Mg - 42.1S - 00.03B - 12.03Cl - 00.3Cu - 53.22Fe - 01.86Mn - 01.38Zn

Summary: 128.95N - 198.67P - 413.01K - 143.13Ca - 46.91Mg - 45.3S - 00.03B - 12.03Cl - 00.3Cu - 53.22Fe - 01.86Mn - 01.38Zn on crop

Fertilizer Detail Report
128.00 acres

fertilizer

DATE	PRODUCT	RATE	AREA	TOTAL	Units / Area
May 30	iNvigorate 0-0-0.5	0.25 gal	128.00 acres	32.00 gal	00N - 00P - 00.01K
May 30	B Sure 0.5-0-0.5	0.25 gal	128.00 acres	32.00 gal	00.01N - 00P - 00.01K
Jun 13	28-0-0-4s Hum	2.83 gal	128.00 acres	362.00 gal	08.76N - 00P - 00.04K - 01.26S
Jun 14	28-0-0-4s Hum	2.73 gal	128.00 acres	350.00 gal	08.47N - 00P - 00.04K - 01.22S
Jul 2	28-0-0-4s Hum	6.05 gal	128.00 acres	775.00 gal	18.75N - 00P - 00.09K - 02.69S
Jul 8	28-0-0-4s Hum	6.25 gal	128.00 acres	800.00 gal	19.35N - 00P - 00.09K - 02.78S
Jul 22	28-0-0-4s Hum	3.62 gal	128.00 acres	463.00 gal	11.2N - 00P - 00.05K - 01.61S
Aug 4	28-0-0-4s Hum	3.41 gal	128.00 acres	437.00 gal	10.57N - 00P - 00.05K - 01.52S
Aug 18	28-0-0-4s Hum	3.41 gal	128.00 acres	437.00 gal	10.57N - 00P - 00.05K - 01.52S

Summary: 87.68N - 00P - 00.43K - 12.59S

APPENDIX B

Soil Sampling Laboratory Reports

Date:	12/11/14
Report No:	S43225-1
Grower:	***ODA***
Client:	IRZ Consulting, Hermiston
Sampler:	IRZ Consulting, Hermiston
Field:	***R-1***
Sample Date:	12/10/14

Kuo Testing Labs, Inc.

337 South 1st
Othello, Washington 99344
(509) 488-0112; Fax (509) 488-0118
E-mail: kuotest.atnet.net
Web site: http://www.kuotesting.com
Customer service is our top priority

SOIL ANALYSIS REPORT

Lab #	Depth Foot	Field ID	NO3-N #/Ac	NO3-N ppm	TKN %	pH (1:2)
		R-1				
4748	1		51	*12.8*	0.079	6.0
4749	2		13	*3.3*	0.045	8.0
4750	3		7	*1.8*	0.016	8.2
4751	4		4	*1.0*	0.031	8.3
4752	5		4	*1.0*	0.020	8.2
4753	6		7	*1.8*	0.041	8.4
4754	7		6	*1.5*	0.023	8.5
4755	8		7	*1.8*	0.035	8.4

Date:	12/11/14
Report No:	S43225-2
Grower:	***ODA***
Client:	IRZ Consulting, Hermiston
Sampler:	IRZ Consulting, Hermiston
Field:	***R-2***
Sample Date:	12/10/14

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Web site: http://www.kuotesting.com
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SOIL ANALYSIS REPORT

Lab #	Depth Foot	Field ID	NO3-N #/Ac	NO3-N ppm	TKN %	pH (1:2)
		R-2				
4756	1		56	*14.0*	0.082	5.7
4757	2		16	*4.0*	0.057	5.9
4758	3		4	*1.0*	0.034	6.7
4759	4		3	*0.8*	0.038	6.9
4760	5		5	*1.3*	0.017	8.0
4761	6		6	*1.5*	0.024	8.3
4762	7		7	*1.8*	0.020	8.3
4763	8		8	*2.0*	0.013	8.4

Date:	12/11/14
Report No:	S43225-3
Grower:	***ODA***
Client:	IRZ Consulting, Hermiston
Sampler:	IRZ Consulting, Hermiston
Field:	***R-3***
Sample Date:	12/10/14

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SOIL ANALYSIS REPORT

Lab #	Depth Foot	Field ID	NO3-N #/Ac	NO3-N ppm	TKN %	pH (1:2)
		R-3				
4764	1		51	*12.8*	0.045	6.2
4765	2		14	*3.5*	0.040	6.7
4766	3		9	*2.3*	0.019	7.7
4767	4		7	*1.8*	0.028	8.3
4768	5		8	*2.0*	0.020	8.4
4769	6		4	*1.0*	0.026	8.4
4770	7		4	*1.0*	0.023	8.3
4771	8		8	*2.0*	0.033	8.4

Date:	08/31/15
Report No:	S45533-1
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-1***
Crop:	

Kuo Testing Labs, Inc.

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
2193	**1**	***R-1***	22	*5.5*
2194	**3**	***R-1***	10	*2.5*
2195	**5**	***R-1***	25	*6.3*

Date: 08/31/15
Report No: S45533-2
Grower: *ODA*
Client: IRZ Consulting
Sampler:
Field: *R-2*
Crop:

Kuo Testing Labs, Inc.

337 South 1st
Othello, Washington 99344
(509) 488-0112; Fax (509) 488-0118
E-mail: kuotest.atnet.net
Web site: http://www.kuotesting.com
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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
2196	**1**	***R-2***	55	*13.8*
2197	**3**	***R-2***	37	*9.3*
2198	**5**	***R-2***	30	*7.5*

Date: 08/31/15
Report No: S45533-3
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-3***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
2199	**1**	***R-3***	37	*9.3*
2200	**3**	***R-3***	19	*4.8*
2201	**5**	***R-3***	9	*2.3*

Date: 12/11/15
Report No: S46171-1
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-1***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
51	**1**	***R-1***	5	1.25
52	**3**	***R-1***	9	2.25
53	**5**	***R-1***	28	7

Date:	12/11/15
Report No:	S46171-2
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-2***
Crop:	

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
54	**1**	***R-2***	3	0.75
55	**3**	***R-2***	7	1.75
56	**5**	***R-2***	39	9.75

Date:	12/11/15
Report No:	S46171-3
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-3***
Crop:	

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
57	**1**	***R-3***	3	0.75
58	**3**	***R-3***	14	3.5
59	**5**	***R-3***	26	6.5

AgSource Laboratories
A Subsidiary of Cooperative Resources International

323 Sixth Street
Umatilla, OR 97882
Tel:541-922-4894
umatilla@agsource.com

Plant/Soil Analysis

Submitted By:

Submitted For:

Laboratory Sample #
AP59937

Date Received:
07/01/2015

Date Processed:
07/02/2015

Information Sheet #
S6736L

Sampler: NACHO

Field Id: P-4

Crop Monitoring Summary Log - 2015

Plant Crop: ONIONS

Variety:

Soil Analysis

Sample Date	Sample Id	Depth	pH	EC mmhos	OM %	Bray P ppm	Olsen P ppm	K ppm	Ca meq	Mg meq	NO3 lb/a	NH4 lb/a	S ppm	B ppm	Zn ppm	Mn ppm	Cu ppm	Fe ppm	Na meq
4/28	0-3`	3									15	3							
4/28	3-6`	3									17	2							
5/5	0-3`	3									27	7							
5/5	3-6`	3									24	8							
5/11	0-3	3									32	3							
5/11	3-6	3									20	2							
5/19		6									29	4							
5/26		6									34	5							
6/1		12									75	9							
6/9		12	7.0				26				67	8							
6/17		12									64	11							
7/1		12									43	9							

Plant Tissue Analysis

Sample Date	Sample Id	TKN %	NO3 ppm	S %	P %	PO4 %	K %	Ca %	Mg %	B ppm	Zn ppm	Mn ppm	Cu ppm	Fe ppm
4/28	0-3`													
4/28	3-6`													
5/5	0-3`													
5/5	3-6`													
5/11	0-3													
5/11	3-6													
5/19														
5/26														
6/1														
6/9														
6/17														
7/1														

Date:	04/26/2016
Report No:	S46171-1
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-1***
Crop:	

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
8044	**1**	***R-1***	23.6	5.9
8045	**3**	***R-1***	2.3	0.6
8046	**5**	***R-1***	12.8	3.2

Date: 04/26/2016
Report No: S46171-2
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-2***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth (ft)	Field ID	NO3-N (#/ac)	NO3-N (ppm)
8047	1	R-2	25.4	6.4
8048	3	R-2	3.2	0.8
8049	5	R-2	5.4	1.4

Date: 04/26/2016
Report No: S46171-3
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-3***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
8050	**1**	***R-3***	12.9	3.2
8051	**3**	***R-3***	2.4	0.6
8052	**5**	***R-3***	12.7	3.2

Date:	06/22/2016
Report No:	S47895-1
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-1***
Crop:	

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
7224	**1**	***R-1***	183.2	45.8
7225	**3**	***R-1***	18.4	4.6
7226	**5**	***R-1***	27.5	6.9

Date:	06/22/2016
Report No:	S47895-2
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-2***
Crop:	

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO_3-N #/ac	NO_3-N ppm
7227	**1**	***R-2***	88.7	22.2
7228	**3**	***R-2***	7.2	1.8
7229	**5**	***R-2***	0.4	0.1

Date: 06/22/2016
Report No: S47895-3
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-3***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
7230	**1**	***R-3***	52.8	13.2
7231	**3**	***R-3***	12.4	3.1
7232	**5**	***R-3***	0.6	0.2

Date: 08/22/2016
Report No: S48586-1
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-1***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
7300	**1**	***R-1***	16	4.1
7301	**3**	***R-1***	22	5.4
7302	**5**	***R-1***	11	2.7

Date: 08/22/2016
Report No: S48586-2
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-2***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO_3-N #/ac	NO_3-N ppm
7303	1	R-2	9	2.1
7304	3	R-2	9	2.3
7305	5	R-2	8	2.1

Date: 08/22/2016
Report No: S48586-3
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-3***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
7306	1	R-3	22	5.4
7307	3	R-3	18	4.5
7308	5	R-3	18	4.4

Date:	12/01/2016
Report No:	S49253-1
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-1***
Crop:	

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
4273	**1**	***R-1***	2	0.4
4274	**2**		7	1.7
4275	**3**		6	1.6
4276	**4**		10	2.4
4277	**5**		4	0.9
4278	**6**		2	0.6
4279	**7**		4	0.9
4280	**8**		11	2.8

Date:	12/01/2016
Report No:	S49253-2
Grower:	***ODA***
Client:	IRZ Consulting
Sampler:	
Field:	***R-2***
Crop:	

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
4281	**1**	***R-2***	3	0.8
4282	**2**		5	1.2
4283	**3**		4	0.9
4284	**4**		6	1.4
4285	**5**		10	2.6
4286	**6**		9	2.1
4287	**7**		12	3.0
4288	**8**		10	2.5

Date: 12/01/2016
Report No: S49253-3
Grower: ***ODA***
Client: IRZ Consulting
Sampler:
Field: ***R-3***
Crop:

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SOIL ANALYSIS REPORT

Lab #	Depth ft	Field ID	NO3 -N #/ac	NO3 -N ppm
4289	**1**	***R-3***	2	0.5
4290	**2**		2	0.6
4291	**3**		3	0.7
4292	**4**		7	1.8
4293	**5**		7	1.7
4294	**6**		5	1.2
4295	**7**		12	3.1
4296	**8**		22	5.4

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Web Site: http://www.kuotesting.com e-mail: kuotest@atnet.net

DATE COLLECTED	DATE RECEIVED	DATE REPORTED
10/19/2016	10/20/201	10/21/2016

SYSTEM / CUSTOMER

IRZ Consulting
500 N 1st St.
Hermiston OR 97838
Project Name:

SEND REPORT TO:

IRZ Consulting
500 N 1st St.
Hermiston OR 97838
Attn:

SAMPLE NO.	CUSTOMER SAMPLE ID	ANALYSIS	RESULTS	MCL	UNITS	ANALYSTS
58442	ODA Irrigation Water	Nitrate as Nitrogen	4.4		mg/L	Kuo Testing Labs

ND: None Detectable, None Detected, below method reporting limit/lower reporting limit.
mg/L: Indicates milligrams per liter
MDL: Method Detection Limit
I indicates the report value is between the lab method detection limit and the labratory practical quantification limit.
BFCHD Accreditation #M93
CFU/100mL: Colony Forming Unit per 100 mL
IJ: An estimated concentration, below calibration curve but above method detection limit.
1 µmho/cm =1 µS/cm =1 Microsiemen/cm (units for conductivity, SI units mS/m = µS/cm/ 10)
APHT: Analyzed Past Hold Time
MRL: Method Reporting Level
* : Washington State Department of Health states these analytes are secondary MCL's (Established for esthetic purposes, not health based).

Comments:

Quality Assurance Personnel

10-21-16
Date

APPENDIX C

High Resolution Moisture Probe Graphs

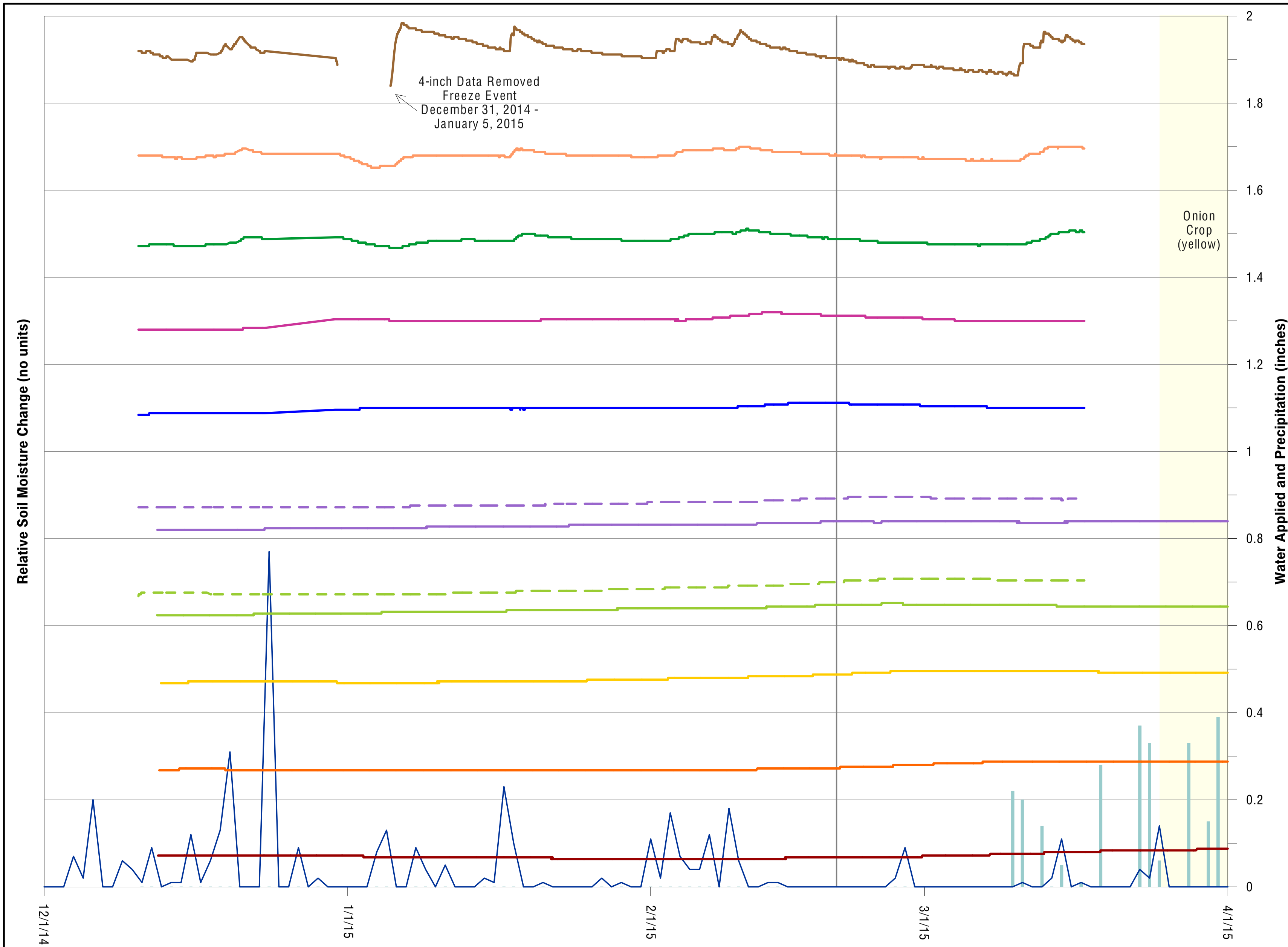

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-1 (Dry Area) December 2014 through March 2015

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. R-1 shallow probe extends to 5 feet, therefore 4 foot and 5 foot measurements are collected by both probes. The 2 foot probe is at 20 inches.

GSI Water Solutions, Inc.
IRZ

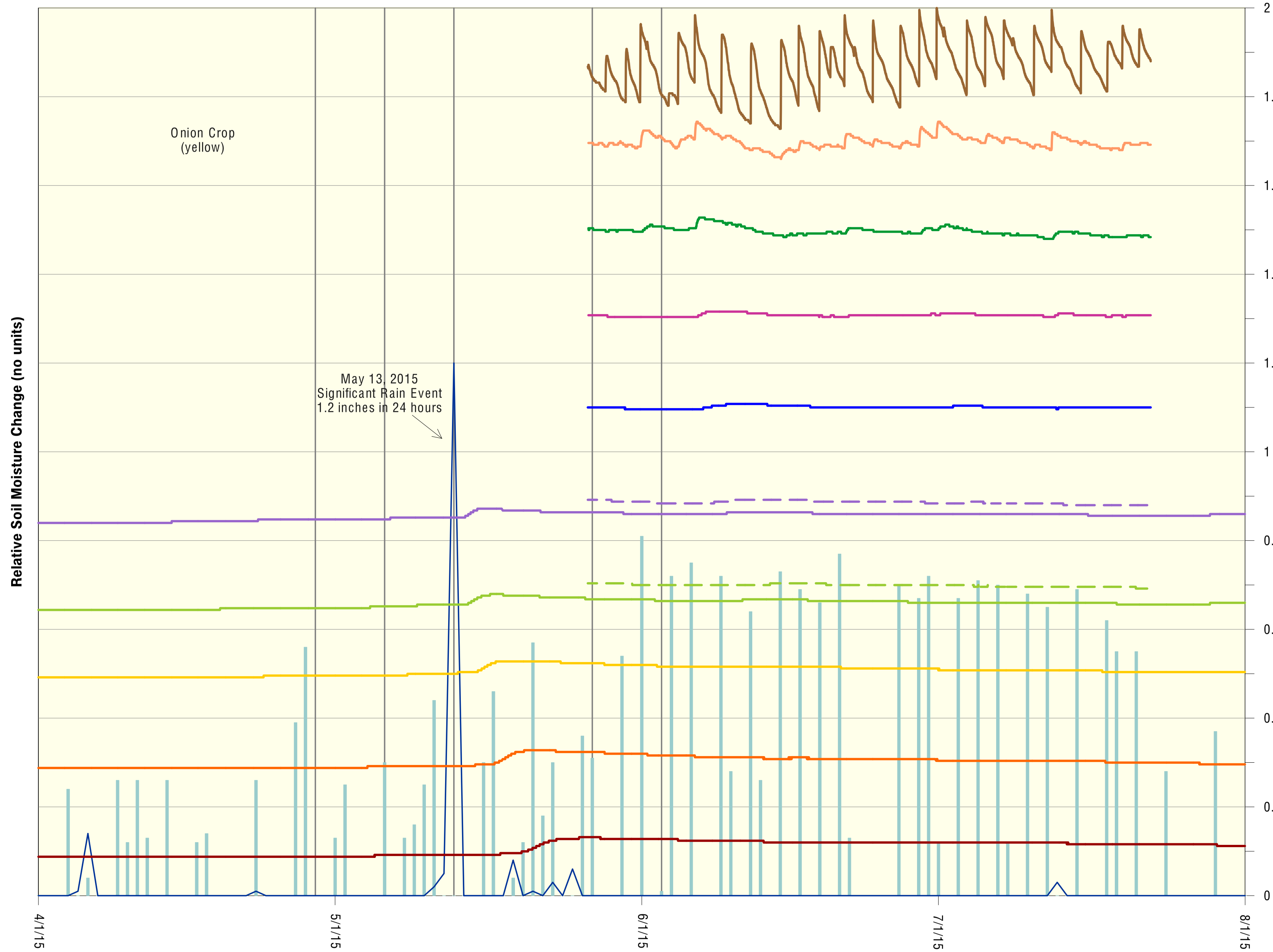

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-1 (Dry Area) April 2015 through July 2015

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. R-1 shallow probe extends to 5 feet, therefore 4 foot and 5 foot measurements are collected by both probes. The 2 foot probe is at 20 inches.

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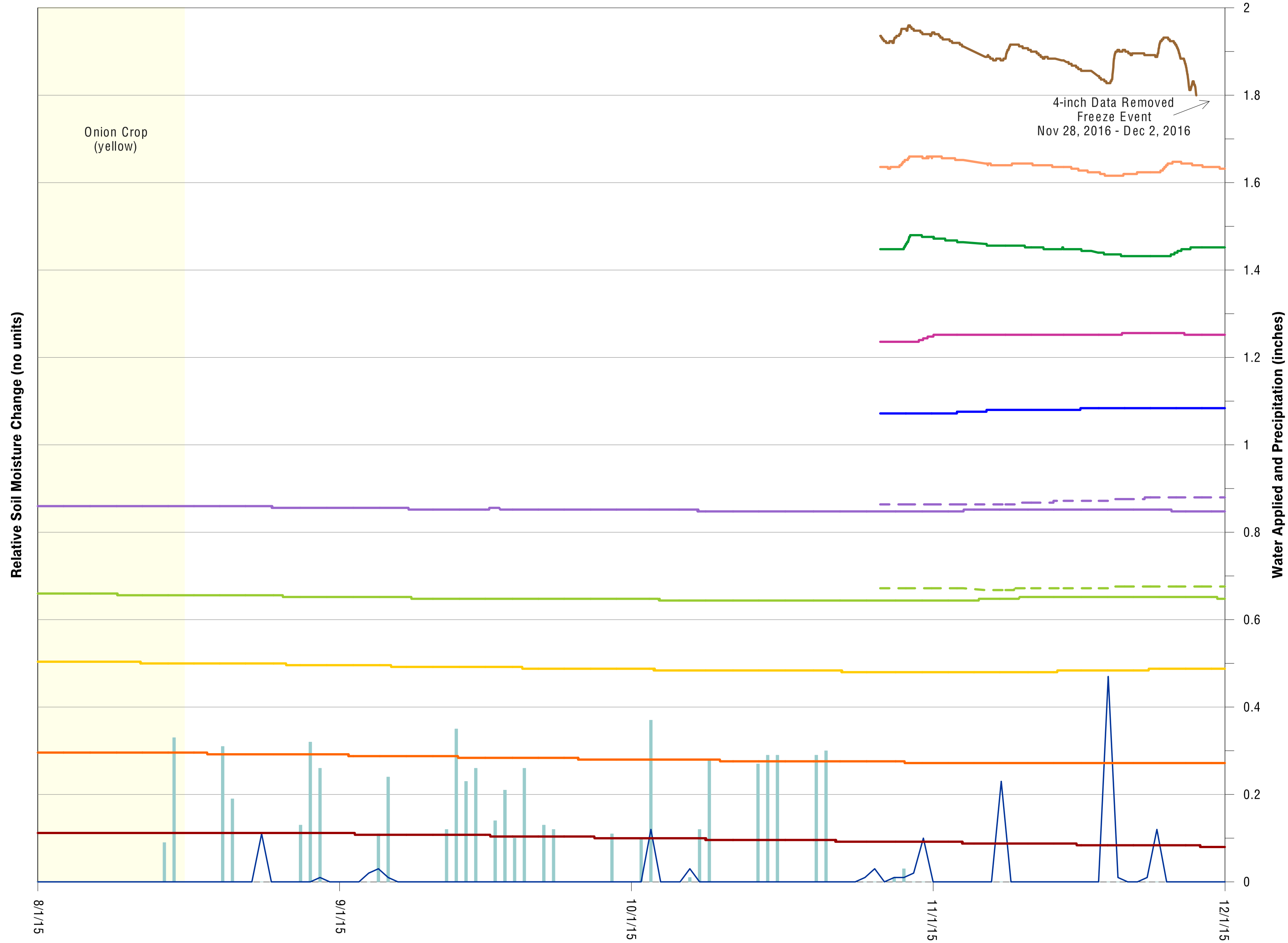

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-1 (Dry Area) August 2015 through November 2015

Year 2 and 3 Monitoring Program

4 inches
8 inches
1 foot
2 feet
3 feet
4 feet, shallow probe
4 feet, deep probe
5 feet, shallow probe
5 feet, deep probe
6 feet
7 feet
8 feet
Fertilizer Applied
Precipitation, daily
Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. R-1 shallow probe extends to 5 feet, therefore 4 foot and 5 foot measurements are collected by both probes. The 2 foot probe is at 20 inches.

GSI Water Solutions, Inc.
IRZ

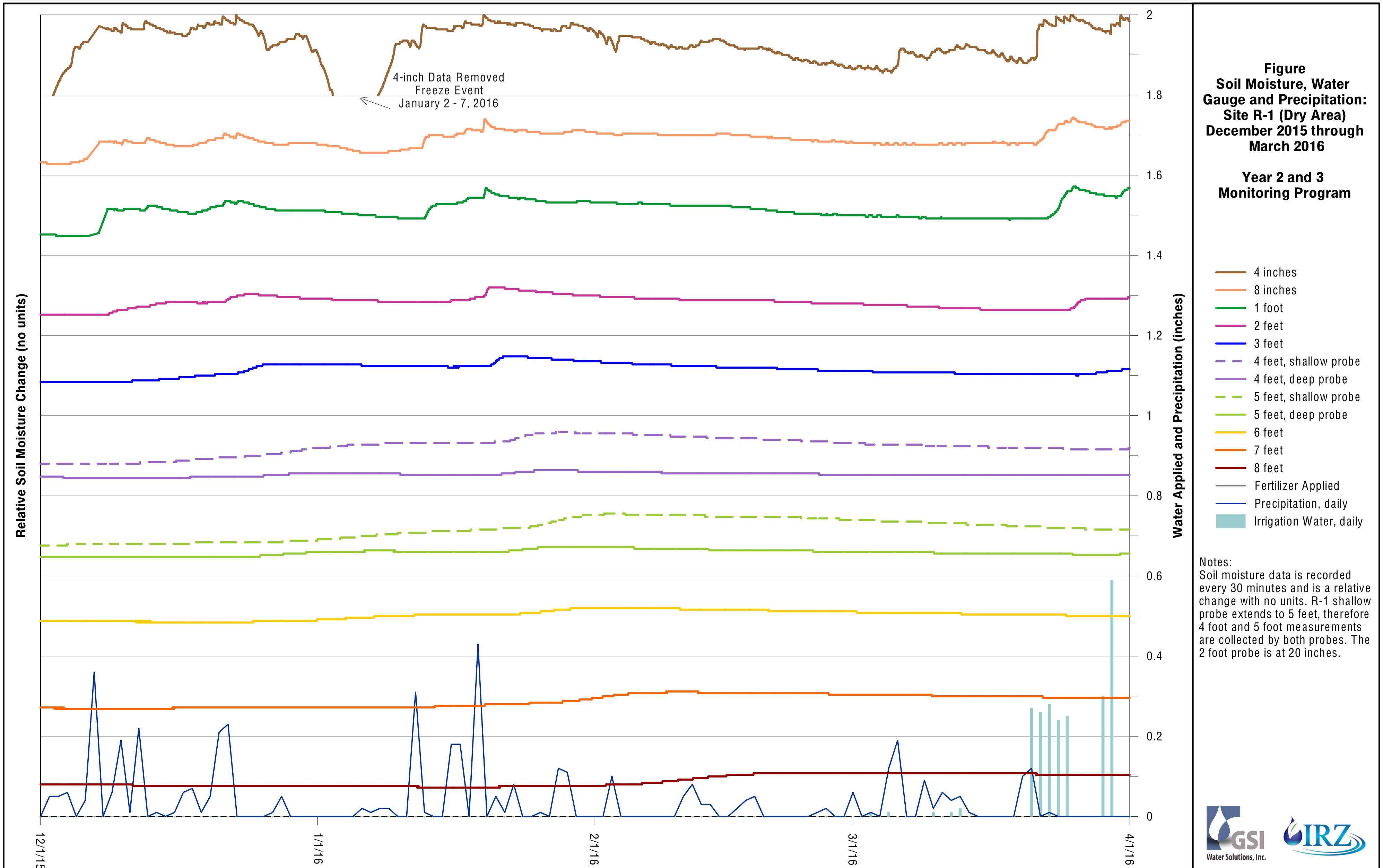

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-1 (Dry Area)
December 2015 through March 2016

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. R-1 shallow probe extends to 5 feet, therefore 4 foot and 5 foot measurements are collected by both probes. The 2 foot probe is at 20 inches.

GSI Water Solutions, Inc. IRZ

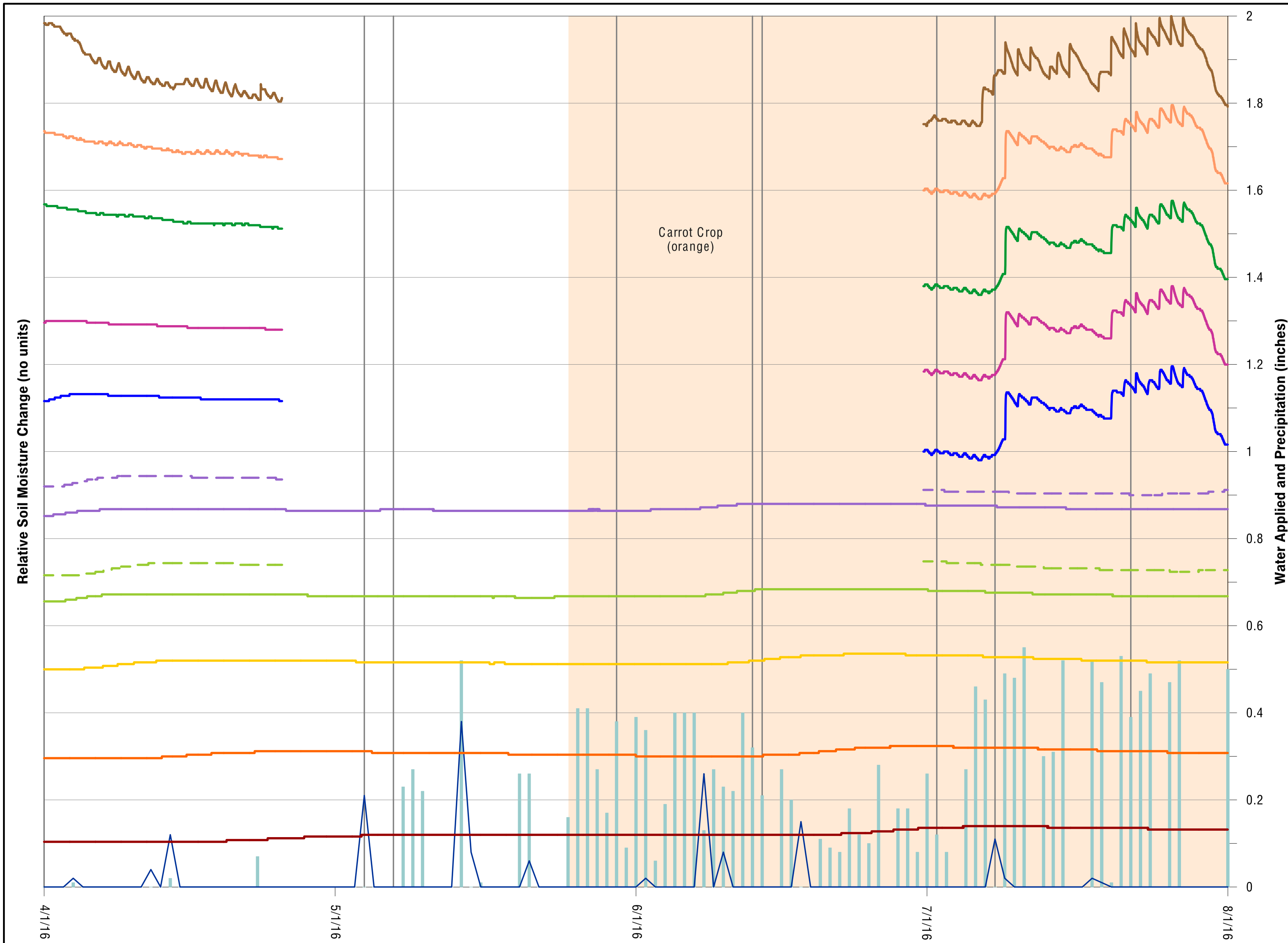

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-1 (Dry Area) April 2016 through July 2016

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. R-1 shallow probe extends to 5 feet, therefore 4 foot and 5 foot measurements are collected by both probes. The 2 foot probe is at 20 inches.

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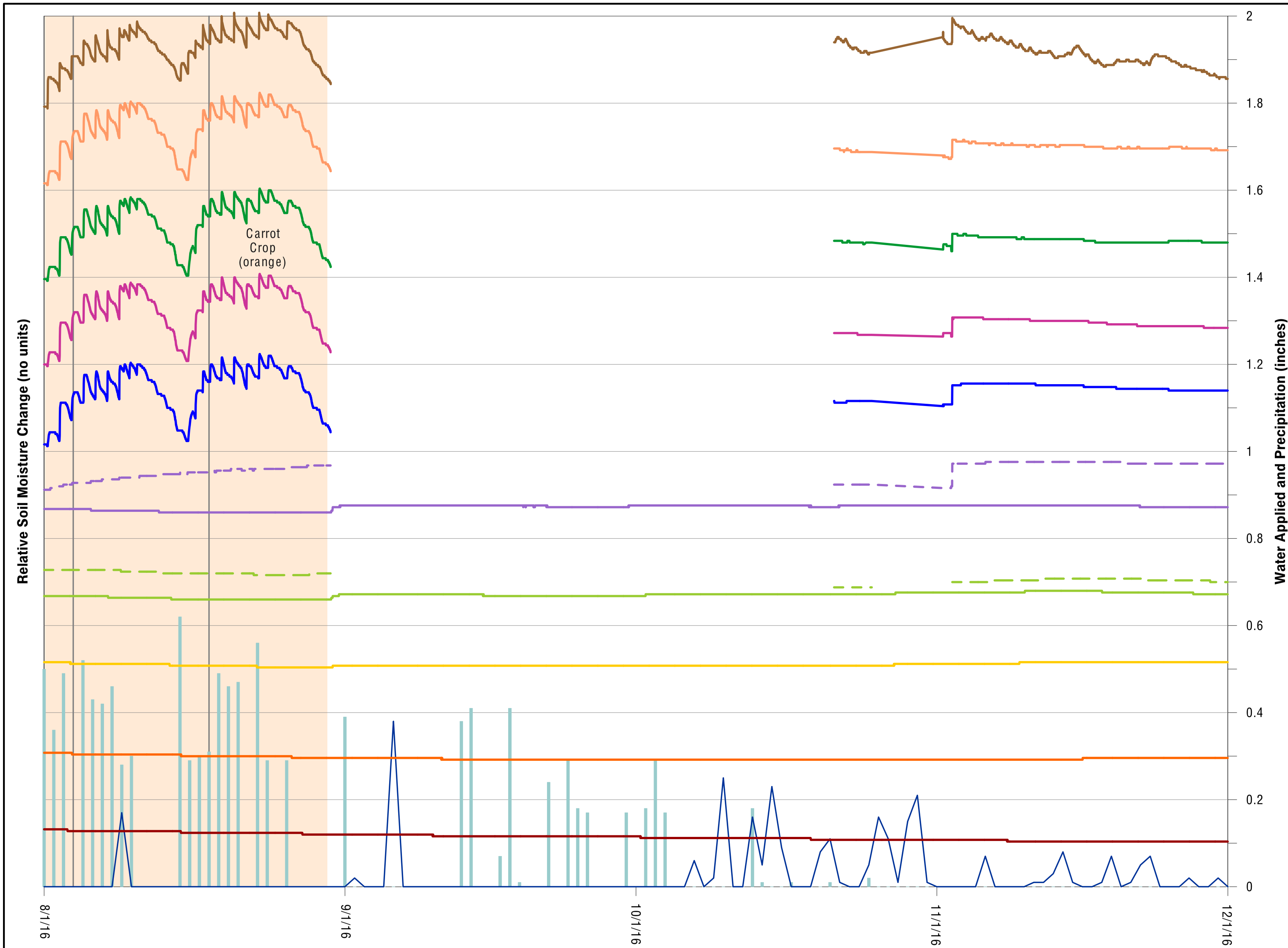

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-1 (Dry Area) August 2016 through November 2016

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet, shallow probe
- 4 feet, deep probe
- 5 feet, shallow probe
- 5 feet, deep probe
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. R-1 shallow probe extends to 5 feet, therefore 4 foot and 5 foot measurements are collected by both probes. The 2 foot probe is at 20 inches.

GSI Water Solutions, Inc.

IRZ

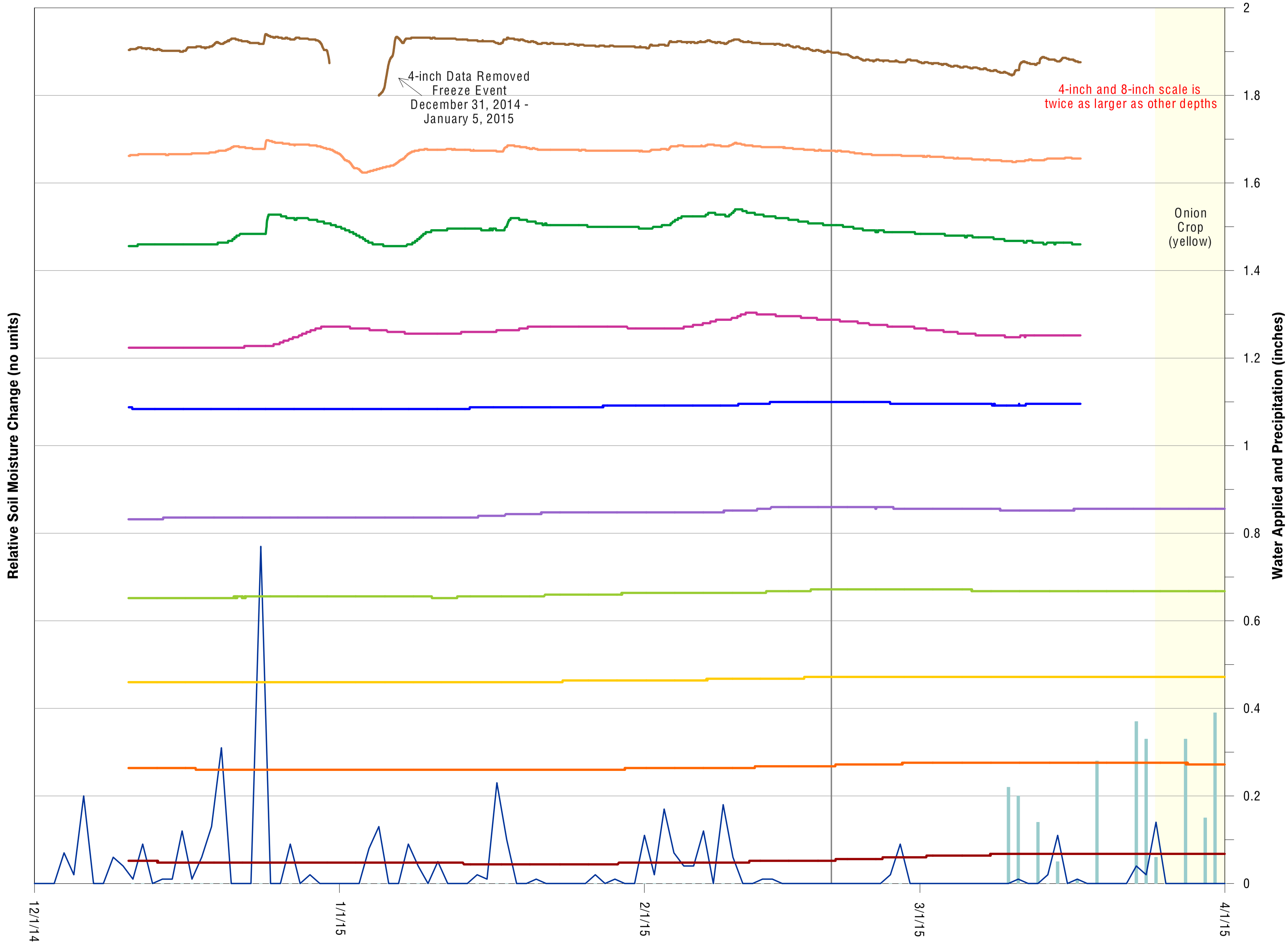

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-2 (Wet Area)
December 2014 through March 2015

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20.

GSI Water Solutions, Inc.

IRZ

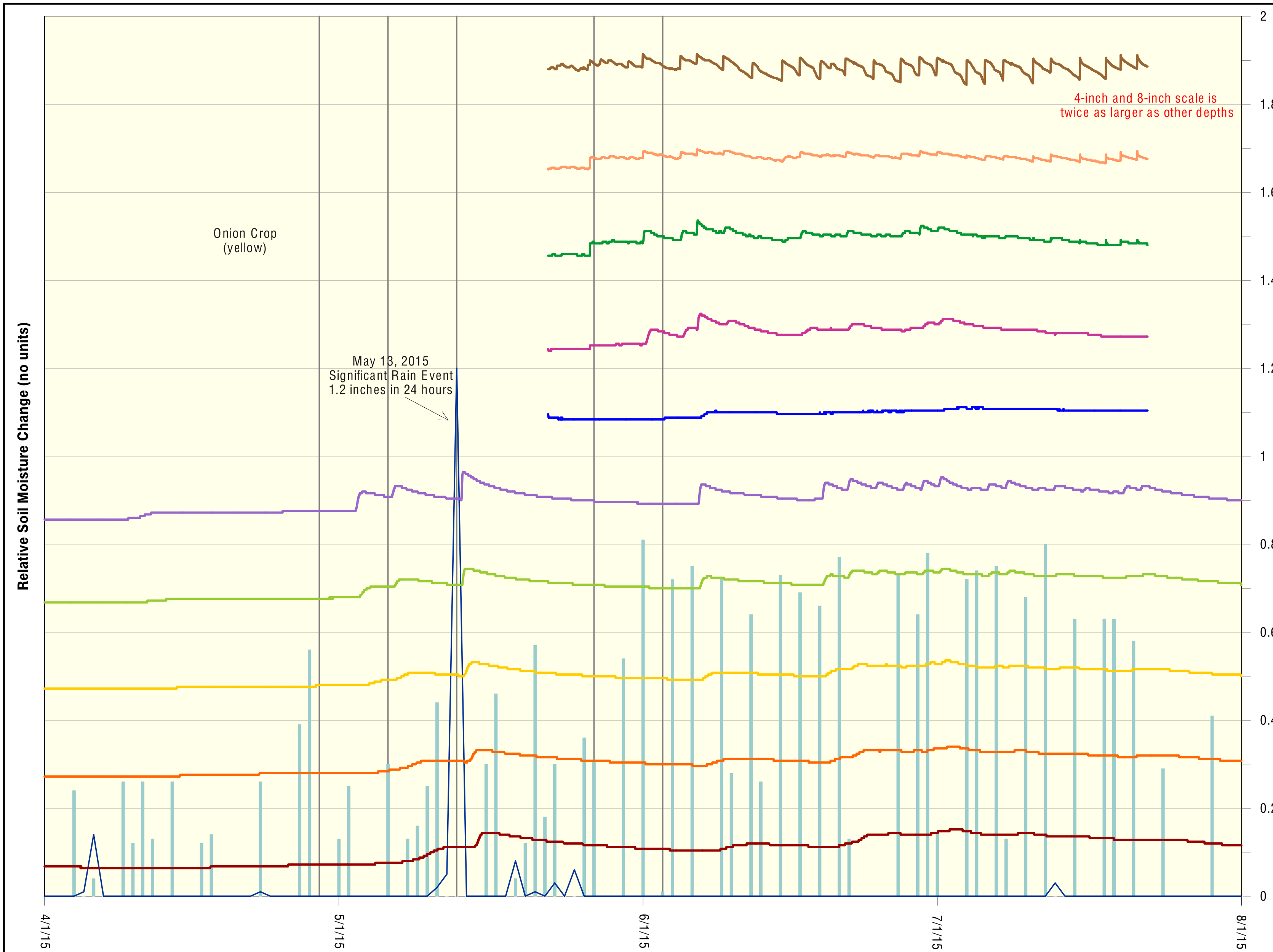

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-2 (Wet Area) April 2015 through July 2015

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20.

GSI Water Solutions, Inc.

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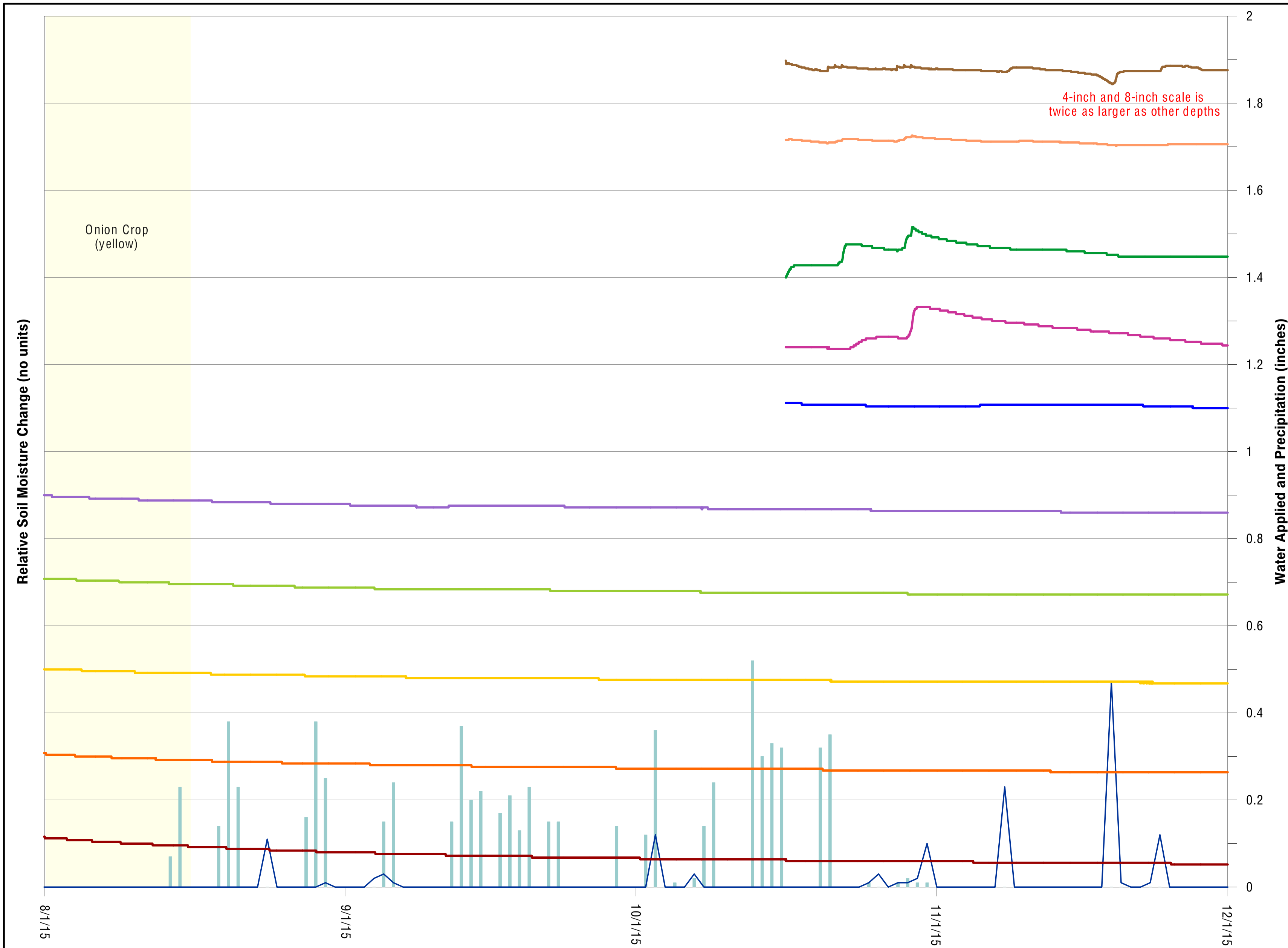

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-2 (Wet Area) August 2015 through November 2015

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20.

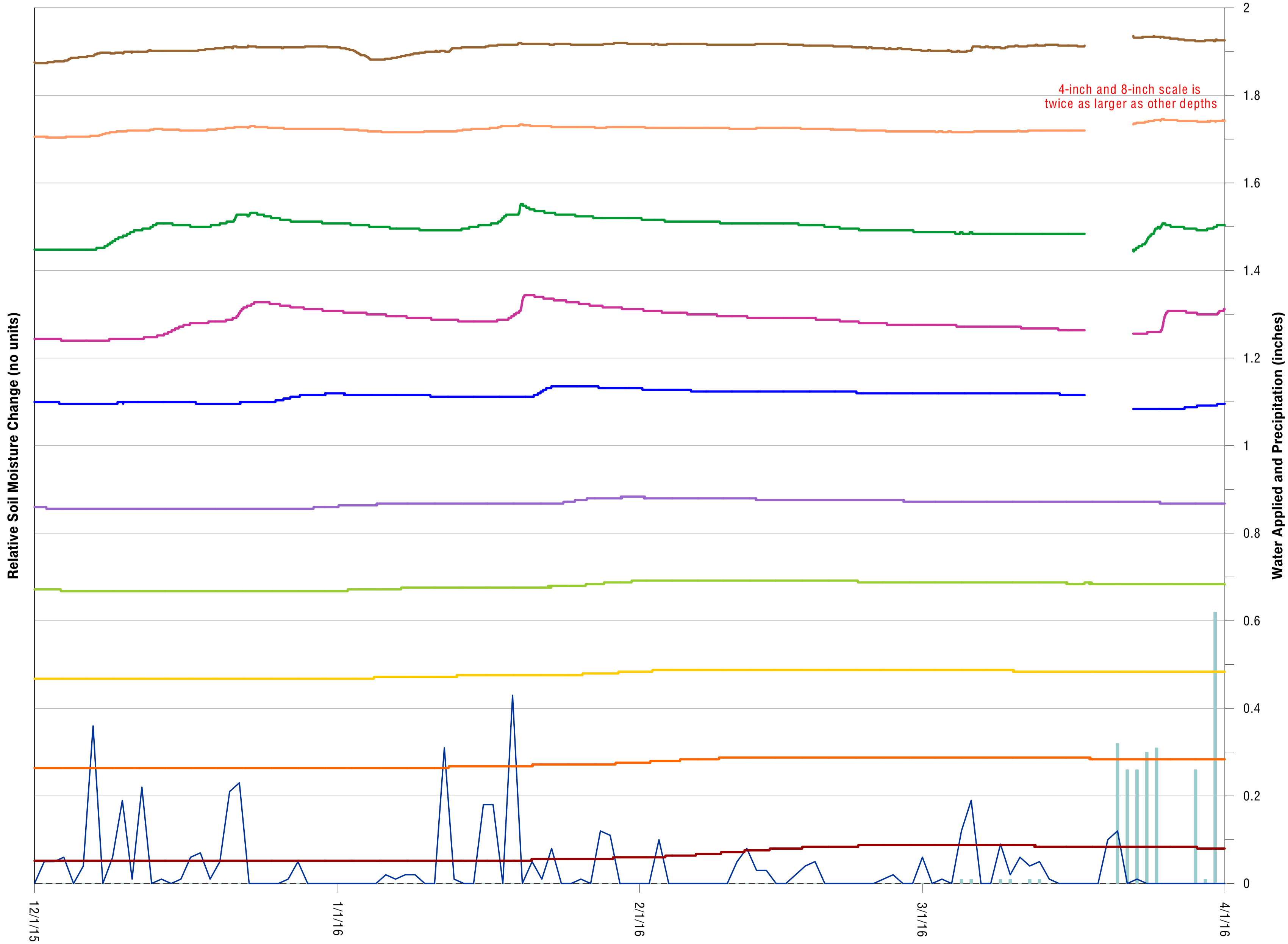

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-2 (Wet Area) December 2015 through March 2016

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20.

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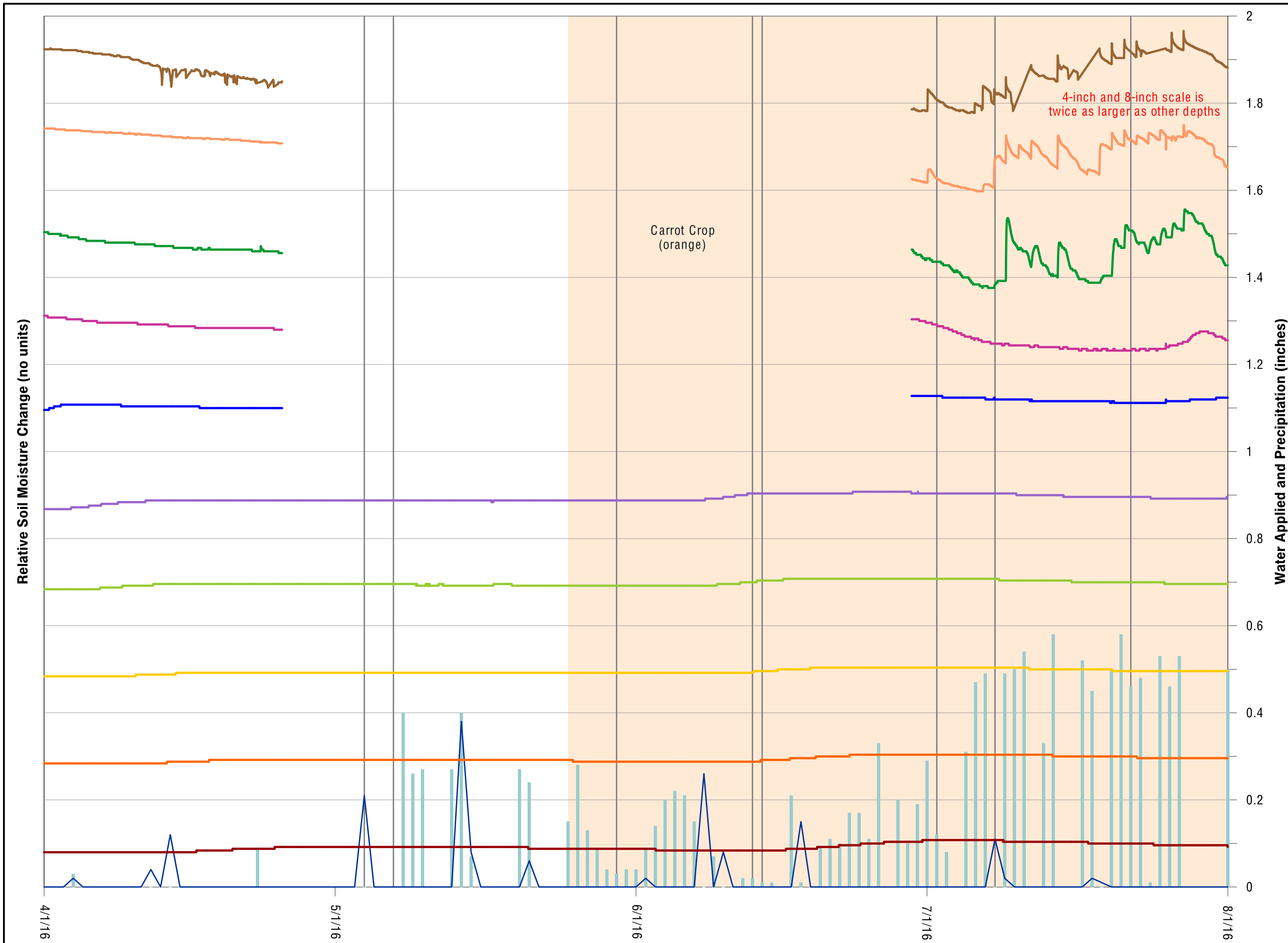

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-2 (Wet Area) April 2016 through July 2016

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20.

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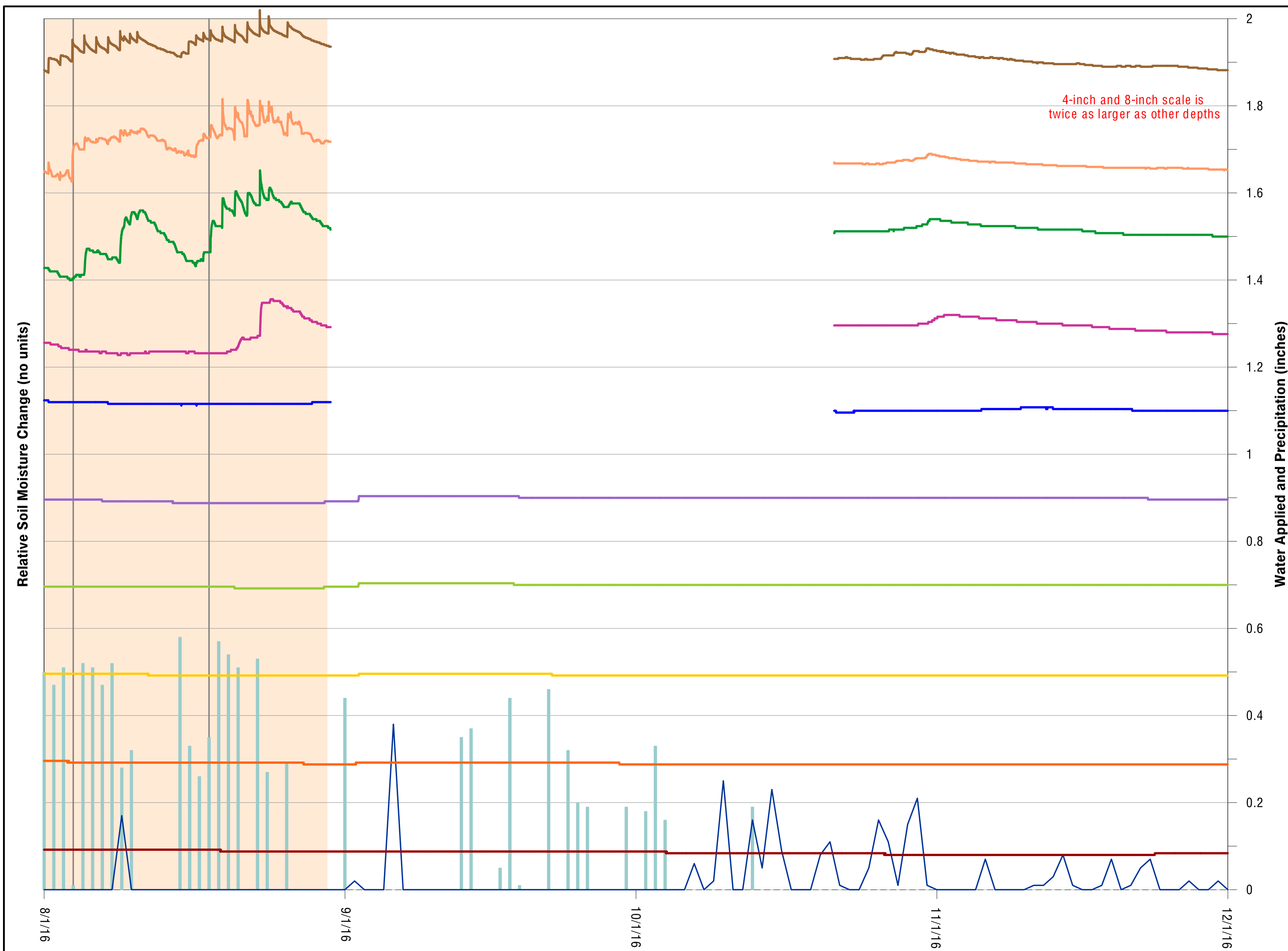

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-2 (Wet Area) August 2016 through November 2016

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20.

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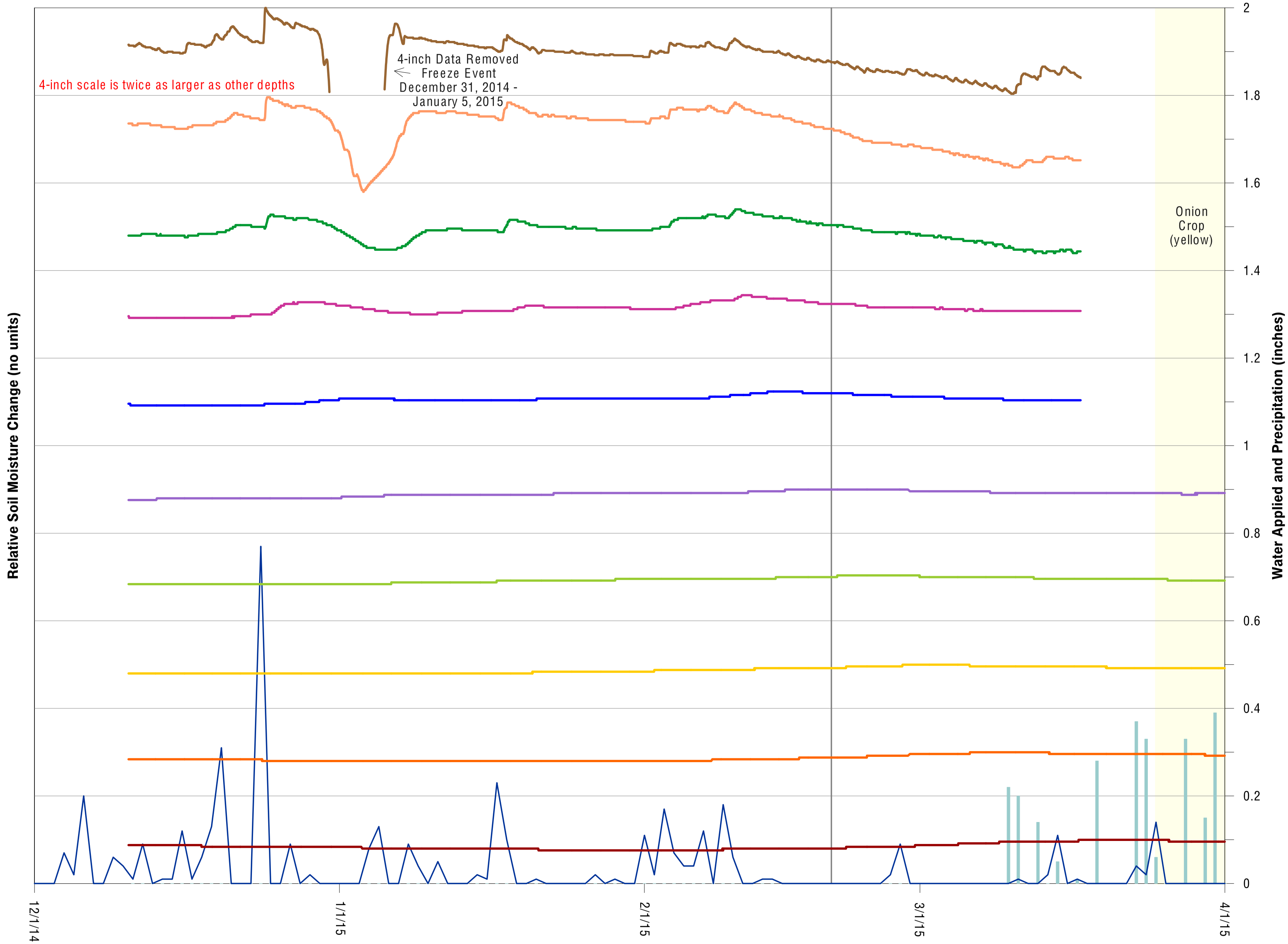

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-3 (Average Area) December 2014 through March 2015

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20 inches.

GSI Water Solutions, Inc.

IRZ

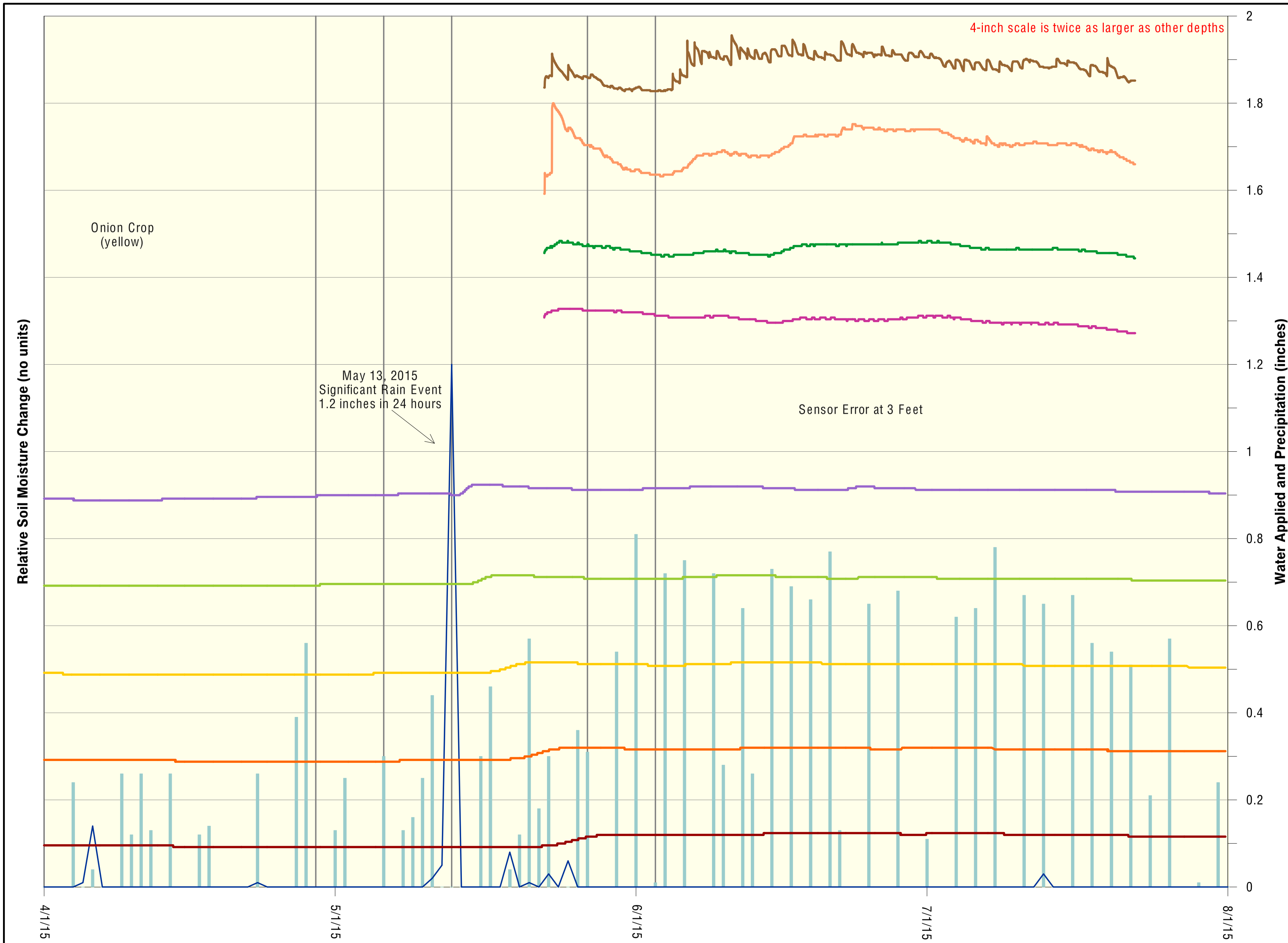

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-3 (Average Area) April 2015 through July 2015

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20 inches.

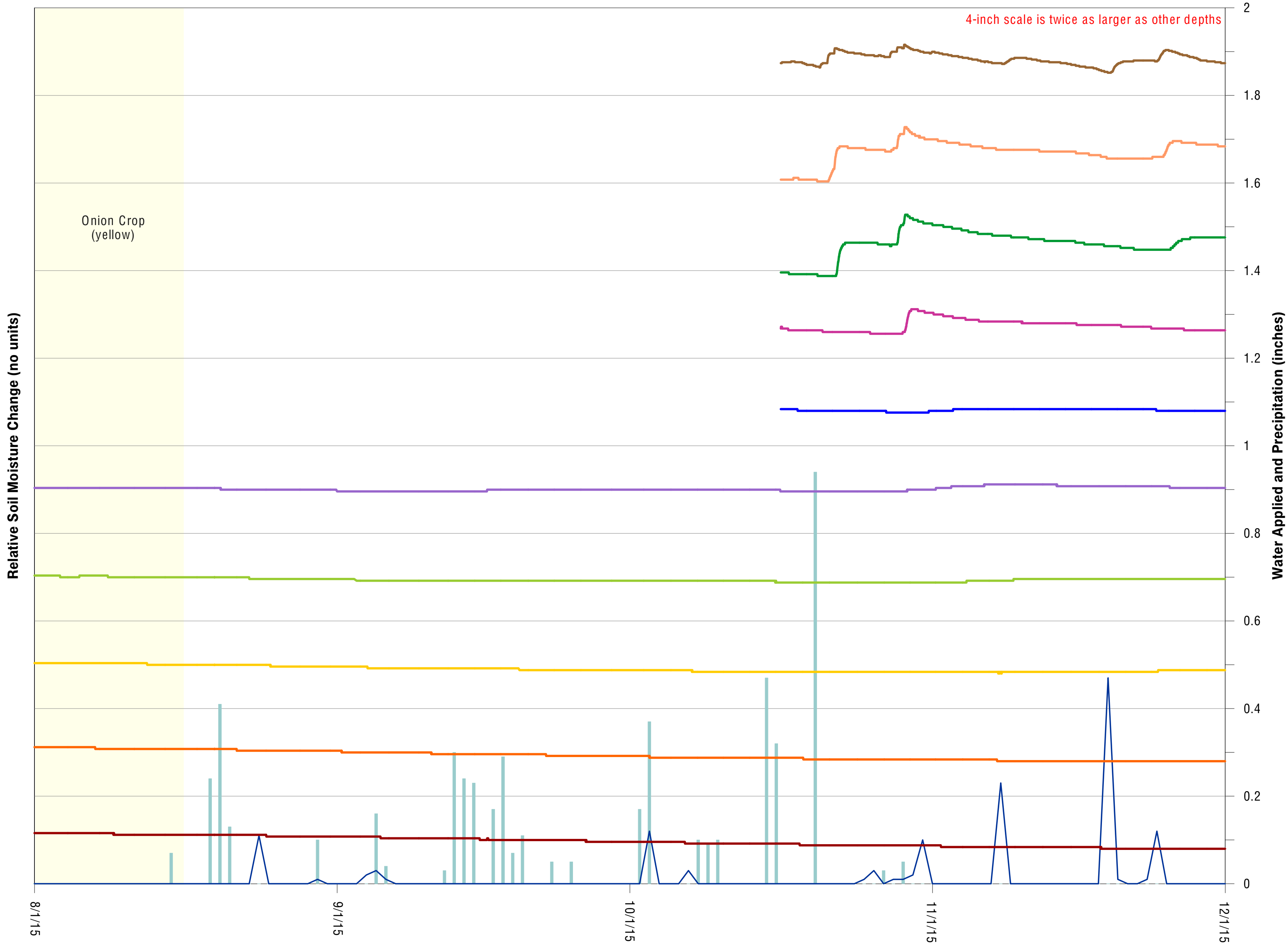

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-3 (Average Area) August 2015 through November 2015

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20 inches.

GSI Water Solutions, Inc. IRZ

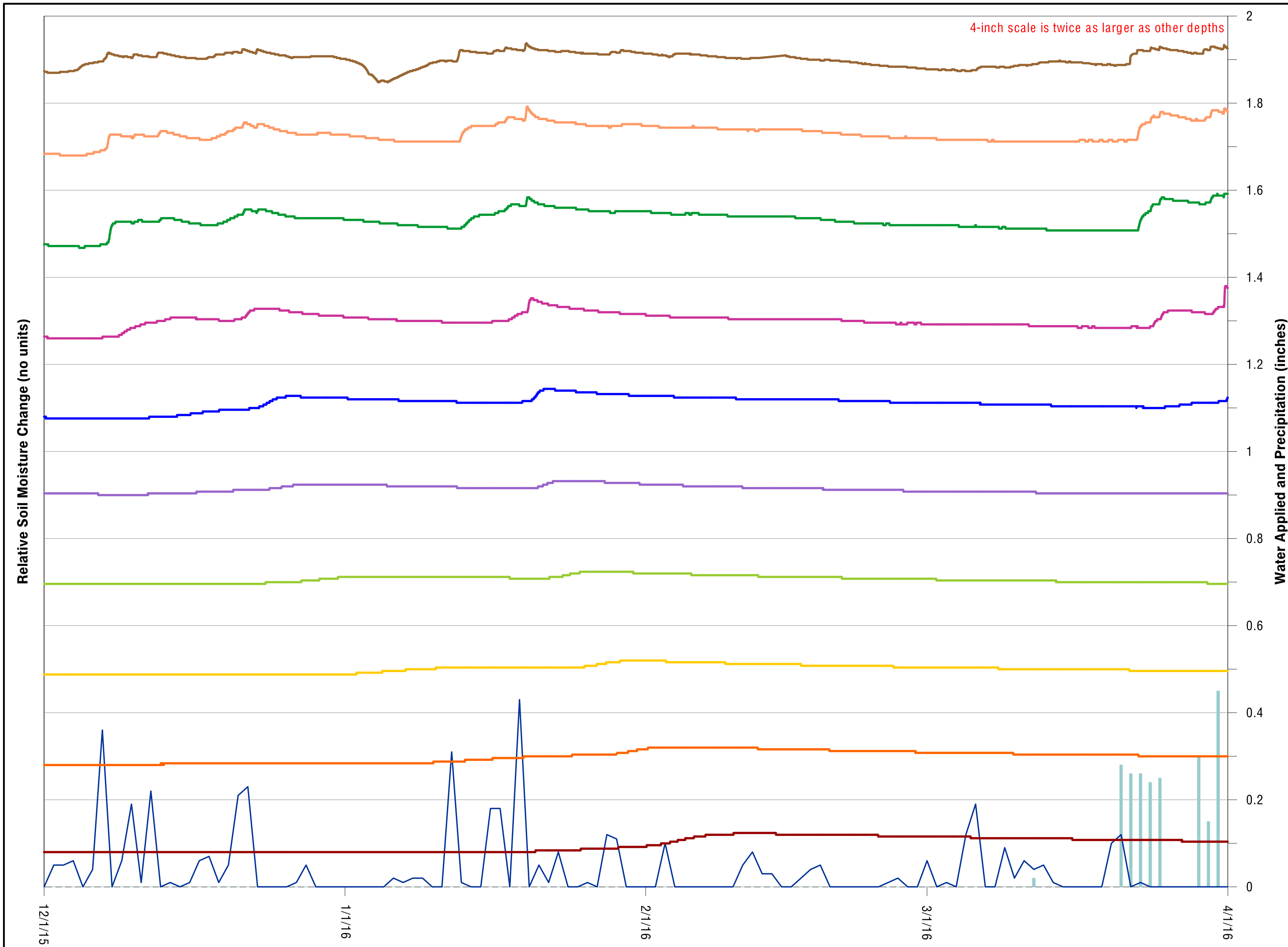

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-3 (Average Area) December 2015 through March 2016

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20 inches.

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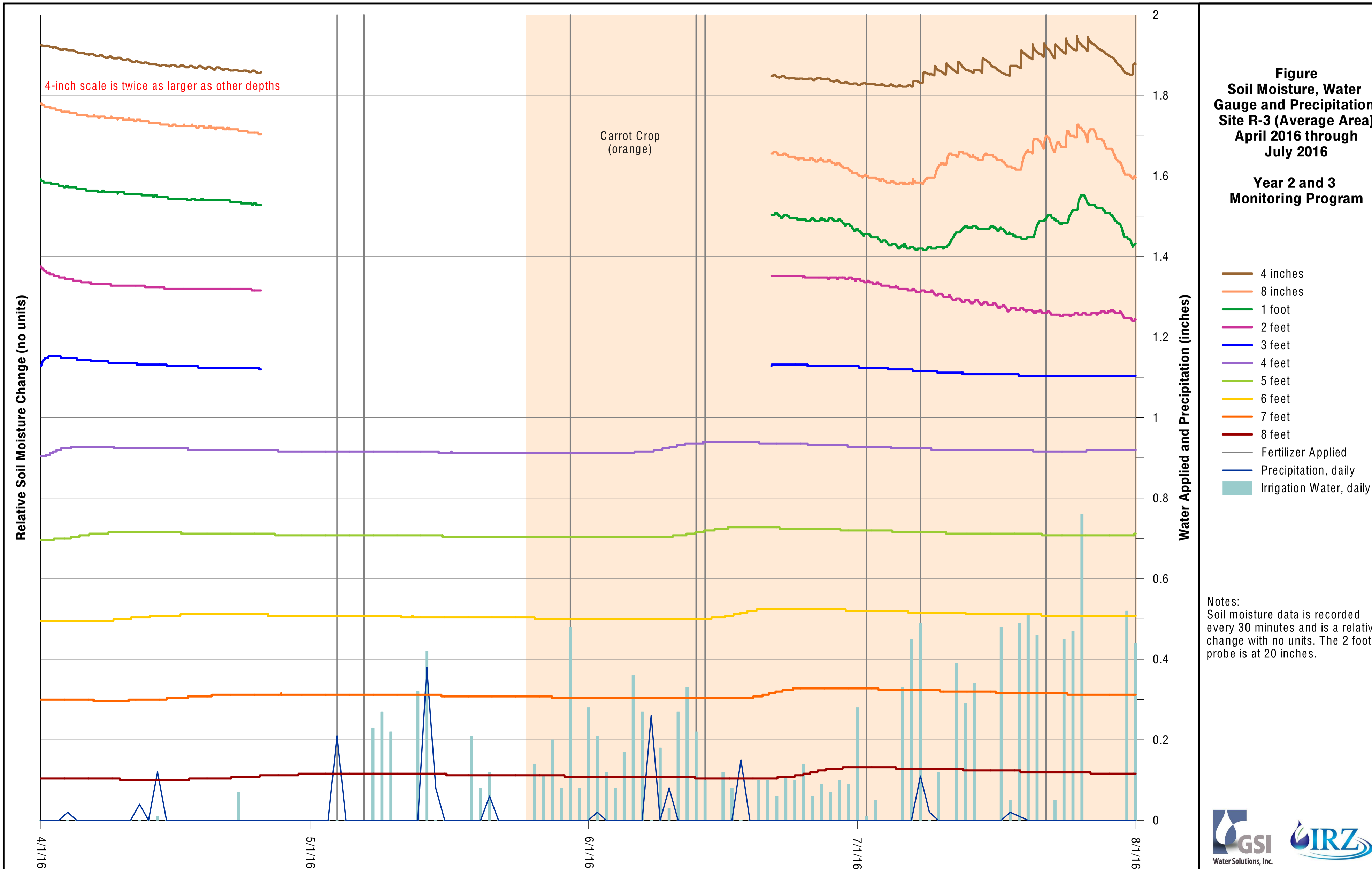

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-3 (Average Area) April 2016 through July 2016

Year 2 and 3 Monitoring Program

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20 inches.

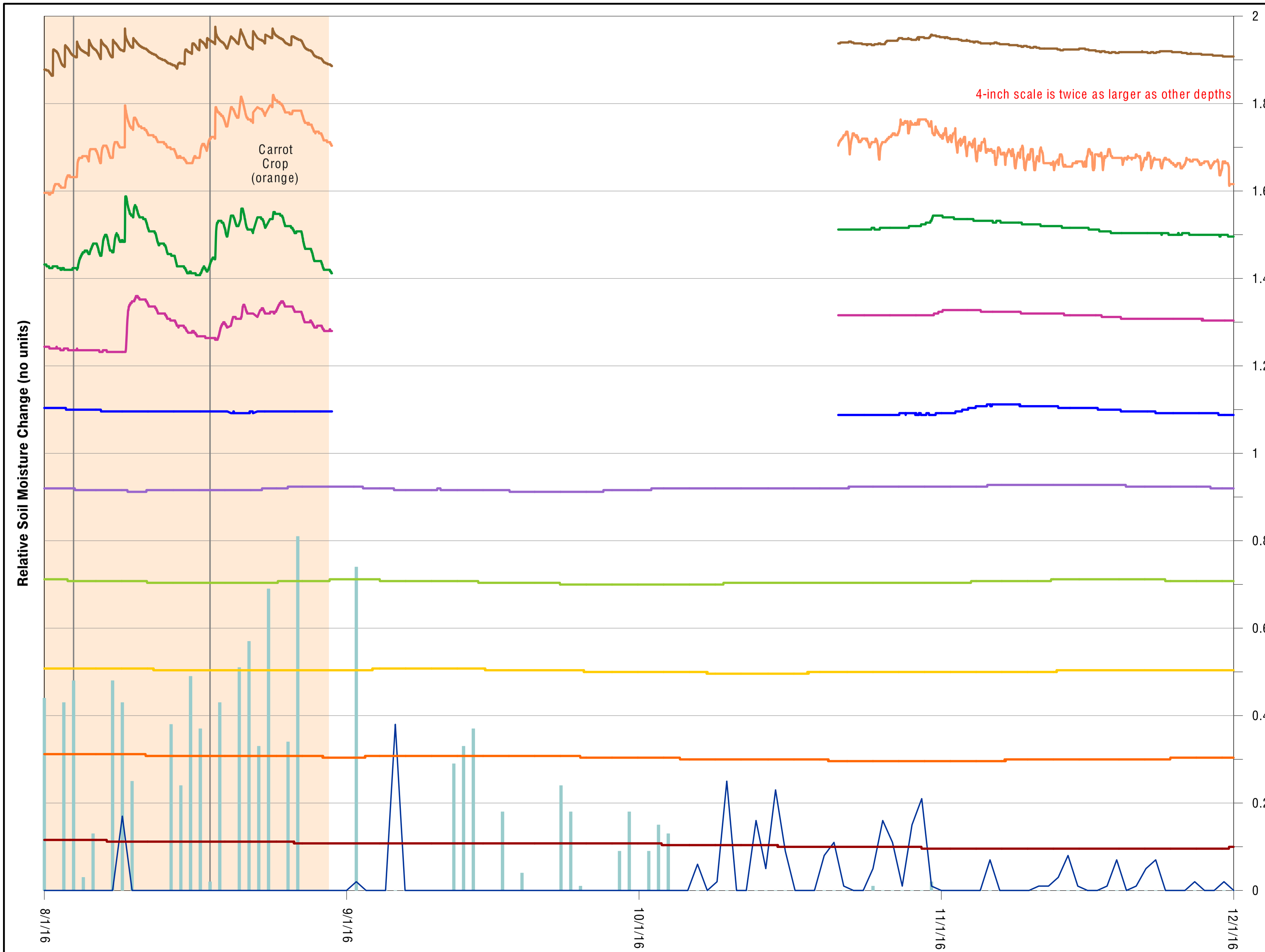

Figure
Soil Moisture, Water Gauge and Precipitation: Site R-3 (Average Area) August 2016 through November 2016

Year 2 and 3 Monitoring Program

- 4 inches
- 8 inches
- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet
- 6 feet
- 7 feet
- 8 feet
- Fertilizer Applied
- Precipitation, daily
- Irrigation Water, daily

Notes:
Soil moisture data is recorded every 30 minutes and is a relative change with no units. The 2 foot probe is at 20 inches.

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