Project Number: TCC-3334 - 41

Dams and Agriculture in the American Southwest and There Possible Association with Change in Rainfall Events, and Cryptobiotic Soil

An Interactive Qualification Project
Submitted to the faculty
of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for the
Degree of Bachelor of Science

12/17/99

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Abstract

This project examined localized precipitation events, which occurred in the Colorado Basin area, to determine if dams and agriculture have increased the average number of precipitation events by an increase in evapotranspiration. It appears using graphical analysis of localized precipitation data that the average precipitation events have increased. This project also examined the possible effect increased precipitation events might have on cryptobiotic soil crusts in nearby areas.

Introduction

The American Southwest has experienced a large increase in human population over the last hundred years. This increase has been facilitated by the building of many dams, which make water more available, enabling the desert-like arid environment to be more hospitable. These dams allow control of the rivers for agriculture, hydroelectric power, flood control, and the ability to expand populations outwards in the arid environment. However, people now have begun to look into what impact those dams and agriculture have on the climate and ecosystems. The dams restrict the flow of water, transforming the river into a series of lakes or reservoirs with a controlled river connecting them. How might turning a river into a lake affect the climate and land ecosystems? What might be the effect of water withdrawn by the dams and used for agriculture? How do the changing climate and ecosystems affect our future?

These questions address a very complex issue; therefore, the project focused on only a portion of the big picture. This project examined how the dams along the Colorado River and corresponding agriculture have affected the climate by possibly altering rainfall events in the Colorado Basin (also called the Colorado Plateau see figure 1, consisting of parts of the Four Corner States Arizona, Colorado, New Mexico, and Utah). Dams and diversions for agriculture in the American Southwestern desert-like environment should cause an increase in evapotranspiration, leading to an increase in atmospheric water vapor. If the water vapor stays in the general area, it should soon return to the ground as rain. This phenomenon should be observable by increasing the number of local precipitation events.

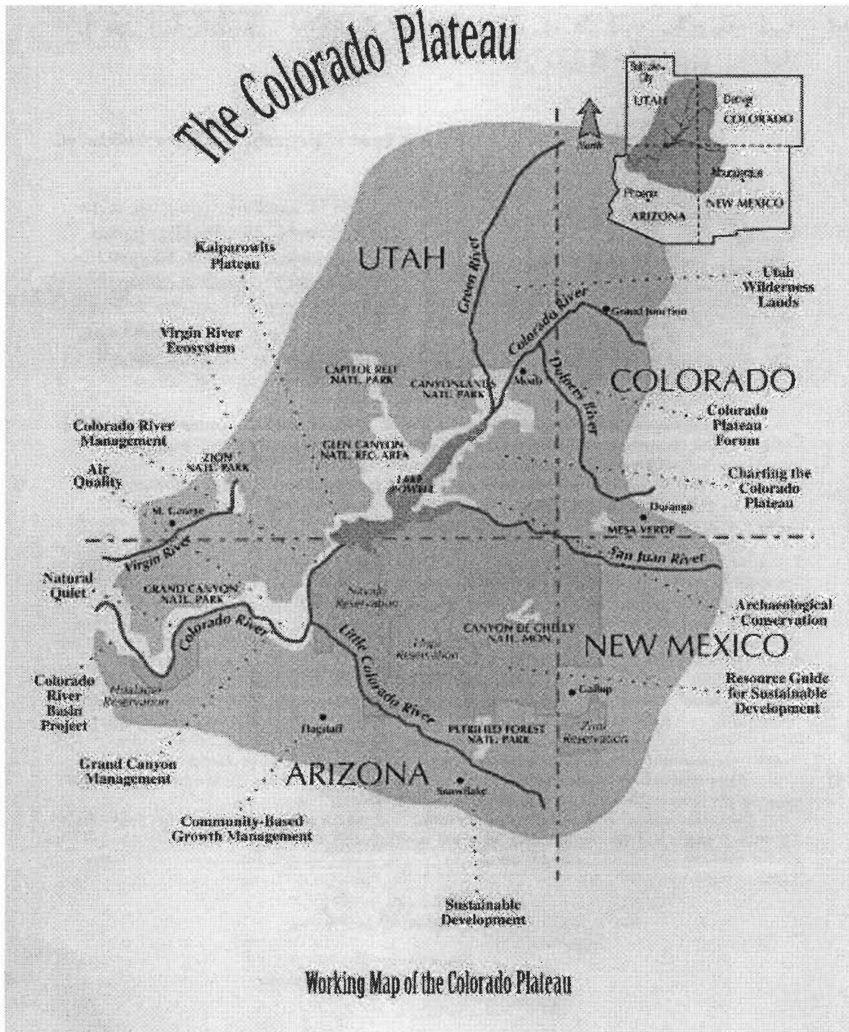

Figure 1: Colorado Basin (otherwise known as Colorado Plateau) Area[1]

A rain event increase could then affect the ecosystems that exist in the area, particularly the indigenous plant life, which survive in the arid environment. This project examined the indigenous plant life of cryptobiotic soil crusts, which have existed in the area longer than humans. Cryptobiotic soil crusts exist throughout the world in arid

[1] http://grand-canyon.az.us/gct/coloplat.htm (6/30/99)

environments and are believed to be some of the earliest land colonizers of Earth with fossil records dating back 3.5 billion years. These crusts are examined because they are important to their ecosystems by stabilizing the soil, reducing erosion, and helping the survival of other indigenous plants[2]. How might they be affected by the change in the number of rain events?

Goal Statement

The purpose of this project was to investigate the hypothesis that dams and agriculture in the American Southwest (particularly the Colorado Basin) affect the climate in the area by causing an increase in the amount of evapotraspiration. The increased amount of water in the atmosphere should lead to an increase in the number of localized rain events in the Colorado Basin area particularly during the agriculturally active months of May through September. This project examined localized rainfall event data, for the months of May through September for the years 1954 to 1998, in the Colorado Basin area. This data was analyzed graphically, to examine if such an effect could be statistically assessed, for a general change in the number of rain events. These rain events should also be critical in the ecology of cryptobiotic soil crusts and their relation to the pinyon-pine juniper woodland ecosystem. In order to evaluate the effects of localized rain events, this project includes background research on cryptobiotic soil crusts and the pinyon-pine juniper woodland ecosystem.

[2] http://www.nps.gov/cany/cryptos.htm (6/7/99)

Background Research

Water Rights, Dams, and Agriculture

The WPI IQP's by Ackman and Watson (1997), Finnegan (1998), and Haidusis (1999) researched the southwestern water rights and policies, dams on the Colorado and Rio Grande Rivers, and water use in agriculture in the American Southwest. This information is important to the understanding of the control of water in the American Southwest and how its use has lead to increased evapotranspiration.

Water rights are of two major types: riparian water rights and appropriation water rights. The majority of the states in the U. S. have either one or the other type of water rights, and the remaining states combine the two water rights. The states east of the Mississippi River have riparian water rights. The riparian water rights belong to people owning land, which borders a natural body of water. The owners are entitled to "reasonable use" of water next to their property. "Reasonable use" means that they should not significantly alter the quality or quantity of water. Some of the western states (Colorado, Arizona, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) which use the appropriation water rights subscribe to the "Colorado doctrine." These rights state "first in time is first in right" meaning the first person to use the water has first water rights; "Beneficial use shall be the basis, measure, and limit to the use of water," meaning that they must use the water for some purpose and that's all which is required; and "use it or lose it," meaning that if they own rights they must keep using their rights or the state can remove their rights. These appropriation water rights lead to wasteful water use. In order for people to keep their rights at the maximum level they have to use the water maximally. The remaining western states (California, Kansas, Nebraska, North Dakota, Oklahoma, Oregon, South Dakota, Texas, and Washington) use the "California doctrine." This doctrine uses a combination of the riparian and appropriation water rights in different degrees[3] (Ackman and Watson, 1997, Haidusis, 1999).

Most of the states using a form of appropriation rights use dams to control water usage. The first of these dams on the Colorado River was the Hoover Dam[4], which began construction in 1931 and was completed five years latter. This dam holds back Lake Mead, the lake that it formed by controlling the flow of water. It is a hydroelectric dam, which generates one and a half million kilowatts (1.5 MKw) of power, and was the greatest single source of electricity in the world at the time it was completed. This dam proved that the Colorado River could be harnessed and controlled for human usage. Other dams along the river followed including the Glen Canyon Dam, Parker Dam and Imperial Dam. All of the dams along the Colorado River now control the water use, by restricting the flow, to such a degree that the River no longer runs to the Gulf of California and now ends in the sands of northern Mexico (Ackman and Watson, 1997).

The Colorado River is not the only river in the American Southwest altered by dams. The Rio Grande has also been affected. The first dam completed on the Rio Grande in 1916 was the Elephant Butte Dam, which was mainly built for irrigation of more than 150,000 acres in the Rio Grande Valley. The subsequent dams built on the Rio Grande were used to control the periodical flooding, provide hydroelectric power, irrigation, and to provide drinking water for the growing human populations in the Southwestern United States (Finnegan, 1998).

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[3] The amount of which each state abides by the different systems is not defined in any of the earlier IQP's because the exact rights are to complicated.

[4] The Hoover Dam is known as both Hoover Dam and Boulder Dam (due to the nearby Nevada town).

Dams on the Colorado, Rio Grande, and other rivers in the American Southwest alter the water flow and increase the amount of water in the atmosphere by evapotranspiration. Evapotranspiration is defined as water discharged into the atmosphere by evaporation from the soil and surface-water bodies, and as a result of plant transpiration. Plant transpiration is defined as a process by, of water absorbed by plants through the roots, evaporating into the atmosphere from the plants surface (Ackman and Watson, 1997, Finnegan, 1998, Haidusis, 1999).

Evapotranspiration in the American Southwest is fairly high due to the desert like arid climate conditions with limited rainfall and hot and dry temperatures (with low dew points). In particular the Four Corner States (Arizona, Colorado, New Mexico, and Utah) typically have an average rainfall of below 10 inches (25 cm) per year, although at higher elevations (above 9,000-ft) the rainfall is higher. In the summer months the low daily temperatures are around 80°F and can reach highs around 125°F with very low humidity. Temperatures at the soil surface are probably even higher. The winter months can range in temperature anywhere from 70°F to below zero. Due to these conditions, the indigenous vegetation consists of plants that can withstand the high summer temperatures, and immediately use or store water from the few rain events. Irrigation has been used to grow non-indigenous plants that require more water and are useful for the growing human population in the American Southwest. Dams are used to provide this irrigation currently in large quantities. In the States Colorado, New Mexico, Utah and Wyoming over 90% of the water withdrawn by dams is used for irrigation, and in the States Arizona, California, and Nevada approximately 85% of the water withdrawn by dams is used for irrigation (Haidusis, 1999).

Evapotranspiration is caused by solar radiation vaporizing water from the surface of water bodies, soil, and the surface of plants. The amount of evaporation in the American Southwest has increased as the result of building dams, impounding water behind them, creating lakes or reservoirs that have a higher surface area than the original river. Evaporation has also increased by water withdrawn by dams for irrigation. When the water is used in farming, a high percentage is lost due to evaporation in the hot dry climate, before even reaching the plants. Once the plants are able to use the remaining water, a percentage is also lost by transpiration. This is why dams have increased the amount of water vapor into the atmosphere in the American Southwest (Ackman and Watson, 1997, Finnegan, 1998, Haidusis, 1999). The increased water vapor in the atmosphere has to go somewhere, and as it slowly traverses the area it should from time to time return to the ground in the form of rain when atmospheric conditions are ideal.

Cryptobiotic Soil

Cryptobiotic, cryptogamic, microbiotic, microphytic, and microfloral are all different names for the same type of biological soil crusts[5]. These cryptobiotic soil crusts are made up algae, cyanobacteria (blue-green algae or cyanochloronta), bacteria, lichens, fungi, mosses, and liverworts that together form water-stable soil aggregate crusts (Valerie, et al. 1998, Johansen, et al. 1993, Ladyman, et al. 1996). They inhabit arid landscapes across the world, but this project focused on the cryptobiotic soil crusts in the Colorado Basin area (covering parts of the Four Corners States Arizona, Colorado, New Mexico, and Utah see figure 1). In the Colorado Basin area cryptobiotic soil crusts

[5] http://www.id.blm.gov/iso/931/soil/microbio.htm (6/9/99)

represent over 70% of the living ground cover[6]. In arid communities, cryptobiotic soil provides soil stabilization, increased water infiltration, and increased soil fertility including nitrogen fixation.

The composition of cryptobiotic soil includes many different lower cryptogams (algae, fungi, mosses and liverworts). Cryptograms are a large category of plants that reproduce by spores rather than seeds. The most important to cryptobiotic soil are algae including cyanobacteria (blue-green algae). Algae are simple photosynthetic organisms with a single or multicellular body (thallus), which can be in three different structures: filament, flattened, or ribbon-like. Algae are differentiated by structure, flagella (a thread-like projection from the cell, which is used for motion), morphology, chemical nature of the cell wall, assimilatory products (including carbohydrates), and pigmentation (Ladyman, et al. 1996). Cyanobacteria are commonly referred to as blue-green algae, due to their bluish phycocyanin pigmentation[7]. The cyanobacteria commonly found in the Colorado Basin are filamentous and surrounded by sticky mucilaginous sheaths[8]. They are unique because they are able to photosynthesize and fix nitrogen. Nitrogen fixation is the conversion of atmospheric nitrogen to ammonia, and is used as the first step in protein synthesis. Some cyanobacteria use special cells called heterocysts to fix nitrogen. These cells have thick cell walls, that aid in excluding oxygen (a nitrogen fixation inhibitor). Heterocysts also produce the nitrogenase enzyme (the biological catalyst for converting nitrogen to ammonia). Cyanobacteria are able to fix nitrogen in the light by using photosynthate (a product of photosynthesis), or in the dark by using carbohydrates. They are able to survive in arid environments, because they have an external layer containing

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[6] http://geochange.er.usgs.gov/sw/impacts/biology/crypto/ (6/9/99)
[7] http://www.ucmp.berkeley.edu/bacteria/cyanolh.html (6/9/99)

protein and polysaccharides, which is believed to act as a water reservoir during dry periods that slows dehydration (Ladyman, et al. 1996). Cyanobacteria are one of the oldest known forms of life with fossil records dating back 3.5 billion years. It is believed that they were among the first land colonizers of Earth, stabilizing the soil of the primitive Earth[9]. The other soil algae are chlorophycophyta (green algae), chrysophycophyta (diatoms and yellow-green algae), euglenophycophyta (euglenoids), and rhodophycophyta (red algae) (Metting, et al. 1981).

The other lower cryptograms lichens, mosses, and liverworts are present in some forms of cryptobiotic soil. Lichens are a symbiotic composition of fungi and algae. The fungi structurally support the enclosed algae in the body of the lichen providing them with a stabilized microenvironment. The algae (particularly cyanobacteria) provide photosynthesized carbohydrates and fixed nitrogen (in the arid nitrogen-deficient environment). Lichens are able to survive in arid environments, enduring long periods (including years) of desiccation, and are able to regain full function upon wetting, although they are only able to undergo photosynthesis while they are wet. The dominant forms of lichens in Southwestern United States cryptobiotic soil are of the lichen species Psora (Ladyman, et al. 1996).

Mosses and Liverworts are similar and because they lack true roots, and transport tissues which vascular plants have. They must absorb moisture and nutrients from the atmosphere or diffusion from nearby cells (Ladyman, et al. 1996). Most mosses do photosynthesize using their leaf-like structures[10]. Mosses consist of a stem with leaves

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[8] http://www.nps.gov/cany/cryptos.htm (6/7/99)
[9] http://www.nps.gov/cany/cryptos.htm (6/7/99)

[10] http://www.winsomedisign.com/Shrub_Steppe/Cryptogamic_crust.html (6/9/99)

anchored by rhizoids. Liverworts are similar to mosses and consist of a stem with ether leaves or a thallus anchored by rhizoids. Mosses and liverworts are able to survive in arid environments because they are able to rehydrate to full function within minutes of wetting after long periods of dehydration (Ladyman, et al. 1996).

All of these components, form together to make up cryptobiotic soil. They grow during moist moderate weather, by the algae (specifically filamentous cyanobacteria) forming a mat on the surface of the soil. This mat of algae holds the surface of the soil together and can rise above regular soil, due to the surrounding soil eroding away (Johansen, et al. 1993). The soil surface is held together in a mat because, when Cyanobacteria are moistened, the filaments they contain become active and move thorough the soil leaving behind a mucilaginous sheath material behind. This sheath material is able to stick to the surfaces of the soil particles, which connect together the intricate particles of the soil. This helps to stabilize the soil surface reducing the effects of wind and erosion (the binding action also does not require living algae) [11].

Belnap, et al. (1993) examined the specific cyanobacteria *Microcoleus vaginatus* specifically at the cyanobacteria sheaths that bind the soil particles together. They observed by scanning electron microscopy, that these cyanobacteria have large and distinct polysaccharide sheaths surrounding their living filaments. When these sheaths are moistened they swell and mechanically extrude the filaments. When the sheaths were then dried the process was somewhat reversed and a portion of the filaments returned to the sheaths. The still exposed portions of the filaments then secreted more polysaccharide material. When completely dry, cyanobacteria are completely encased in this polysaccharide sheath (Belnap, et al. 1993).

Mosses and lichen also help to hold the soil particles together. Mosses have rhizoids, which entwine in the soil and form a network holding together the soil particles. Lichens have fungal hyphae (fine threadlike structures, which are attached to the thallus), that infiltrate and adhere to the soil particles (Ladyman, et al. 1996). All of the aggregation of the soil particles by cryptobiotic soil improves the amount of water in the soil and reduce the effects of erosion. The soil in most areas covered by cryptobiotic soil tends to contain a higher amount of water than bare soil in the same areas (Metting, et al. 1981).

Brotherson, et al. (1983) studied soil moisture characteristics of cryptobiotic soil crusts, and they concluded that the cryptobiotic soil crust increased the depth of water penetration, enhanced the rate of water infiltration with mosses present, decreased the rate of water infiltration with only algal/lichen crusts present, and reduced erosion. The crusts increased the depth of water penetration because they formed hills and valleys across the surface, which pools water on the surface, holding water at the surface longer allowing longer infiltration time, and decreasing water induced soil runoff at the surface. Mosses enhance the rate of water infiltration, because they have thalli, which act as a sponge. Crusts without mosses have a lower water infiltration rate because the algae at the surface form a layer, which impedes water entering the surface, but also impedes water evaporation below the algal layer. Cryptobiotic soil crusts reduce erosion by binding the soil particles together, reducing water movement across the soil surface, and the surface of the crust is irregular, which breaks up microwind patterns and reduces surface soil movement by the wind (Brotherson, et al. 1983).

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[11] http://geochange.er.usgs.gov/sw/impacts/biology/crypto/ (6/9/99)

Increased water content in cryptobiotic soil crusts and increased soil stability are two reasons for their positive interactions with other plant growth, the others include increased availability of nutrients and nitrogen fixation. It has been reported that in cryptobiotic soil the percentage of nutrients in the soil is higher than in bare soil, which correlates with increased plant life (Belnap, 1994). It has also been shown by numerous sources that cyanobacteria, in cryptobiotic soil crusts, fix nitrogen which also helps with other plant life and seedling establishment.

Belnap, et al. (1994) looked at two desert seed plants (Festuca octoflora, *Podceae* and Mentzelia multiflora, *Loasaceae*) and their relation to cryptobiotic soil. They observed that N, P, K, Ca, Mg and Fe were present in increased quantities in Festuca, which had grown in cryptobiotic soil compared to uncovered soil sites. The other plant Mentzelia had increased quantities of N, Mg, and Fe present when grown in cyptobiotic soil, compared to blow-sand soil sites. Belnap, et al (1994) believes that the nitrogen content increased due to cyanobacteria fixing nitrogen and making nitrogen available by decomposition and cellular secretion processes. They believe the other nutrients are available in higher quantities because of the cyanobateria sheath material. This material holds the soil together, and is negatively charged so it can electrostatically adsorb positively charged elements (K, Ca, Fe, Mg, Cu, Mo, Zn, Co, and Mn), useful for cyanobaterial growth. This ability makes these elements more available for other plants. Belnap, et al. (1994) also concluded that the effects of cryptobiotic soil are more noticeable in annual plants of small stature (including Festuca), which have there roots primarily within the level of soil taken up by cryptogamic cover. The other plant investigated (Mentzelia) had a less notable effect because the plant is perennial, deeper rooting during most of the year below the cryptobiotic layer. Mentzelia develop some additional surface rooting in the spring, which can take advantage of the cryptobiotic cover, so it may have been influenced more than other perennial plants (Belnap, et al. 1994).

Harper, et al. (1985) examined the emergence and survival of seedlings of useful range plants (Ceratoides lanata, Elymus junceus, Kochia prostrata, Oryzopsis hymenoides, and Sphaeralcea coccinea) grown in cryptobiotic soil. They observed that 2.82 times as many seedlings were seen in cryptobiotic soil after one year of planting and 1.62 times as many seedlings after 3 years. This data demonstrates that cryptobiotic soil correlates well with seedling establishment (Harper, et al. (1985).

Nitrogen fixation in cryptobiotic soil has been reported by numerous sources due to cyanobacteria. The particular sources Shields, et al. (1957), Rychert, et al. (1974), and Thomas, et al. (1994) investigated the nitrogen fixation in the cryptobiotic soils.

Shields, et al. (1957) reported that nitrogen fixation was only observed in recently wetted cryptobiotic soil and when the blue-green algae of the four genera: *Microcoleus, Porphyrosiphon, Schizothrix,* and *Scytonema* were present. Shields, et al. (1957) believed that the algae in cryptobiotic soil contribute their nitrogen content to the rest of the ecosystem when they die and decompose.

Rychert, et al. (1974) reported that blue-green algae and algae-lichen crusts, of the Great Basin Desert, have a laboratory potential of fixing nitrogen at rates up to 84 g of N ha^{-1} $hour^{-1}$. They believed the limiting factors on nitrogen fixation are moisture, temperature and light intensity. During the winter months temperature would be the major limiting factor and during the hot dry summer months, in arid environments, moisture would be the major limiting factor. Rychert, et al. (1974) observed fixation rate to be optimized in the laboratory when the cryptobiotic soil crust has been moistened to -1/3 bar pressure, temperature 19-23°C, and has incandescent light with intensity 200 microeinsteins m^{-2} sec^{-1}.

Thomas, et al. (1994) looked particularly at the soil nitrogen patterns caused by cryptobiotic crusts in pinyon-juniper woodland. They reported cyanobacteria of the genera *Anbaena, Calothrix, Nostoc, Scytonema,* and *Stigonema* fix nitrogen. They observed for pinyon-juniper woodland 40-75 kg ha^{-1} $year^{-1}$ nitrogen production, and that the specific rate is determined by species diversity and abundance in the crusts. They observed that nitrogen fixation rates were optimized when the crusts had been moistened to 18-20% moisture content. Thomas, et al. (1994) believe that nitrogen can be lost to the ecosystem by microbial mediated denitrification and/or physical ammonia volatilization.

The elevation, soil type, soil pH, oxidation-reduction potential, temperature, moisture, and climate effect the survival of cryptobiotic soil crusts. Cryptobiotic soil crusts tend to grow at elevations between 3,000 and 7,000 ft[12] in the Colorado Basin similar to the elevations pinyon-pine and juniper woodlands occur in the same area. The crusts tend to be well developed in soil containing silt and they tend to be less developed on soil with a lot of rocks and sand (Anderson, et al. 1982).

The soil cryptobiotic crusts grow on tends to be neutral to alkaline pH 7-11 (Anderson, et al. 1982, Brock, et al. 1975, Metting, et al. 1981, Starks, et al. 1981, Shlichting, et al. 1974, Stokes, et al. 1939)[13]. Most blue-green algae grow well at pH values above 8 and none grow at pH values below 4 (Shlichting, et al. 1974). Stokes, et

[12] These elevations have not been printed directly in any report but were approximated from known elevations in reports and known elevations of Juniper-Pinion Pine Woodland.

al. (1939) examined increasing pH of soil from 4.2 to 7.6 while observing algal growth. They reported that as they increased the pH algal growth correspondingly increased. They also noted that numbers of bacteria and actimomycetes greatly increased with increasing pH. Metting, et al. (1981) believes that even though cryptobiotic soil grows well in alkaline soils, the reason may be because of higher nutrient levels in the alkaline soils, not necessarily the alkalinity. Low oxidation-reduction potentials with moistened soils also correlate well with increased growth and nitrogen fixation with blue-green algae. Metting, et al. (1981) reported blue-green algae optimal growth at moisture content 20-40% and oxidation-reduction potential of –410 to –456 mv.

Different algae can survive in different temperature ranges -192°C to 113°C depending on the specific types of algae. The algae *Nostoc, Cylindrospermum,* and *Hantzchia* can photosynthesize at reduced rates, even at temperatures as low as –30°C in the laboratory. Algal growth rates also tend to be inhibited in the 30°C to 50°C range. The upper temperature limits on the algae: *Microcoleus vaginatus* is 113°C, *Schizothrix* is 112°C, and *Sctonemaocellatum* is 110°C, however other algae tend not to have such high temperature limits instead having increased death rates beginning around 42°C. Soil algae may also be altered by temperature fluxuations like freezing and thawing rates[14] (Metting, et al. 1981).

Moisture appears to be the most limiting factor to cryptobiotic soil growth. Stokes, et al. (1939) reported that the optimal moisture range for algal growth was 40-60% of the moisture holding capacity. They also observed that an excessive amount of moisture was less detrimental to algal growth than sub-optimal moisture. The excessive

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[13] None of these references listed exactly 7-11 pH, but they all listed pH's within this range.

moisture content affected the surface algae more than the lower levels, because the algae on the surface are able to perform photosynthesis. Stokes, et al. (1939) believe that algae therefore are active only during certain periods when they are in a proper moisture range and survive the rest of the time inactive.

Brock, et al. (1975) reported on cyanobateria *Microleus*, which is from soil crusts, are able to grow in low water potentials, and able to survive during drought conditions. At low water potentials *Microleus* is unable to perform photosynthesis, and at high water potentials photosynthesis is inhibited. Brock, et al. (1975) believes that this leads to growth during brief moist periods, where conditions are favorable, due to brief rainfall or from water condensing in the form of dew. They suggest further work on the favorable conditions, but these conditions would vary year to year due to climate variations.

Starks, et al. (1981) believes that this moisture range is affected by seasons. They site a study on alkaline Indian soils where the soil moisture in the summer increased from <1% to 46%, which leaches out hydronium ion concentration, changing the pH from 11 to 8.5. These conditions supported a rich summer algae community. When the season changed to winter the soil moisture went down from 46% to <1%, the pH went up from 8.5 to 11, and algal growth decreased (Starks, et al. 1981).

Metting, et al. (1981) state that soil algae are able to survive very long periods without water, with successful revival when moistened. They also show that in some moist temperature zones soil algae can grow with nightly dew formation, which has been shown to correspond with fluctuations of algal population's overnight. Metting, et al. (1981) reported microenvironmental and climatic factors are responsible for wide morphological variation within taxa of coccoid and filamentous blue green algae.

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[14] The location of theese different algae were not reporteed in Metting, et al. 1981.

Overall Cryptobiotic Soil is quite important to the ecosystem that it inhabits, through soil stabilization, protecting the soil from erosion, electrostaticaly adsorbing useful nutrients, and fixing nitrogen. The environment that cryptobiotic soil inhabits however impeding other plant growth by being arid is still important to its own growth. Altering its environment may lead to a change in its overall characteristics and it may change fundamentally, at least by type of algal growth, if the environment and ecosystem change. The most important of these environmental factors is the moisture level caused by rain events, which should be altered by the dams and agriculture increasing the water in the atmosphere and possibly the rain events where the soil exists.

Pinyon Pine-Juniper Ecosystems

In many cases the cryptobiotic soil in the Colorado Basin area grows in pinyon pine-juniper woodlands. Pinyon pine-juniper woodlands occur in the area between arid desert ecosystems of low elevation and ponderosa pine forest higher elevations. This area is between elevations 4,000 and 7,500 ft. pinyon pine dominates at the higher elevations of their zone, with juniper dominating at the lower elevations. The exact composition of species of both pinyon pine and juniper varies between regions. Cryptobiotic soil appears in the lower elevations of the pinyon-juniper woodland, where juniper is more dominant and forms open-canopied areas (Collings, et al. 1966, Ladyman, et al. 1996, Lanner, et al. 1975).

Pinyon-juniper woodland is prominent in the Southwestern United States with 90% of its range over the Four Corner States (Arizona, Colorado, New Mexico, and Utah) (see figure 1) (Ladyman, et al. 1996). pinyon-juniper woodland extends from the east slope of the Sierra Nevada eastward through the mountains of the Great Basin in Nevada, Utah and southern Idaho, and the foothills of Wyoming, onto the flanks of the Rocky Mountains in Colorado, southward into Arizona, New Mexico, western Texas, and northern Mexico (see figure 2). The major species are two pinyon pine *P. edulis, P. monophylla*, and seven juniper *J. moosperma, J. occidentalis* var. *occidntalis, J. occidentalis* var. *australis, J. osteosperma, J. scopulorum, J. deppeana,* and *J. coahuilensis* (Chambers, et al. 1999). The woodland provides wildlife habitats, and has some commercial uses such as pinyon-pine nuts, Christmas trees, fuel wood, and wood for fence posts (Ladyman, et al. 1996).

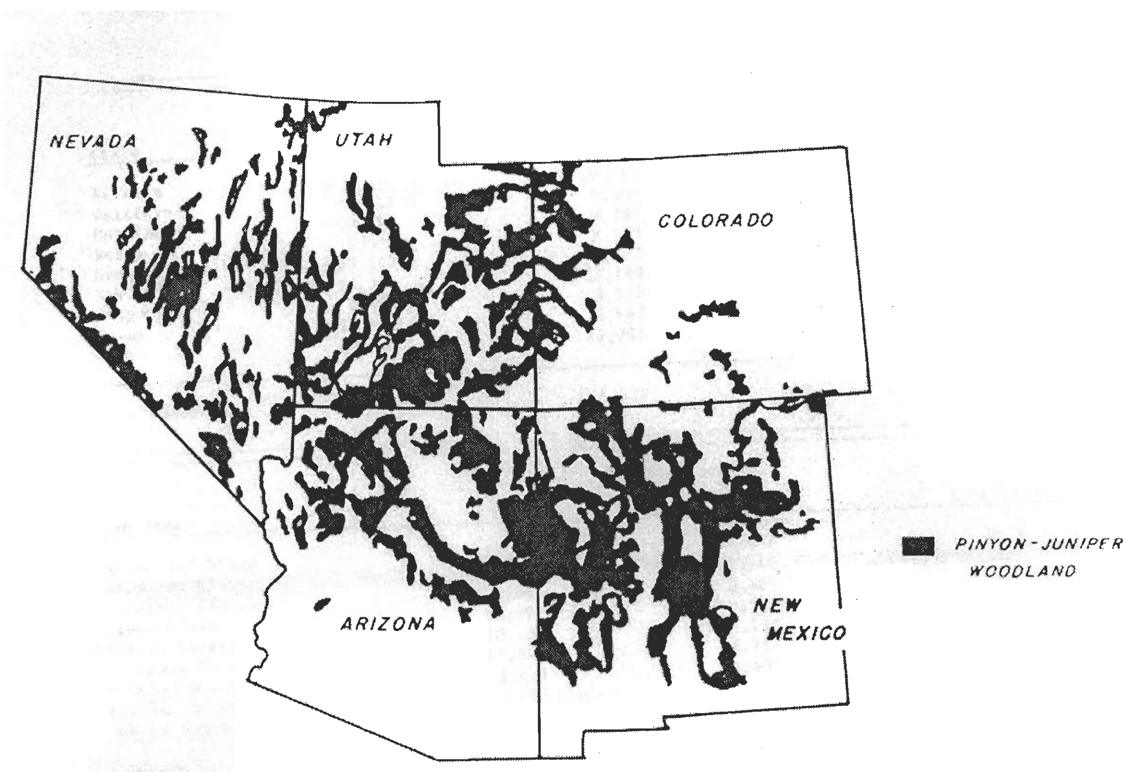

Figure 2: Distribution of pinyon-pine juniper woodlands in Arizona, Colorado, Nevada, New Mexico, and Utah (Lanner, et al. 1975).

Methodology

In order to look at the number of localized rainfall events in the Colorado Basin area (see figure 1), data was obtained from the National Climatic Data Center (NCDC) web pages[15] for individual rain stations. The localized rainfall events were examined by data on the number of precipitation events greater than 0.1 inch each month for the years 1954-1998. The reason 1954 was chosen as the starting year was that prior to 1954 recorded rain events as all possible rain events greater than 0.01 inch, which could not be correlated with only rain events greater than 0.1 inch recorded after 1954. Data starting 1900 or earlier would have been more useful providing a baseline prior to the construction of dams in the early part of the twentieth century. However some dams were still constructed after 1954, lakes or reservoirs behind the dams had not fully formed, and water usage in agriculture has increased over time. The months of May through September were examined because agriculture begins with planting in May and harvesting in September. These are the months water is used for agriculture, which should greatly affect the water content in the atmosphere, and thereby increase the likelihood of rainfall events in this time interval.

The rain stations were chosen for their data availability and location including elevation. The data availability required the station location to be fairly constant[16] during the years 1954 to 1998 and to have data on the number of precipitation events greater

[15]NCDC Web page: http://www.ncdc.noaa.gov/ol/climate/aasc.html (7/13/99)
Web page for station listing: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~SelectStation (7/20/99)
Web page for precipitation data: http://www5.ncdc.noaa.gov:7777/plcmdev/plsql/poemain.poe (7/13/99)
[16] Some of the rain stations have listed slight changes in longitude, latitude, and elevation over the time period (see station listing web page), but all were fairly close.

than 0.1 inch[17]. The locations were chosen within the Colorado Basin area where cryptobiotic soil should exist. In order to evaluate rainfall in areas with cryptobiotic soil, the elevation range of 3,000 and 7,000ft[18] was used. However, some rain stations in this elevation range were not used because they were located in valleys next to higher elevation ponderosa pine woodlands where no cryptobiotic soil should exist. The original plan was to find five rain stations in each of the Four Corner States, but due to inconsistent data availability and certain station locations, only nineteen stations spread unevenly over the Colorado Basin were available. Five of the rain stations were located in Arizona (see figure 3), three rain stations in Colorado (see figure 4), six rain stations in New Mexico (see figure 5), and five rain stations in Utah (see figure 6) [19].

Once the data from the rain stations were obtained from the NCDC web pages, in Microsoft Notepad format, the data sets were converted to Microsoft Excel spreadsheets (see Appendices A-D). The Excel spreadsheets contain data sets for each rain station on the number of precipitation events greater than 0.1 inch, for each year 1954 through 1998, for the months May, June, July, August, and September. Microsoft Excel formulas were used to produce: totals for the number of rain events in May through September, July through September, and July through August, as well as: averages, standard deviations, maximums, and minimums for the number of precipitation events for each month and for the totaled time periods. Each of the data sets were also used to produce figures of year vs. number of precipitation events greater than 0.1 inch with two

[17] Some of the data from individual rain stations obtained from the NCDC web pages was missing or not recorded, so on some of the spreadsheets a few years within the 1954 to 1998 period were not included where data was not available.
[18] These elevations are approximated by elevations listed in most of the cryptobiotic soil references.
[19] Background maps for figures 3-6 were found at: http://www.nationalgeographic.com/resources/ngo/maps/atlas/cindex.html (9/16/99). Rain Stations were added on top of the map in PowerPoint.

trendlines for each month and totaled time period (see Appendices A-D). One of the trendlines[20] was linear and has its equation (in the form y = mx +B, with m being slope) and the correlation coefficient (R^2 value) depicted on each graph. This trendline was added to examine the general increase by positive slope (+m) or general decrease by negative slope (-m) in the number of precipitation event data. The second trendline[21] on each of the graphs was a five-year moving average, done to smooth out the data and attempt to observe general trends. Station information (State, Latitude, Longitude, and Elevation) was then reported on spreadsheets with the slopes of the linear trendlines[22] and average number of precipitation events per month or total (see tables 1 and 2), to make the information easier to examine and to attempt to correlate locations with the precipitation event trends.

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[20] Depicted on the graphs by a straight line thinner than the line connecting each of the data points.
[21] Depicted on the graphs by a dotted line starting at the fifth year.
[22] The positive slopes are bolded to ease comparison.

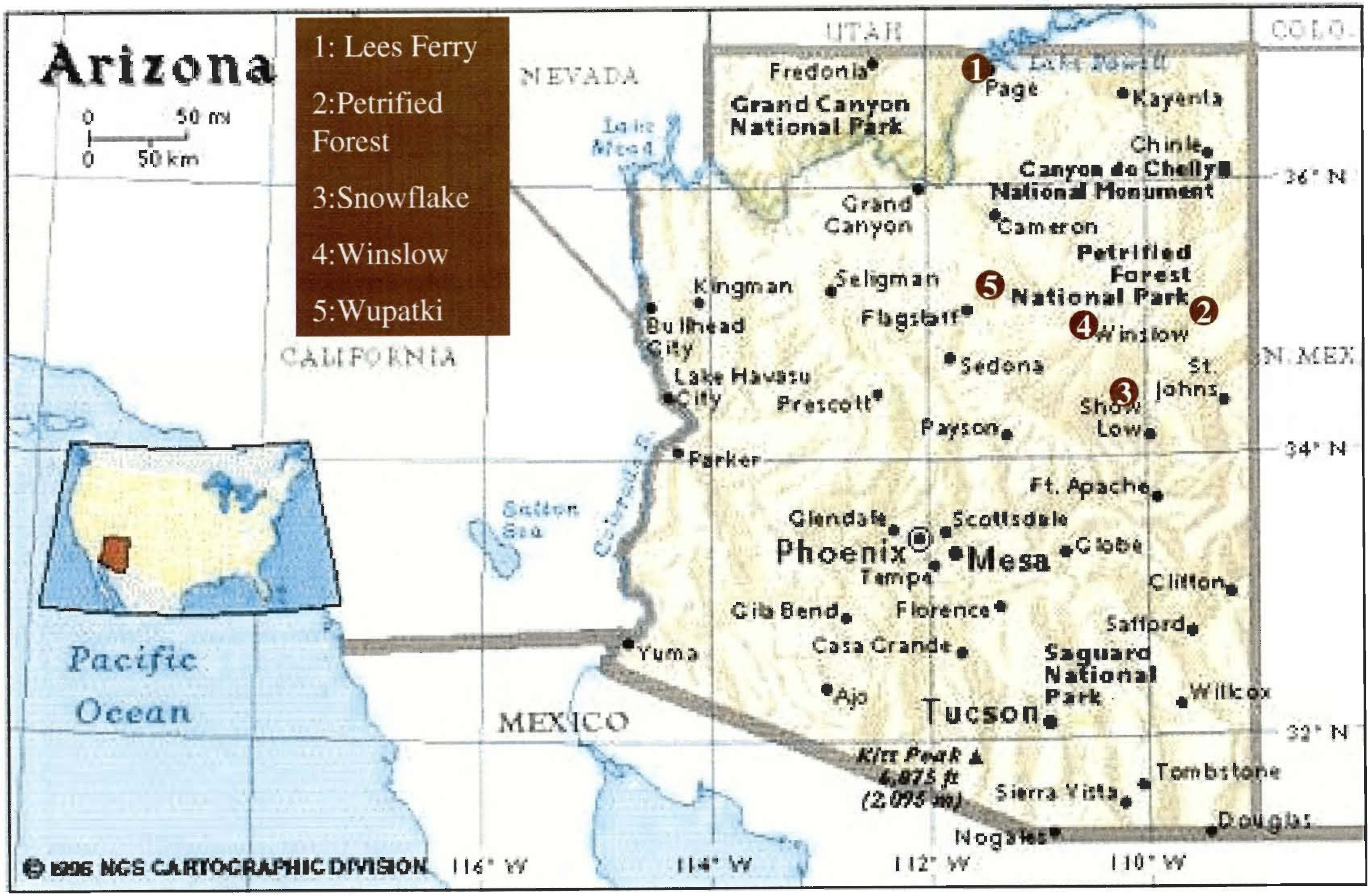

Figure 3: Rain stations in Arizona

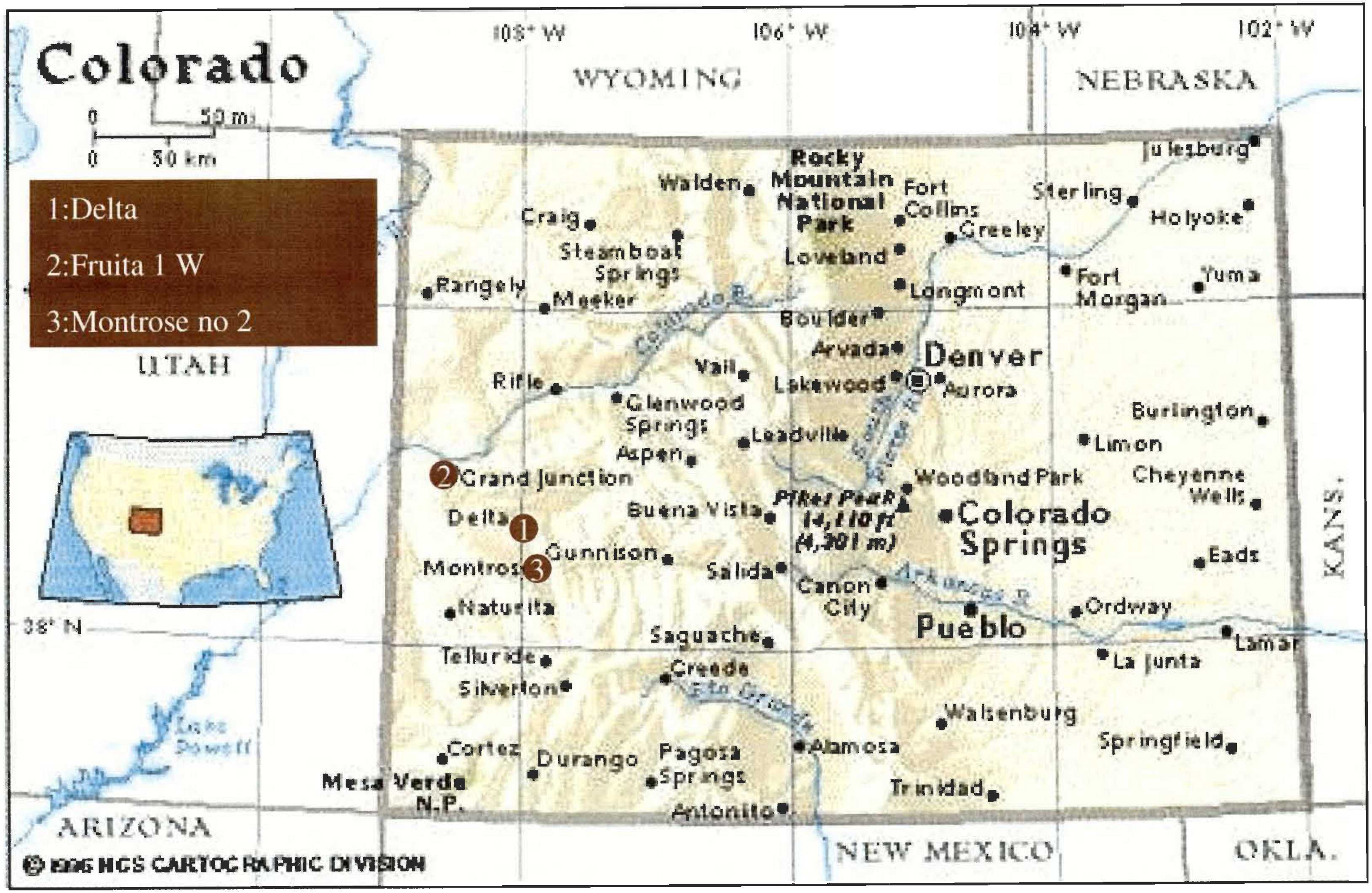

Figure 4: Rain stations in Colorado

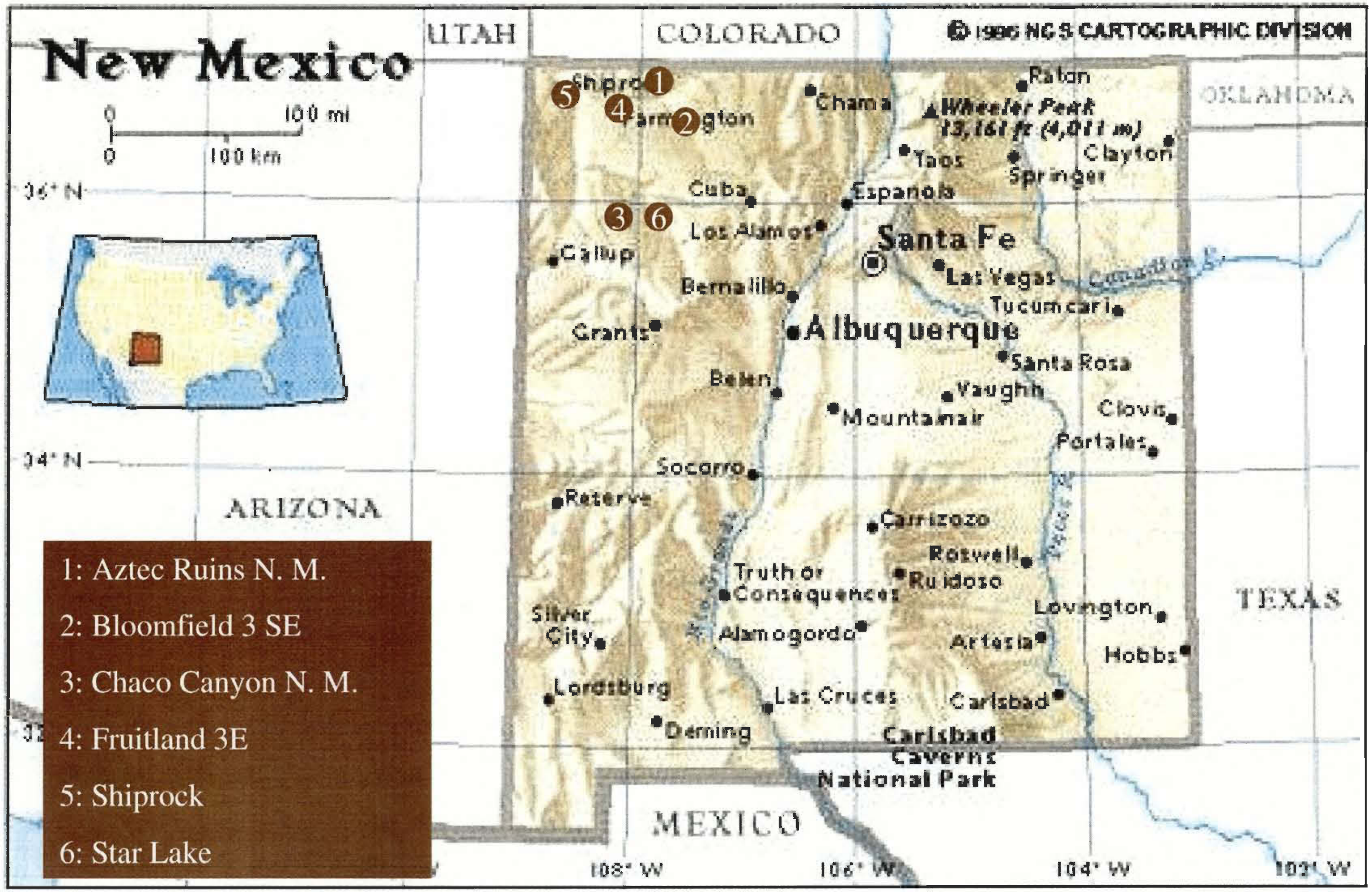

Figure 5: Rain stations in New Mexico

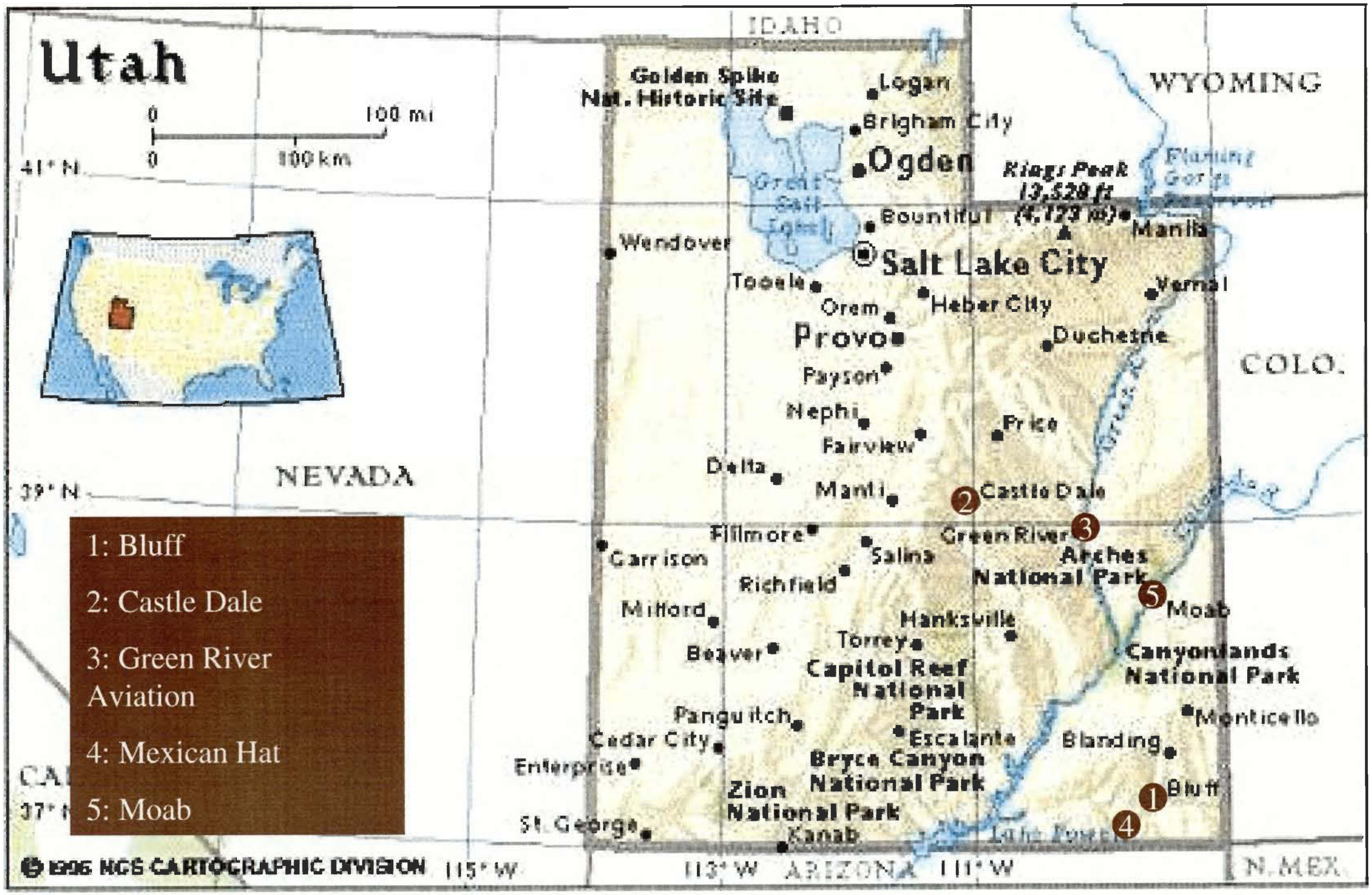

Figure 6: Rain stations in Utah

Station Information						Number of Precipitation Events >0.1 in Slopes					
Station Name	**#**	**State**	**Latitude**	**Longitude**	**Elevation**	**Total**	**May**	**June**	**July**	**August**	**September**
Lees Ferry	1	Arizona	36, 52, 00	-111, 35, 00	3143-3210	**0.0316**	**0.023**	-0.0128	**0.0033**	**0.0094**	**0.0048**
Petrified Forest	2	Arizona	36, 48, 00	-109, 52, 00	5433-5463	-0.0177	-0.0089	**0.0021**	-0.004	-0.0275	**0.0207**
Snowflake	3	Arizona	34, 30, 00	-110, 05, 00	5642	-0.0285	**0.0161**	-0.0003	-0.0201	-0.0664	**0.0421**
Winslow M. AP.	4	Arizona	35, 01, 00	-110, 44, 00	4890	-0.0339	**0.0126**	-0.0126	-0.0044	-0.0385	**0.009**
Wupatki N. M.	5	Arizona	35, 31, 00	-111, 22, 00	4908	-0.0351	**0.0165**	-0.0047	-0.0525	-0.0183	**0.0239**
Delta	6	Colorado	38, 45, 00	-108, 04, 00	4930-5135	**0.0567**	**0.0211**	**0.0051**	**0.0268**	-0.0175	**0.0212**
Fruita 1 W	7	Colorado	39, 08, 00	-108, 44, 00	4491	-0.0312	**0.0259**	-0.0042	**0.02**	-0.0364	-0.0364
Montrose no 2	8	Colorado	38, 29, 00	-107, 53, 00	5785-5833	**0.055**	**0.0346**	**0.0014**	-0.0069	-0.0048	**0.0307**
Aztec Ruins N. M.	9	New Mexico	36, 50, 00	-108, 00, 00	5644	**0.0077**	**0.0149**	**0.0105**	-0.0199	**0.0001**	**0.0021**
Bloomfield 3 SE	10	New Mexico	36, 40, 00	-107, 58, 00	5807	-0.0349	**0.004**	**0.0147**	-0.0388	-0.0147	-0.0001
Chaco Canyon N. M.	11	New Mexico	36, 02, 00	-107, 54, 00	6184	**0.0097**	**0.0069**	**0.0031**	**0.0061**	-0.0217	**0.0153**
Fruitland 3E	12	New Mexico	36, 44, 00	-108, 21, 00	5220	**0.0066**	**0.0005**	**0.0055**	-0.012	-0.0187	**0.0314**
Shiprocck	13	New Mexico	36, 47, 00	-108, 44, 00	4872-4993	**0.0358**	-0.012	-0.0046	-0.0047	**0.0362**	**0.0201**
Star Lake	14	New Mexico	35, 56, 00	-107, 28, 00	6644	**0.036**	**0.0194**	**0.0273**	-0.004	-0.0316	**0.0249**
Bluff	15	Utah	37, 37, 00	-109, 28, 00	6040-6135	**0.039**	**0.0219**	**0.054**	**0.0068**	-0.0084	**0.0132**
Castle Dale	16	Utah	39, 13, 00	-111, 01, 00	5505-5764	**0.0217**	-0.0072	-0.0045	**0.0024**	**0.0206**	**0.0105**
Green River Aviation	17	Utah	38, 59, 00	-110, 09, 00	4070	**0.0249**	**0.0239**	-0.0118	**0.0193**	**0.0116**	-0.0181
Mexican Hat	18	Utah	37, 08, 00	-109, 53, 00	4203-4432	**0.0814**	**0.036**	-0.0065	-0.0003	**0.0157**	**0.0365**
Moab	19	Utah	38, 35, 00	-109, 33, 00	3965-4134	**0.0802**	**0.0436**	-0.0012	**0.0063**	**0.0096**	**0.0219**

Table 1: Station Information, Elevation, and Slopes for Each Month and Total May Through September

Table 2: Station Information, Elevation, Slopes and Averages For Each Month and All Three Totals

Arizona					
Station Name	**Lees Ferry**	**Petrified Forest**	**Snowflake**	**Winslow M. AP.**	**Wupatki N. M.**
Latitude	36, 52, 00	36, 48, 00	34, 30, 00	35, 01, 00	35, 31, 00
Longitude	-111, 35, 00	-109, 52, 00	-110, 05, 00	-110, 44, 00	-111, 22, 00
Elevation	3143-3210	5433-5463	5642	4890	4908
Slope May-Sept.	**0.0316**	-0.0177	-0.0285	-0.0339	-0.0351
Average May-Sept.	8.26	13.39	17.57	10.75	12.64
Slope July-Sept.	**0.0214**	-0.0109	-0.0443	-0.0339	-0.047
Average July-Sept.	6.29	11.23	14.9	8.75	10.6
Slope July-Aug.	**0.0126**	-0.0315	-0.0864	-0.0429	-0.0708
Average July-Aug.	4.77	8.36	11.24	6.34	7.95
Slope May	**0.023**	-0.0089	0.0161	**0.0126**	**0.0165**
Average May	1.57	1.07	1.52	1.2	1.24
Slope June	-0.0128	**0.0021**	-0.0003	-0.0126	-0.0047
Average June	0.4	1.09	1.14	0.8	0.81
Slope July	**0.0033**	-0.004	-0.0201	-0.0044	-0.0525
Average July	2.34	3.84	5.07	2.75	3.48
Slope August	**0.0094**	-0.0275	-0.0664	-0.0385	-0.0183
Average August	2.43	4.52	6.17	3.59	4.48
Slope September	**0.0048**	**0.0207**	**0.0421**	**0.009**	**0.0239**
Average September	1.51	2.86	3.67	2.41	2.64

Colorado			
Station Name	**Delta**	**Fruita 1 W**	**Montrose no 2**
Latitude	38, 45, 00	39, 08, 00	38, 29, 00
Longitude	-108, 04, 00	-108, 44, 00	-107, 53, 00
Elevation	4930-5135	4491	5785-5833
Slope May-Sept.	**0.0567**	-0.0312	**0.055**
Average May-Sept.	11.66	10.9	14.67
Slope July-Sept.	**0.0305**	-0.0529	**0.019**
Average July-Sept.	7.92	7.15	9.88
Slope July-Aug.	**0.0093**	-0.0165	-0.0117
Average July-Aug.	5.03	4.9	6.42
Slope May	**0.0211**	**0.0259**	**0.0346**
Average May	2.39	2.51	3
Slope June	**0.0051**	-0.0042	**0.0014**
Average June	1.34	1.23	1.79
Slope July	**0.0268**	**0.02**	-0.0069
Average July	2.26	2.05	3.07
Slope August	-0.0175	-0.0364	-0.0048
Average August	2.76	2.85	3.35
Slope September	**0.0212**	-0.0364	**0.0307**
Average September	2.89	2.26	3.47

Table 2: Station Information, Elevation, Slopes and Averages For Each Month and All Three Totals

New Mexico						
Station Name	**Aztec Ruins**	**Bloomfield**	**Chaco Canyon**	**Fruitland**	**Shiproock**	**Star Lake**
Latitude	36, 50, 00	36, 40, 00	36, 02, 00	36, 44, 00	36, 47, 00	35, 56, 00
Longitude	-108, 00, 00	-107, 58, 00	-107, 54, 00	-108, 21, 00	-108, 44, 00	-107, 28, 00
Elevation	5644	5807	6184	5220	4872-4993	6644
Slope May-Sept.	**0.0077**	-0.0349	**0.0097**	**0.0066**	**0.0358**	**0.036**
Average May-Sept.	12.05	11.52	14.15	9.79	8.52	15.87
Slope July-Sept.	-0.0177	-0.0537	-0.0003	**0.0007**	**0.0516**	-0.0107
Average July-Sept.	9.05	8.6	10.87	7.51	6.03	12.27
Slope July-Aug.	-0.0198	-0.0535	-0.0156	-0.0307	**0.0315**	-0.0356
Average July-Aug.	6.18	6.19	7.72	5.07	4.24	9
Slope May	**0.0149**	**0.004**	**0.0069**	**0.0005**	-0.012	**0.0194**
Average May	1.93	1.71	1.79	1.49	1.79	2
Slope June	**0.0105**	**0.0147**	**0.0031**	**0.0055**	-0.0046	**0.0273**
Average June	1.07	1.21	1.49	0.79	0.69	1.6
Slope July	-0.0199	-0.0388	**0.0061**	-0.012	-0.0047	-0.004
Average July	2.75	2.79	3.38	2.21	1.79	4
Slope August	**0.0001**	-0.0147	-0.0217	-0.0187	**0.0362**	-0.0316
Average August	3.43	3.4	4.33	2.86	2.45	5
Slope September	**0.0021**	-0.0001	**0.0153**	**0.0314**	**0.0201**	**0.0249**
Average September	2.86	2.4	3.15	2.44	1.79	3.27

Utah					
Station Name	**Bluff**	**Castle Dale**	**Green River**	**Mexican Hat**	**Moab**
Latitude	37, 37, 00	39, 13, 00	38, 59, 00	37, 08, 00	38, 35, 00
Longitude	-109, 28, 00	-111, 01, 00	-110, 09, 00	-109, 53, 00	-109, 33, 00
Elevation	6040-6135	5505-5764	4070	4203-4432	3965-4134
Slope May-Sept.	**0.039**	**0.0217**	**0.0249**	**0.0814**	**0.0802**
Average May-Sept.	8.57	11.45	9	8.02	9.48
Slope July-Sept.	**0.0116**	**0.0334**	**0.0128**	**0.0519**	**0.0378**
Average July-Sept.	6.14	7.62	5.76	5.83	6.3
Slope July-Aug.	-0.0016	**0.023**	**0.0309**	**0.0154**	**0.0159**
Average July-Aug.	4.3	5.17	382	4.02	4.25
Slope May	**0.0219**	-0.0072	**0.0239**	**0.036**	**0.0436**
Average May	1.8	2.1	2.16	1.46	2.28
Slope June	**0.054**	-0.0045	-0.0118	-0.0065	-0.0012
Average June	0.64	1.74	1.08	0.73	0.9
Slope July	**0.0068**	**0.0024**	**0.0193**	-0.0003	**0.0063**
Average July	1.93	2.31	1.5	1.93	1.93
Slope August	-0.0084	**0.0206**	**0.0116**	**0.0157**	**0.0096**
Average August	2.36	2.86	2.32	2.1	2.33
Slope September	**0.0132**	**0.0105**	-0.0181	**0.0365**	**0.0219**
Average September	1.84	2.45	1.95	1.8	2.05

Results and Conclusions

Observing the data from the figures and spreadsheets (see Appendices A-D) it appears that for the total number of precipitation events for May through September, thirteen out of nineteen rain stations have positive slopes (see tables 1 and 2), so there appears to be an increase in the number of precipitation events on average over the time period of 1954 through 1998. To examine the data further a total number of precipitation events removing May and June, the months with the lowest average number of precipitation events, was created. Slopes from these total precipitation events of July through September had ten positive slopes and nine negative slopes. The three slopes, which had become negative when, May and June were removed, had the lowest flattest slopes that oscillated slightly positive and slightly negative month to month. The data totals were also examined without the month of September, the month most agriculture is harvested; therefore, water should be used less and there would be fewer growing plants contributing to transpiration. It was observed however that September slopes were mostly positive for sixteen out of the nineteen rain stations (more than any other month). Examining the slopes of totaled rain events for July and August the remaining two stations with data depicting flat oscillating trendlines also became slightly negative. Overall it was observed that eight rain stations had mostly positive slopes, five rain stations had flat oscillating slopes, and six had mostly negative slopes (see tables 1,2, and figure 7). The number of positive slopes was still higher than negative slopes suggesting that on average the number of precipitation events have increased between 1954 to 1998, which should be due to increased water amounts in the atmosphere of the area due to dams and agriculture increasing evapotranspiration.

Positive Slope for Trendlines of Total May-September, Total July-September, and Total July-August
Negative Slope for Trendlines of Total May-September, Total July-September, and Total July-August

Negative Slopes only for Trendline of Total July-August

Figure 7: Colorado Basin Area with Rain Stations Colored to Show Trends

To try and understand why some of the slopes were negative the rain stations were plotted on a map of the Colorado Basin (see figure 7) color coded with mostly positive slope rain stations[23], oscillating slope rain stations[24], and mostly negatively sloped rain stations[25]. Most of the positive sloped rain stations were located in Utah and Colorado between latitude 38, 29,00 to 39, 13, 00. This range only had one negative slope rain station Fruita (latitude 39, 08, 00, longitude –108, 44, 00) near Grand Junction and the Colorado River. The Stations with oscillating slopes were relatively close, primarily in New Mexico near the San Juan River, with one station in Utah also near the San Juan River. This region only had one negative sloped rain station Bloomfield. All three stations with elevations listed at above 6,000ft had oscillating slopes[26]. The majority of the negative sloped rain stations were in Arizona four of which near the Little Colorado River. There was however one rain station in Arizona, which had mostly positive slopes, Lees Ferry located near Lake Powel and Glen Dam. This rain station in particular should have mostly positive slopes, because Glen Canyon Dam was completed in 1966, creating Lake Powel behind it slowly over a seventeen year period (Ackman and Watson, 1997). Lake Powel's increased surface area and agriculture's increased water use over the 1966-1998 time period should have resulted in increased evapotranspiration and therefore increased localized precipitation events.

[23] Labeled on the map as positive slope for trendlines of total May-September, total July-September and total July-August.
[24] Labeled on the map as negative slopes for trendlines of total July-Septmeber and total July-August or negative slopes only for trenline of total July-August.
[25] Labeled on the map as negative slope for trendlines of total May-September, total July-September, and total July-August.
[26]Other than above 6,000ft correlating with oscillating slopes, elevation did not correlate with anything else.

Recommendations for Further Work

This project and the IQP groups before this one have examined rainfall data, which appear to be affected by dams in the American Southwest. The first three IQP's focused on the rainfall in the Jet stream affected by these dams, where this project focused at the localized precipitation events close to where the dams should affect directly. It appears from these projects that the rainfall has been affected; however climate data is extremely hard to predict and analyze do to variation year to year. The next stage of the project is to understand how these increased rainfall events truly affect the ecology of the area. In particular this project examined cryptobiotic soil crusts in the American Southwest, but more work needs to be done to fully understand how the crusts are affected.

Cryptobiotic soil crusts have been researched for their composition, positive affects on their ecosystem, and general growth requirements. This information is relatively available and some was examined in this paper; however complete understanding of moisture relationships has not been done. Analysis of what moisture ratios promoting and hampering growth have been reported and summarized in the background research of this project, but what has happened over the last hundred years to the cryptobiotic soil ecosystem with increased rainfall? This question is beyond this project to answer at this point due to its complexity.

First other questions need to be answered beginning with what exact conditions favor cryptobiotic soil? From the background research of this paper cryptobiotic soil appears to grow in: arid environments, within the elevations of 3,000-7,000ft, were the pH is neutral to alkaline between 7-11, with low oxidation-reduction potentials, in a wide temperature range (depending on the exact components), often within pinyon-pine juniper woodlands, and require occasional moisture even though cryptobiotic soil can survive without moisture for quite some time. This seems like it answers the question but again the big confusion is exactly on the moisture requirements? Reported in the background section is some research on optimal conditions, but not the range in which they exist and how the moisture completely affects the growth of the different parts that make up cryptobiotic soil, which should be examined more thoroughly. Another factor within the growth requirements the pH of 7-11 how does increased rain affect the soil pH especially with acid rain induced by industrial pollution? Also other factors have influenced the growth of cryptobiotic soil in the last hundred years including direct damage by humans who trample the soil, destroy it to make way for other plants, and who have introduced animals that graze on or around the soil.

So far it is known that cryptobiotic soil is useful for stabilizing the soil, reducing erosion, holding useful nutrients in the soil for other plants, and fixing nitrogen. What happens if cryptobiotic soil is lost or altered? This question has not been researched at this point because cryptobiotic soil is still available in most areas around the world and nobody knows if it has been altered already.

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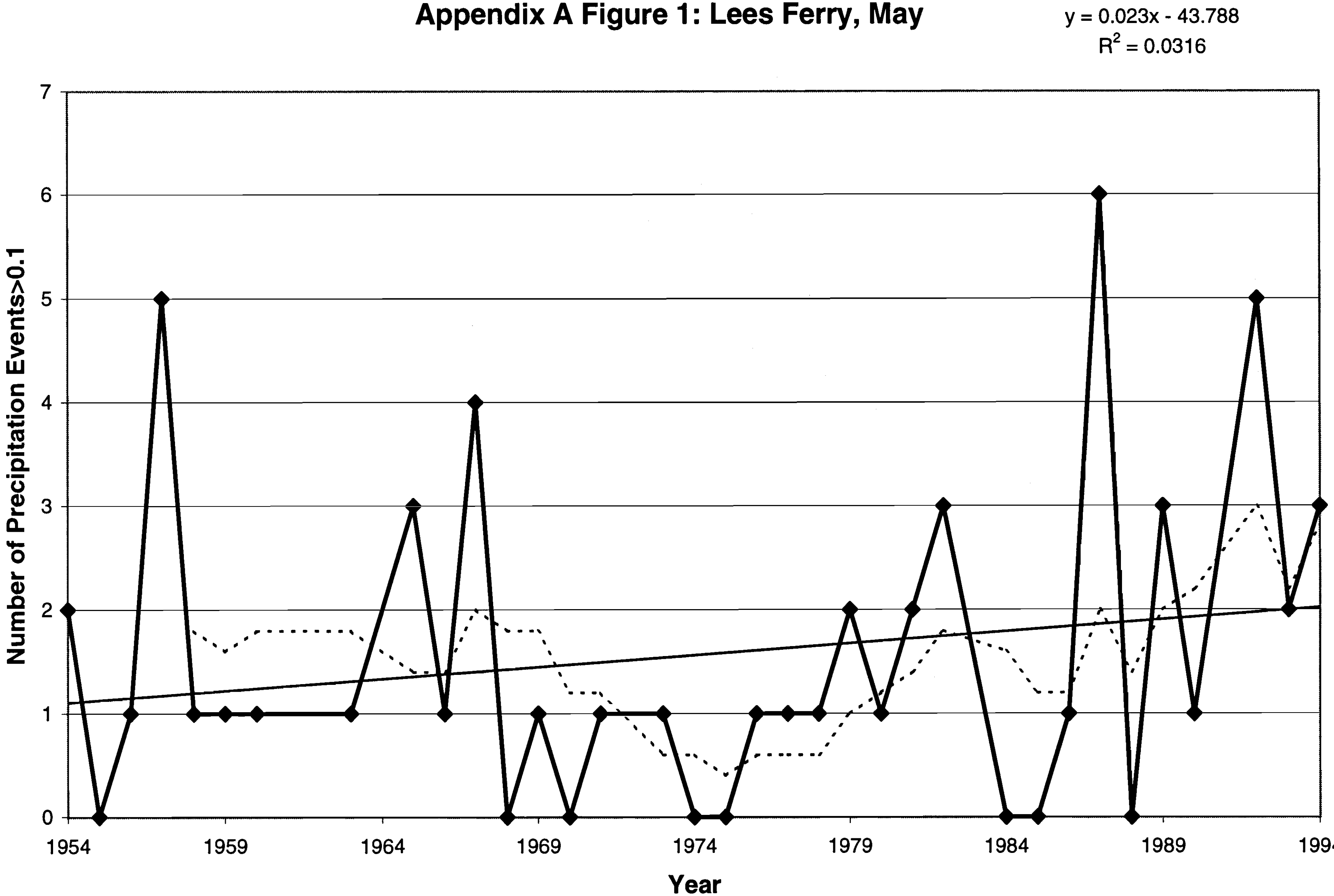
Appendix A Table 1: Number of Precipitation Events >0.1 in, Lees Ferry, Arizona, 1954-1994

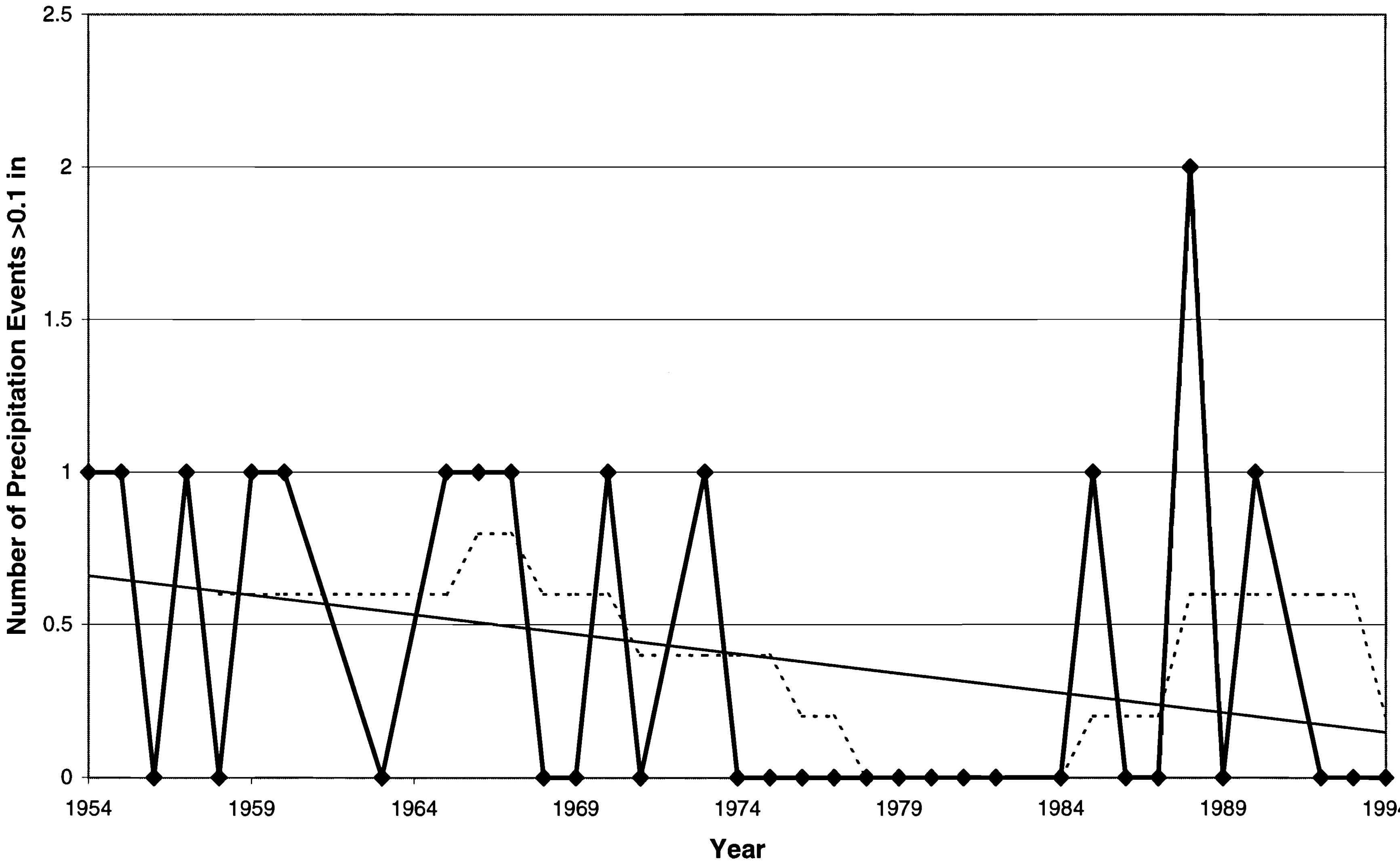
	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1954	2	1	4	1	3	11	8	5
1955	0	1	1	0	0	2	1	1
1956	1	0	3	1	0	5	4	4
1957	5	1	4	5	0	15	9	9
1958	1	0	2	3	4	10	9	5
1959	1	1	0	3	0	5	3	3
1960	1	1	1	1	2	6	4	2
1963	1	0	1	6	2	10	9	7
1965	3	1	0	1	1	6	2	1
1966	1	1	4	3	1	10	8	7
1967	4	1	2	3	4	14	9	5
1968	0	0	3	3	0	6	6	6
1969	1	0	3	3	1	8	7	6
1970	0	1	3	3	0	7	6	6
1971	1	0	1	3	1	6	5	4
1973	1	1	2	1	0	5	3	3
1974	0	0	3	0	1	4	4	3
1975	0	0	3	1	3	7	7	4
1976	1	0	5	0	4	10	9	5
1977	1	0	6	3	1	11	10	9
1978	1	0	1	1	1	4	3	2
1979	2	0	0	1	0	3	1	1
1980	1	0	4	1	3	9	8	5
1981	2	0	0	5	6	13	11	5
1982	3	0	1	7	1	12	9	8
1984	0	0	5	6	2	13	13	11
1985	0	1	3	1	2	7	6	4
1986	1	0	4	5	3	13	12	9
1987	6	0	0	1	1	8	2	1
1988	0	2	1	3	0	6	4	4
1989	3	0	2	2	0	7	4	4
1990	1	1	5	1	2	10	8	6
1992	5	0	3	4	1	13	8	7
1993	2	0	0	2	0	4	2	2
1994	3	0	2	1	3	9	6	3
Ave.	**1.57**	**0.40**	**2.34**	**2.43**	**1.51**	**8.26**	**6.29**	**4.77**
S.D.	**1.56**	**0.55**	**1.70**	**1.85**	**1.52**	**3.42**	**3.19**	**2.54**
Max	**6**	**2**	**6**	**7**	**6**	**15**	**13**	**11**
Min	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**1**

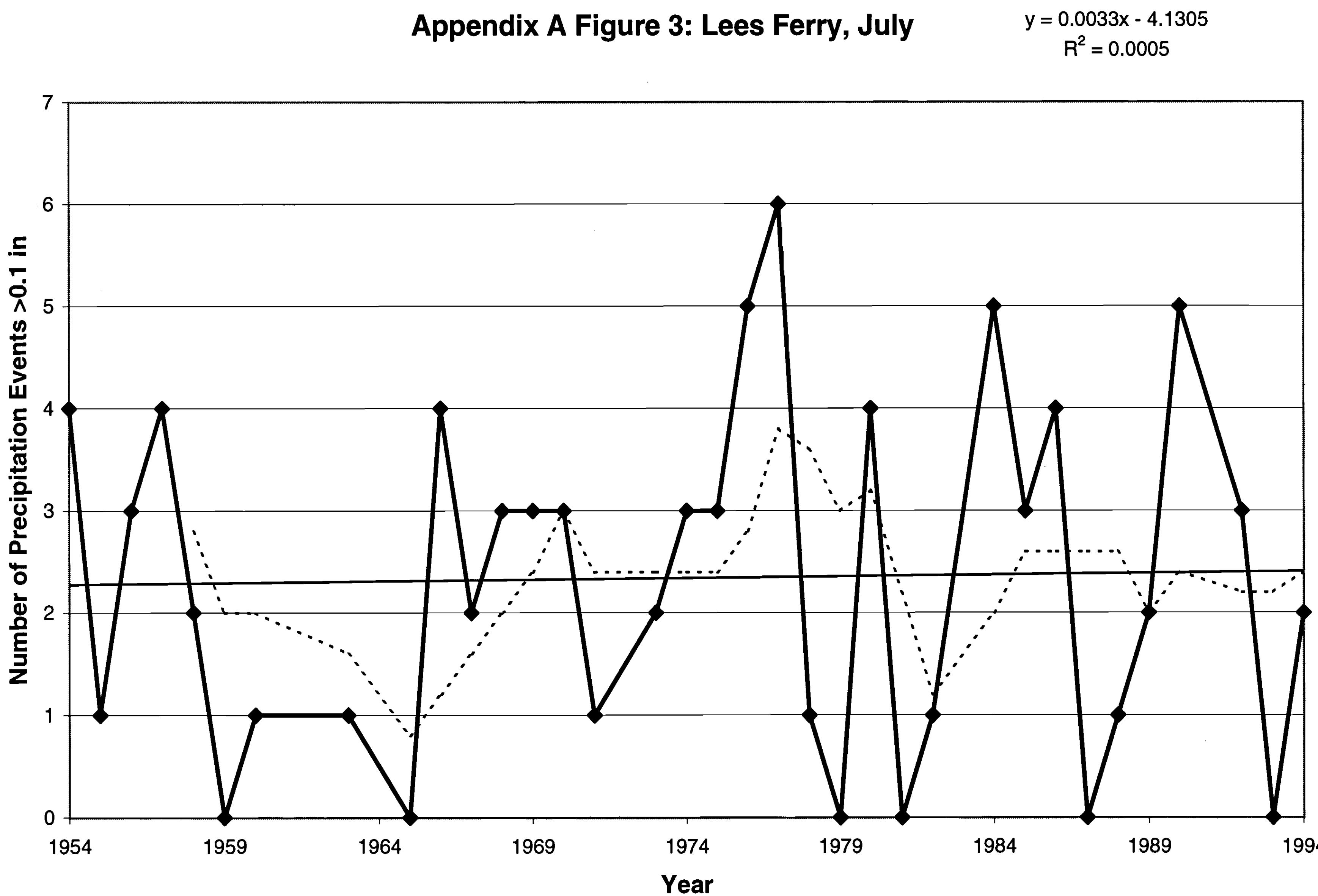
Appendix A Figure 1: Lees Ferry, May

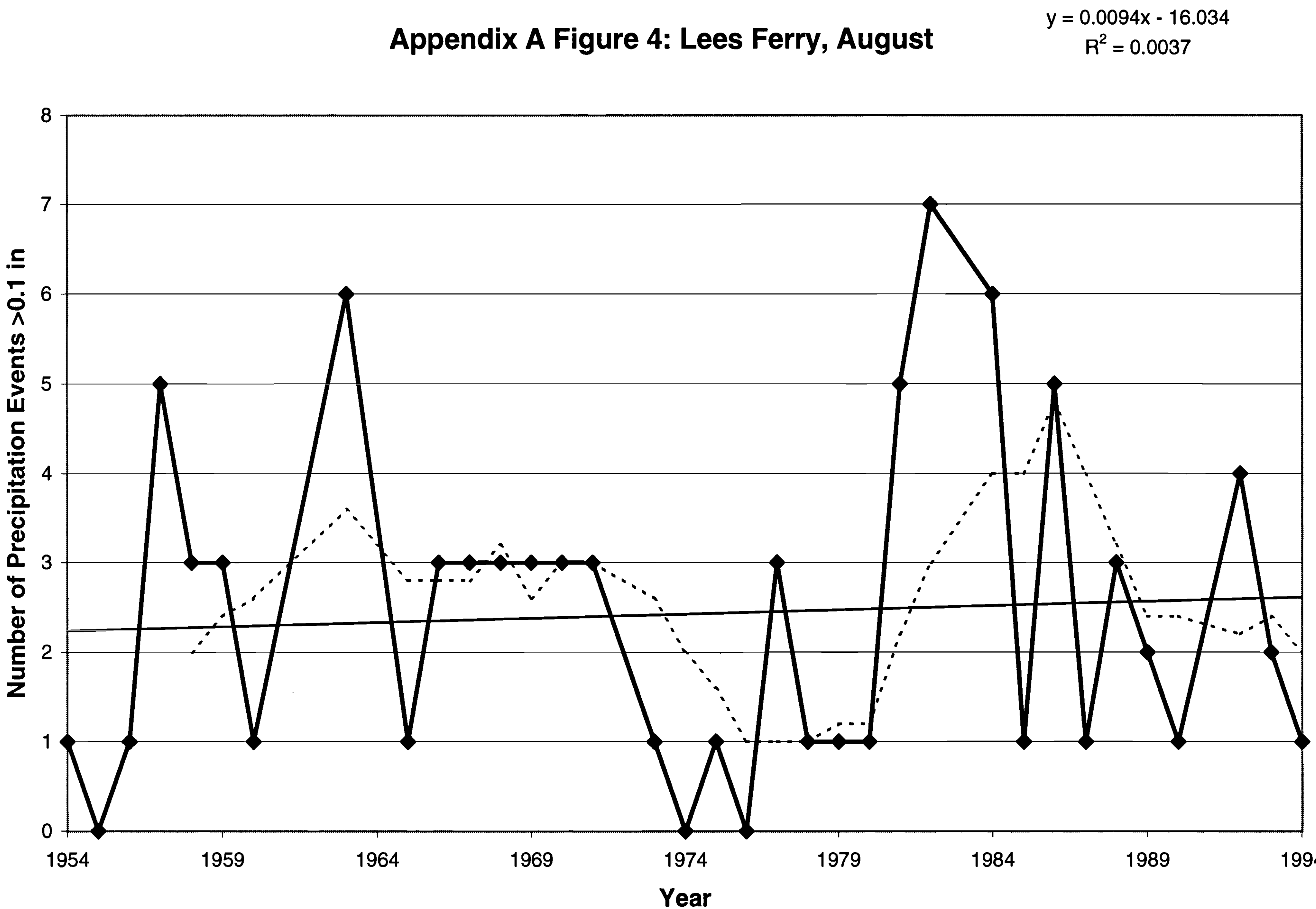


Appendix A Figure 2: Lees Ferry, June

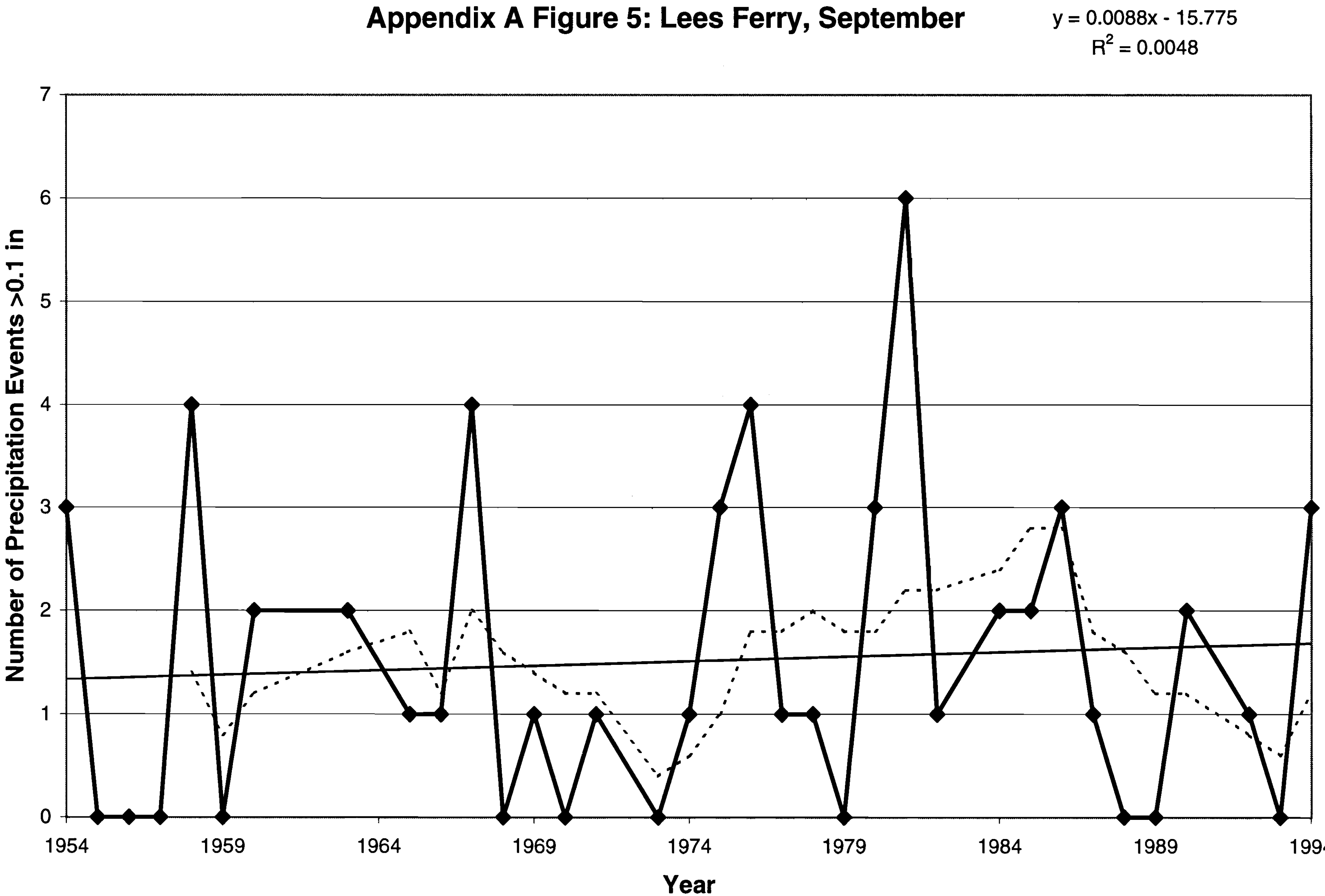
$y = -0.0128x + 25.69$
$R^2 = 0.0781$

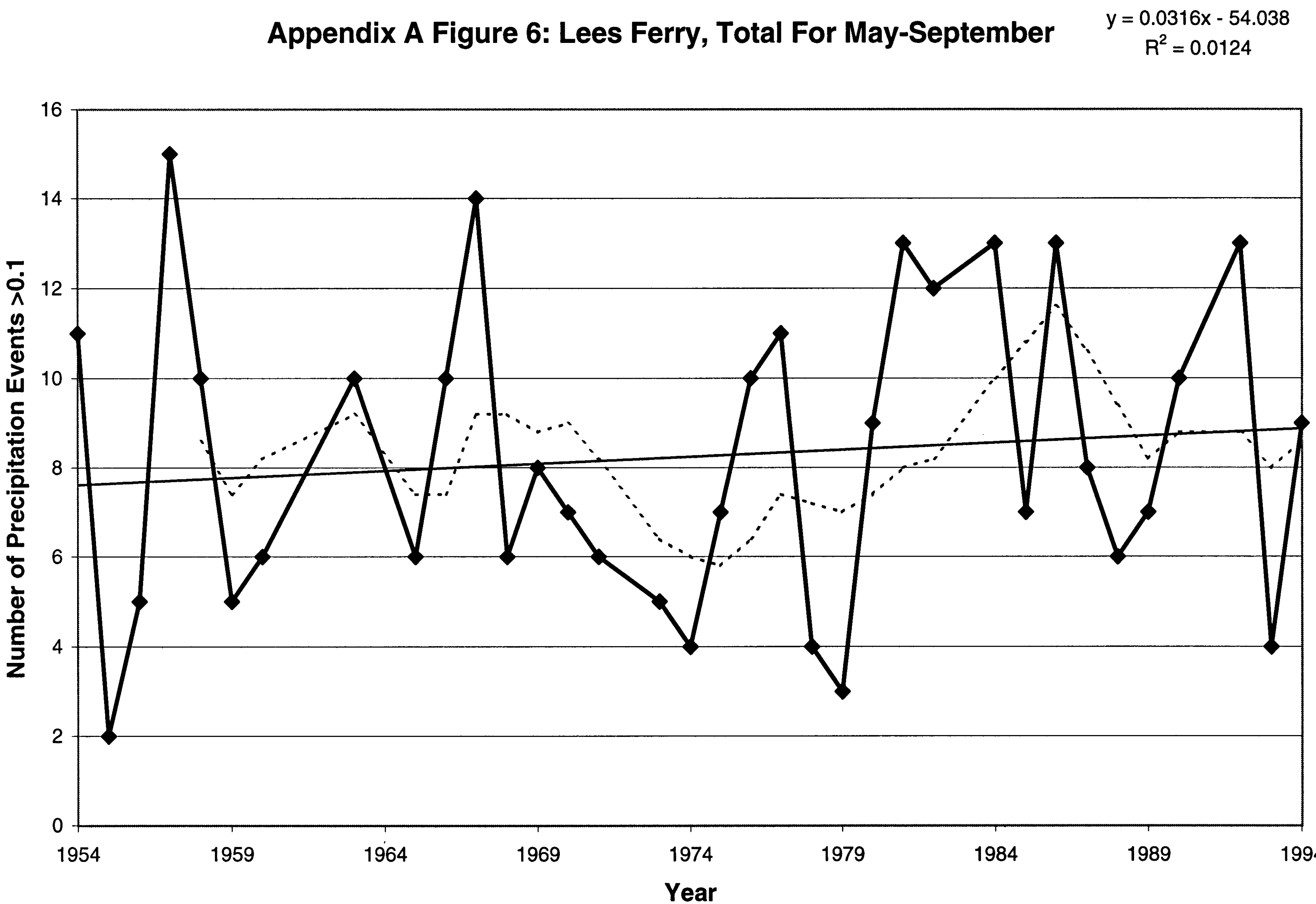



Appendix A Figure 3: Lees Ferry, July
y = 0.0033x - 4.1305
R2 = 0.0005
Number of Precipitation Events >0.1 in
0
1
2
3
4
5
6
7
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

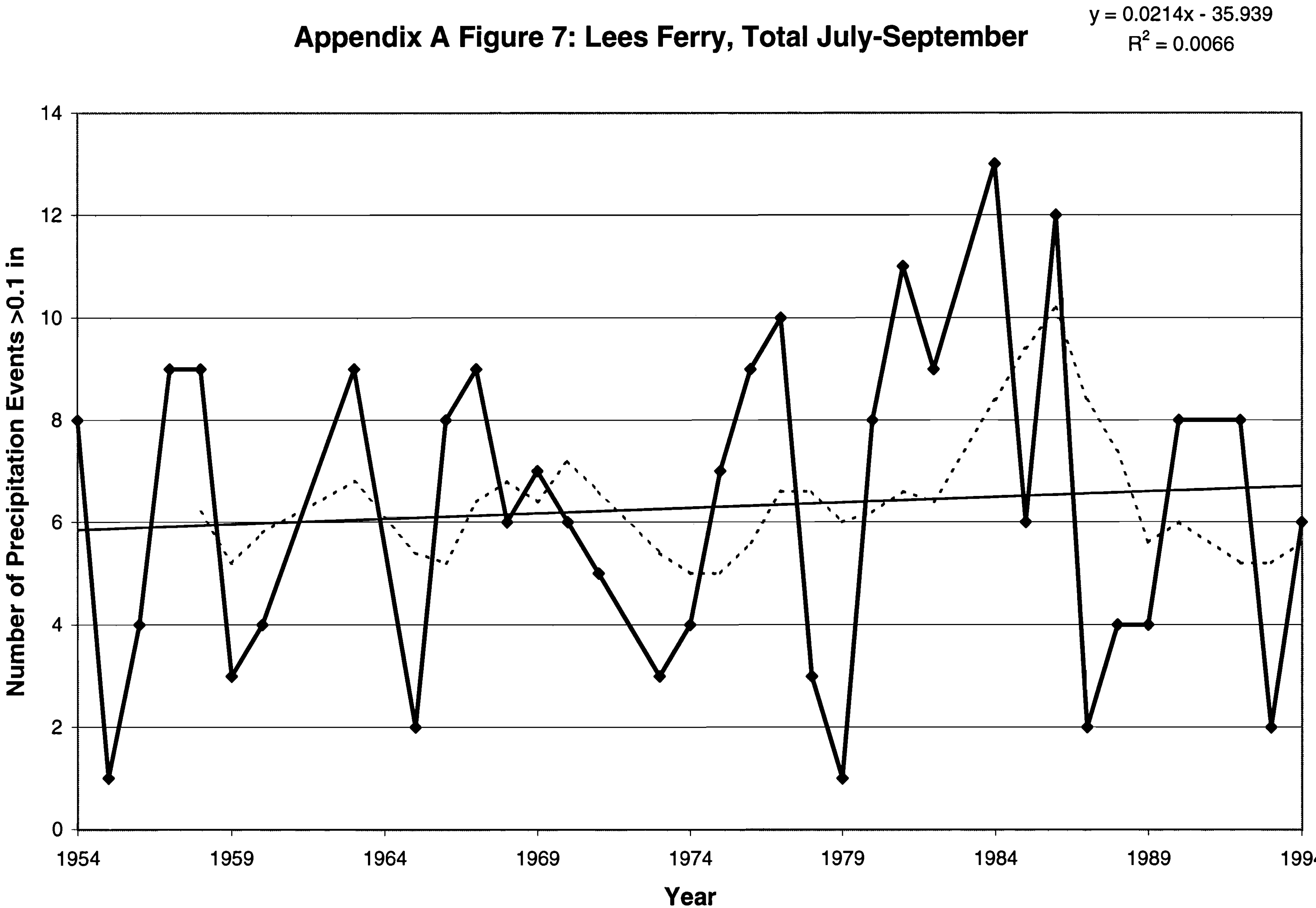

Appendix A Figure 4: Lees Ferry, August
y = 0.0094x - 16.034
R2 = 0.0037
Number of Precipitation Events >0.1 in
0
1
2
3
4
5
6
7
8
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

Appendix A Figure 5: Lees Ferry, September

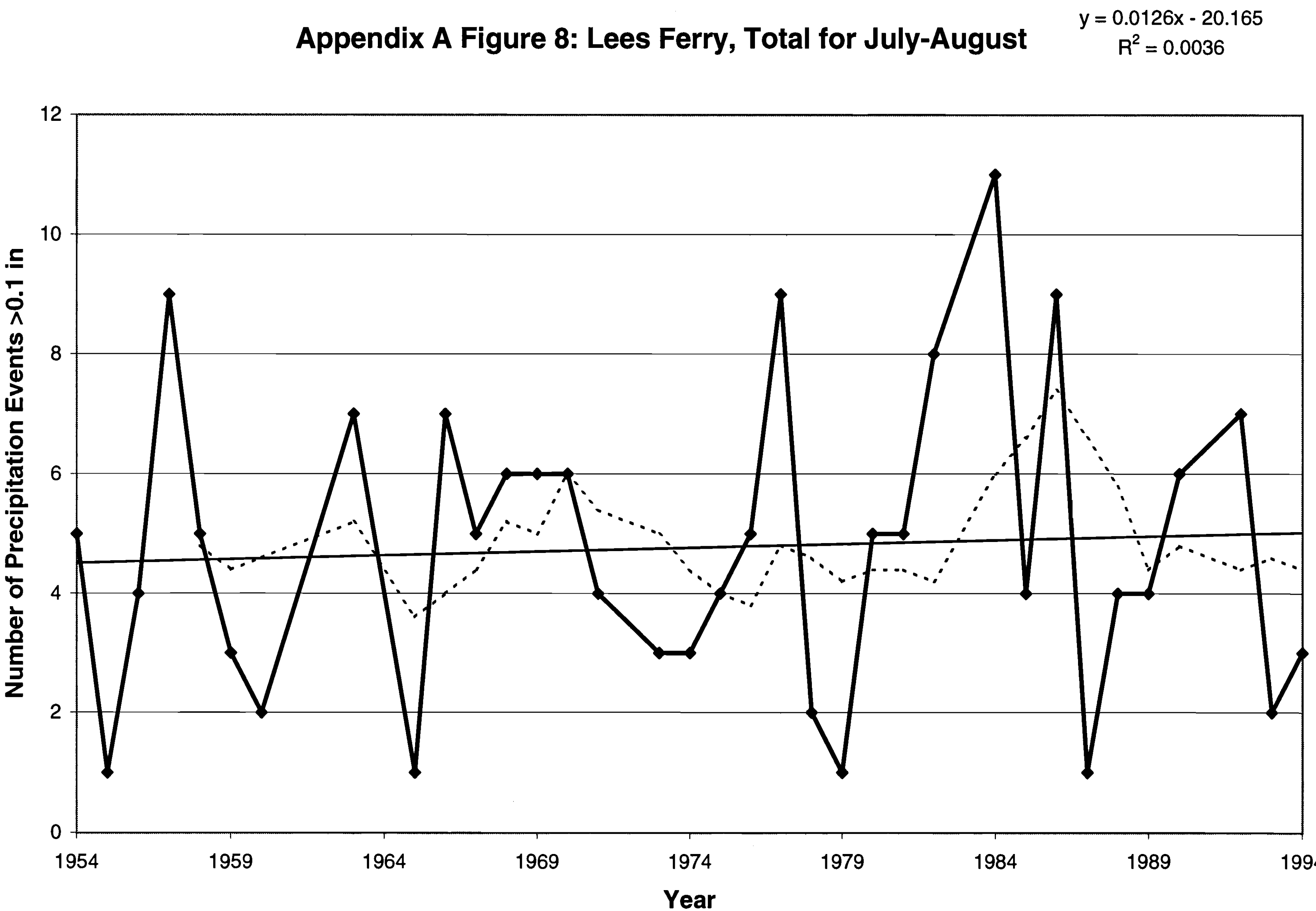



Appendix A Figure 6: Lees Ferry, Total For May-September
y = 0.0316x - 54.038
R2 = 0.0124
Number of Precipitation Events >0.1
Year
0
2
4
6
8
10
12
14
16
1954
1959
1964
1969
1974
1979
1984
1989
1994

Appendix A Figure 7: Lees Ferry, Total July-September



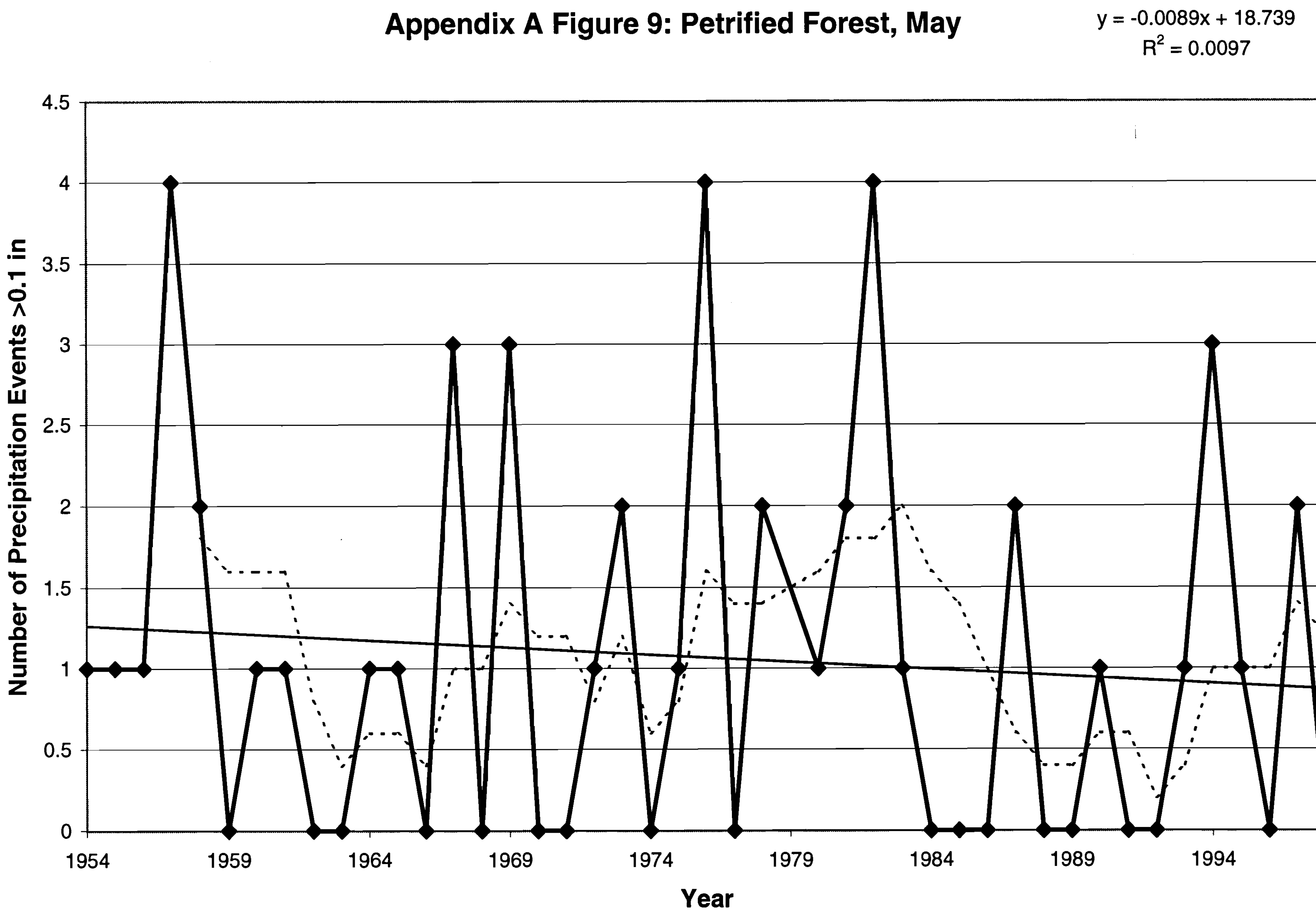
Appendix A Figure 8: Lees Ferry, Total for July-August



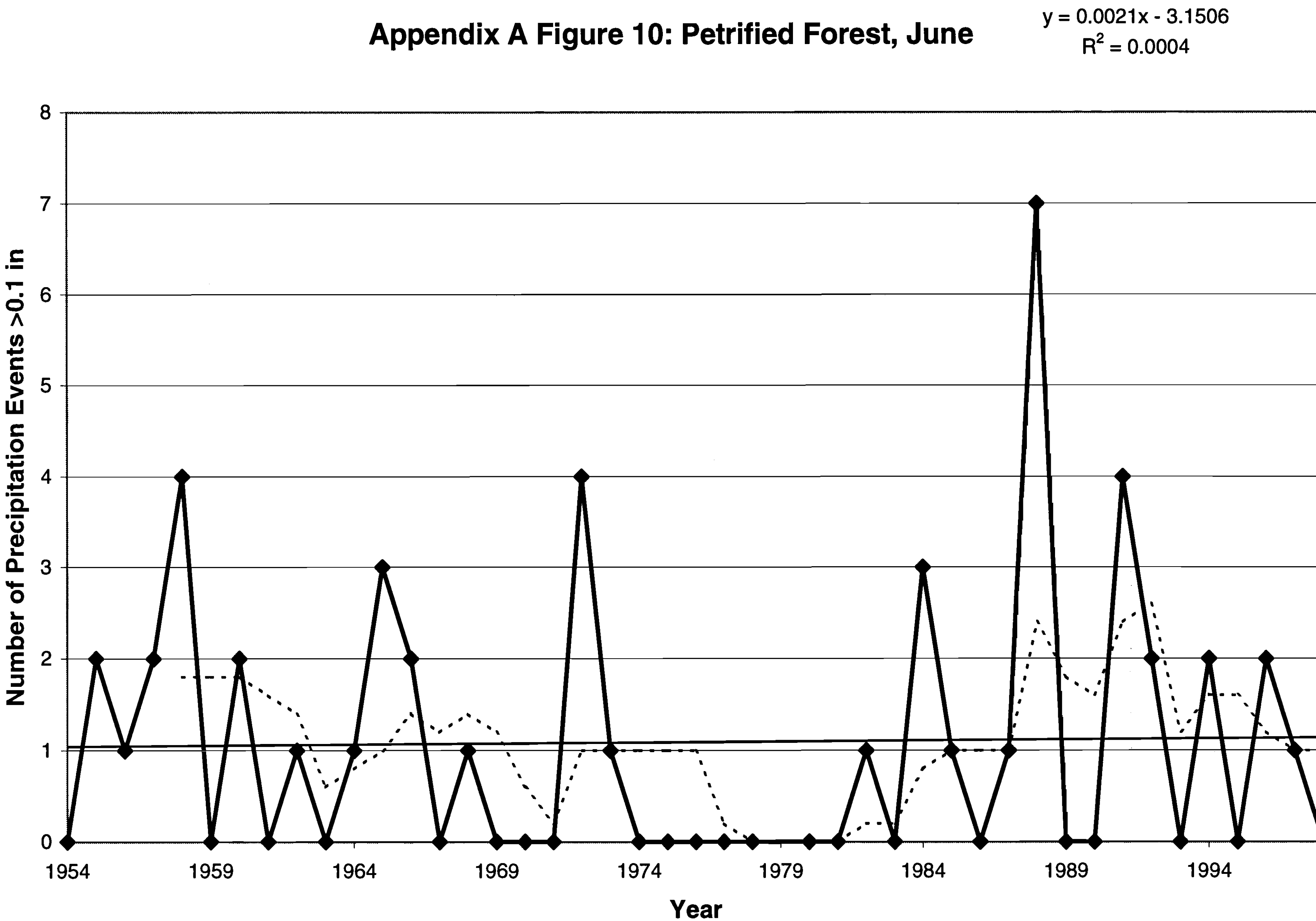
Appendix A Table 2: Number of Precipitation Events >0.1 in, Petrified Forest, Arizona, 1954-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1954	1	0	7	4	4	16	15	11
1955	1	2	4	9	0	16	13	13
1956	1	1	4	2	0	8	6	6
1957	4	2	3	7	0	16	10	10
1958	2	4	3	8	6	23	17	11
1959	0	0	6	6	1	13	13	12
1960	1	2	1	3	1	8	5	4
1961	1	0	1	4	3	9	8	5
1962	0	1	1	2	5	9	8	3
1963	0	0	1	7	5	13	13	8
1964	1	1	5	5	4	16	14	10
1965	1	3	6	4	3	17	13	10
1966	0	2	8	5	3	18	16	13
1967	3	0	3	5	4	15	12	8
1968	0	1	5	7	0	13	12	12
1969	3	0	4	7	2	16	13	11
1970	0	0	4	4	3	11	11	8
1971	0	0	3	5	3	11	11	8
1972	1	4	2	3	1	11	6	5
1973	2	1	1	3	0	7	4	4
1974	0	0	4	4	1	9	9	8
1975	1	0	6	3	6	16	15	9
1976	4	0	5	1	5	15	11	6
1977	0	0	6	3	4	13	13	9
1978	2	0	1	4	3	10	8	5
1980	1	0	1	5	2	9	8	6
1981	2	0	4	3	2	11	9	7
1982	4	1	4	3	3	15	10	7
1983	1	0	5	5	5	16	15	10
1984	0	3	9	9	8	29	26	18
1985	0	1	7	2	4	14	13	9
1986	0	0	10	4	2	16	16	14
1987	2	1	2	2	1	8	5	4
1988	0	7	2	5	2	16	9	7
1989	0	0	6	7	1	14	14	13
1990	1	0	4	5	6	16	15	9
1991	0	4	1	3	3	11	7	4
1992	0	2	5	6	2	15	13	11
1993	1	0	0	7	1	9	8	7
1994	3	2	2	6	2	15	10	8
1995	1	0	1	4	5	11	10	5
1996	0	2	2	1	5	10	8	3
1997	2	1	4	4	5	16	13	8
1998	0	0	6	3	0	9	9	9
Ave.	**1.07**	**1.09**	**3.84**	**4.52**	**2.86**	**13.39**	**11.23**	**8.36**
S.D.	**1.21**	**1.52**	**2.38**	**1.99**	**2.01**	**4.21**	**4.01**	**3.27**
Max	**4**	**7**	**10**	**9**	**8**	**29**	**26**	**18**
Min	**0**	**0**	**0**	**1**	**0**	**7**	**4**	**3**

Appendix A Figure 9: Petrified Forest, May

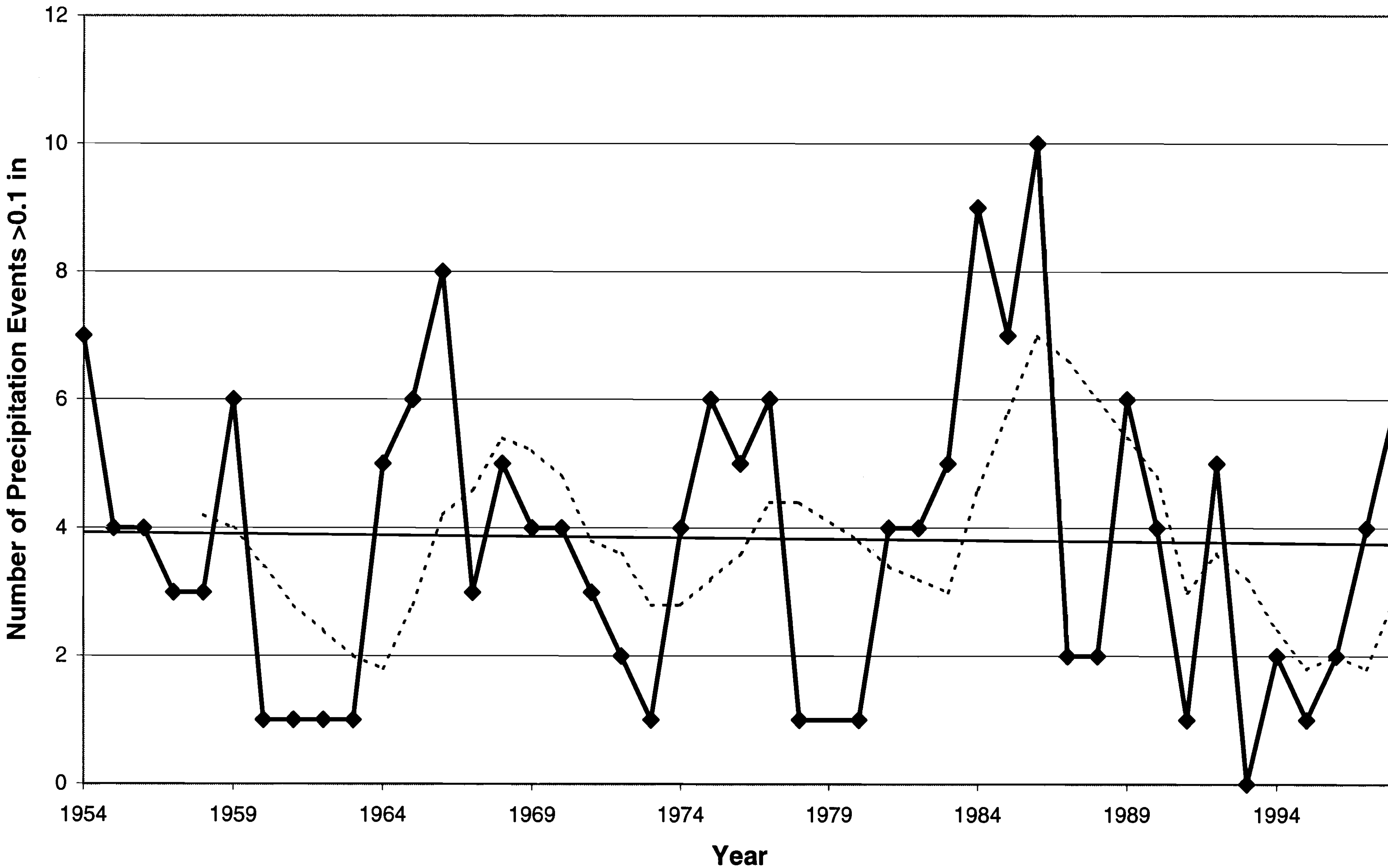


Appendix A Figure 10: Petrified Forest, June

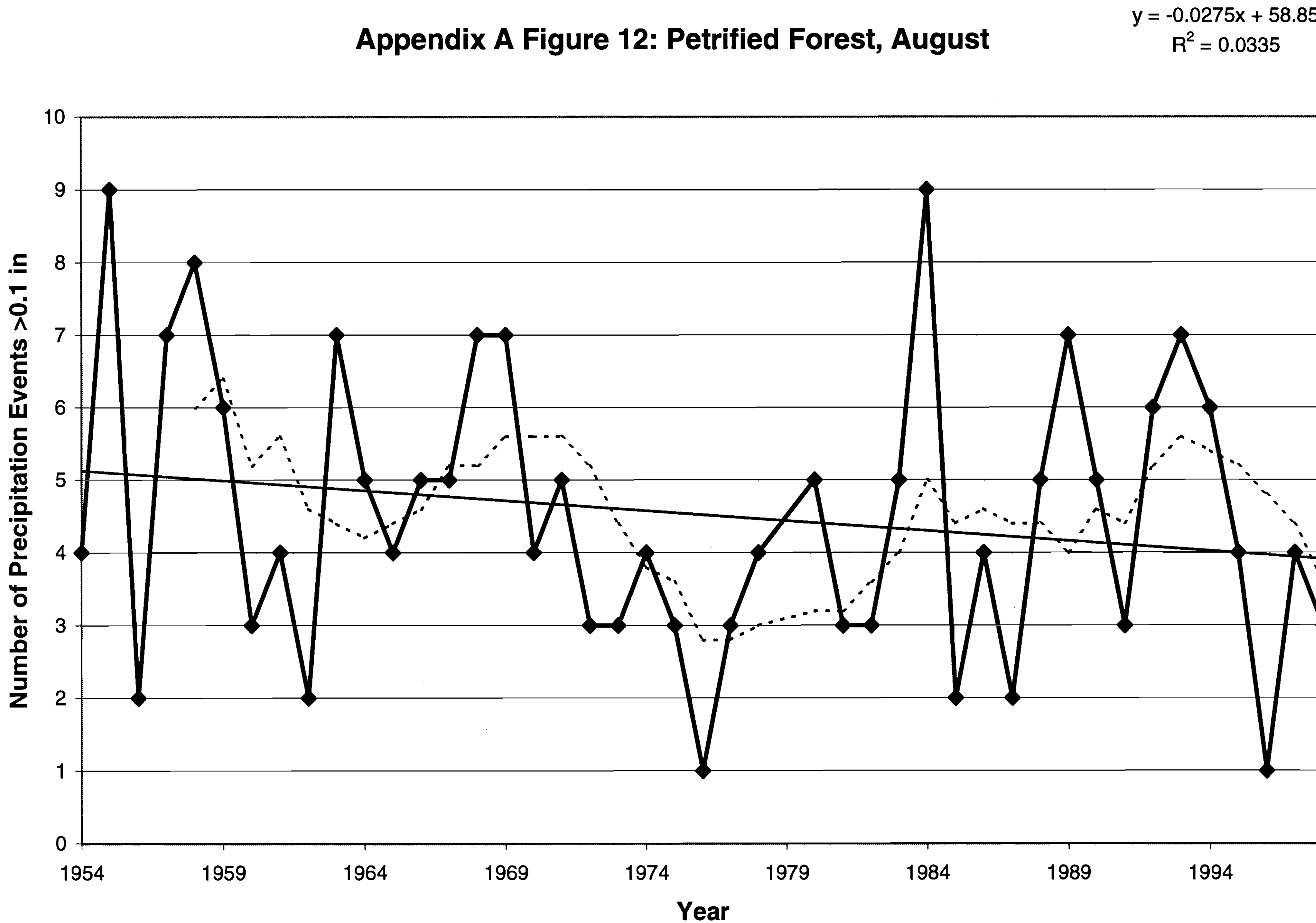


Appendix A Figure 11: Petrified Forest, July

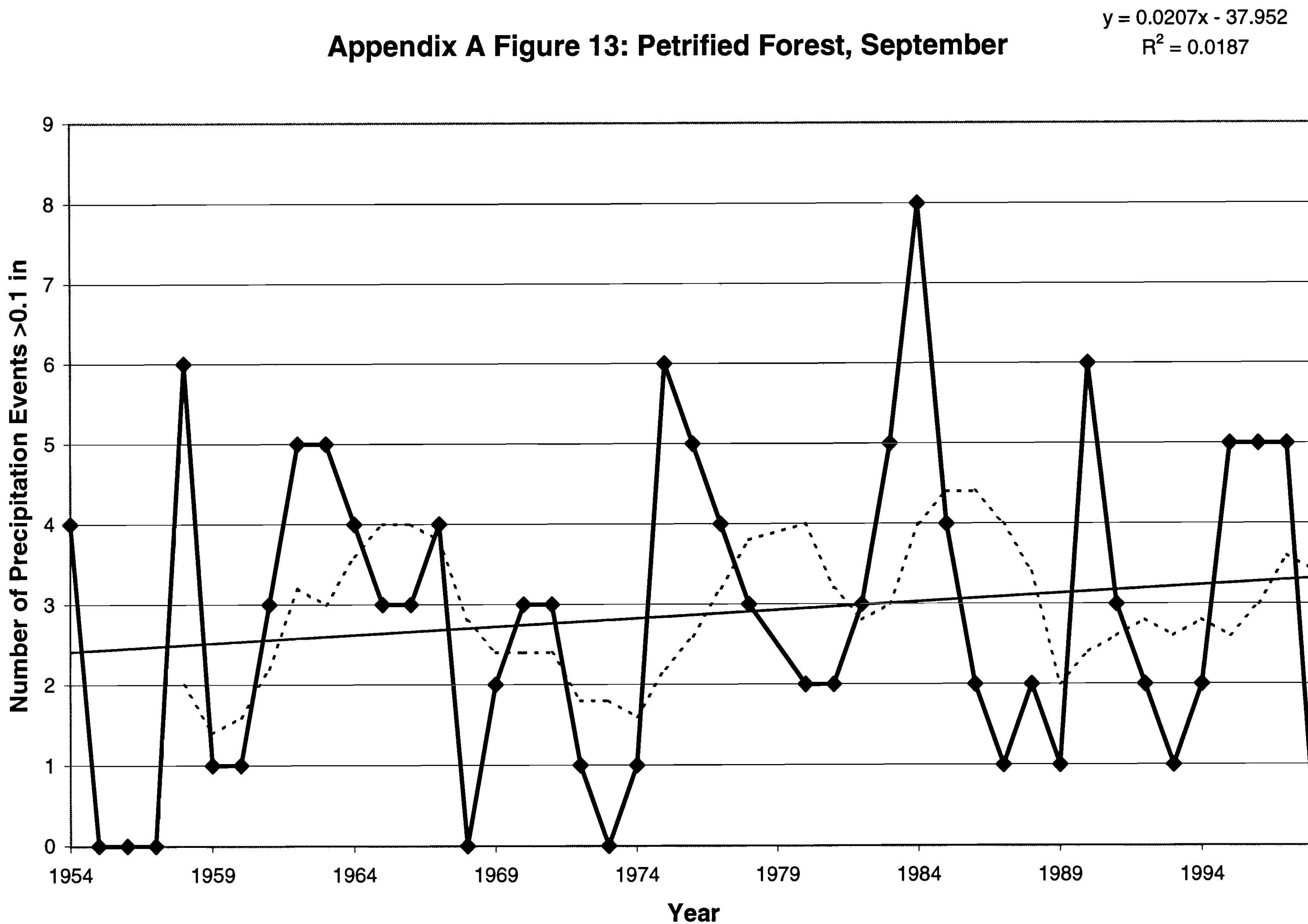
$y = -0.004x + 11.785$
$R^2 = 0.0005$



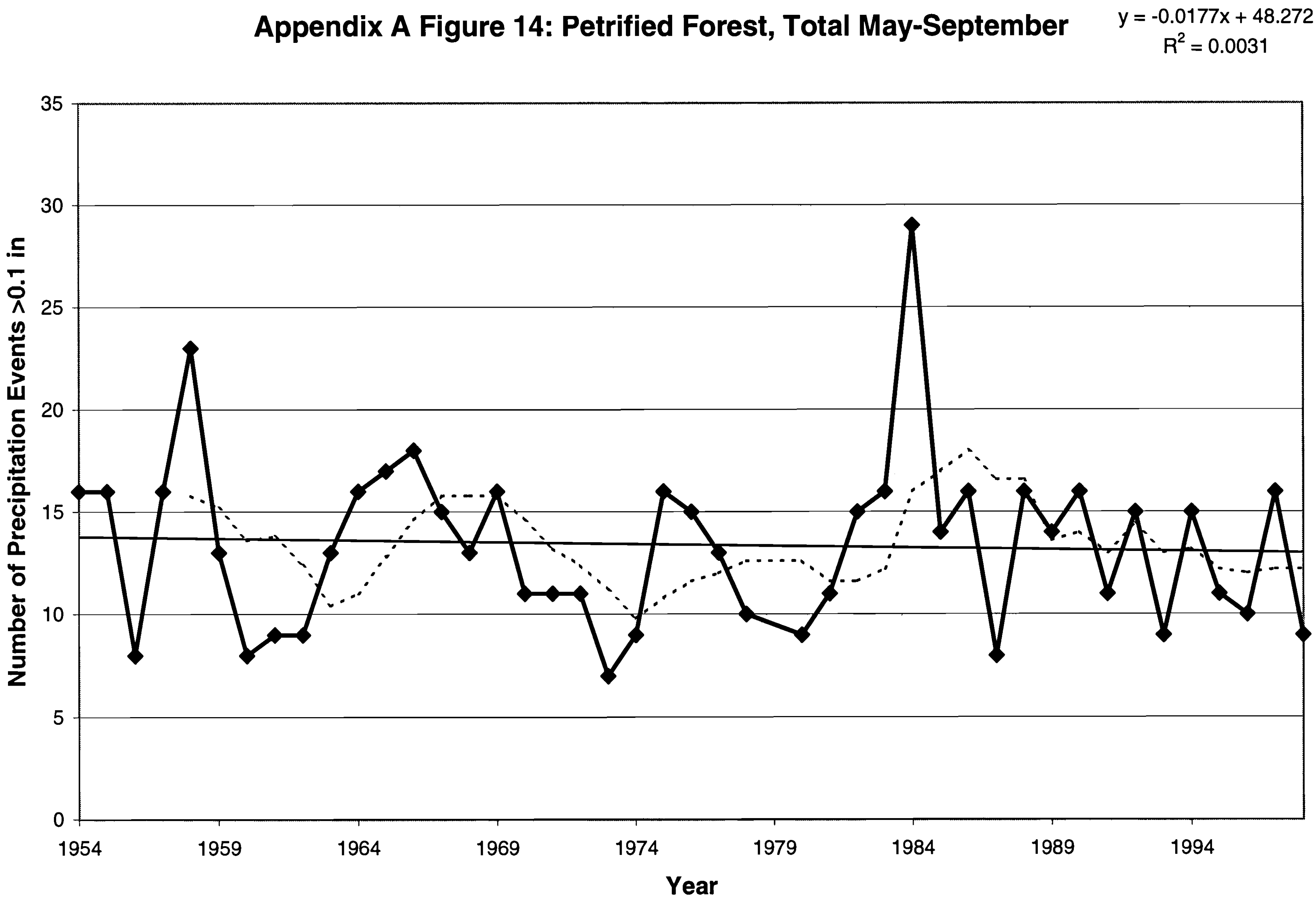
Appendix A Figure 12: Petrified Forest, August



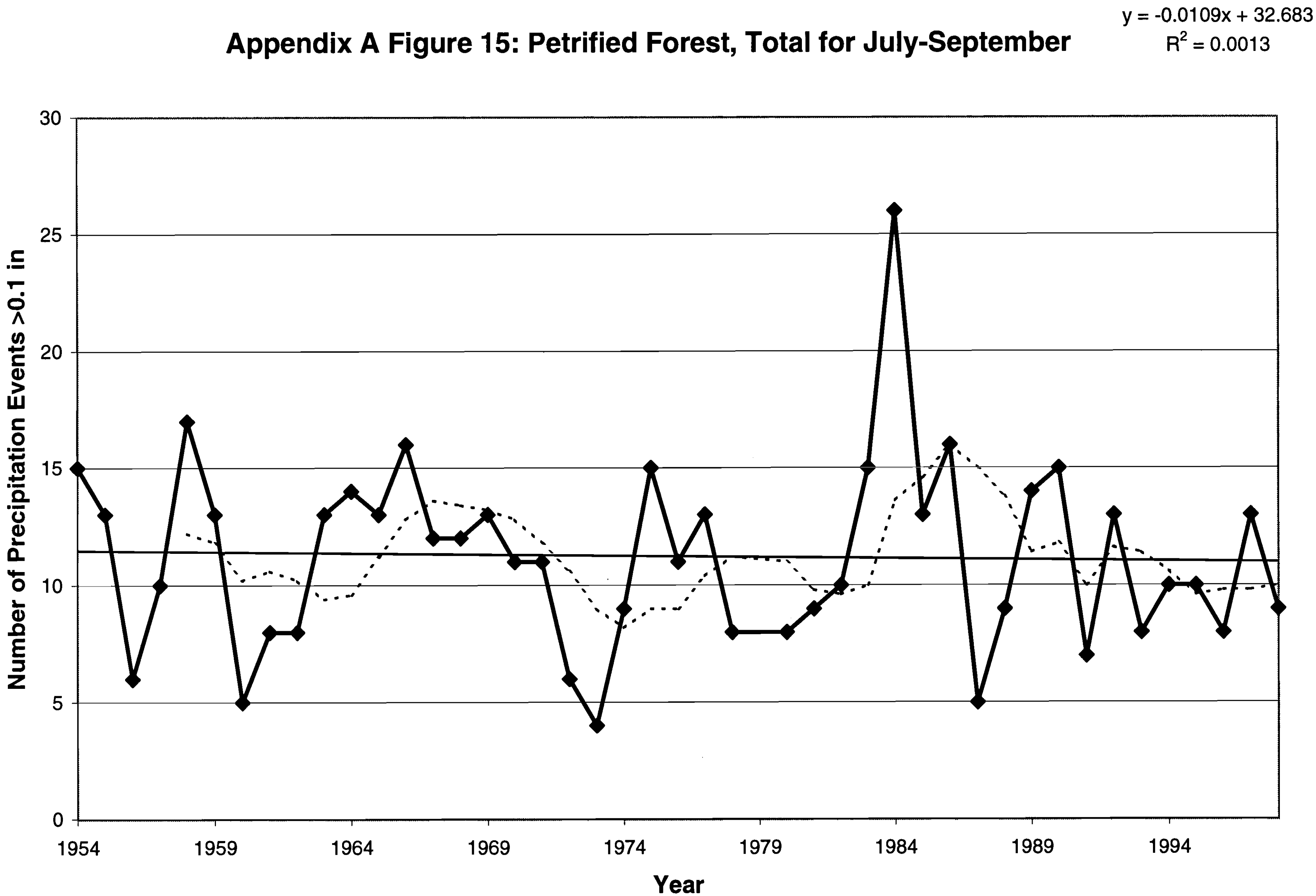
Appendix A Figure 13: Petrified Forest, September

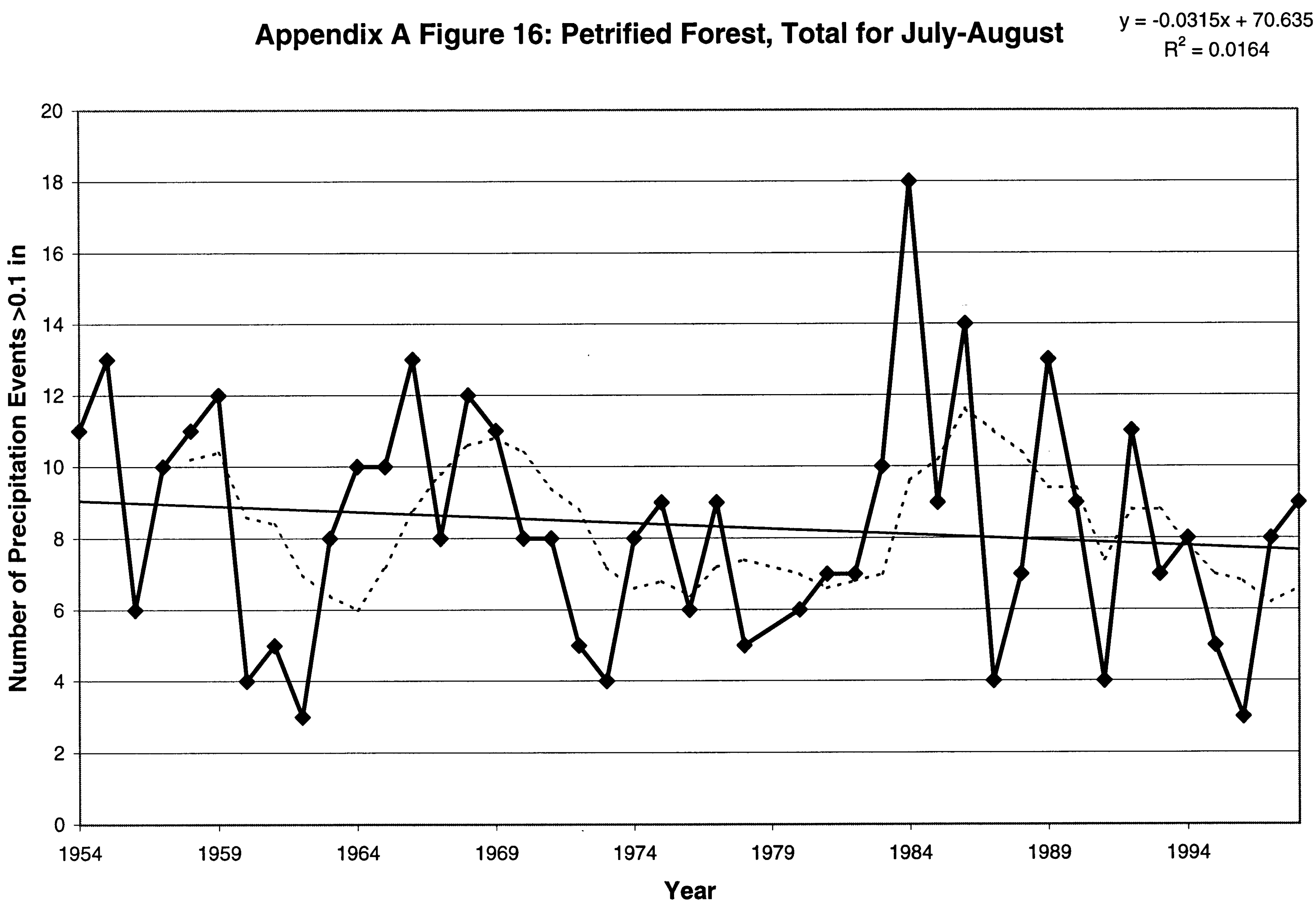


Appendix A Figure 14: Petrified Forest, Total May-September



Appendix A Figure 15: Petrified Forest, Total for July-September

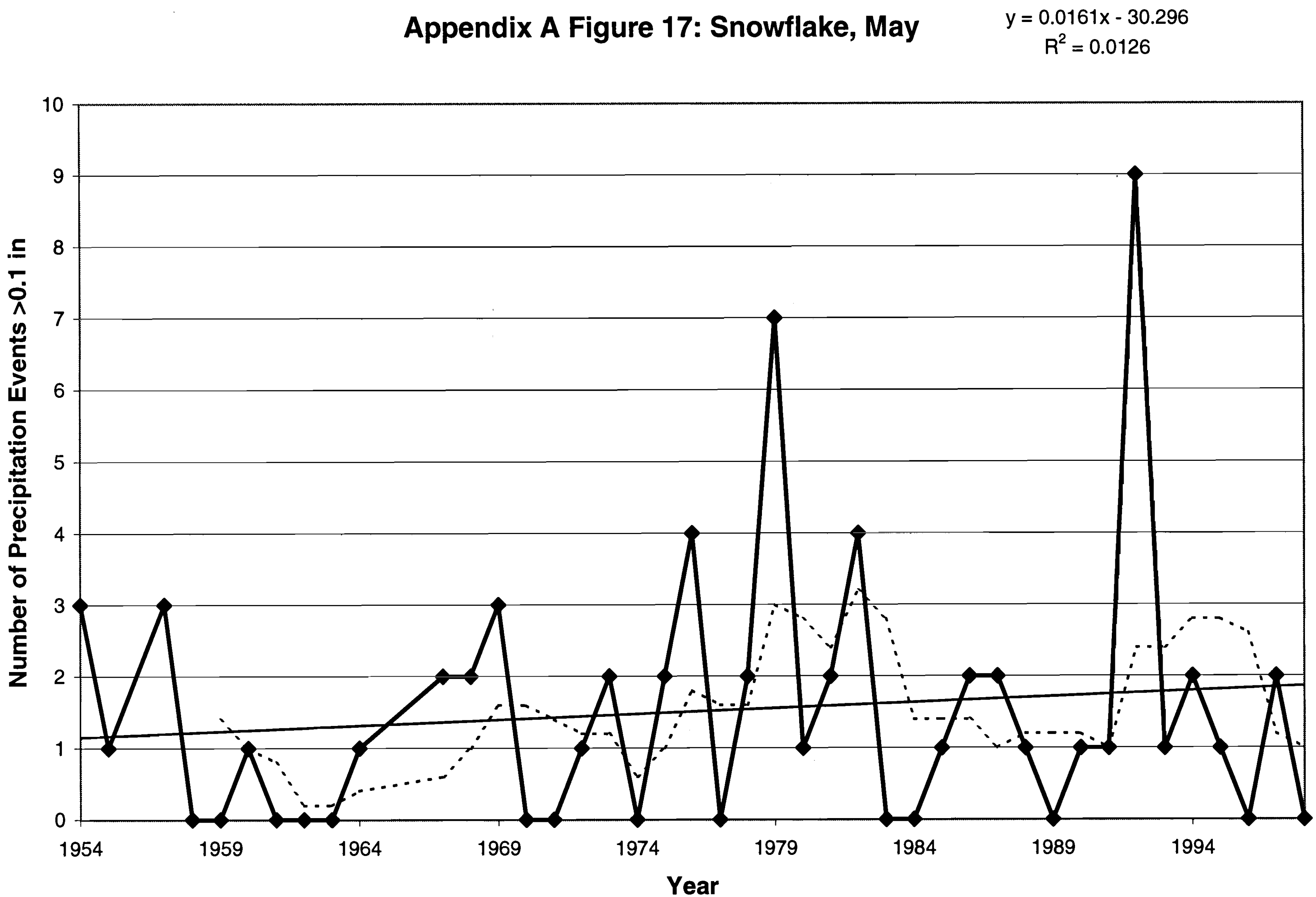



Appendix A Figure 16: Petrified Forest, Total for July-August
y = -0.0315x + 70.635
R2 = 0.0164
Number of Precipitation Events >0.1 in
20
18
16
14
12
10
8
6
4
2
0
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

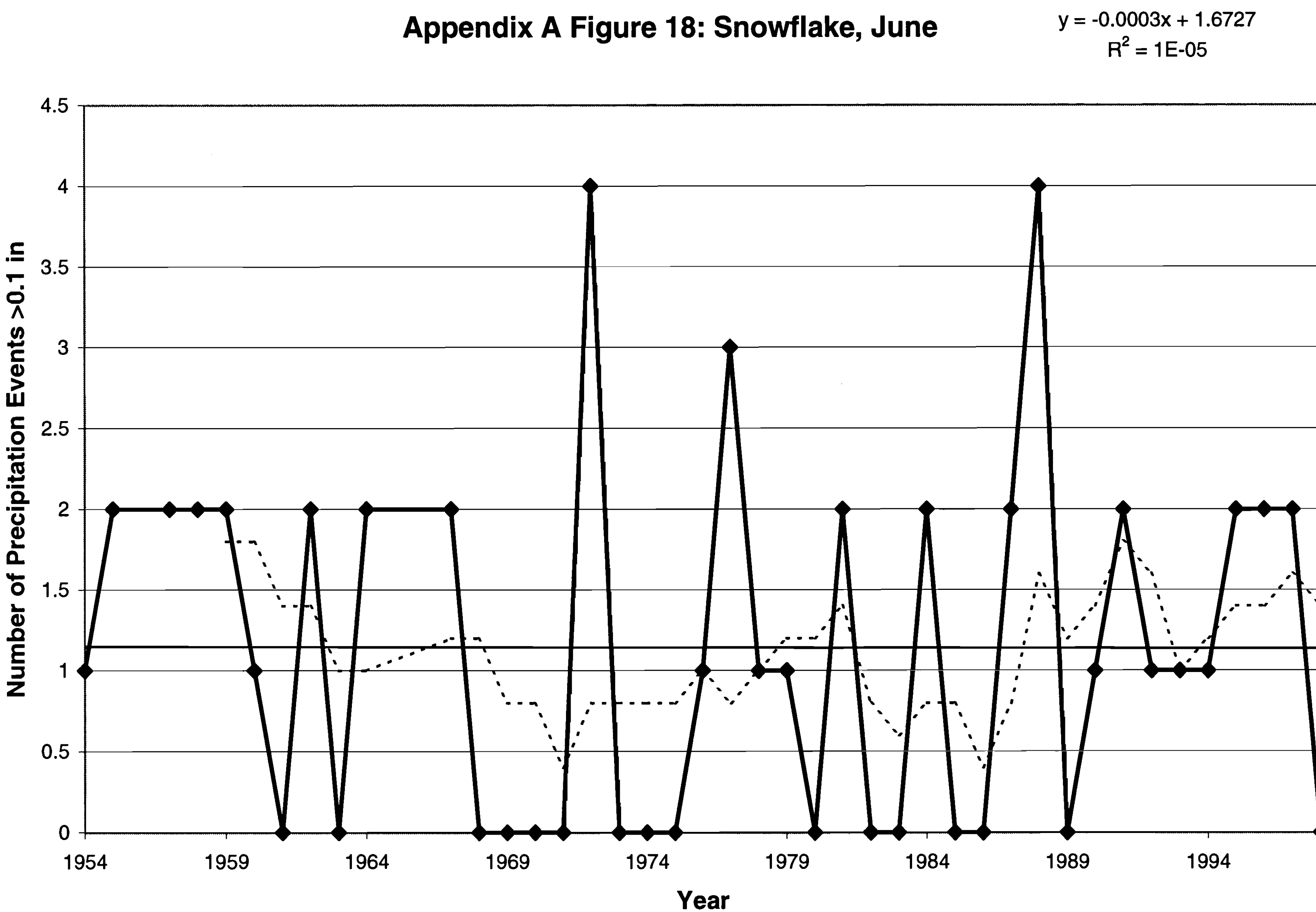
Appendix A Table 3: Number of Precipitation Events >0.1 in, Snowflake, Arizona, 1954-1998

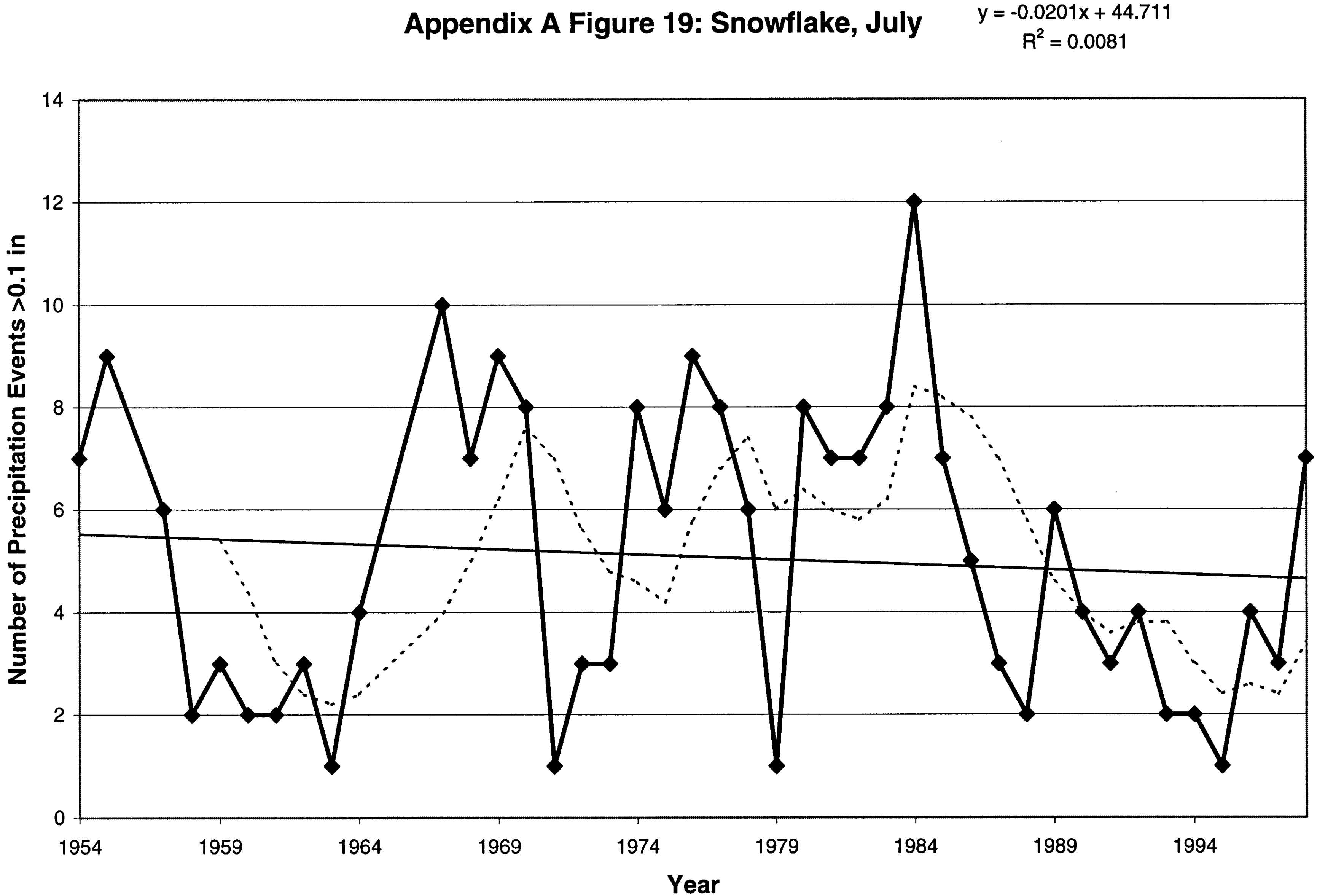
	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1954	3	1	7	4	4	19	15	11
1955	1	2	9	12	0	24	21	21
1957	3	2	6	11	0	22	17	17
1958	0	2	2	5	8	17	15	7
1959	0	2	3	9	1	15	13	12
1960	1	1	2	4	3	11	9	6
1961	0	0	2	5	4	11	11	7
1962	0	2	3	3	6	14	12	6
1963	0	0	1	9	2	12	12	10
1964	1	2	4	9	8	24	21	13
1967	2	2	10	4	1	19	15	14
1968	2	0	7	7	2	18	16	14
1969	3	0	9	8	2	22	19	17
1970	0	0	8	8	2	18	18	16
1971	0	0	1	12	2	15	15	13
1972	1	4	3	8	1	17	12	11
1973	2	0	3	6	0	11	9	9
1974	0	0	8	4	4	16	16	12
1975	2	0	6	5	10	23	21	11
1976	4	1	9	5	8	27	22	14
1977	0	3	8	7	3	21	18	15
1978	2	1	6	6	4	19	16	12
1979	7	1	1	5	0	14	6	6
1980	1	0	8	6	1	16	15	14
1981	2	2	7	5	4	20	16	12
1982	4	0	7	4	4	19	15	11
1983	0	0	8	5	8	21	21	13
1984	0	2	12	8	5	27	25	20
1985	1	0	7	5	8	21	20	12
1986	2	0	5	8	1	16	14	13
1987	2	2	3	7	2	16	12	10
1988	1	4	2	10	1	18	13	12
1989	0	0	6	3	2	11	11	9
1990	1	1	4	7	5	18	16	11
1991	1	2	3	2	6	14	11	5
1992	9	1	4	7	1	22	12	11
1993	1	1	2	6	1	11	9	8
1994	2	1	2	5	3	13	10	7
1995	1	2	1	4	5	13	10	5
1996	0	2	4	1	15	22	20	5
1997	2	2	3	5	5	17	13	8
1998	0	0	7	5	2	14	14	12
Ave.	**1.52**	**1.14**	**5.07**	**6.17**	**3.67**	**17.57**	**14.90**	**11.24**
S.D.	**1.86**	**1.12**	**2.90**	**2.51**	**3.18**	**4.37**	**4.22**	**3.86**
Max	**9**	**4**	**12**	**12**	**15**	**27**	**25**	**21**
Min	**0**	**0**	**1**	**1**	**0**	**11**	**6**	**5**

Appendix A Figure 17: Snowflake, May

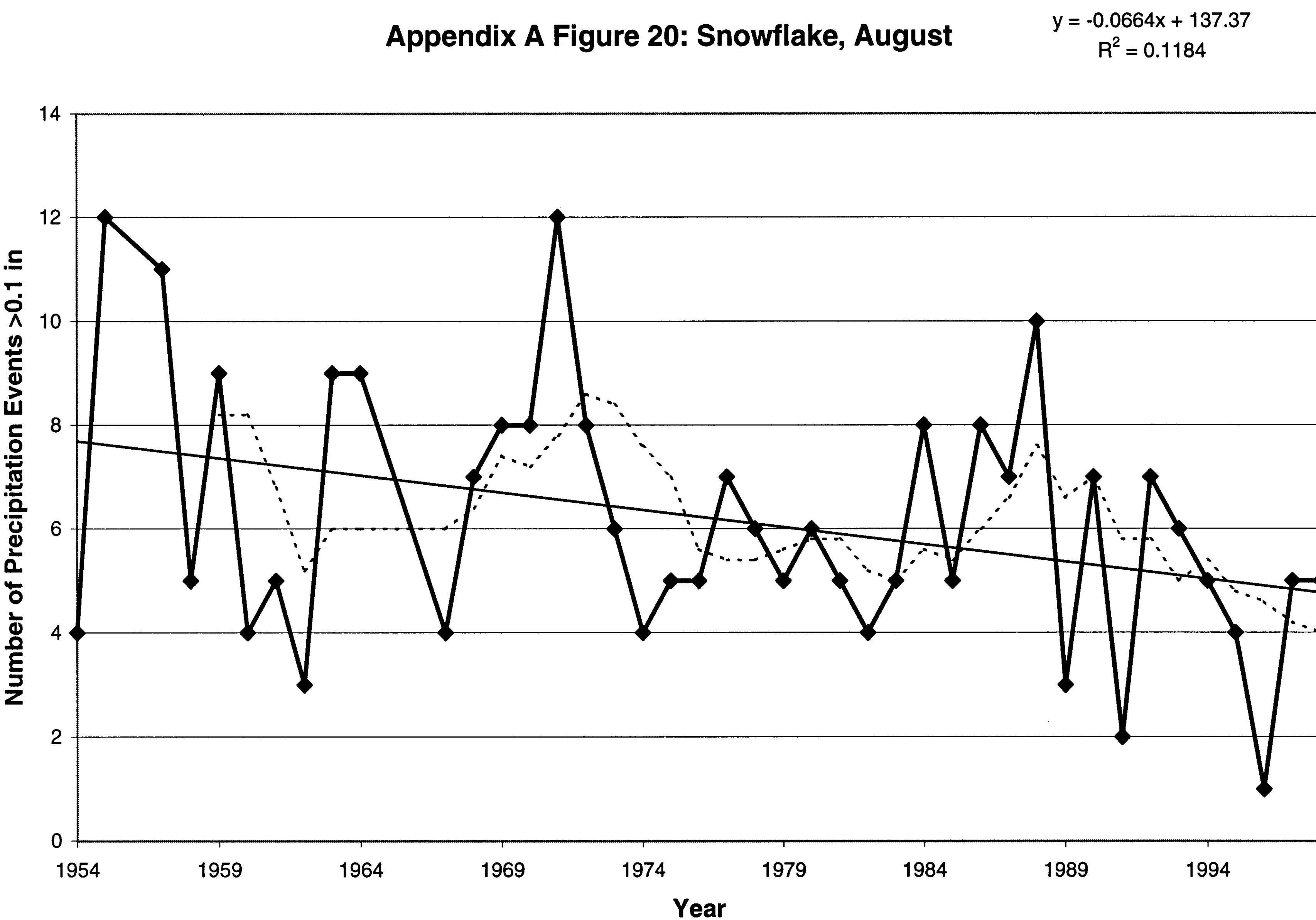


Appendix A Figure 18: Snowflake, June

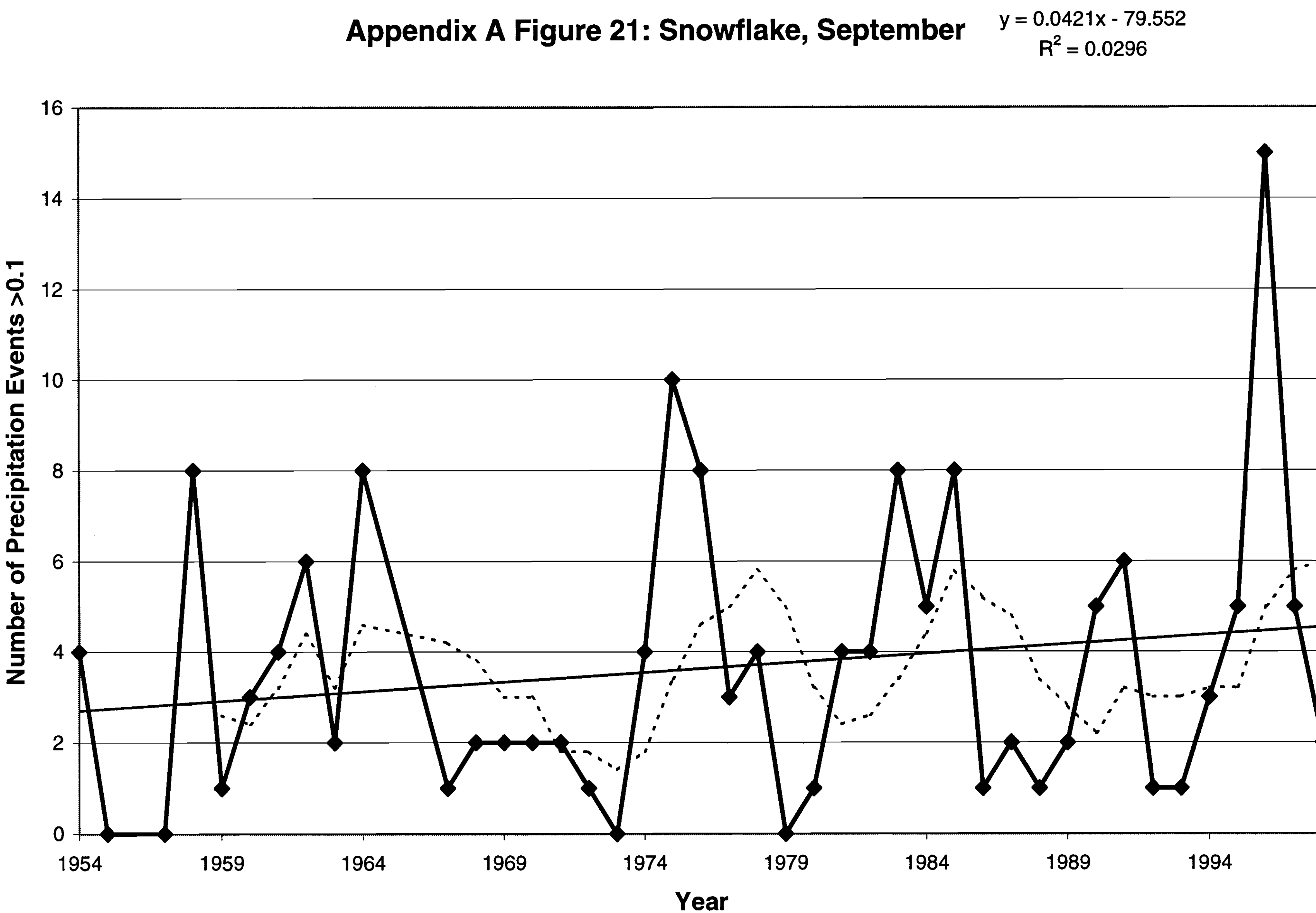



Appendix A Figure 19: Snowflake, July
y = -0.0201x + 44.711
R2 = 0.0081
Number of Precipitation Events >0.1 in
14
12
10
8
6
4
2
0
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

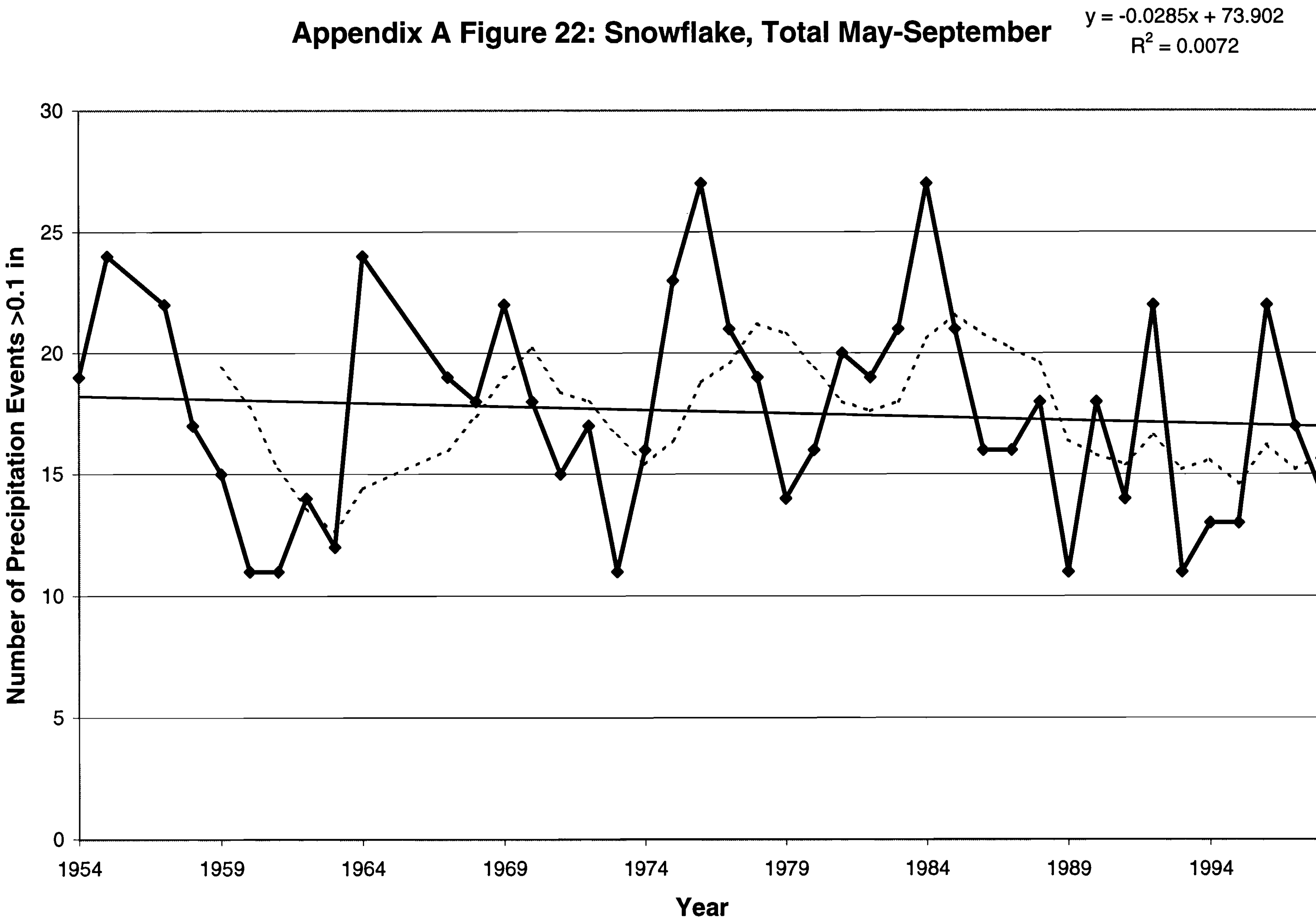
Appendix A Figure 20: Snowflake, August



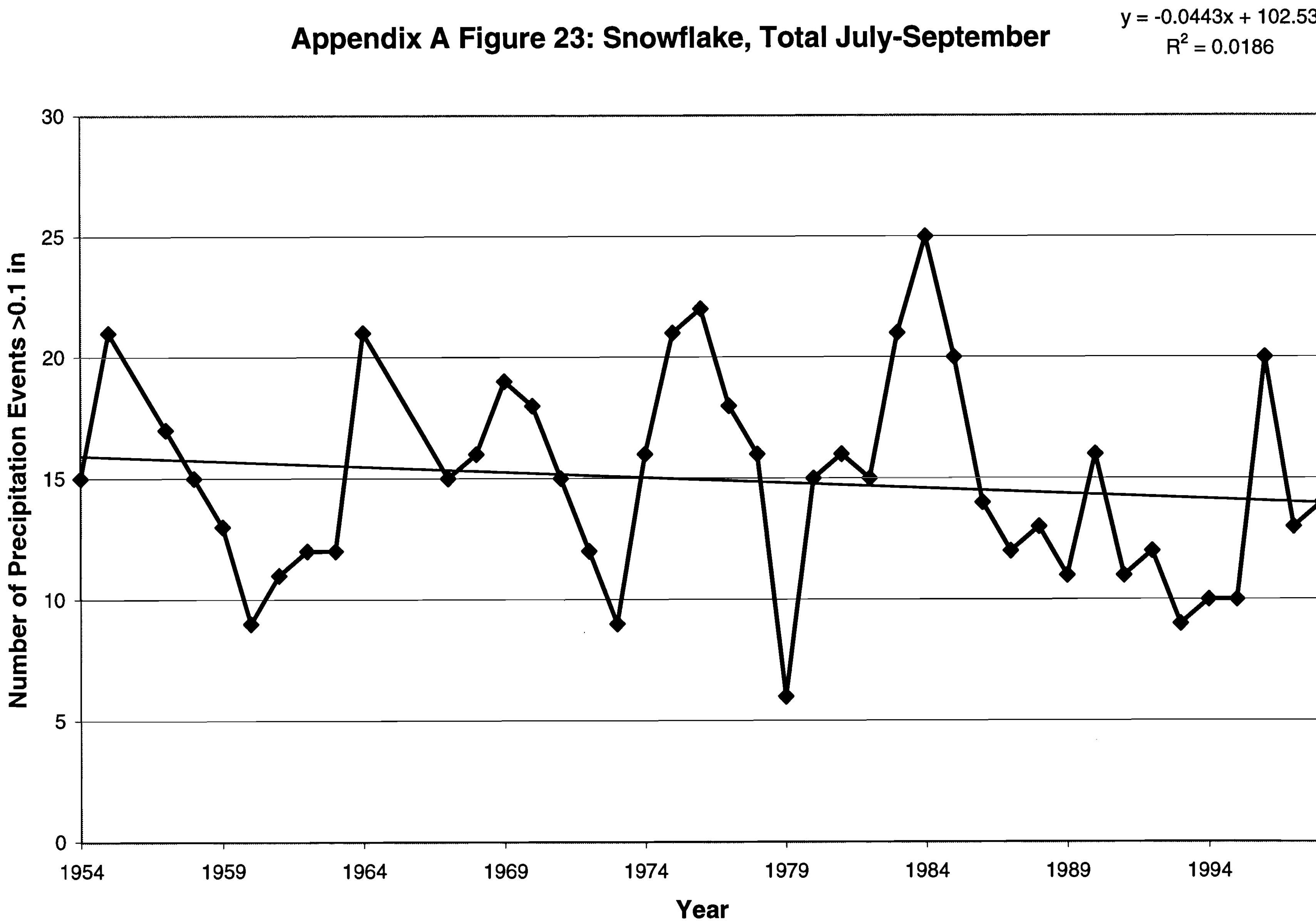
Appendix A Figure 21: Snowflake, September

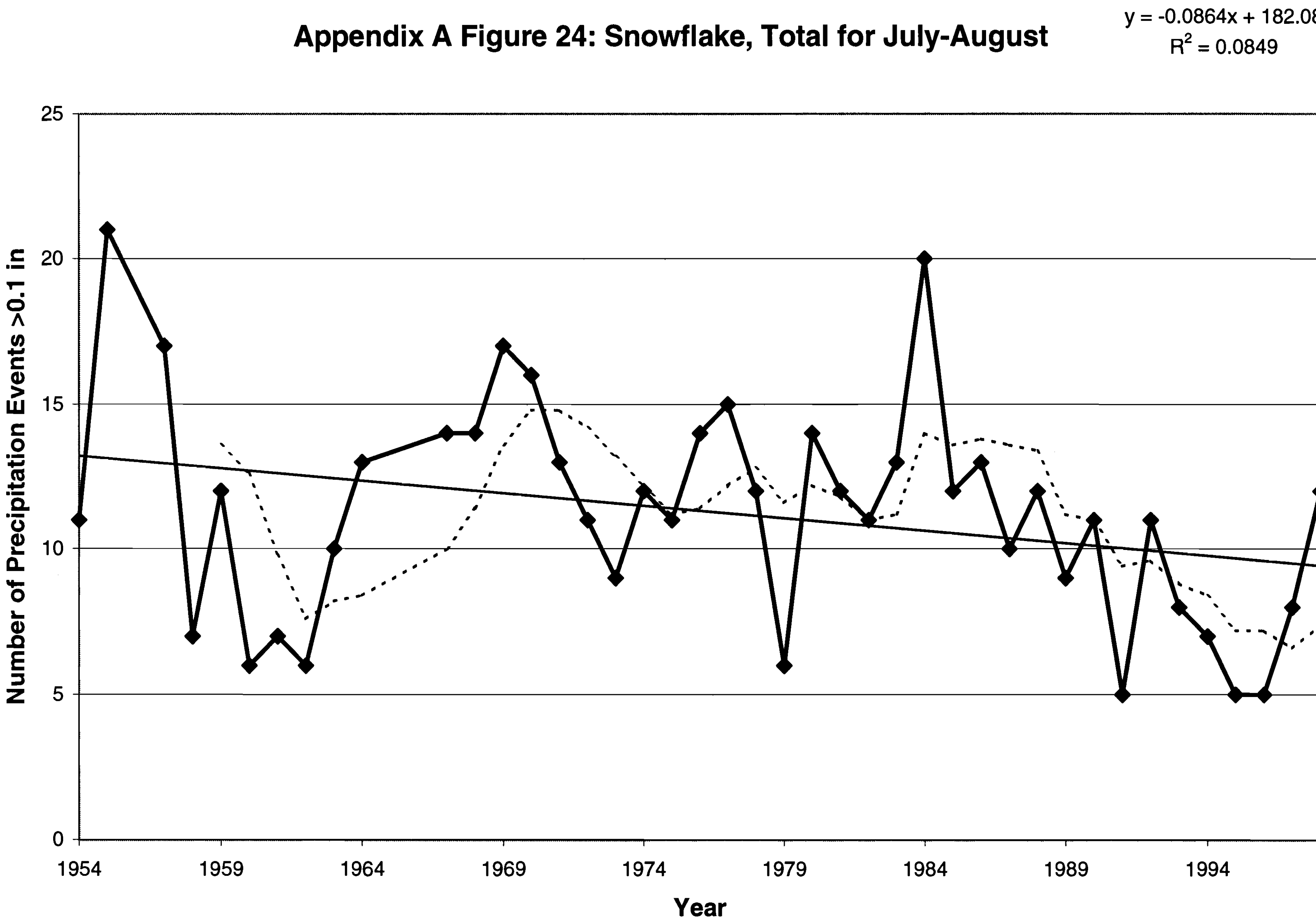


Appendix A Figure 22: Snowflake, Total May-September



Appendix A Figure 23: Snowflake, Total July-September

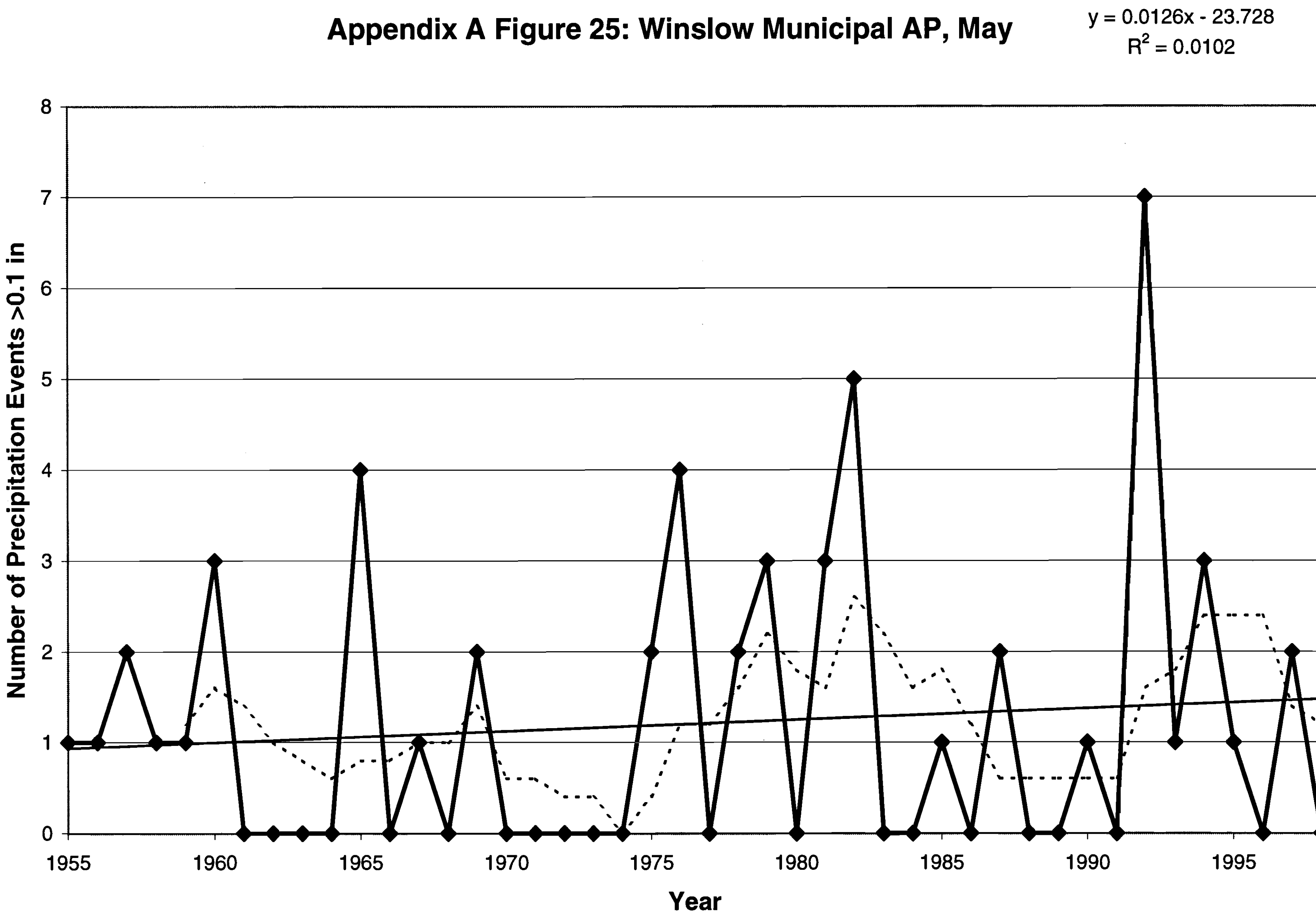



Appendix A Figure 24: Snowflake, Total for July-August
y = -0.0864x + 182.08
R2 = 0.0849
Number of Precipitation Events >0.1 in
25
20
15
10
5
0
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

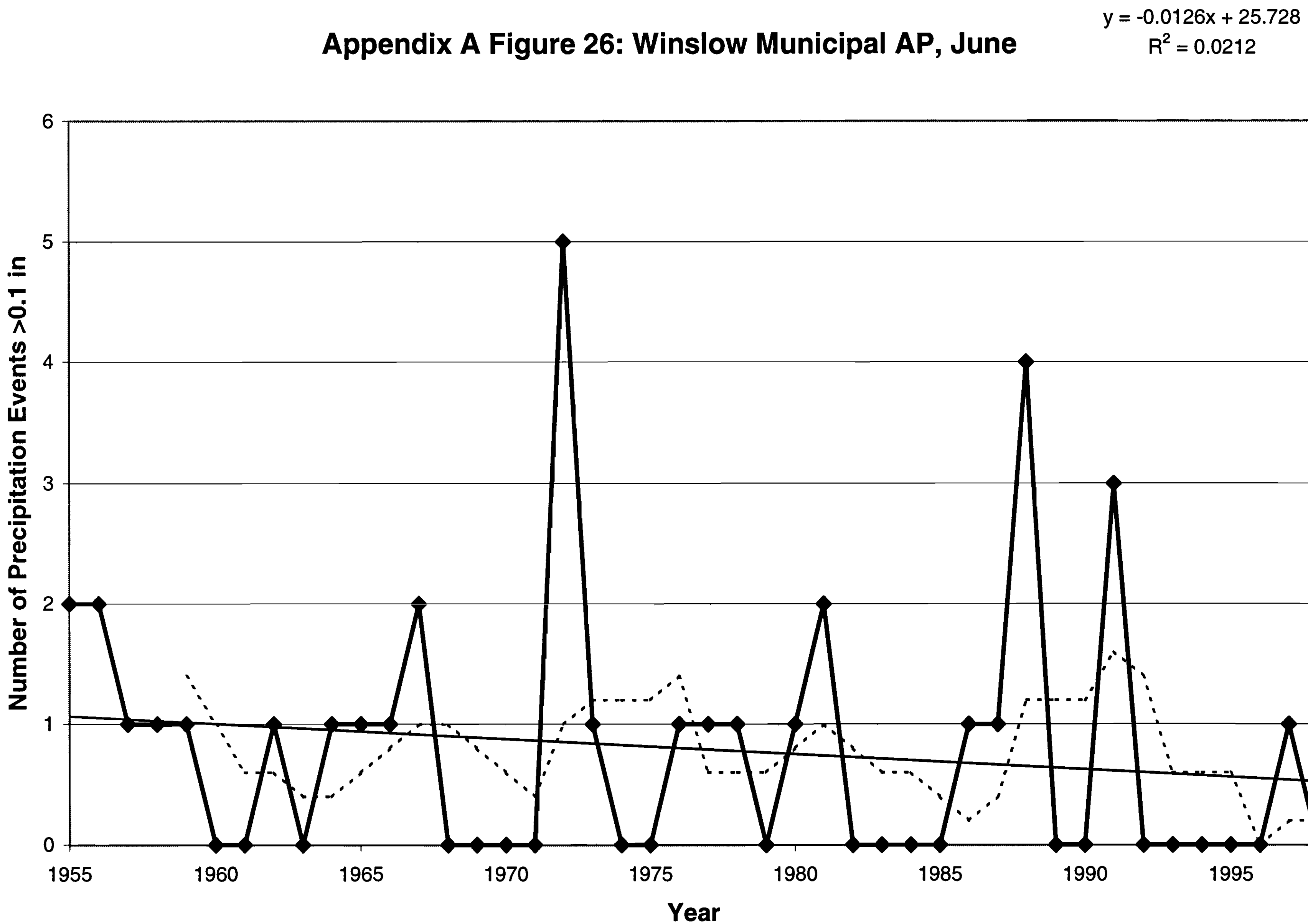
Appendix A Table 4: Number of Precipitation Events >0.1 in, Winslow Municipal AP, Arizona, 1955-1998

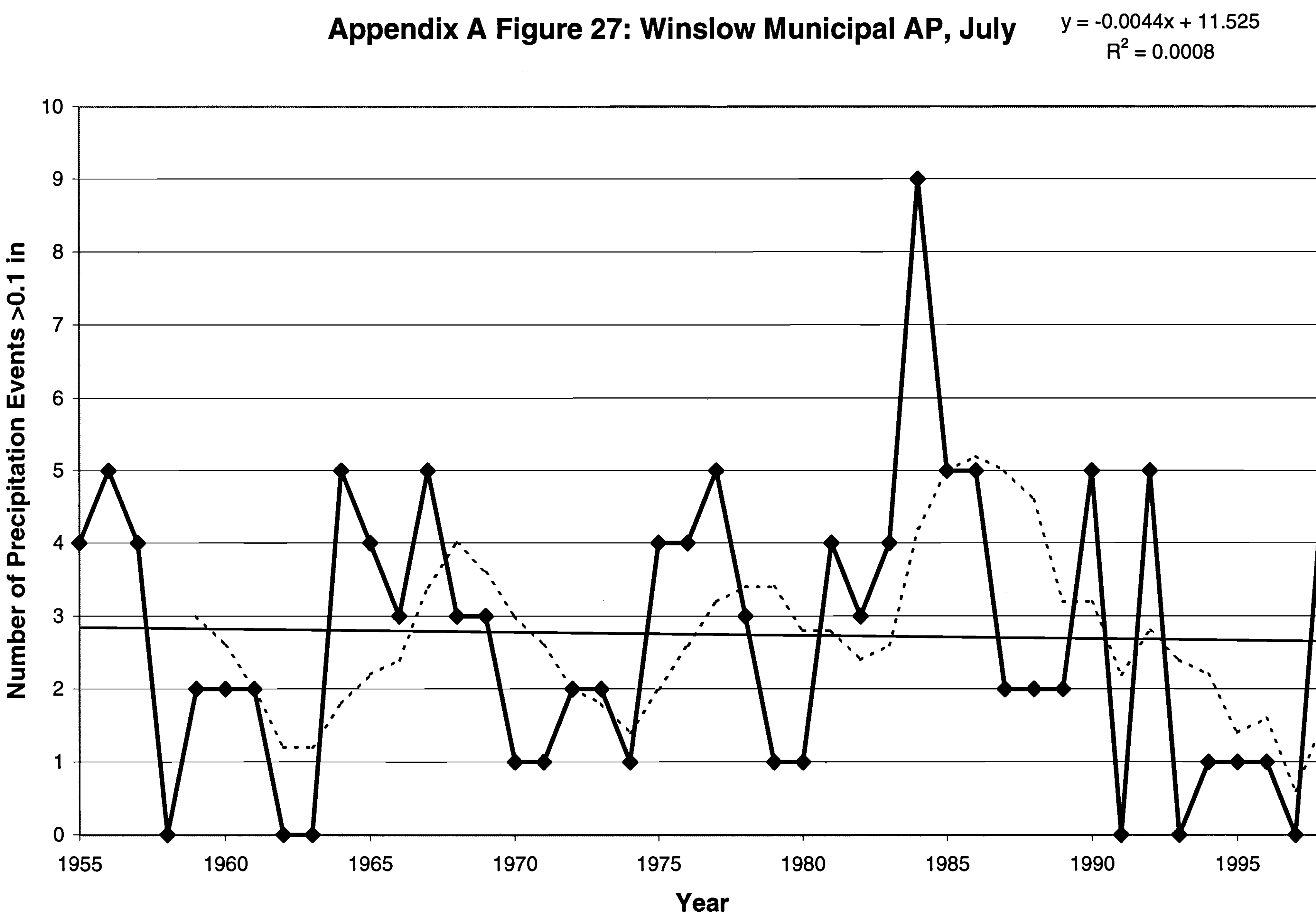
	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1955	1	2	4	5	0	12	9	9
1956	1	2	5	3	0	11	8	8
1957	2	1	4	3	0	10	7	7
1958	1	1	0	3	6	11	9	3
1959	1	1	2	6	1	11	9	8
1960	3	0	2	3	2	10	7	5
1961	0	0	2	7	4	13	13	9
1962	0	1	0	4	2	7	6	4
1963	0	0	0	10	5	15	15	10
1964	0	1	5	3	4	13	12	8
1965	4	1	4	3	4	16	11	7
1966	0	1	3	4	3	11	10	7
1967	1	2	5	3	3	14	11	8
1968	0	0	3	0	1	4	4	3
1969	2	0	3	5	1	11	9	8
1970	0	0	1	4	2	7	7	5
1971	0	0	1	5	2	8	8	6
1972	0	5	2	3	1	11	6	5
1973	0	1	2	6	0	9	8	8
1974	0	0	1	2	3	6	6	3
1975	2	0	4	2	5	13	11	6
1976	4	1	4	2	5	16	11	6
1977	0	1	5	5	3	14	13	10
1978	2	1	3	1	2	9	6	4
1979	3	0	1	1	0	5	2	2
1980	0	1	1	2	2	6	5	3
1981	3	2	4	5	2	16	11	9
1982	5	0	3	6	2	16	11	9
1983	0	0	4	4	6	14	14	8
1984	0	0	9	5	6	20	20	14
1985	1	0	5	3	2	11	10	8
1986	0	1	5	1	2	9	8	6
1987	2	1	2	7	0	12	9	9
1988	0	4	2	5	0	11	7	7
1989	0	0	2	3	0	5	5	5
1990	1	0	5	2	3	11	10	7
1991	0	3	0	1	2	6	3	1
1992	7	0	5	5	1	18	11	10
1993	1	0	0	6	0	7	6	6
1994	3	0	1	2	3	9	6	3
1995	1	0	1	5	4	11	10	6
1996	0	0	1	0	8	9	9	1
1997	2	1	0	3	3	9	6	3
1998	0	0	5	0	1	6	6	5
Ave.	**1.20**	**0.80**	**2.75**	**3.59**	**2.41**	**10.75**	**8.75**	**6.34**
S.D.	**1.61**	**1.11**	**1.99**	**2.11**	**1.98**	**3.70**	**3.36**	**2.74**
Max	**7**	**5**	**9**	**10**	**8**	**20**	**20**	**14**
Min	**0**	**0**	**0**	**0**	**0**	**4**	**2**	**1**

Appendix A Figure 25: Winslow Municipal AP, May



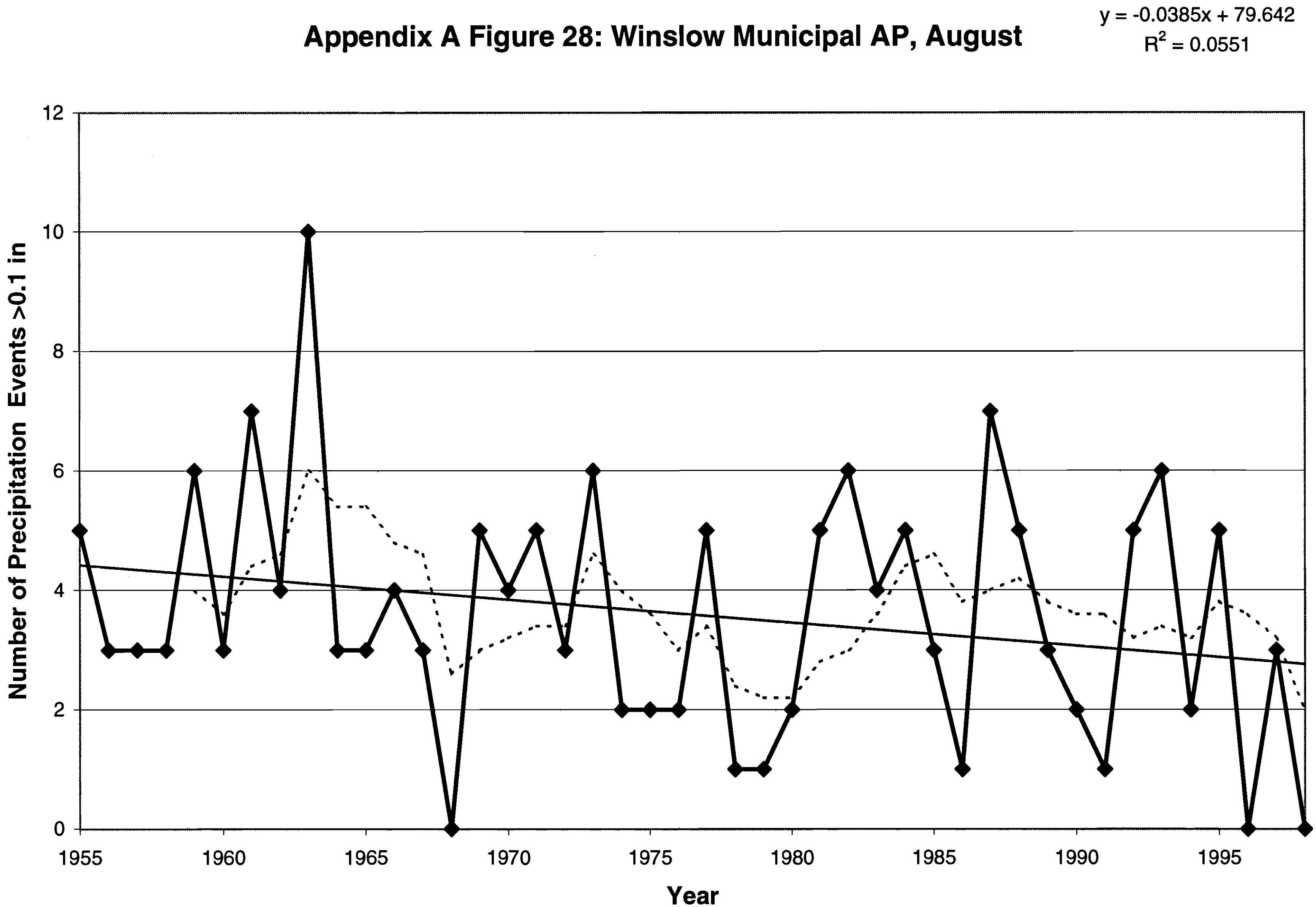
Appendix A Figure 26: Winslow Municipal AP, June



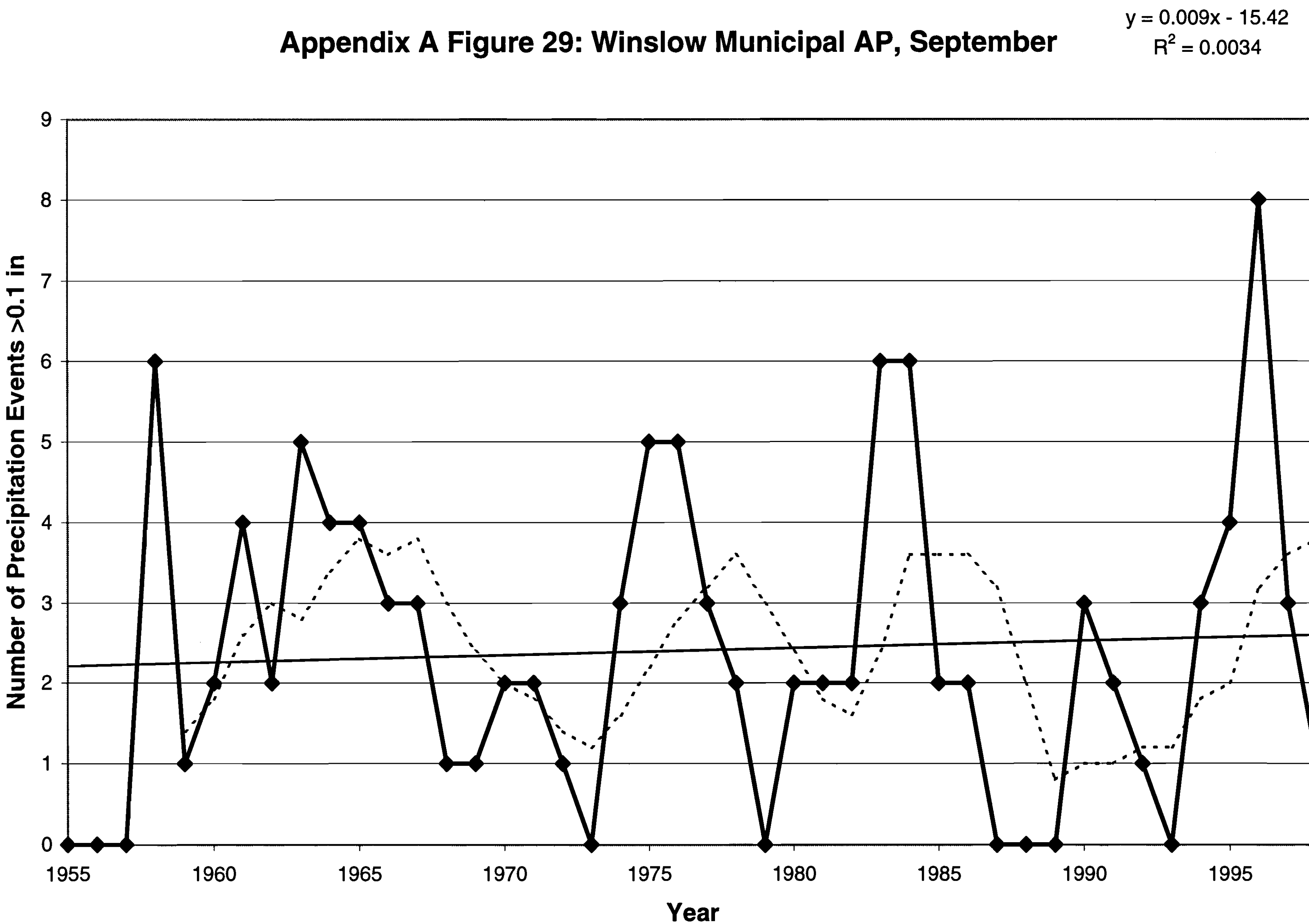


Appendix A Figure 27: Winslow Municipal AP, July
y = -0.0044x + 11.525
R2 = 0.0008
Number of Precipitation Events >0.1 in
Year
0
1
2
3
4
5
6
7
8
9
10
1955
1960
1965
1970
1975
1980
1985
1990
1995

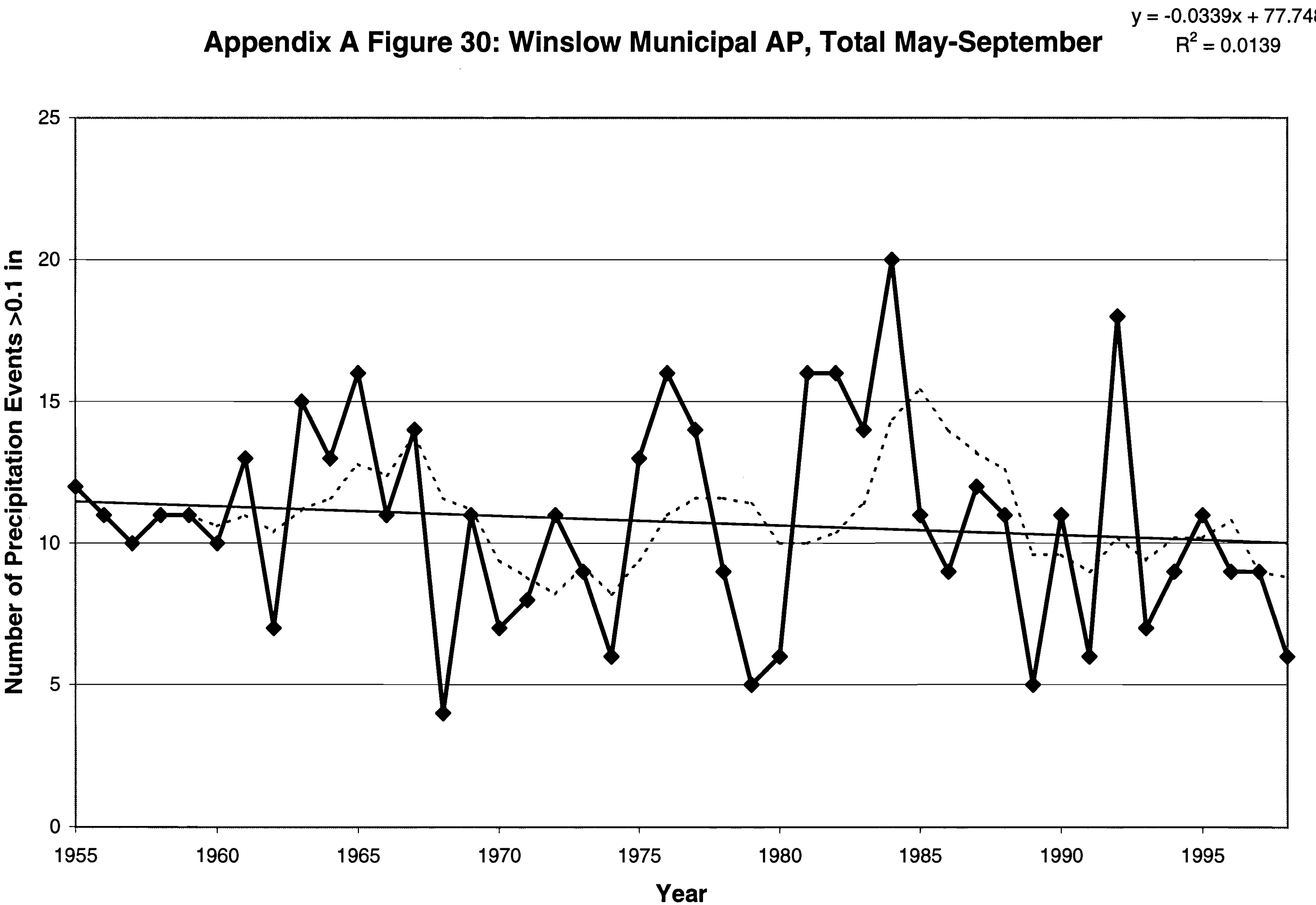
Appendix A Figure 28: Winslow Municipal AP, August



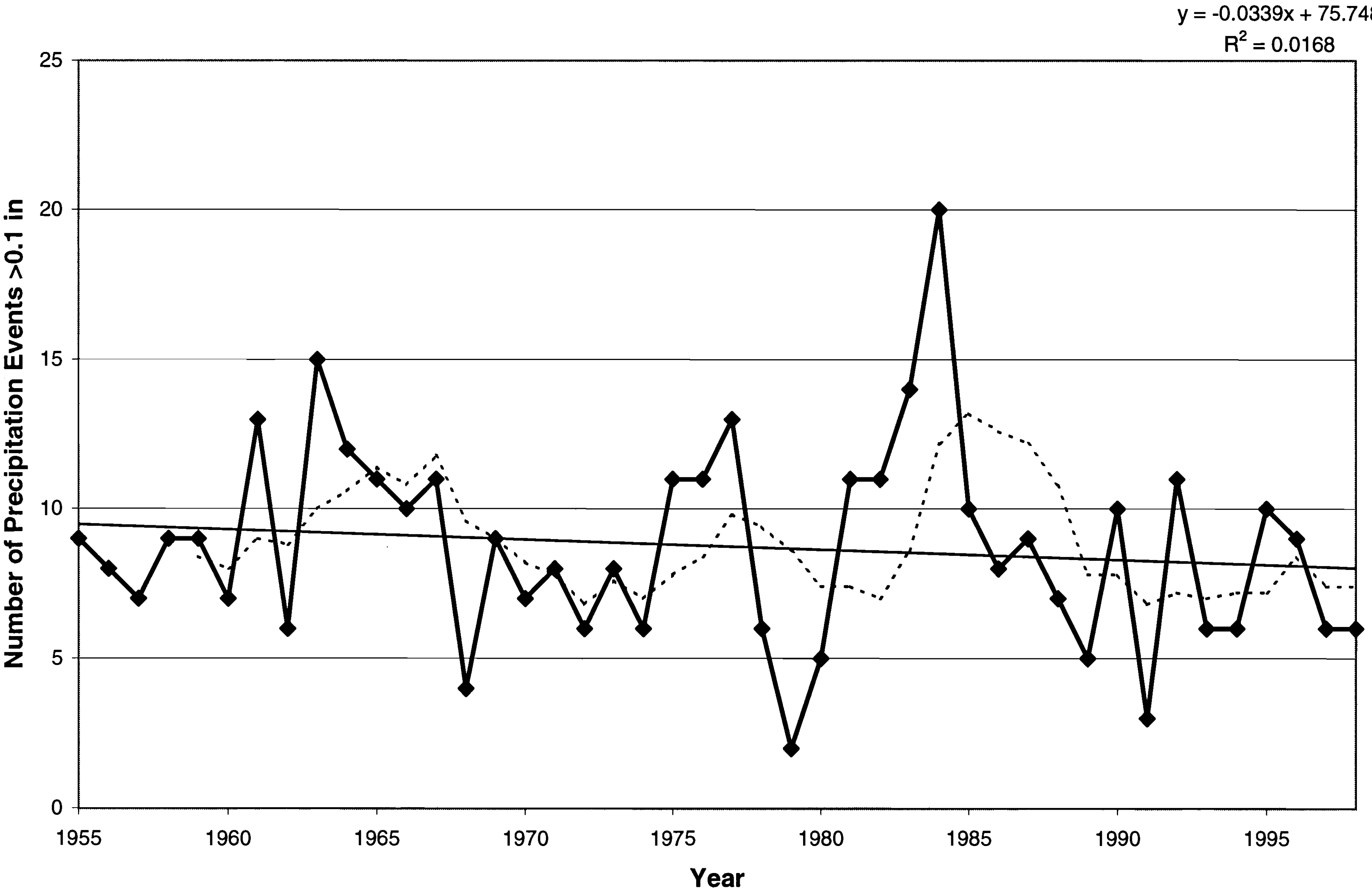
Appendix A Figure 29: Winslow Municipal AP, September

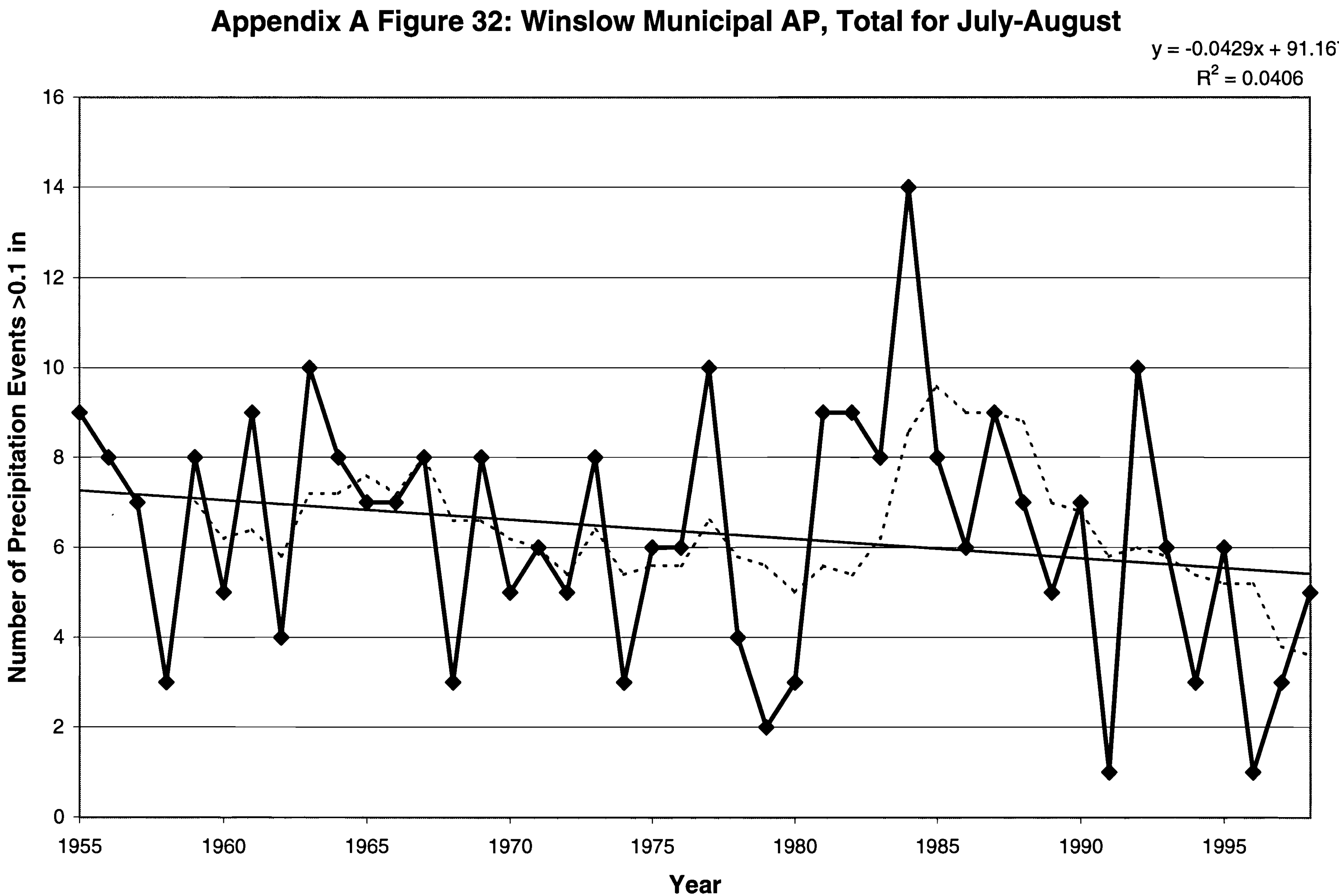


Appendix A Figure 30: Winslow Municipal AP, Total May-September



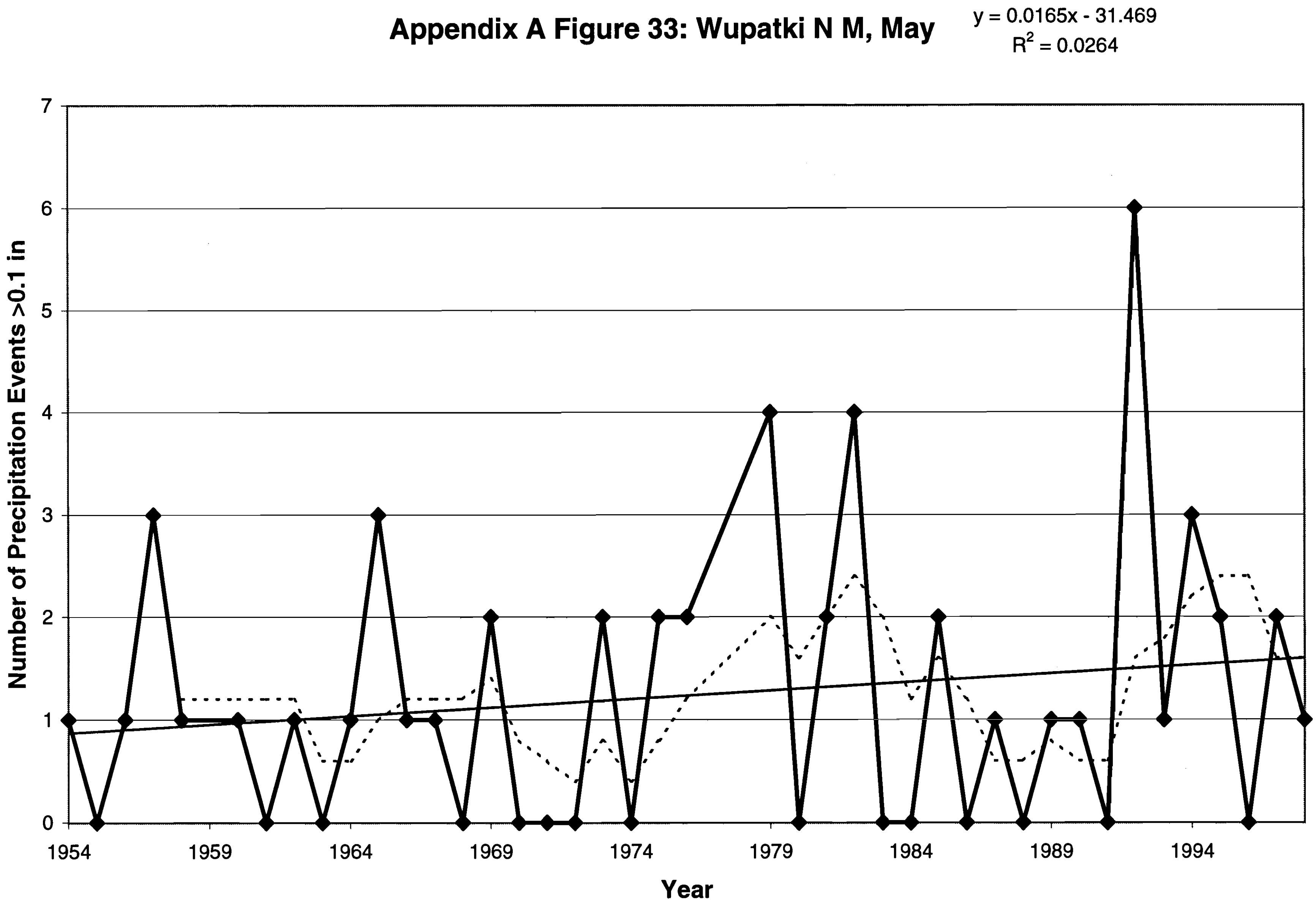
Appendix A Figure 31: Winslow Municipal AP, Total for July-September



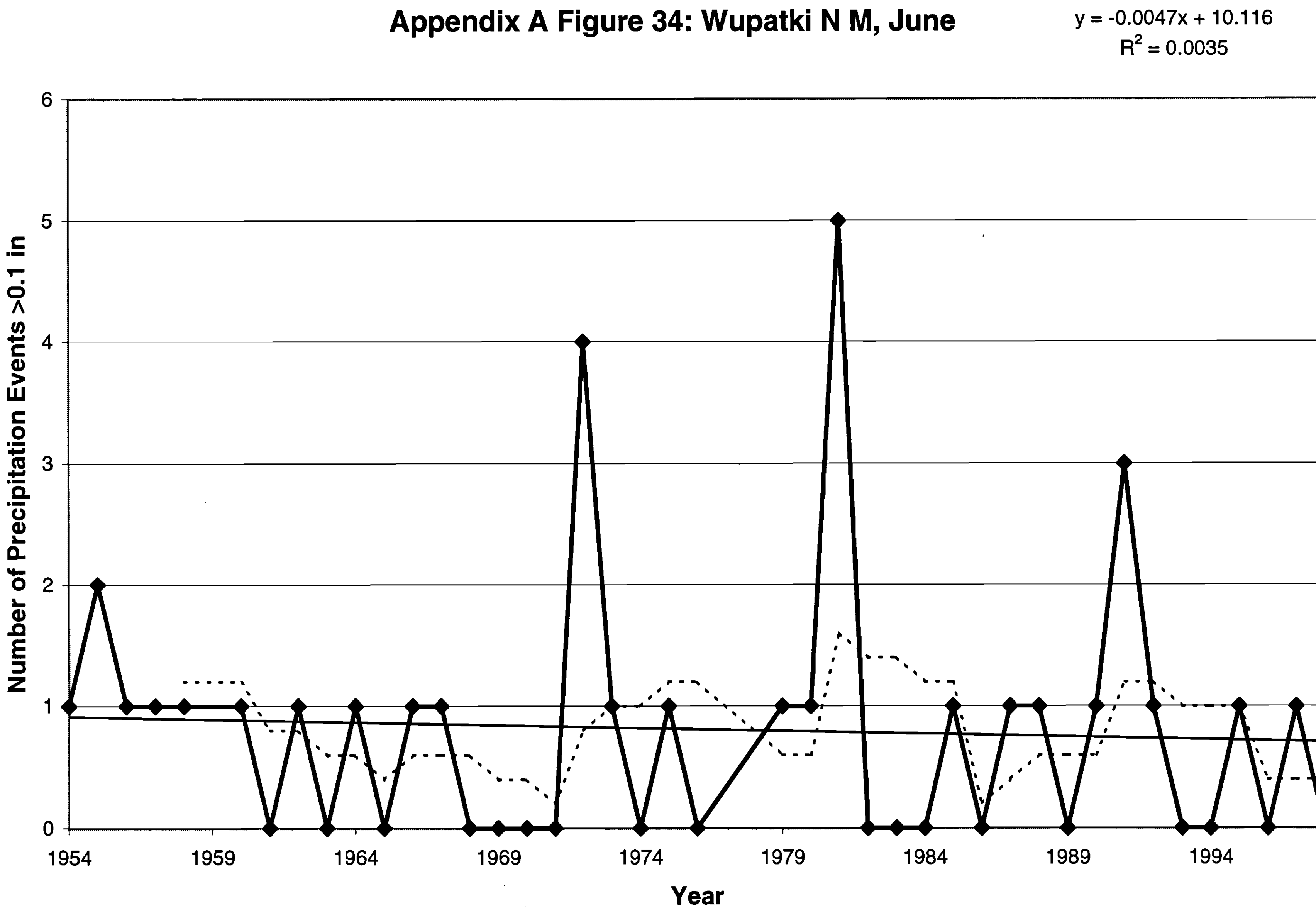

Appendix A Figure 32: Winslow Municipal AP, Total for July-August
y = -0.0429x + 91.167
R^2 = 0.0406
Number of Precipitation Events >0.1 in
Year
16
14
12
10
8
6
4
2
0
1955
1960
1965
1970
1975
1980
1985
1990
1995

Appendix A Table 5: Number of Precipitation Events >0.1 in, Wupatki N M, Arizona, 1954-1998

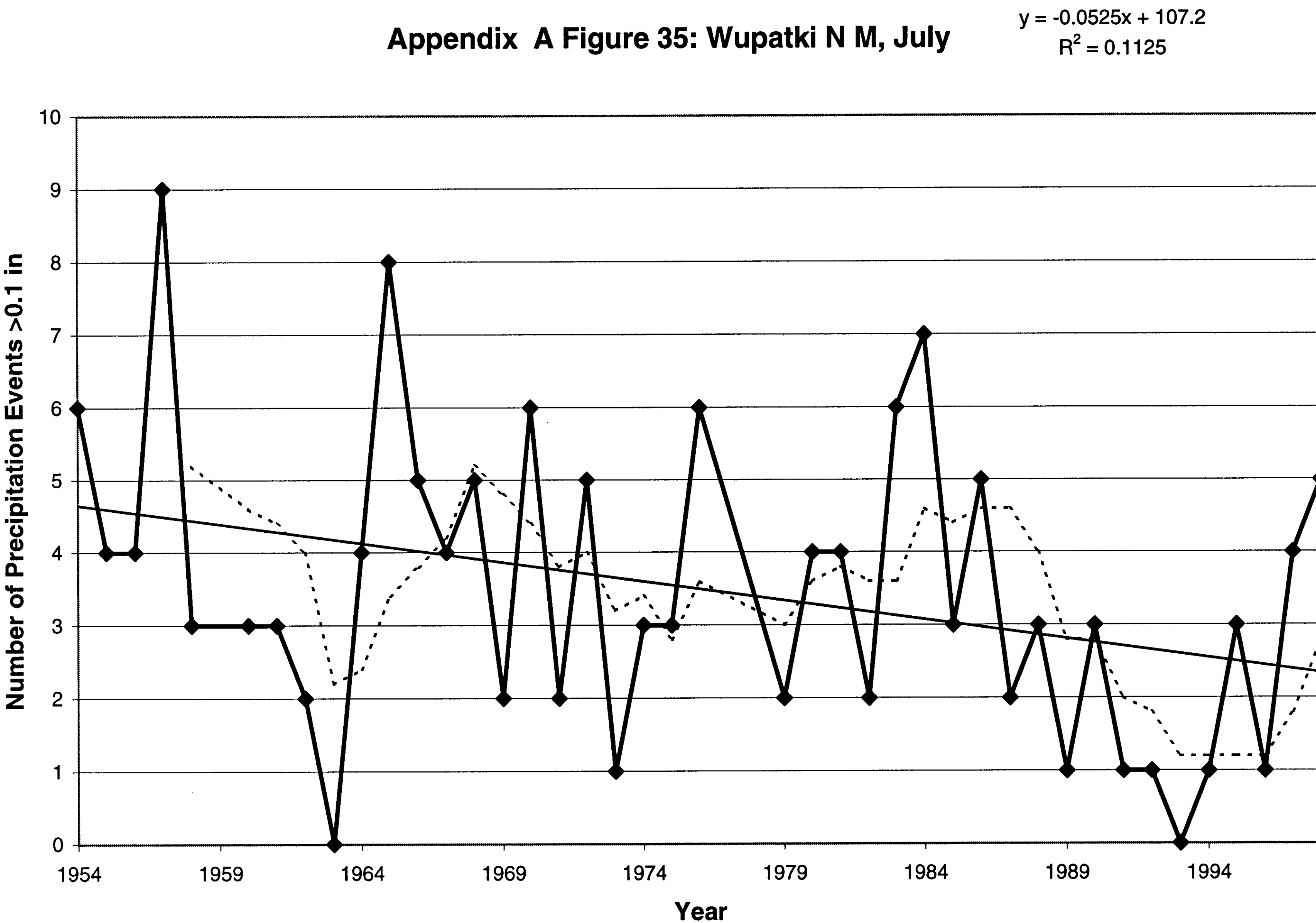
	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1954	1	1	6	5	5	18	16	11
1955	0	2	4	6	0	12	10	10
1956	1	1	4	3	1	10	8	7
1957	3	1	9	8	0	21	17	17
1958	1	1	3	4	7	16	14	7
1960	1	1	3	3	2	10	8	6
1961	0	0	3	7	1	11	11	10
1962	1	1	2	3	3	10	8	5
1963	0	0	0	7	1	8	8	7
1964	1	1	4	5	3	14	12	9
1965	3	0	8	2	3	16	13	10
1966	1	1	5	7	2	16	14	12
1967	1	1	4	5	4	15	13	9
1968	0	0	5	3	0	8	8	8
1969	2	0	2	5	5	14	12	7
1970	0	0	6	4	2	12	12	10
1971	0	0	2	7	3	12	12	9
1972	0	4	5	4	1	14	10	9
1973	2	1	1	3	0	7	4	4
1974	0	0	3	1	3	7	7	4
1975	2	1	3	4	4	14	11	7
1976	2	0	6	1	6	15	13	7
1979	4	1	2	5	0	12	7	7
1980	0	1	4	2	2	9	8	6
1981	2	5	4	6	4	21	14	10
1982	4	0	2	7	1	14	10	9
1983	0	0	6	3	6	15	15	9
1984	0	0	7	7	4	18	18	14
1985	2	1	3	3	3	12	9	6
1986	0	0	5	8	1	14	14	13
1987	1	1	2	5	0	9	7	7
1988	0	1	3	8	1	13	12	11
1989	1	0	1	4	0	6	5	5
1990	1	1	3	1	6	12	10	4
1991	0	3	1	5	3	12	9	6
1992	6	1	1	4	1	13	6	5
1993	1	0	0	3	0	4	3	3
1994	3	0	1	7	3	14	11	8
1995	2	1	3	2	4	12	9	5
1996	0	0	1	2	5	8	8	3
1997	2	1	4	7	4	18	15	11
1998	1	0	5	2	7	15	14	7
Ave.	**1.24**	**0.81**	**3.48**	**4.48**	**2.64**	**12.64**	**10.60**	**7.95**
S.D.	**1.36**	**1.06**	**2.09**	**2.10**	**2.09**	**3.81**	**3.49**	**3.00**
Max	**6**	**5**	**9**	**8**	**7**	**21**	**18**	**17**
Min	**0**	**0**	**0**	**1**	**0**	**4**	**3**	**3**

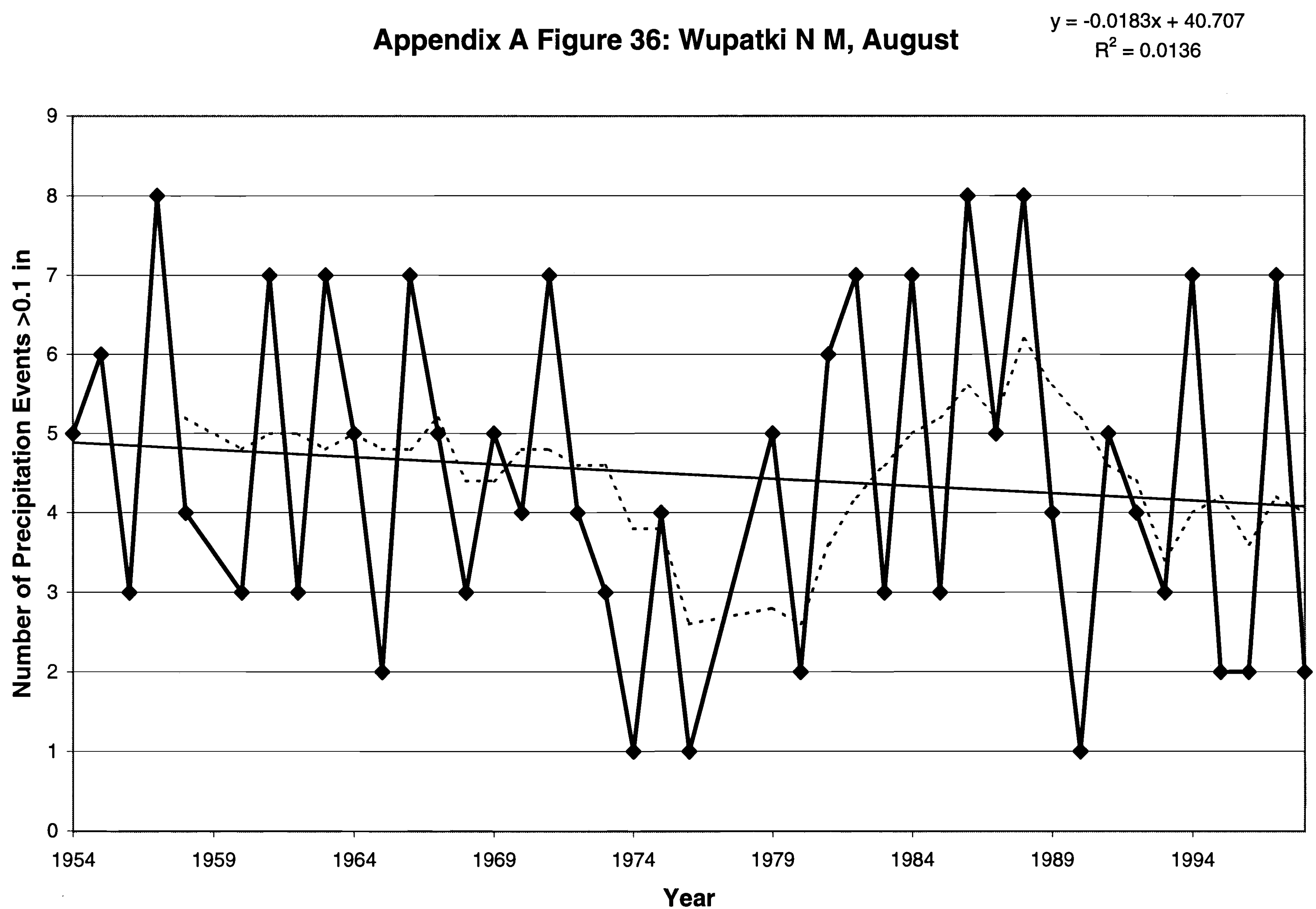

Appendix A Figure 33: Wupatki N M, May
y = 0.0165x - 31.469
R2 = 0.0264
Number of Precipitation Events >0.1 in
Year
0
1
2
3
4
5
6
7
1954
1959
1964
1969
1974
1979
1984
1989
1994

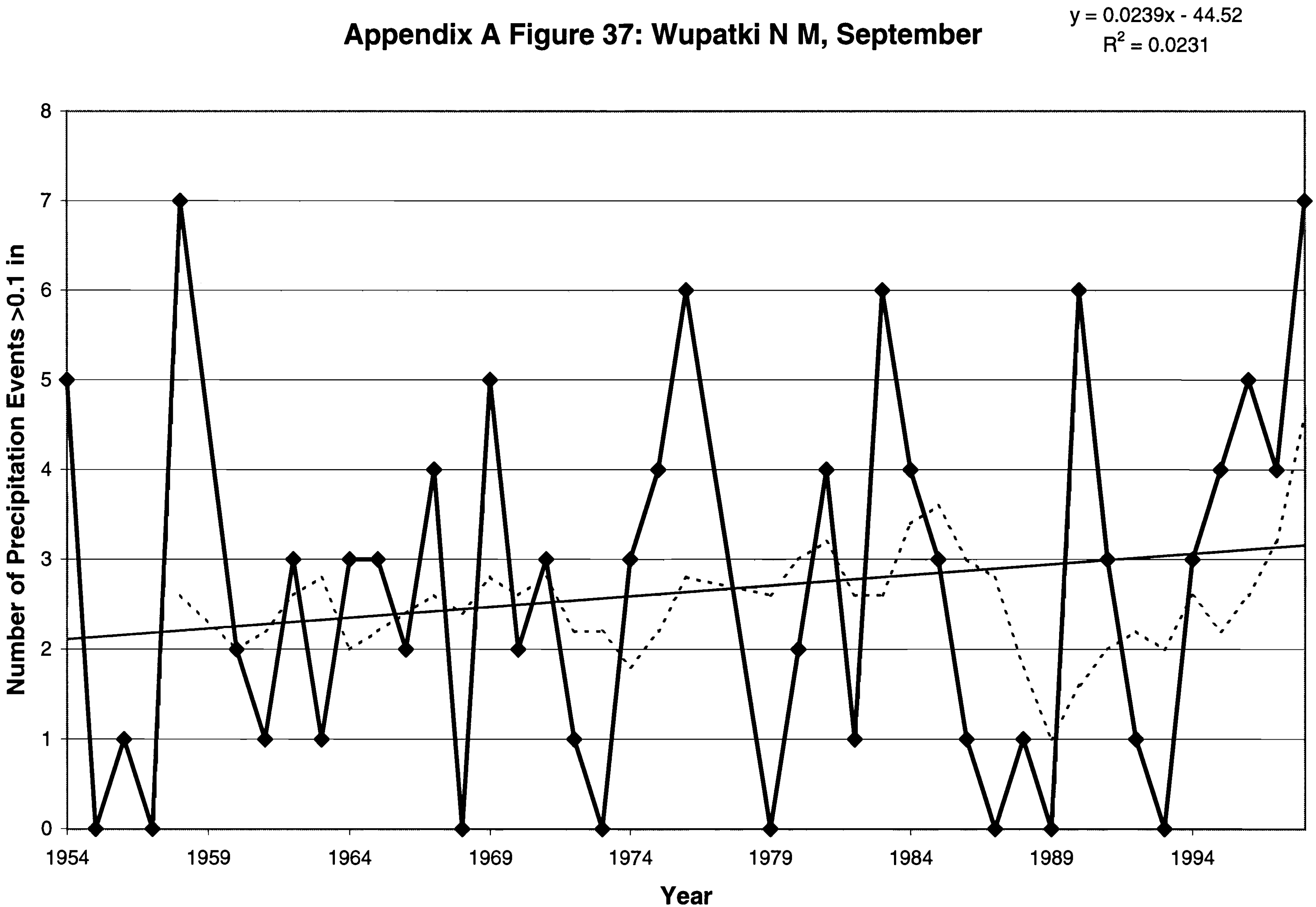
Appendix A Figure 34: Wupatki N M, June



Appendix A Figure 35: Wupatki N M, July

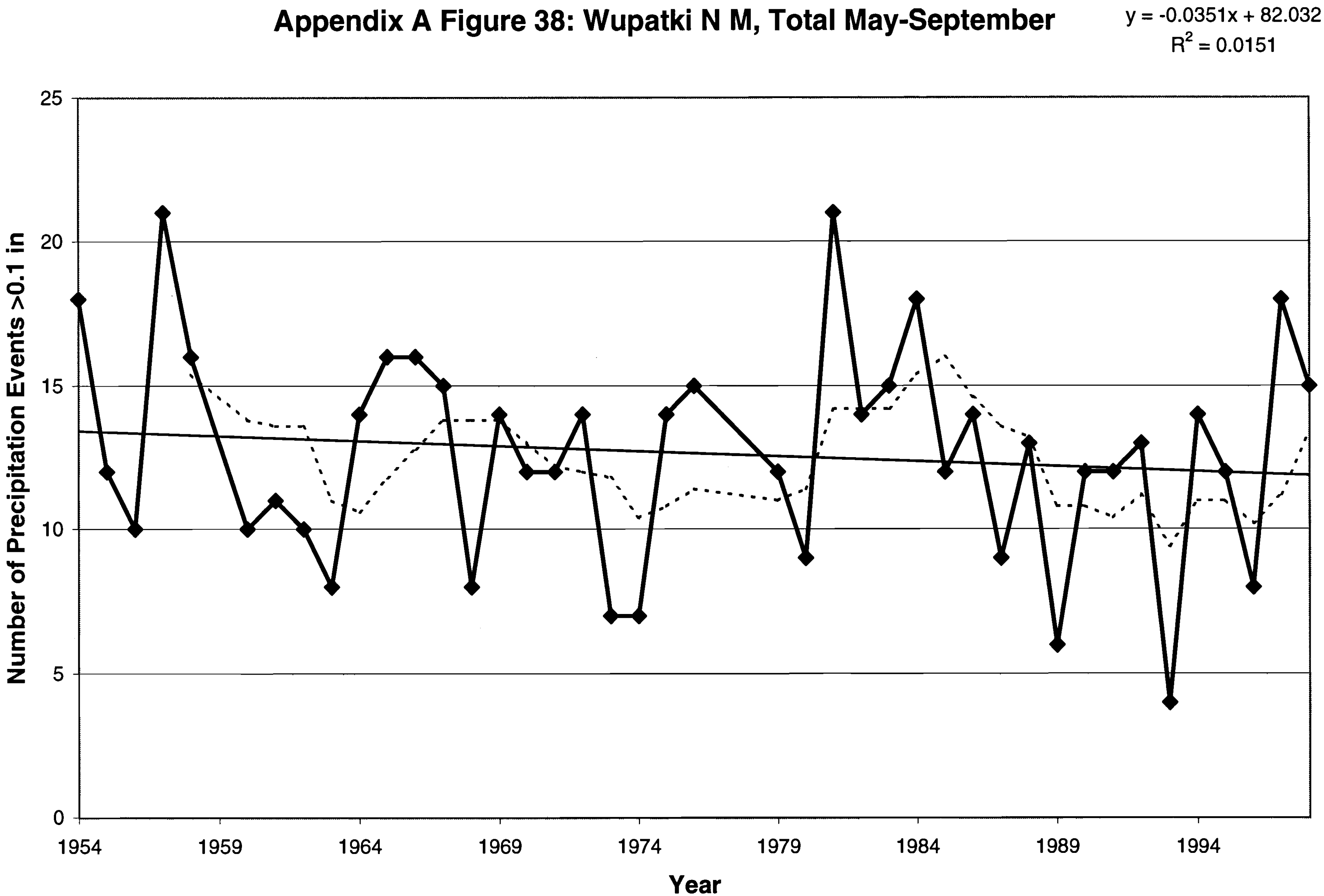


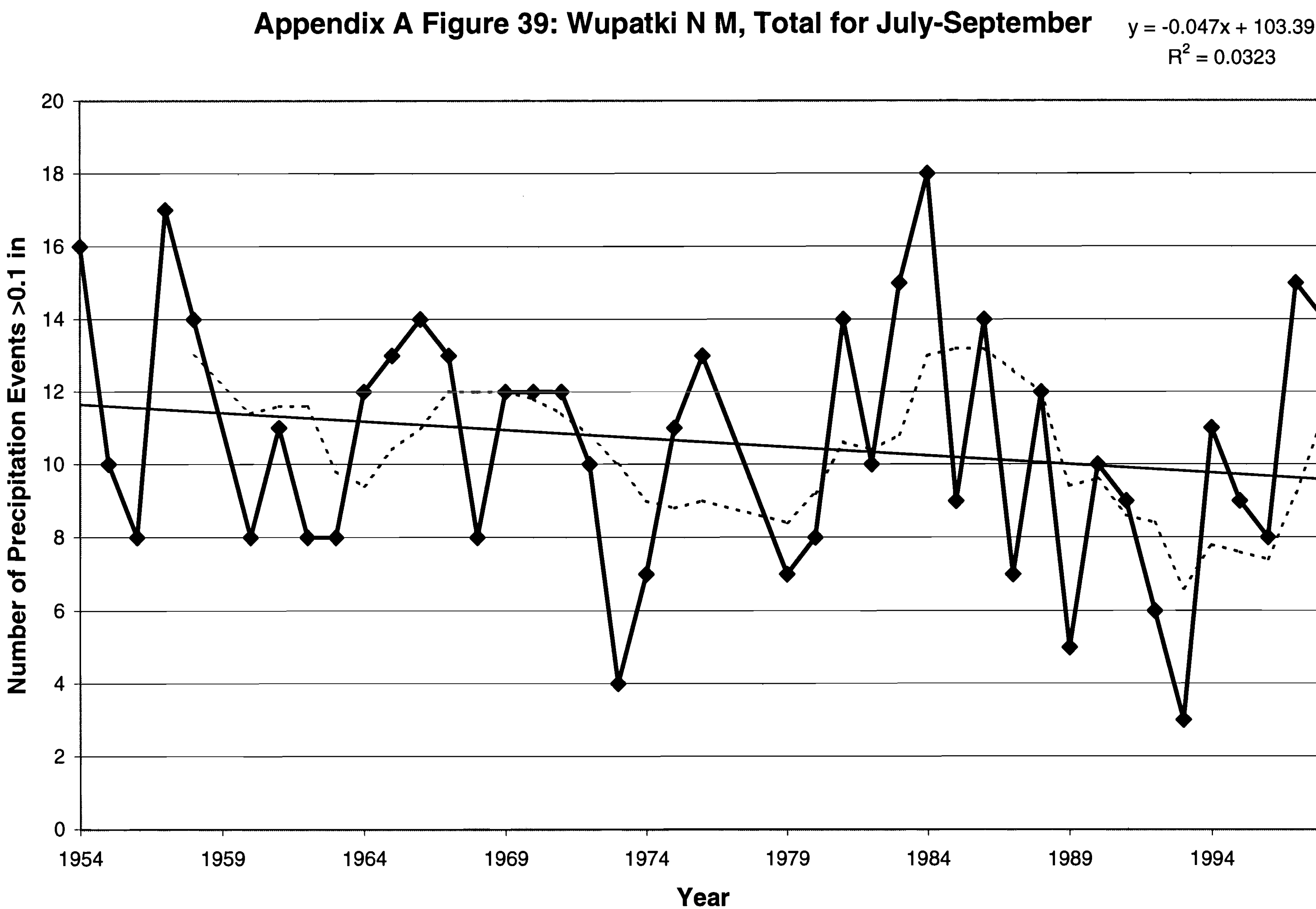

Appendix A Figure 36: Wupatki N M, August
y = -0.0183x + 40.707
R^2 = 0.0136
Number of Precipitation Events >0.1 in
Year
0
1
2
3
4
5
6
7
8
9
1954
1959
1964
1969
1974
1979
1984
1989
1994



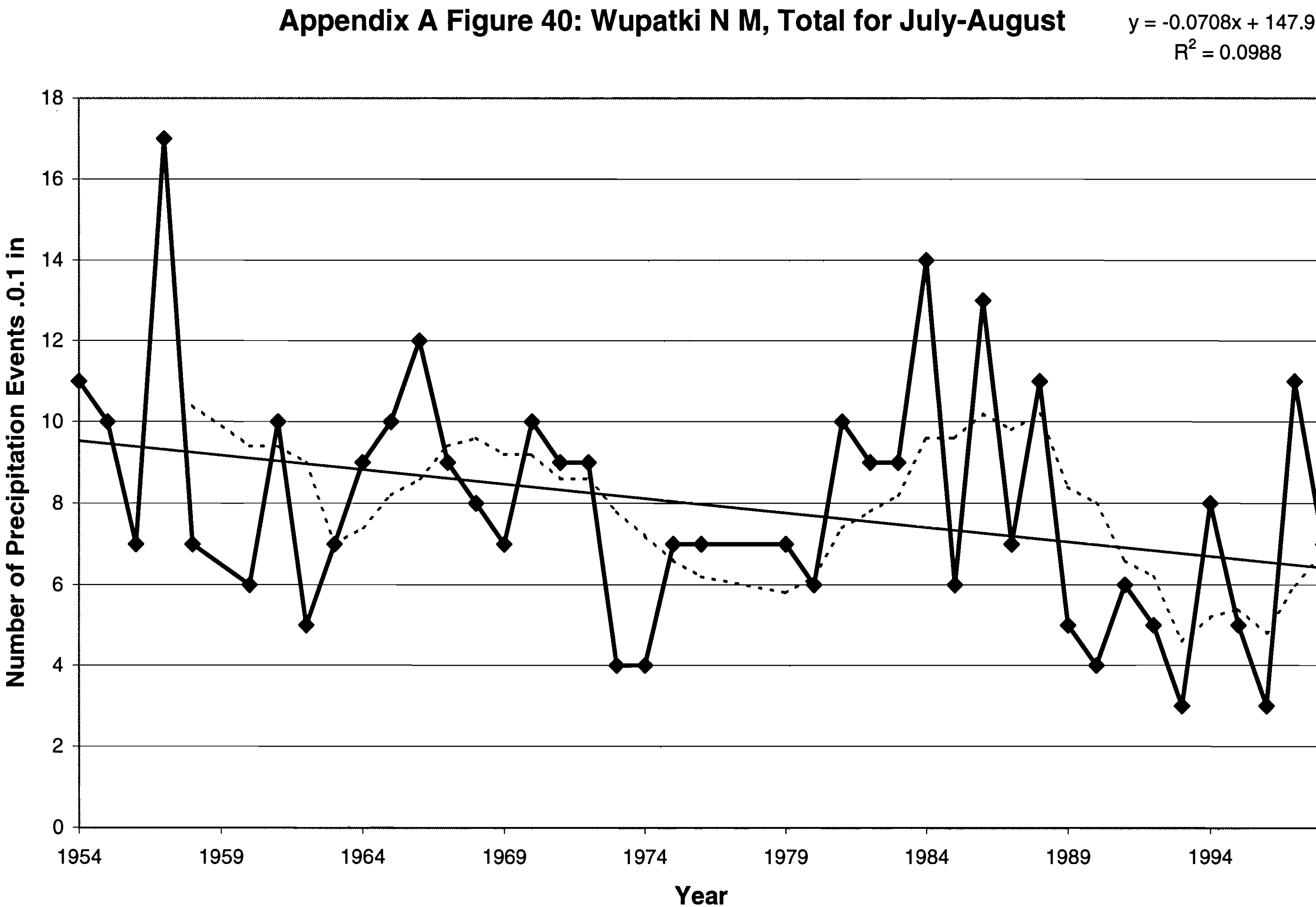
Appendix A Figure 37: Wupatki N M, September
y = 0.0239x - 44.52
R2 = 0.0231
Number of Precipitation Events >0.1 in
Year
0
1
2
3
4
5
6
7
8
1954
1959
1964
1969
1974
1979
1984
1989
1994

Appendix A Figure 38: Wupatki N M, Total May-September





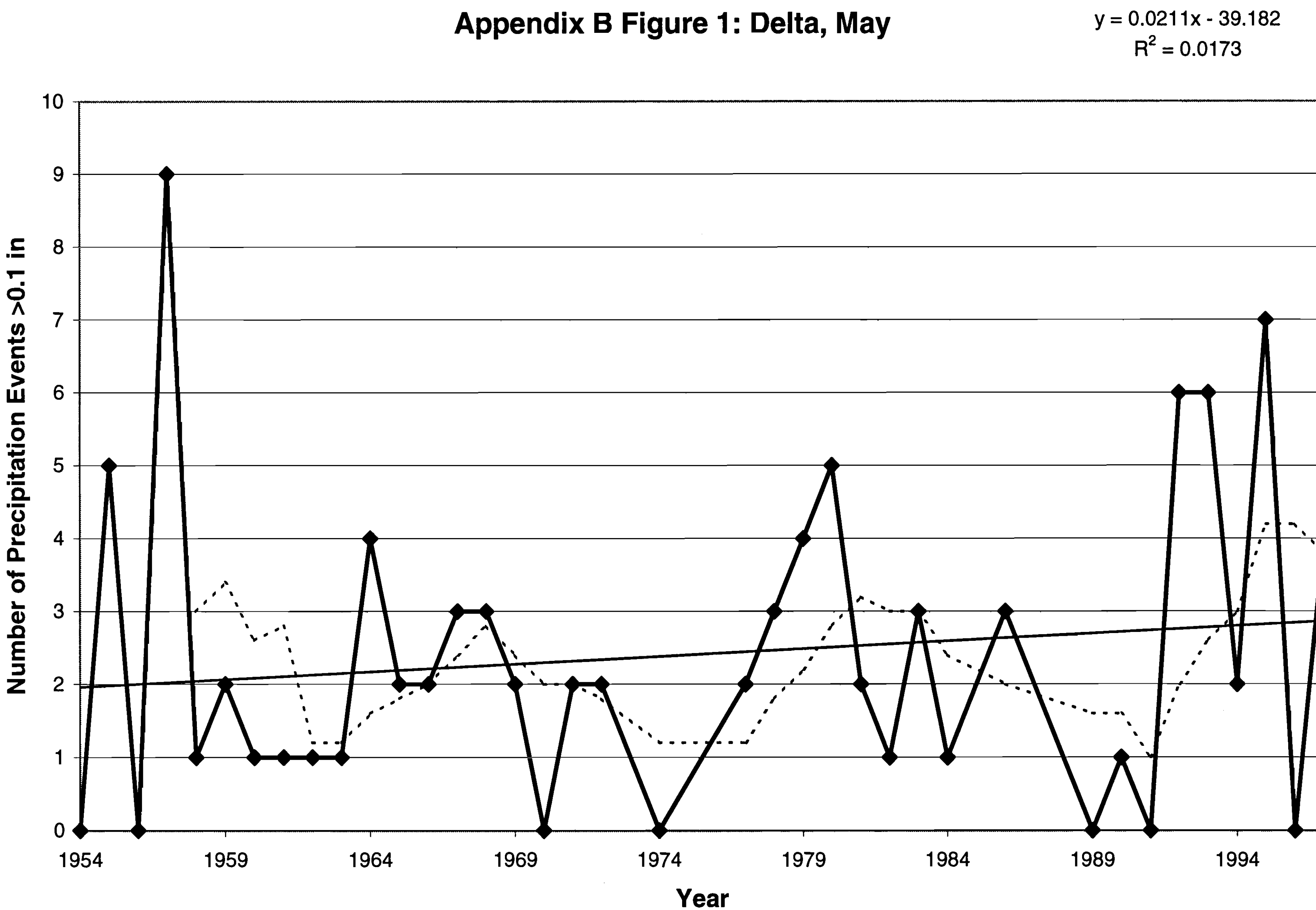
Appendix A Figure 39: Wupatki N M, Total for July-September
y = -0.047x + 103.39
R2 = 0.0323
Number of Precipitation Events >0.1 in
20
18
16
14
12
10
8
6
4
2
0
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year



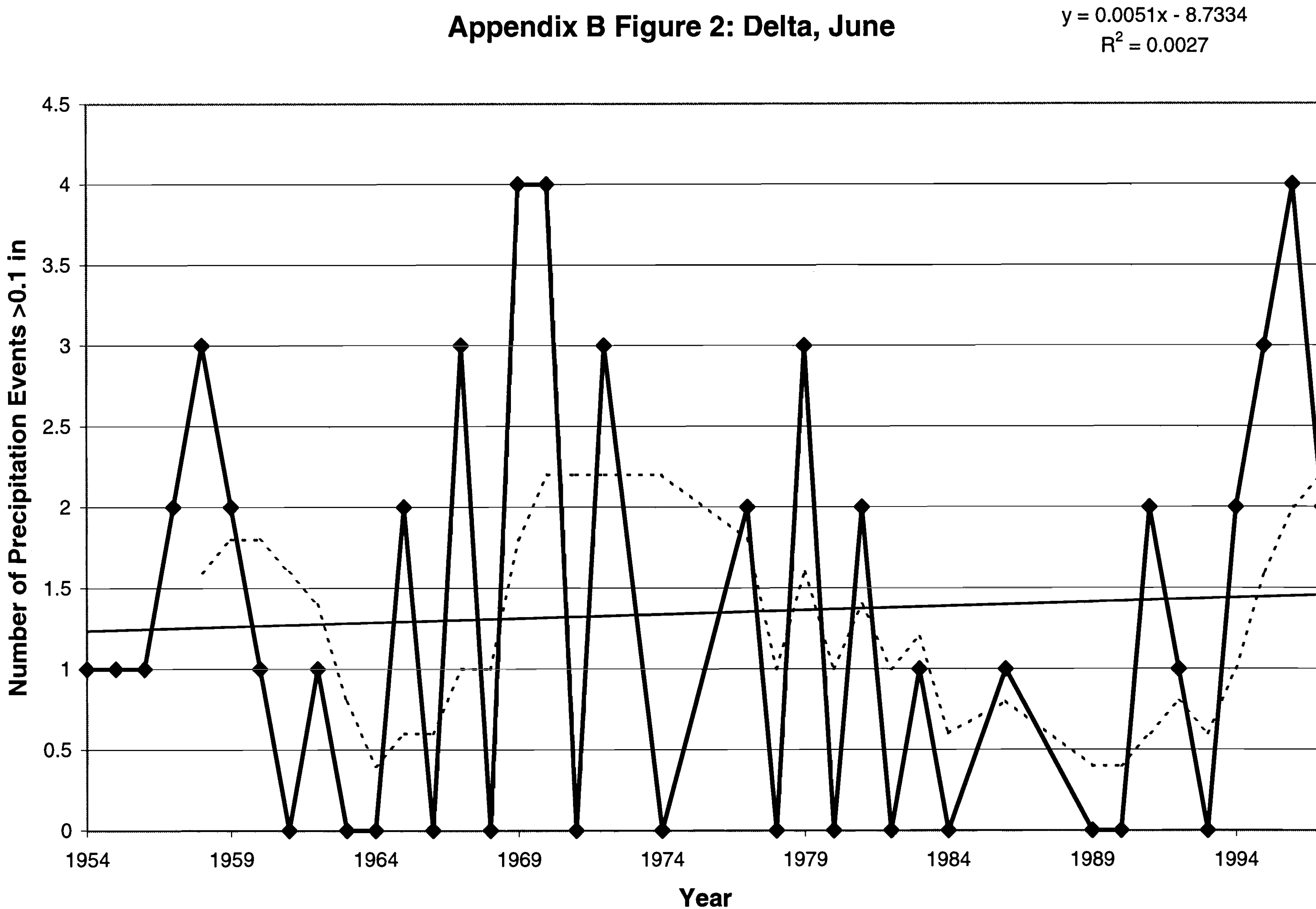
Appendix A Figure 40: Wupatki N M, Total for July-August
y = -0.0708x + 147.91
R2 = 0.0988
18
16
14
12
10
8
6
4
2
0
Number of Precipitation Events .0.1 in
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

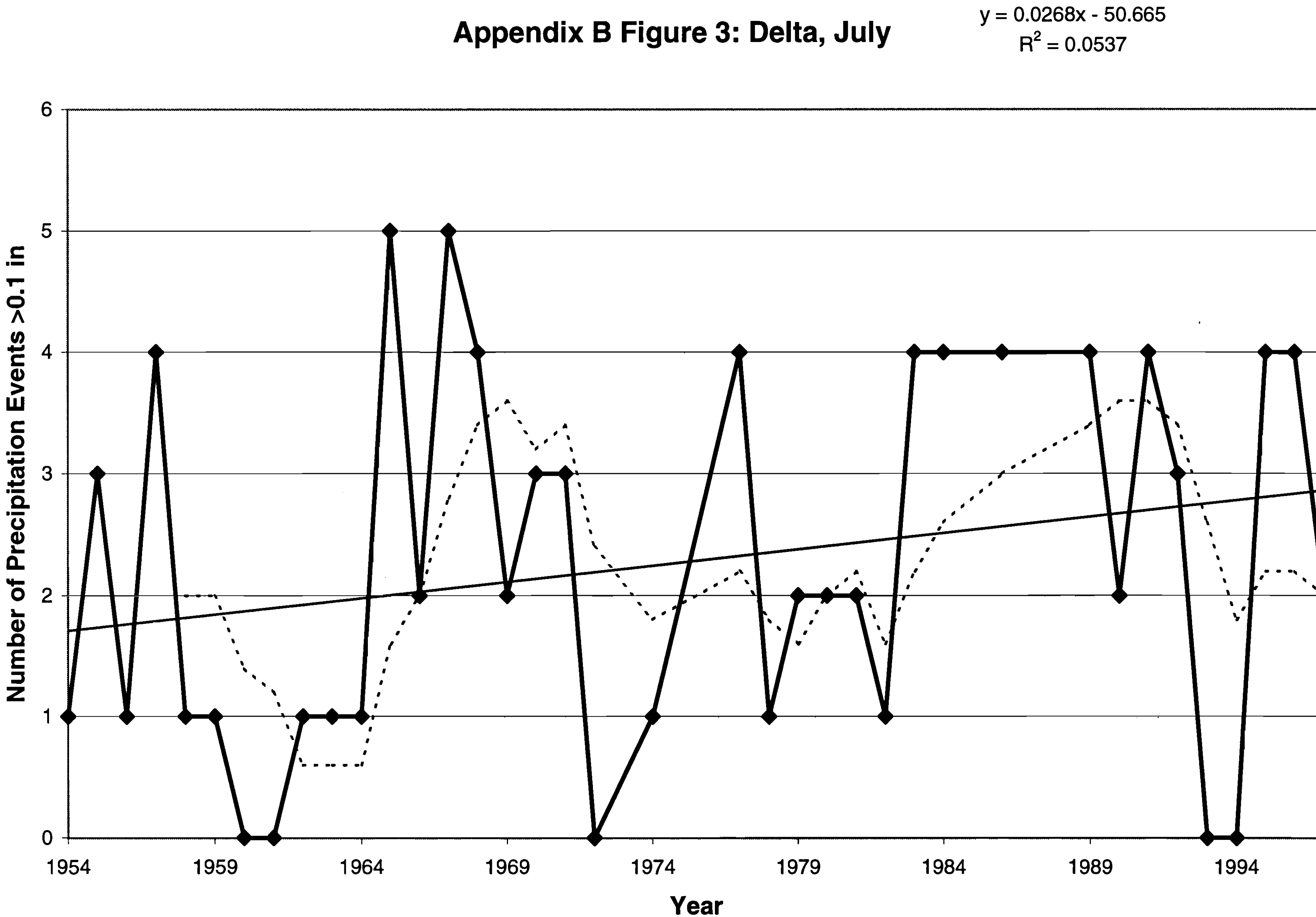
Appendix B Table 1: Number of Precipitation Events >0.1 in, Delta, Colorado, 1954-1997

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1954	0	1	1	0	4	6	5	1
1955	5	1	3	3	1	13	7	6
1956	0	1	1	2	0	4	3	3
1957	9	2	4	7	0	22	11	11
1958	1	3	1	2	1	8	4	3
1959	2	2	1	7	2	14	10	8
1960	1	1	0	2	0	4	2	2
1961	1	0	0	3	8	12	11	3
1962	1	1	1	1	5	9	7	2
1963	1	0	1	5	2	9	8	6
1964	4	0	1	8	2	15	11	9
1965	2	2	5	2	6	17	13	7
1966	2	0	2	1	3	8	6	3
1967	3	3	5	5	4	20	14	10
1968	3	0	4	2	0	9	6	6
1969	2	4	2	2	6	16	10	4
1970	0	4	3	3	5	15	11	6
1971	2	0	3	2	4	11	9	5
1972	2	3	0	0	4	9	4	0
1974	0	0	1	2	2	5	5	3
1977	2	2	4	3	2	13	9	7
1978	3	0	1	0	0	4	1	1
1979	4	3	2	1	0	10	3	3
1980	5	0	2	3	1	11	6	5
1981	2	2	2	3	3	12	8	5
1982	1	0	1	5	8	15	14	6
1983	3	1	4	2	0	10	6	6
1984	1	0	4	2	4	11	10	6
1986	3	1	4	3	7	18	14	7
1989	0	0	4	3	1	8	8	7
1990	1	0	2	3	3	9	8	5
1991	0	2	4	3	3	12	10	7
1992	6	1	3	1	0	11	4	4
1993	6	0	0	4	2	12	6	4
1994	2	2	0	4	3	11	7	4
1995	7	3	4	2	4	20	10	6
1996	0	4	4	0	3	11	7	4
1997	4	2	2	4	7	19	13	6
Ave.	**2.39**	**1.34**	**2.26**	**2.76**	**2.89**	**11.66**	**7.92**	**5.03**
S.D.	**2.15**	**1.32**	**1.55**	**1.90**	**2.37**	**4.55**	**3.45**	**2.43**
Max	**9**	**4**	**5**	**8**	**8**	**22**	**14**	**11**
Min	**0**	**0**	**0**	**0**	**0**	**4**	**1**	**0**


Appendix B Figure 1: Delta, May
y = 0.0211x - 39.182
R2 = 0.0173
Number of Precipitation Events >0.1 in
10
9
8
7
6
5
4
3
2
1
0
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

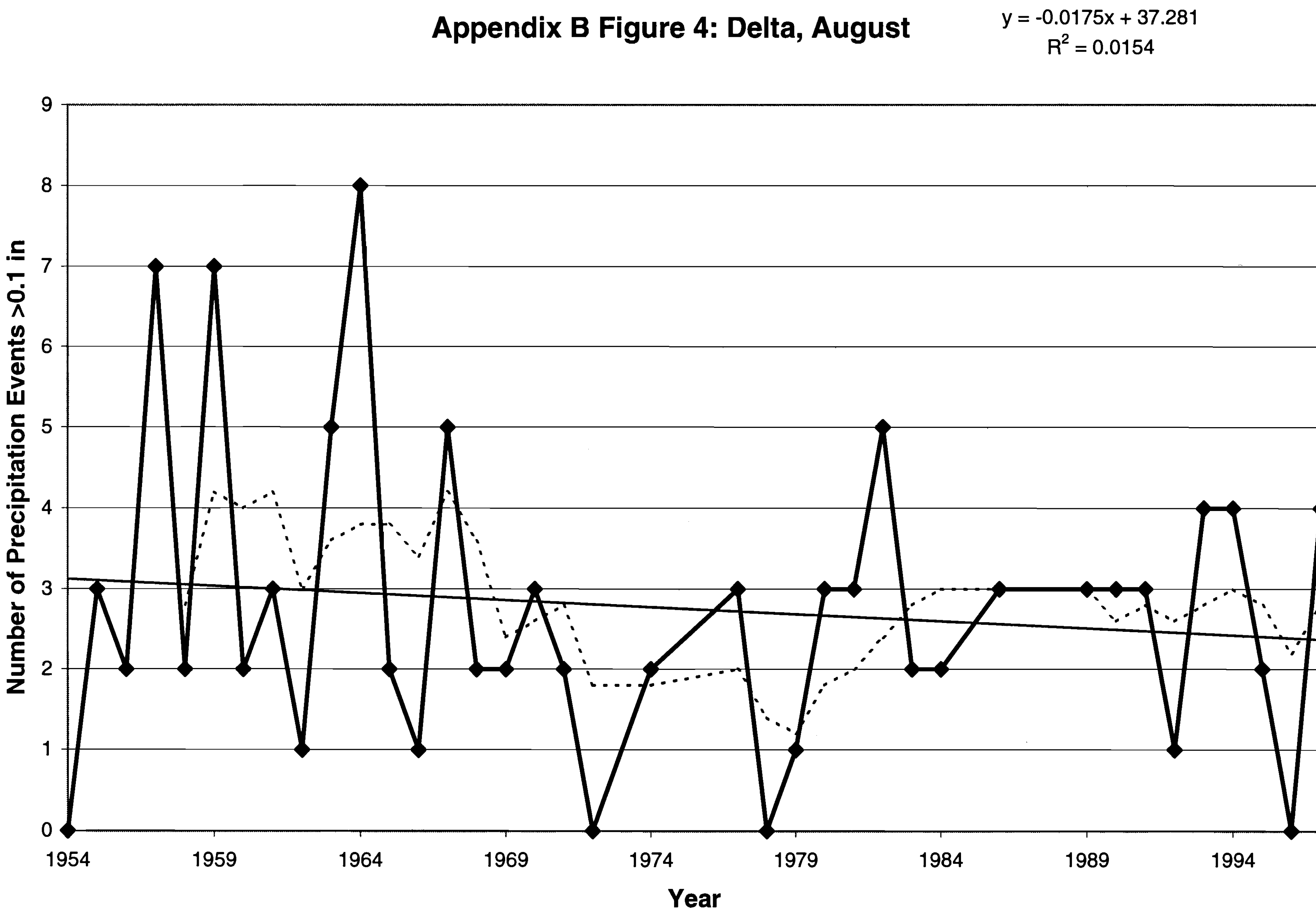
Appendix B Figure 2: Delta, June

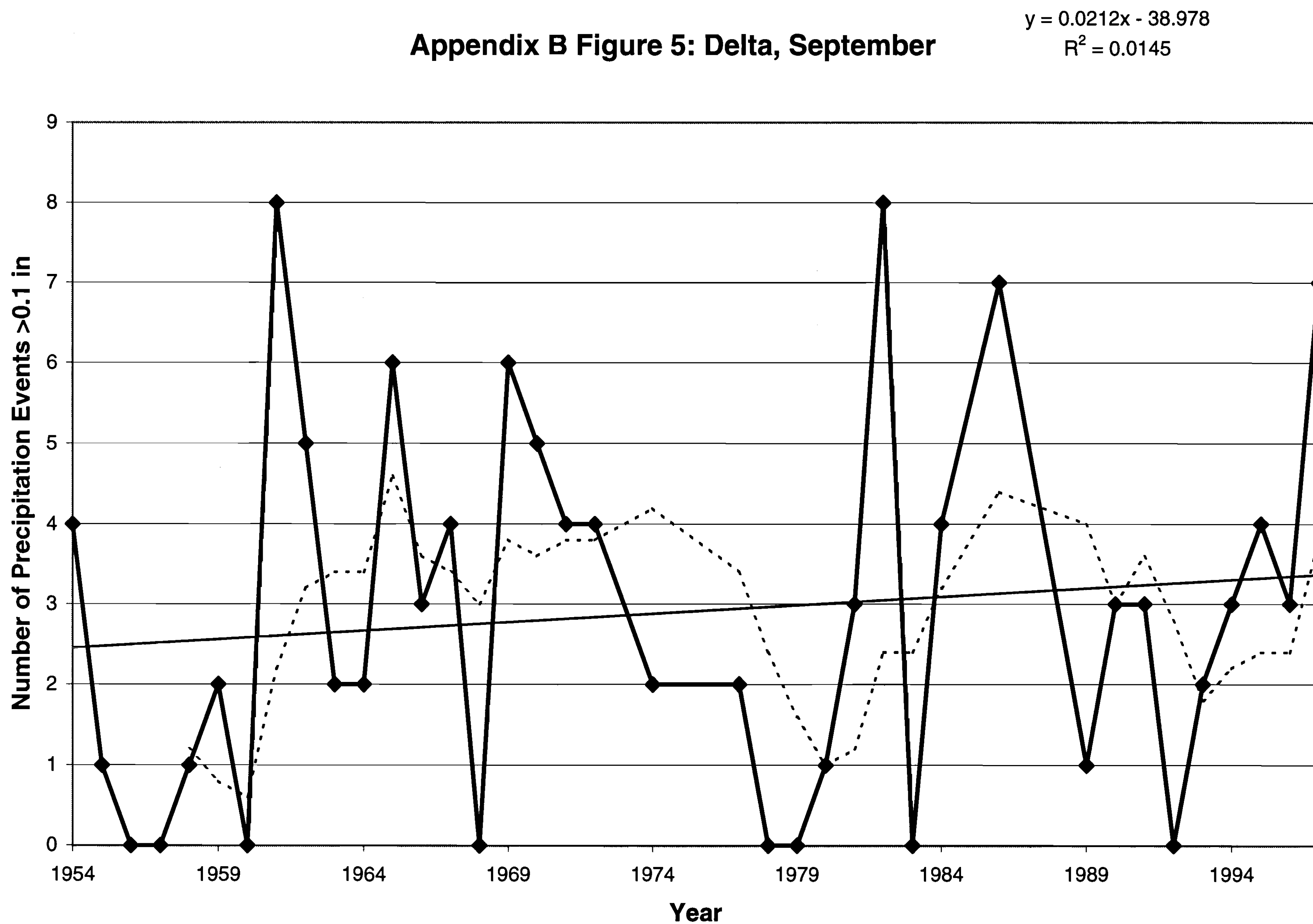




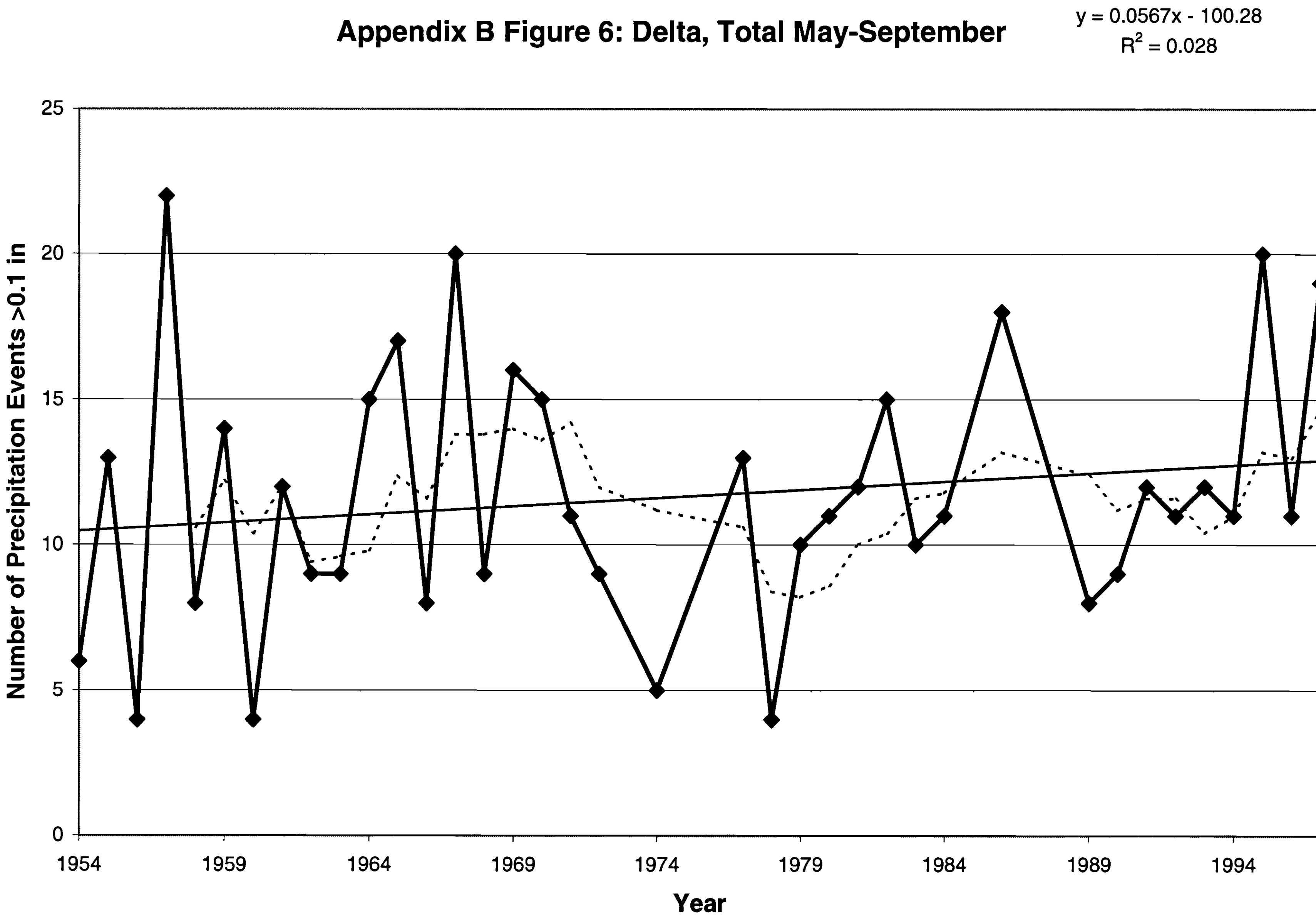
Appendix B Figure 3: Delta, July
y = 0.0268x - 50.665
R2 = 0.0537
Number of Precipitation Events >0.1 in
0
1
2
3
4
5
6
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

Appendix B Figure 4: Delta, August

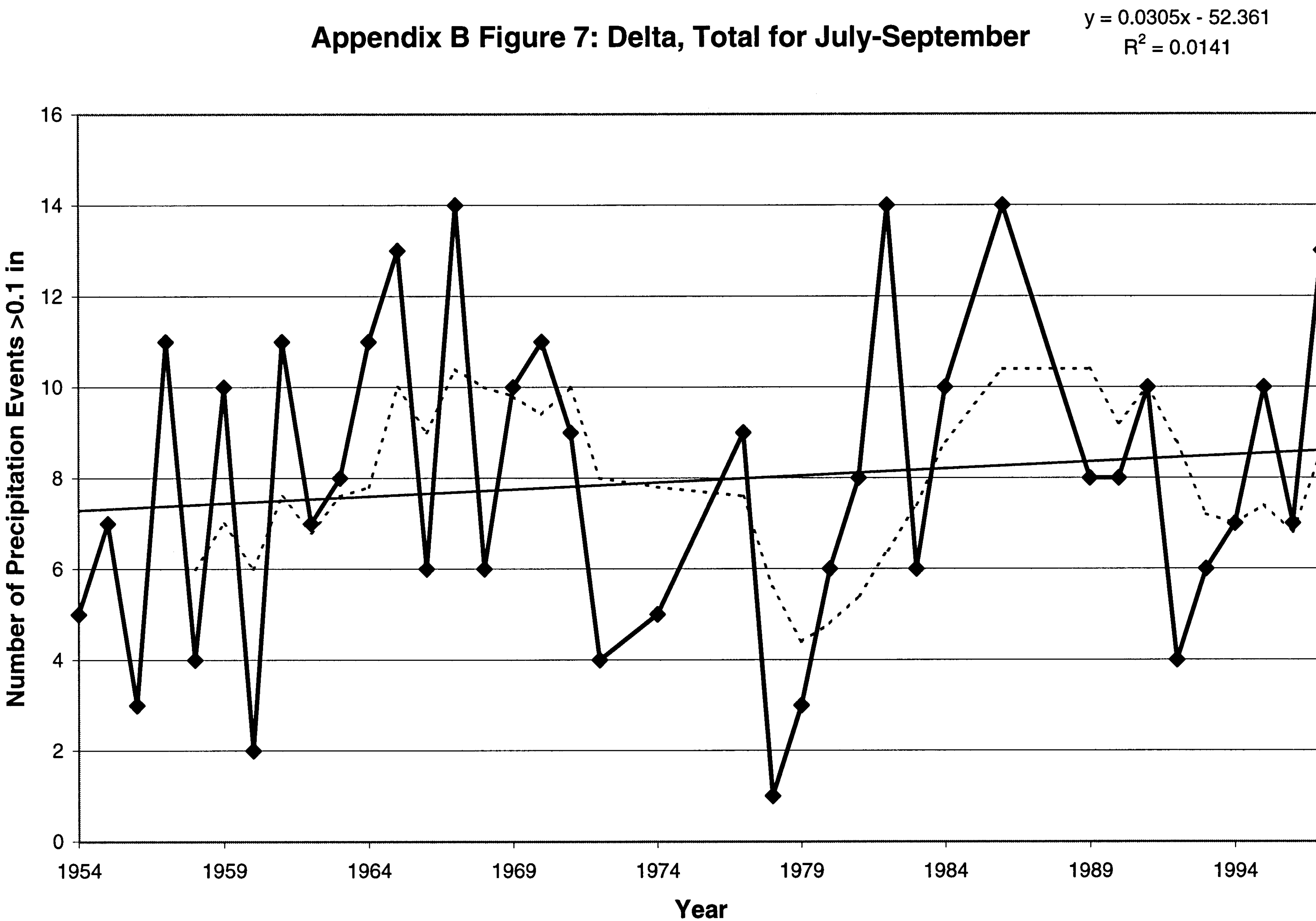



Appendix B Figure 5: Delta, September
y = 0.0212x - 38.978
R2 = 0.0145
Number of Precipitation Events >0.1 in
Year
0
1
2
3
4
5
6
7
8
9
1954
1959
1964
1969
1974
1979
1984
1989
1994

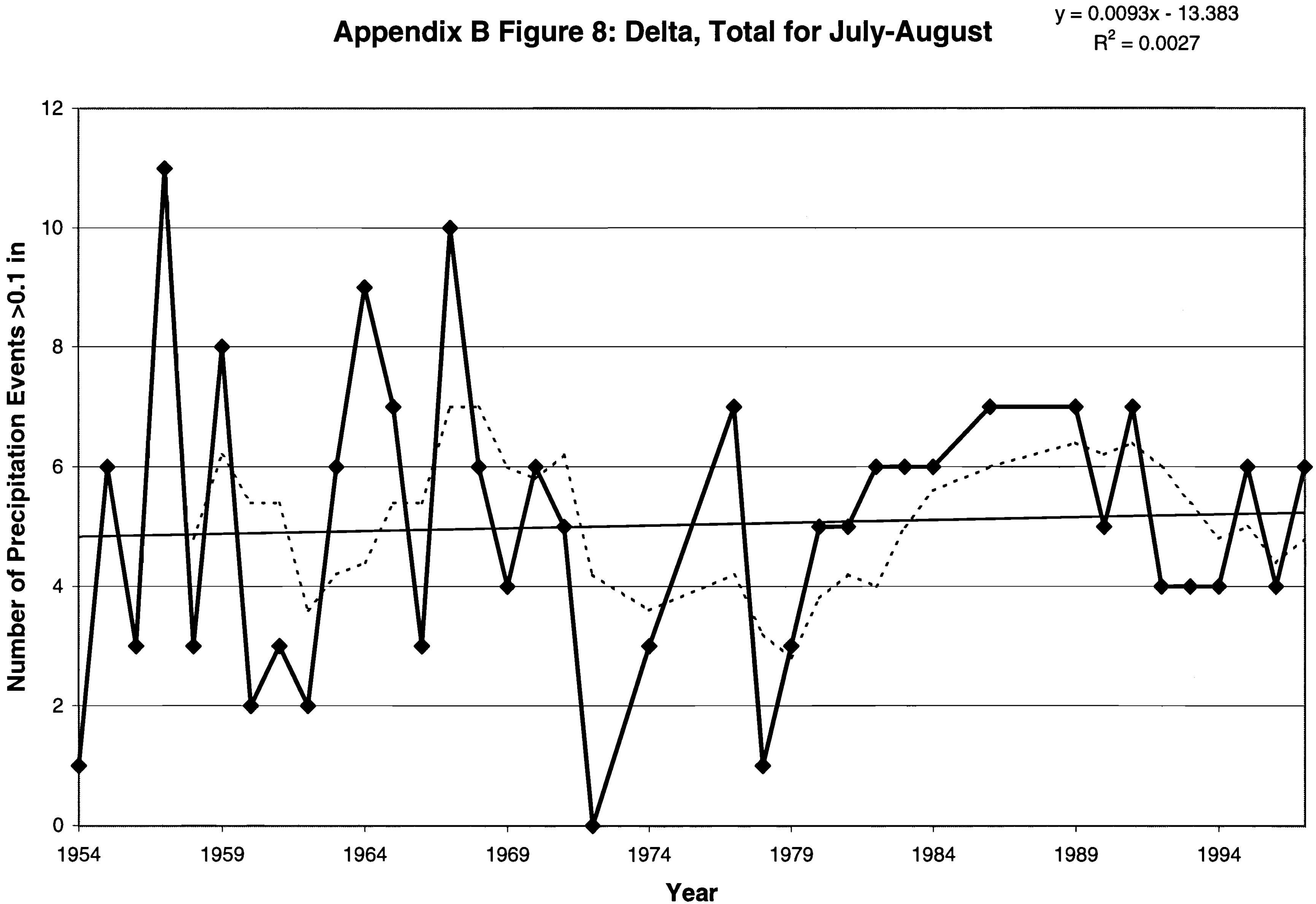
Appendix B Figure 6: Delta, Total May-September



Appendix B Figure 7: Delta, Total for July-September



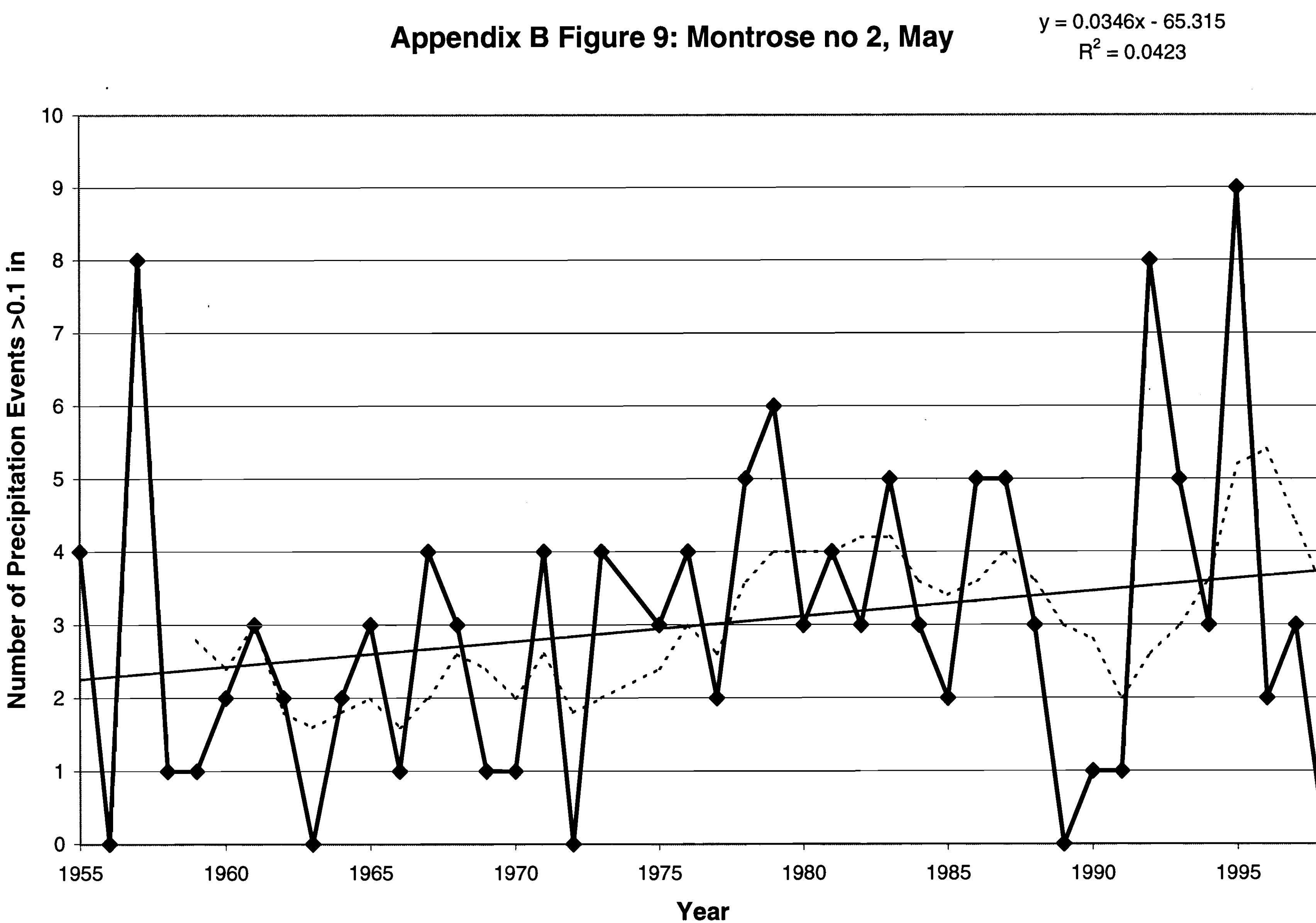
Appendix B Figure 8: Delta, Total for July-August



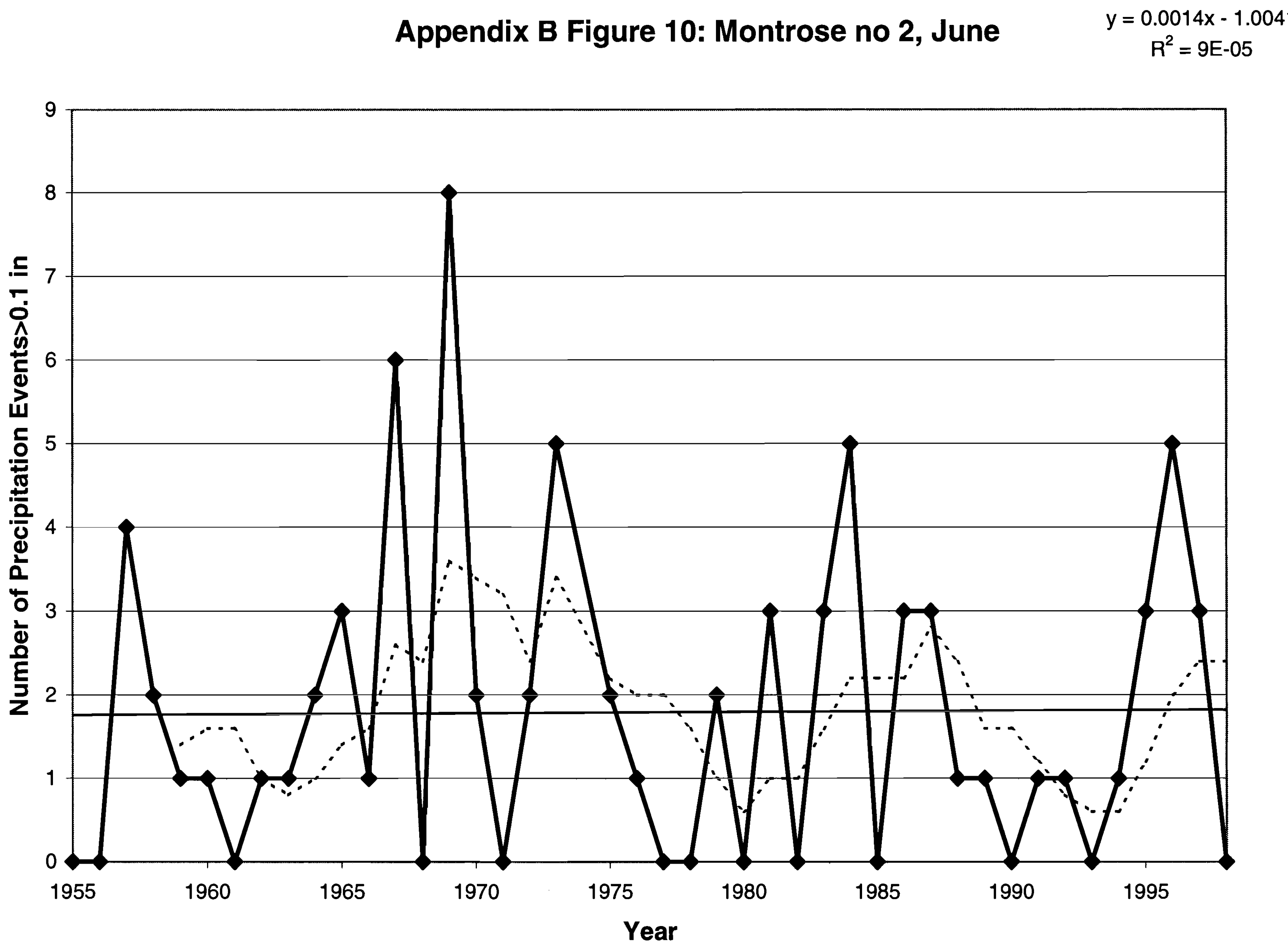
Number of Appendix B Table 2: Precipitation Events >0.1 in, Montrose no 2, Colorado, 1955-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1955	4	0	5	4	0	13	9	9
1956	0	0	1	4	0	5	5	5
1957	8	4	8	6	1	27	15	14
1958	1	2	0	0	4	7	4	0
1959	1	1	1	7	5	15	13	8
1960	2	1	1	2	0	6	3	3
1961	3	0	0	3	8	14	11	3
1962	2	1	2	2	5	12	9	4
1963	0	1	5	5	2	13	12	10
1964	2	2	4	5	4	17	13	9
1965	3	3	6	3	7	22	16	9
1966	1	1	3	2	3	10	8	5
1967	4	6	3	2	5	20	10	5
1968	3	0	4	5	1	13	10	9
1969	1	8	3	2	5	19	10	5
1970	1	2	3	2	5	13	10	5
1971	4	0	1	1	3	9	5	2
1972	0	2	4	1	2	9	7	5
1973	4	5	2	6	2	19	10	8
1975	3	2	4	2	1	12	7	6
1976	4	1	6	3	7	21	16	9
1977	2	0	5	6	4	17	15	11
1978	5	0	0	0	1	6	1	0
1979	6	2	2	2	0	12	4	4
1980	3	0	3	4	2	12	9	7
1981	4	3	7	6	3	23	16	13
1982	3	0	1	5	9	18	15	6
1983	5	3	7	6	1	22	14	13
1984	3	5	4	4	3	19	11	8
1985	2	0	2	1	10	15	13	3
1986	5	3	6	5	5	24	16	11
1987	5	3	3	4	0	15	7	7
1988	3	1	1	2	3	10	6	3
1989	0	1	1	3	2	7	6	4
1990	1	0	5	2	3	11	10	7
1991	1	1	1	3	3	9	7	4
1992	8	1	6	5	1	21	12	11
1993	5	0	1	6	2	14	9	7
1994	3	1	0	4	4	12	8	4
1995	9	3	5	3	3	23	11	8
1996	2	5	1	1	8	17	10	2
1997	3	3	3	3	10	22	16	6
1998	0	0	2	2	2	6	6	4
Ave.	**3.00**	**1.79**	**3.07**	**3.35**	**3.47**	**14.67**	**9.88**	**6.42**
S.D.	**2.18**	**1.90**	**2.18**	**1.82**	**2.72**	**5.71**	**3.95**	**3.38**
Max	**9**	**8**	**8**	**7**	**10**	**27**	**16**	**14**
Min	**0**	**0**	**0**	**0**	**0**	**5**	**1**	**0**

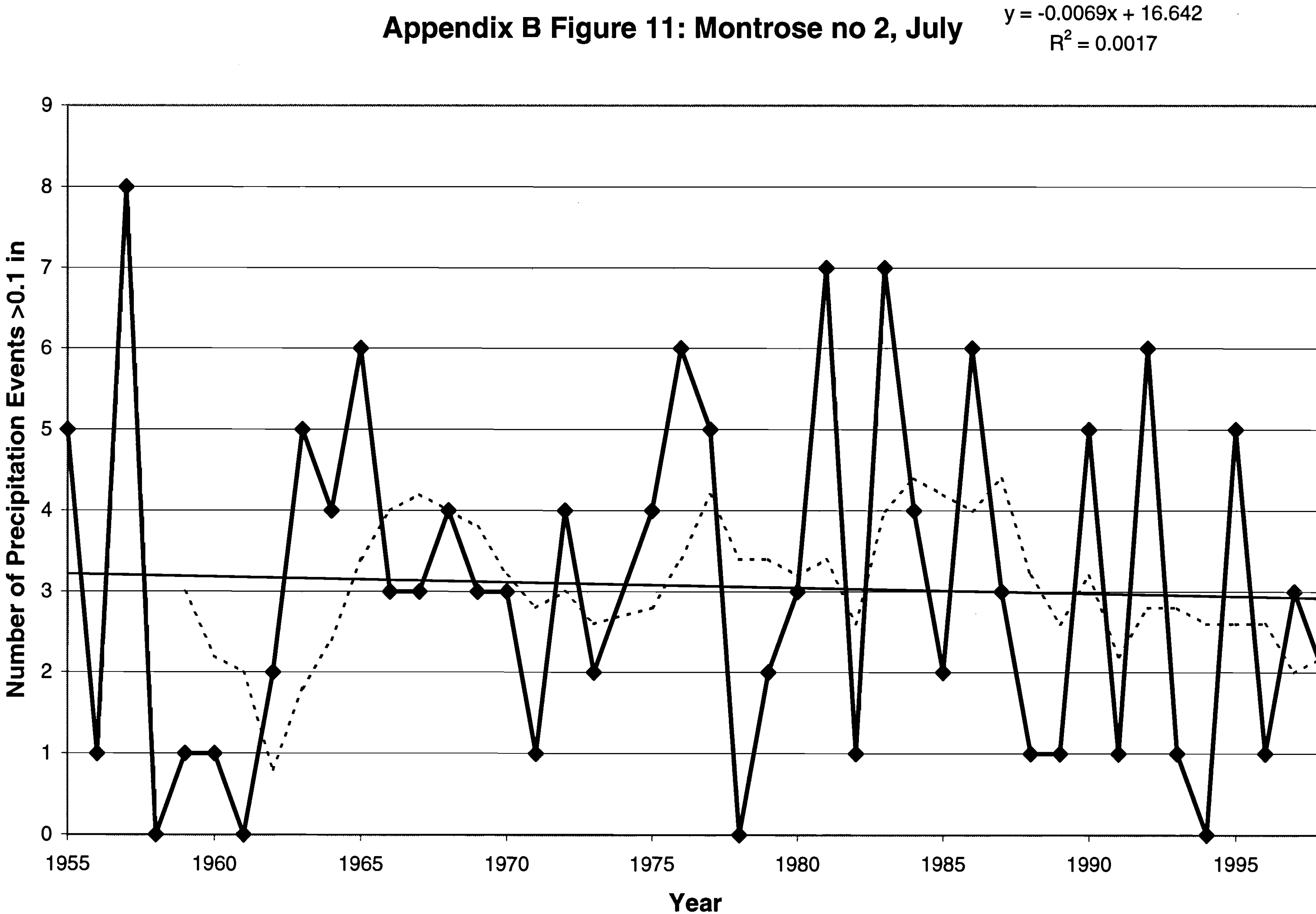
Appendix B Figure 9: Montrose no 2, May

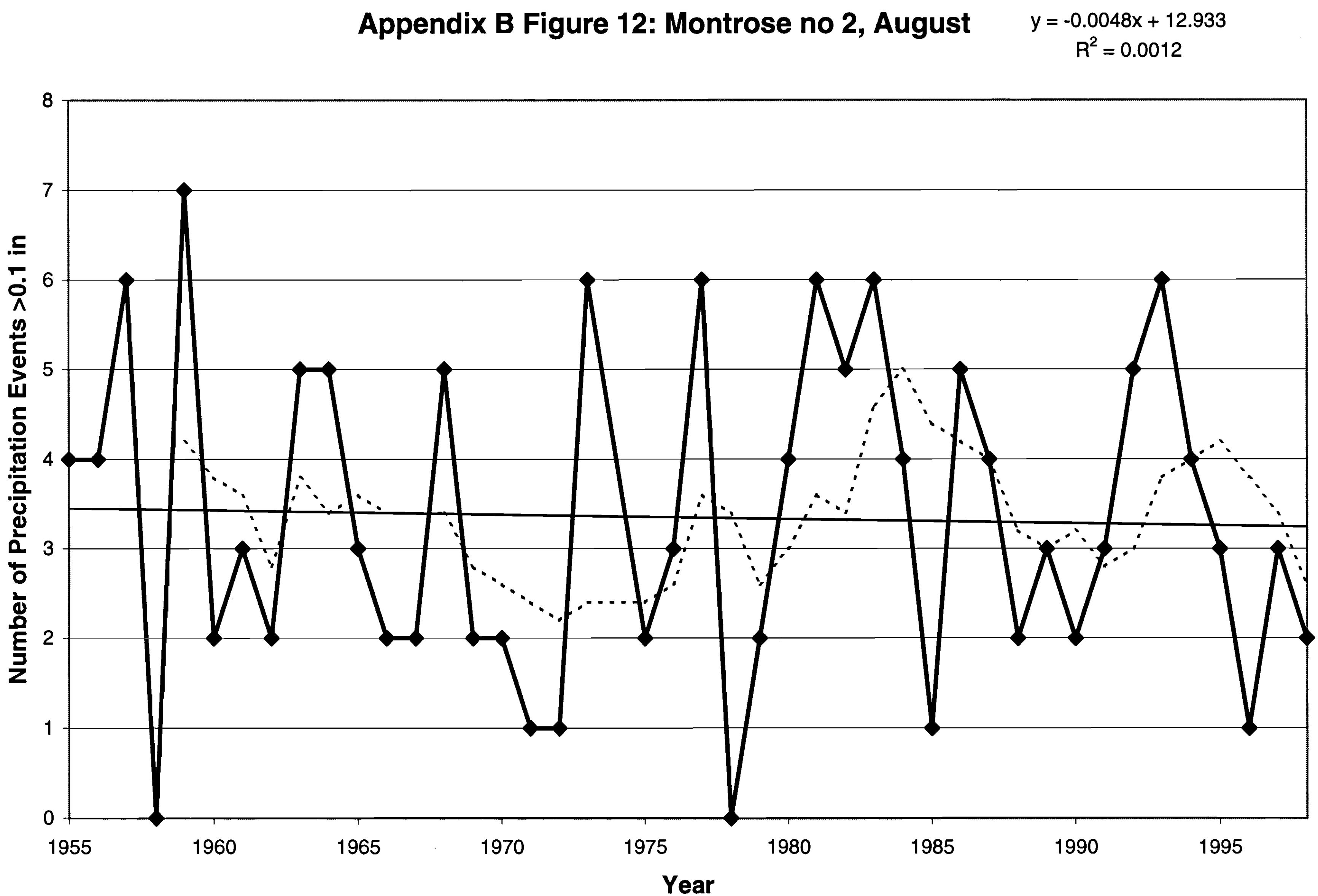


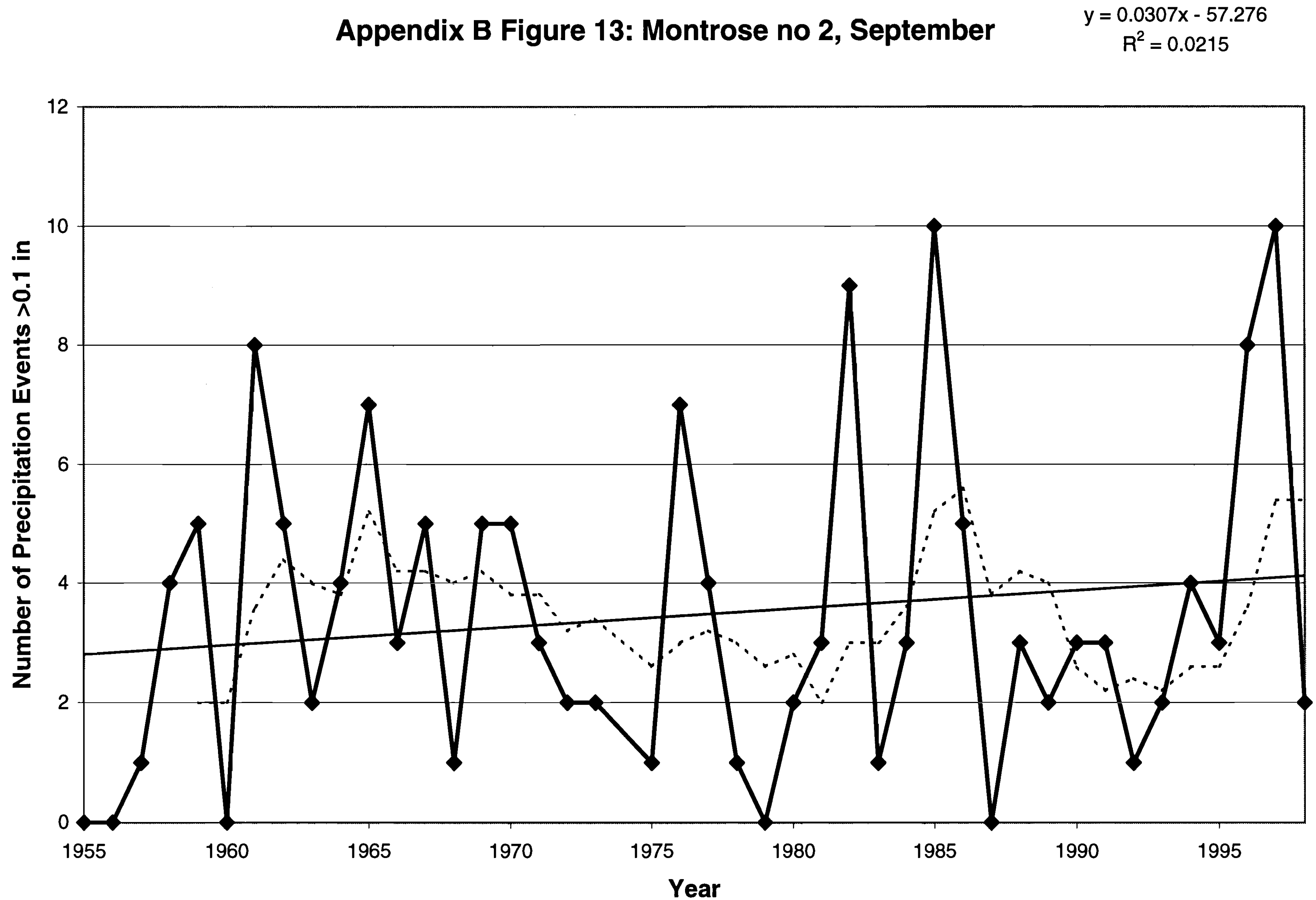
Appendix B Figure 10: Montrose no 2, June



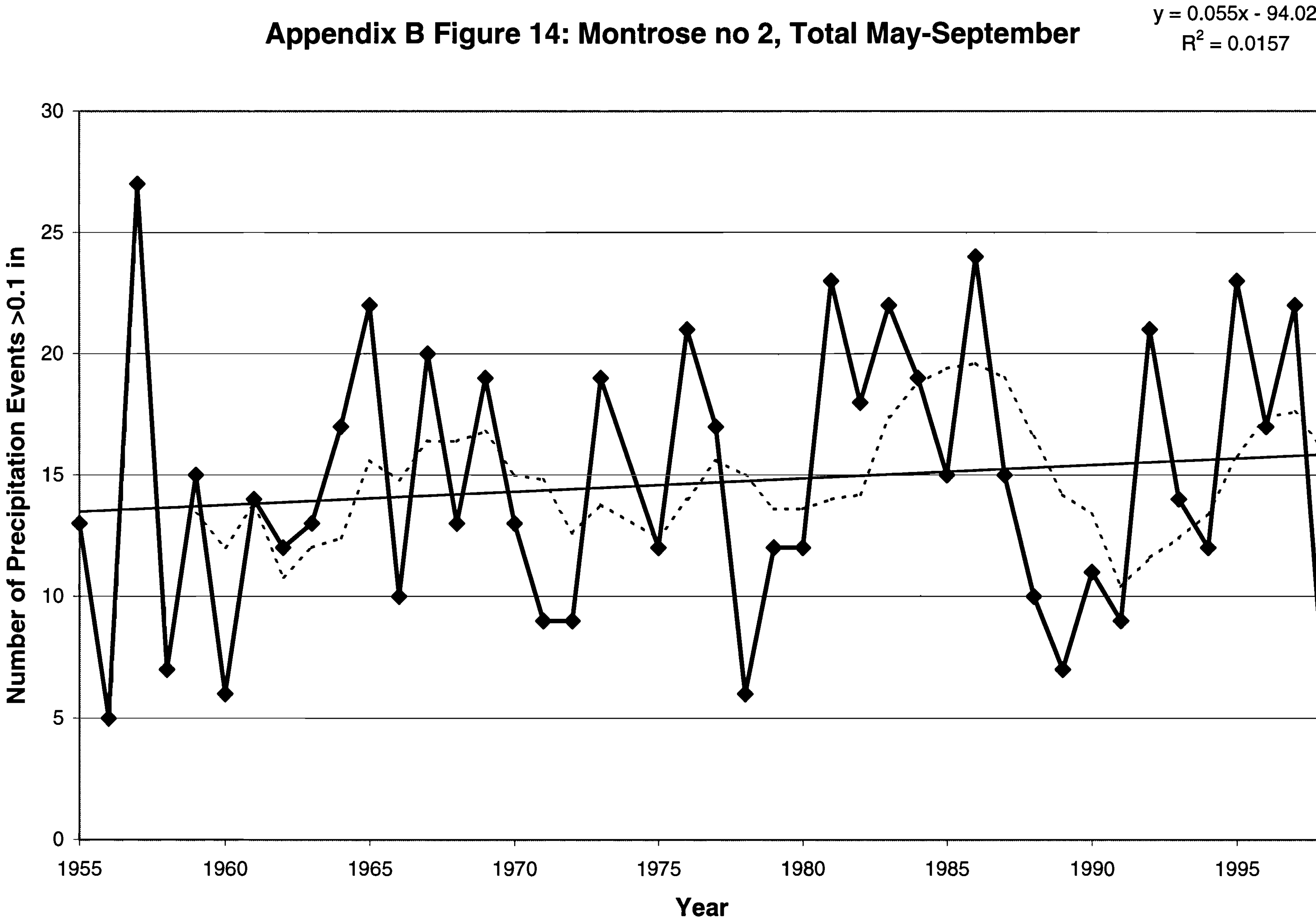
Appendix B Figure 11: Montrose no 2, July



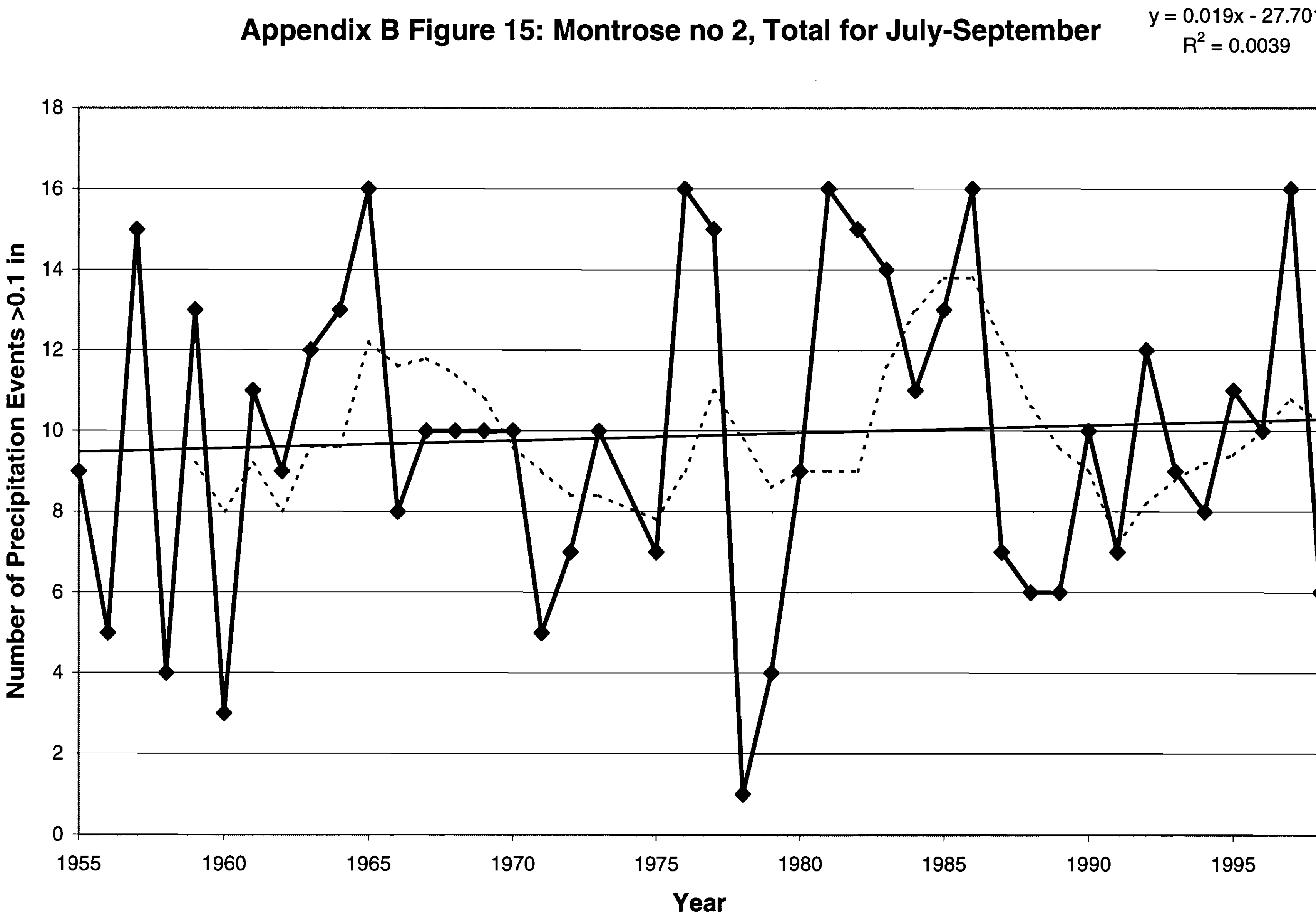

Appendix B Figure 12: Montrose no 2, August
y = -0.0048x + 12.933
R2 = 0.0012
Number of Precipitation Events >0.1 in
0
1
2
3
4
5
6
7
8
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year


Appendix B Figure 13: Montrose no 2, September
y = 0.0307x - 57.276
R2 = 0.0215
Number of Precipitation Events >0.1 in
Year
0
2
4
6
8
10
12
1955
1960
1965
1970
1975
1980
1985
1990
1995

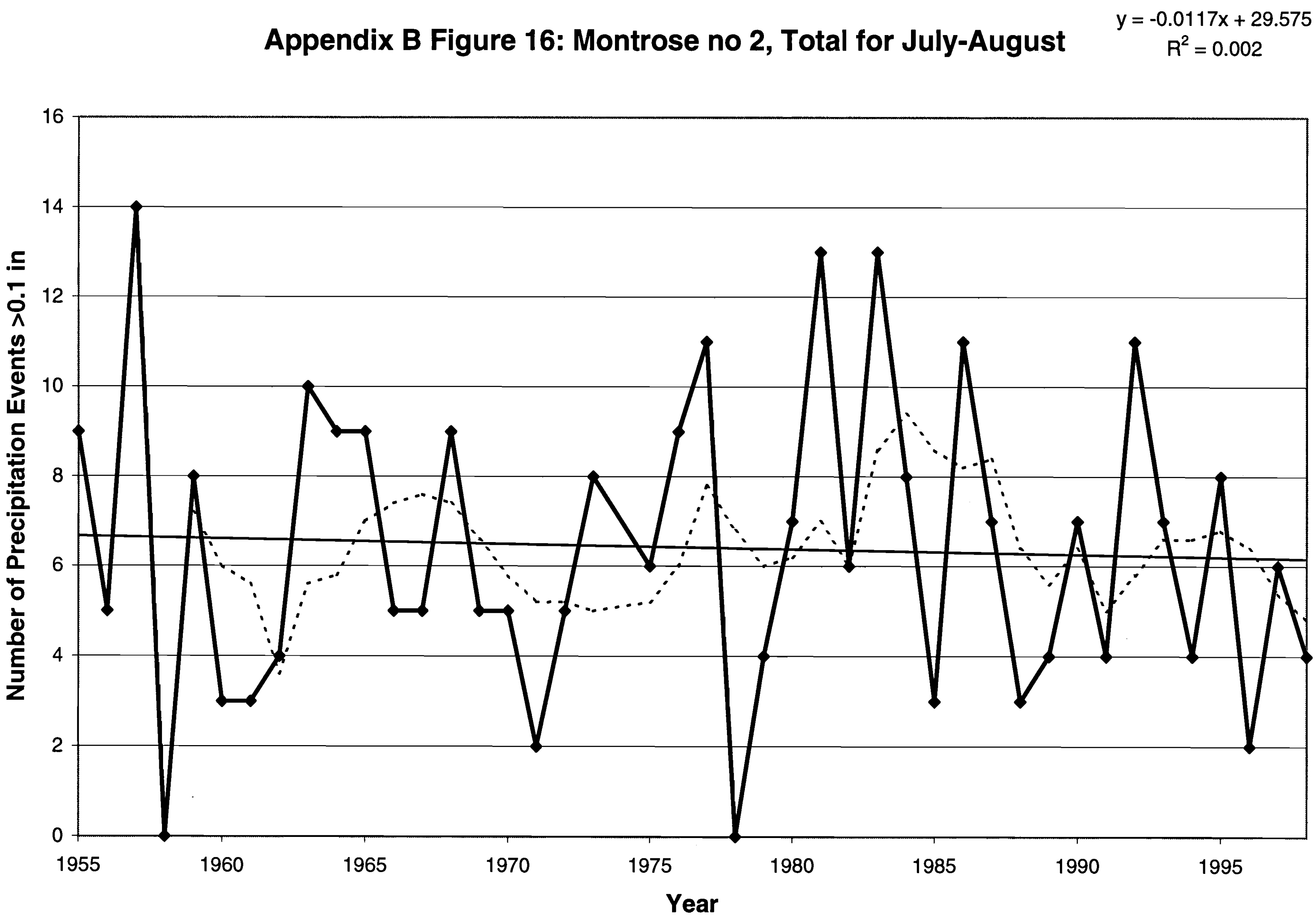
Appendix B Figure 14: Montrose no 2, Total May-September



Appendix B Figure 15: Montrose no 2, Total for July-September



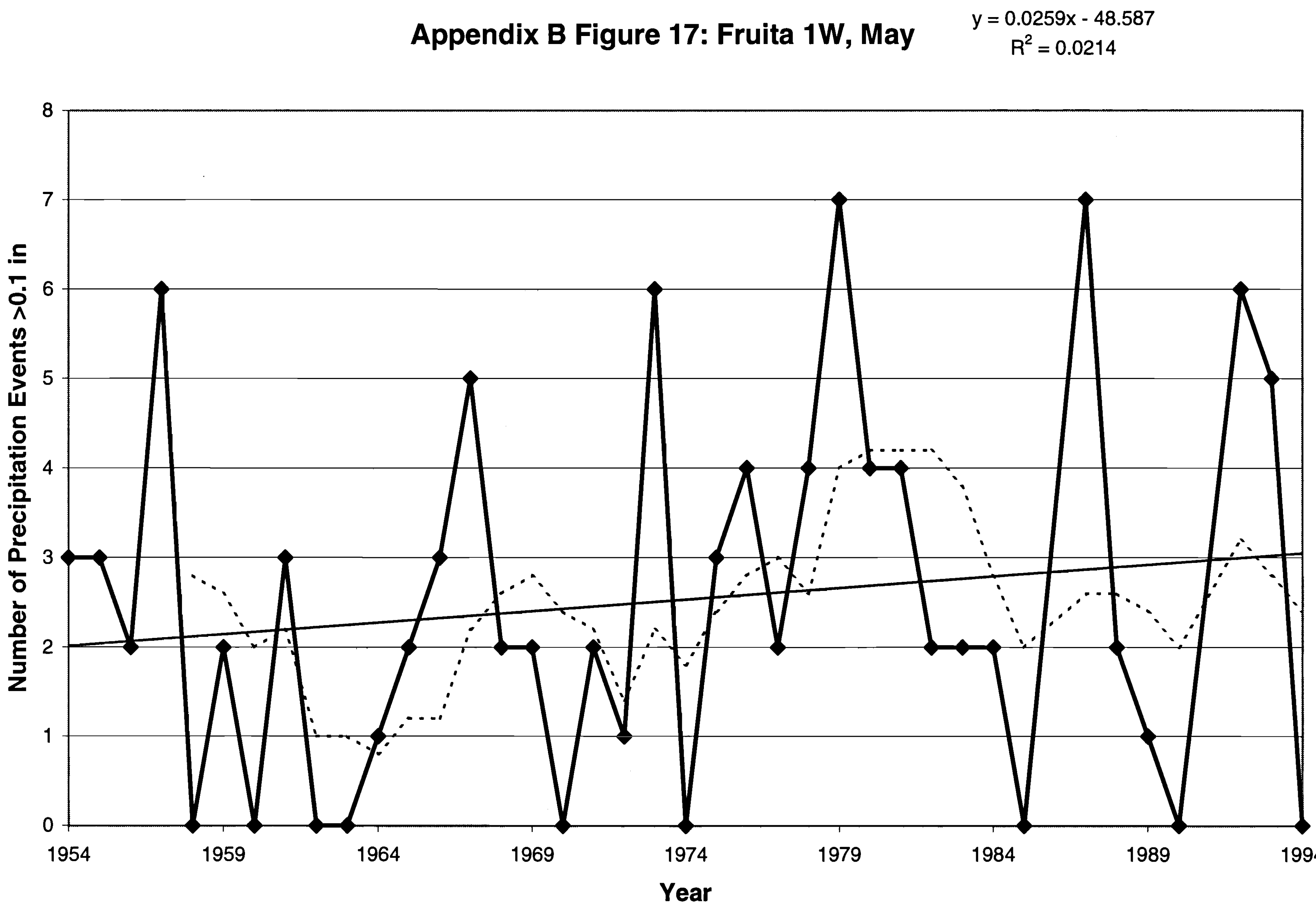
Appendix B Figure 16: Montrose no 2, Total for July-August



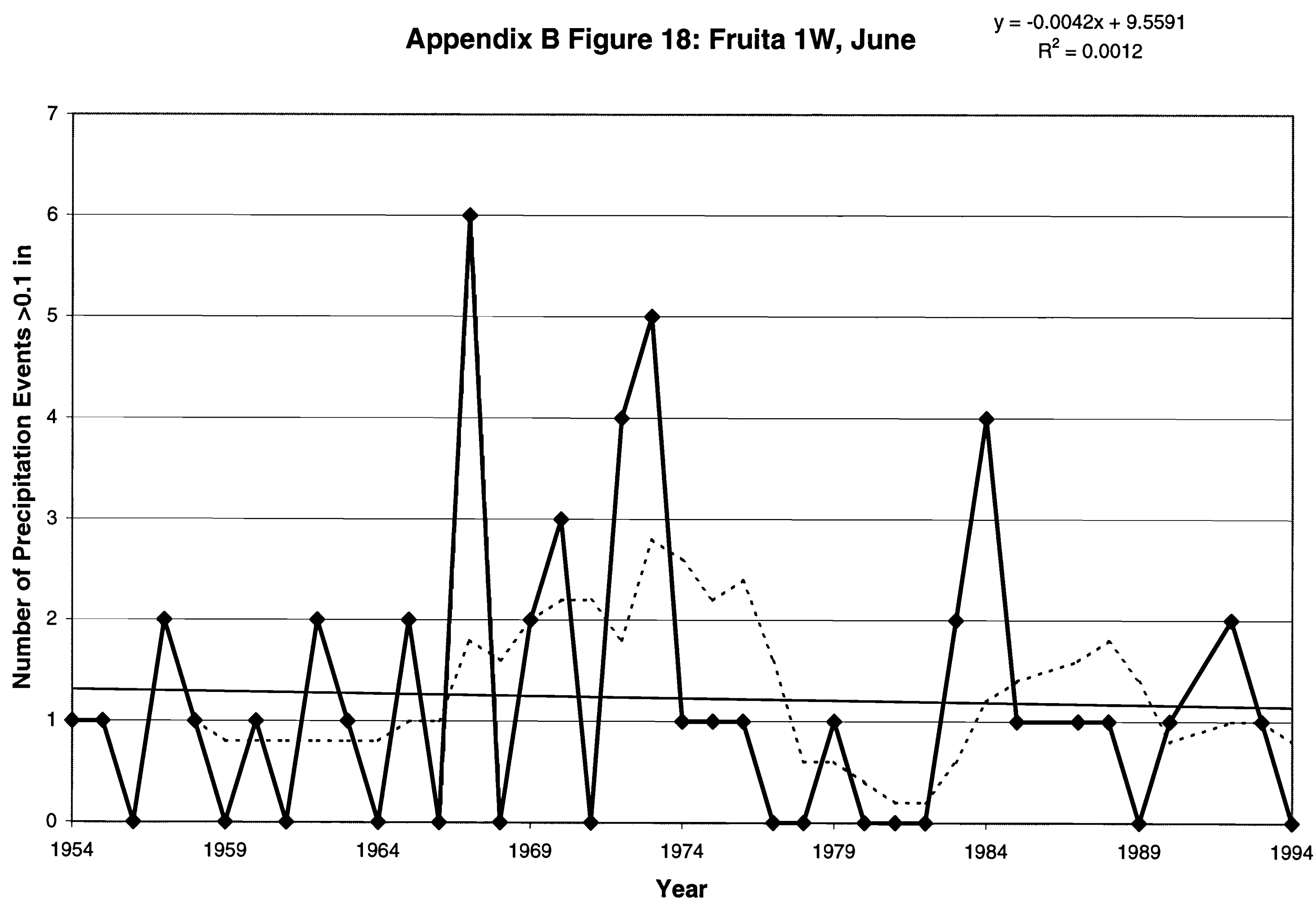
Appendix B Table 3: Number of Precipitation Events >0.1 in, Fruita 1W, Colorado, 1954-1994

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1954	3	1	2	2	5	13	9	4
1955	3	1	1	5	1	11	7	6
1956	2	0	4	1	0	7	5	5
1957	6	2	2	13	1	24	16	15
1958	0	1	0	2	2	5	4	2
1959	2	0	0	5	5	12	10	5
1960	0	1	0	1	2	4	3	1
1961	3	0	0	4	6	13	10	4
1962	0	2	0	0	4	6	4	0
1963	0	1	4	6	2	13	12	10
1964	1	0	1	3	3	8	7	4
1965	2	2	4	4	6	18	14	8
1966	3	0	4	1	2	10	7	5
1967	5	6	3	3	2	19	8	6
1968	2	0	1	5	0	8	6	6
1969	2	2	2	3	3	12	8	5
1970	0	3	4	2	4	13	10	6
1971	2	0	1	3	2	8	6	4
1972	1	4	1	3	3	12	7	4
1973	6	5	2	2	1	16	5	4
1974	0	1	2	1	0	4	3	3
1975	3	1	3	0	1	8	4	3
1976	4	1	2	3	5	15	10	5
1977	2	0	3	1	3	9	7	4
1978	4	0	1	2	1	8	4	3
1979	7	1	2	0	0	10	2	2
1980	4	0	2	3	0	9	5	5
1981	4	0	1	2	3	10	6	3
1982	2	0	1	4	6	13	11	5
1983	2	2	4	1	1	10	6	5
1984	2	4	5	2	1	14	8	7
1985	0	1	4	0	2	7	6	4
1987	7	1	6	5	0	19	11	11
1988	2	1	1	2	3	9	6	3
1989	1	0	2	6	1	10	9	8
1990	0	1	3	1	2	7	6	4
1992	6	2	2	1	1	12	4	3
1993	5	1	0	4	2	12	6	4
1994	0	0	0	5	2	7	7	5
Ave.	**2.51**	**1.23**	**2.05**	**2.85**	**2.26**	**10.90**	**7.15**	**4.90**
S.D.	**2.09**	**1.46**	**1.57**	**2.39**	**1.77**	**4.31**	**3.06**	**2.71**
Max	**7**	**6**	**6**	**13**	**6**	**24**	**16**	**15**
Min	**0**	**0**	**0**	**0**	**0**	**4**	**2**	**0**

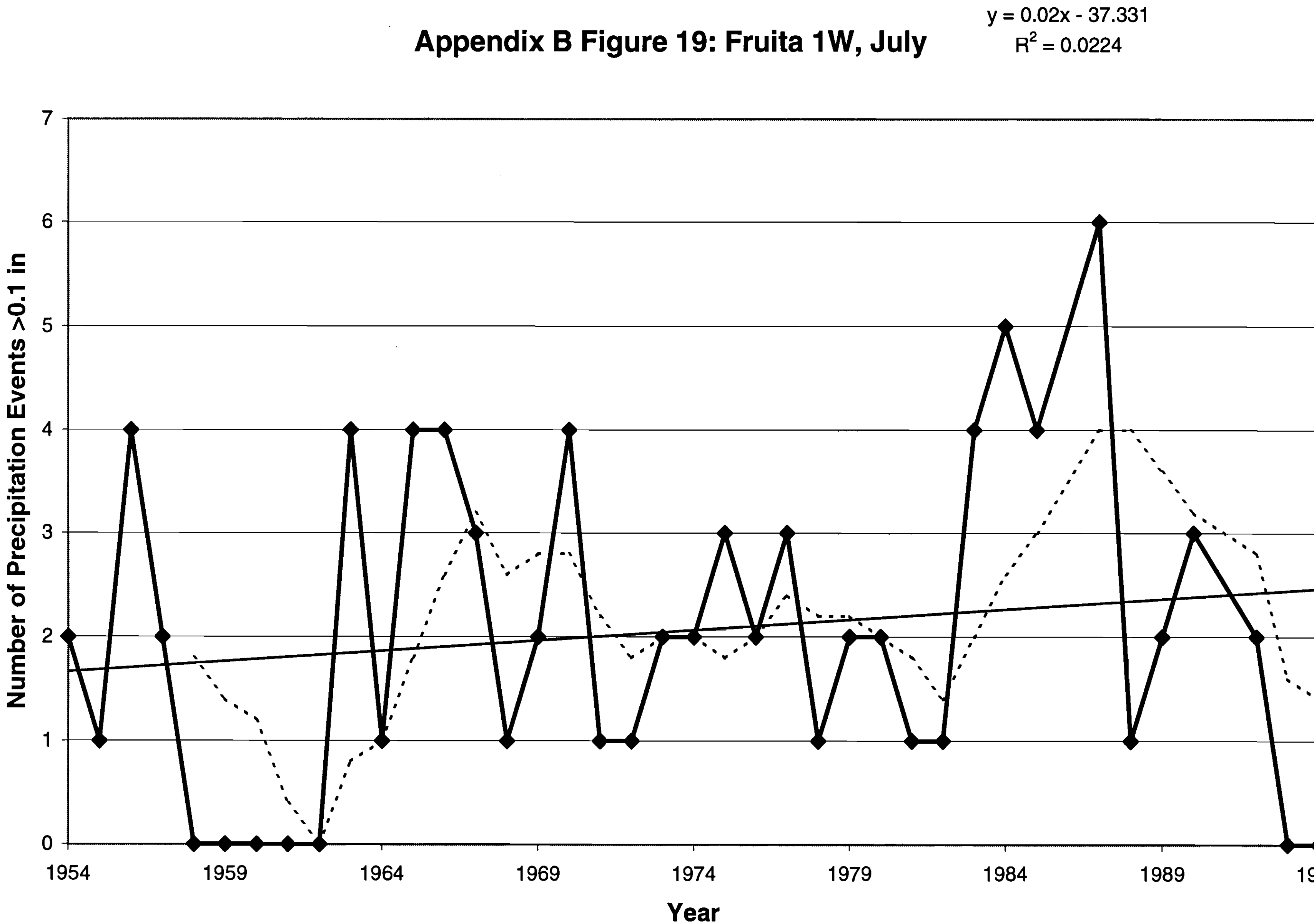
Appendix B Figure 17: Fruita 1W, May



Appendix B Figure 18: Fruita 1W, June

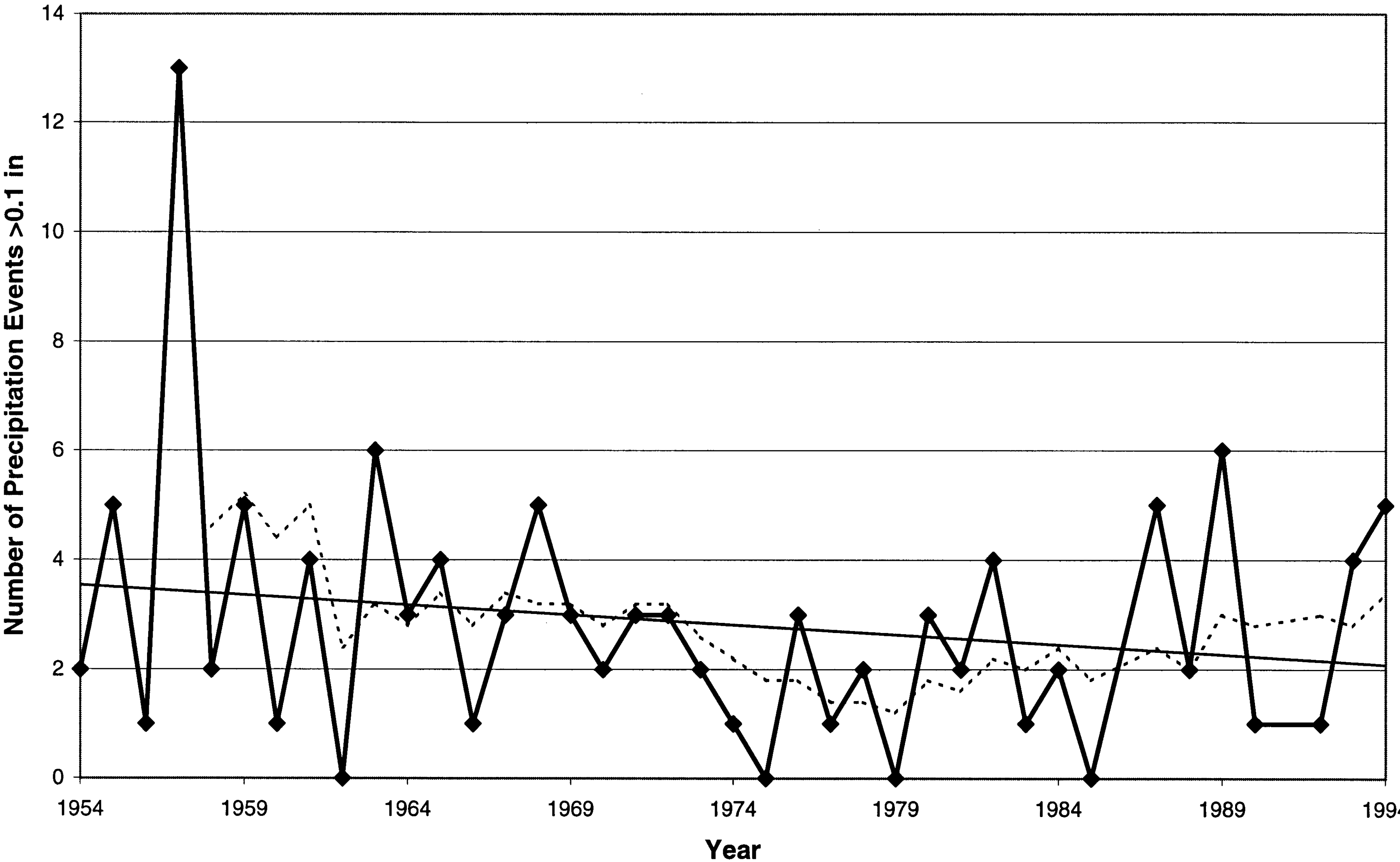


Appendix B Figure 19: Fruita 1W, July

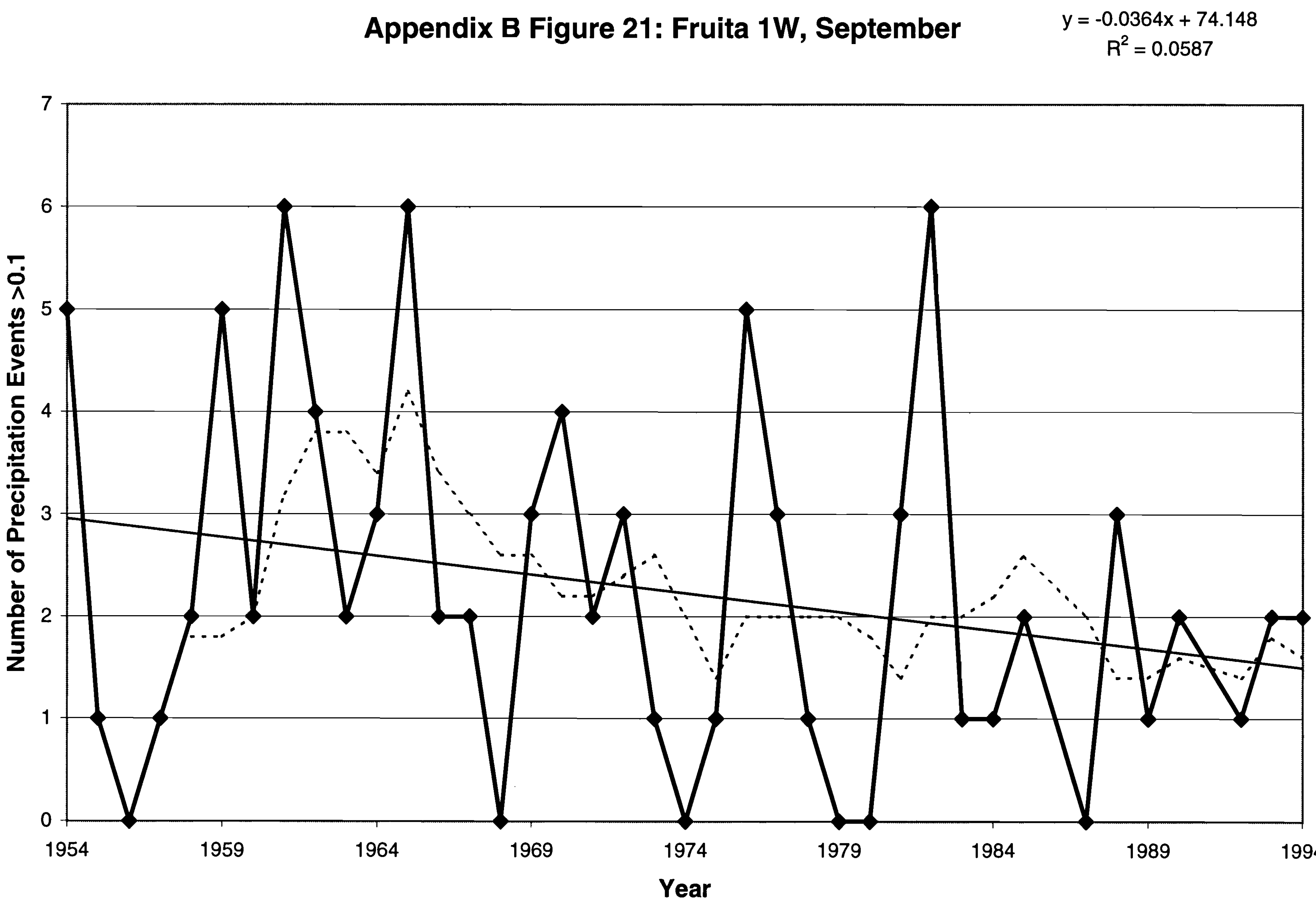


Appendix B Figure 20: Fruita 1W, August

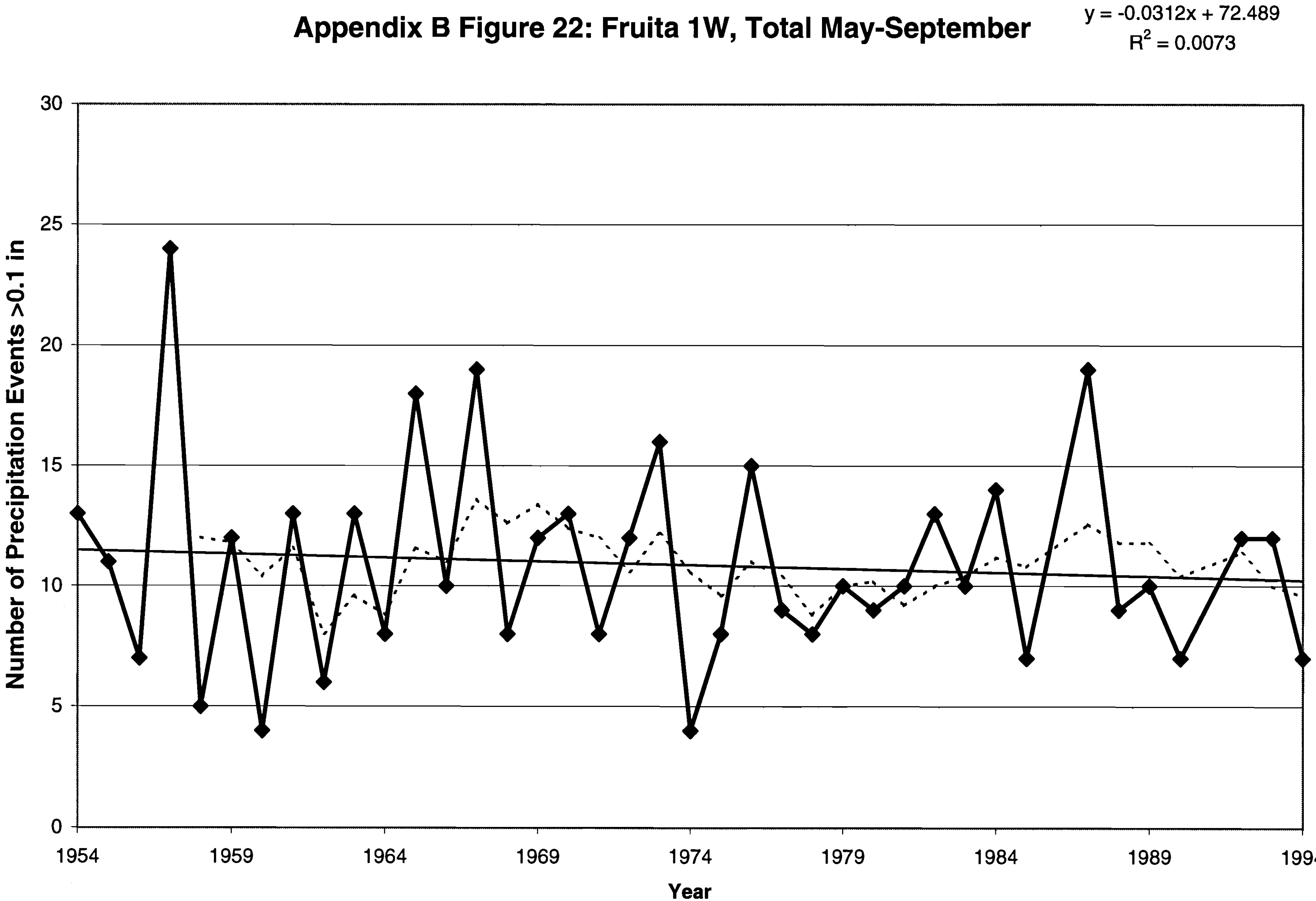
$y = -0.0364x + 74.699$
$R^2 = 0.0323$



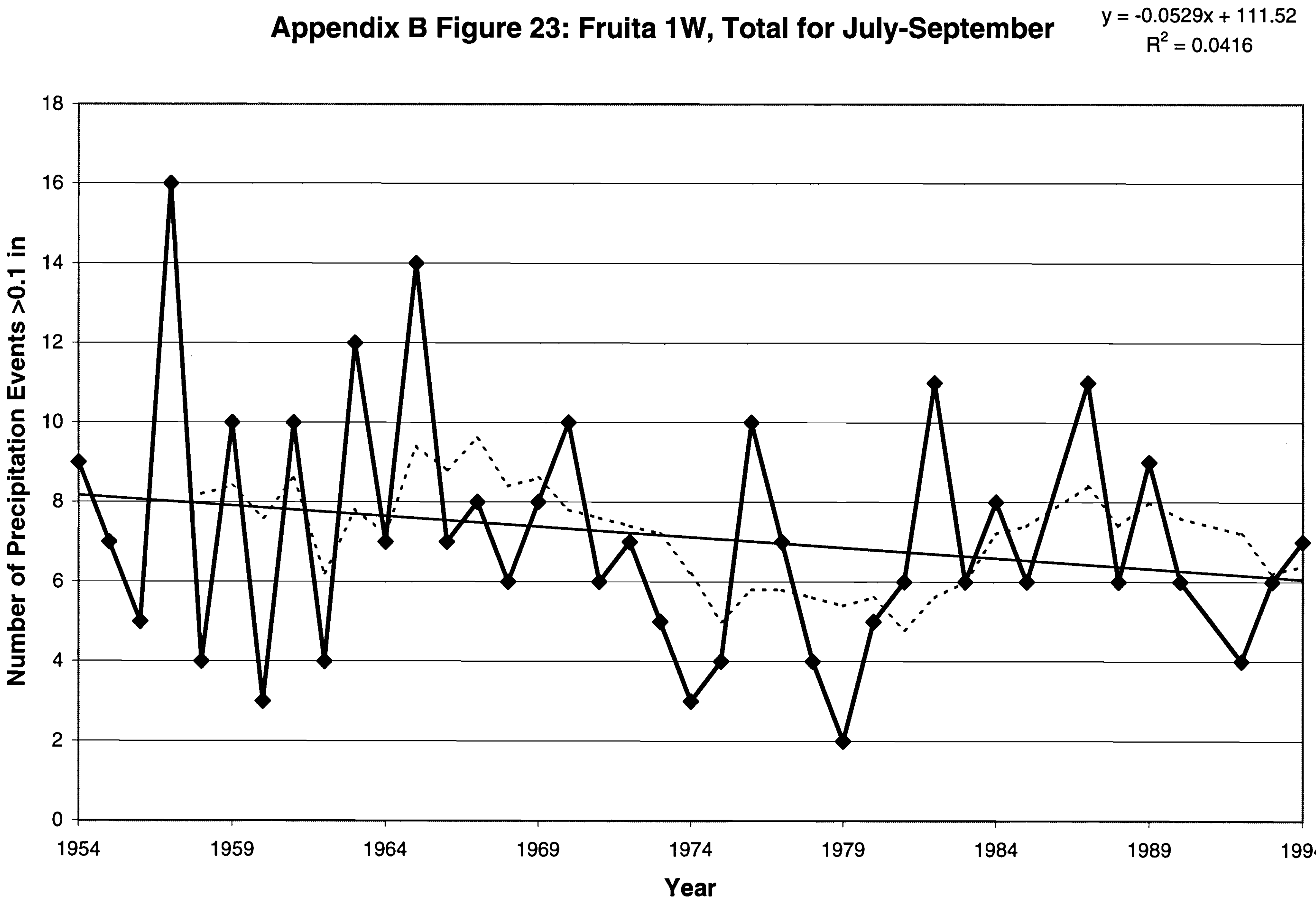
Appendix B Figure 21: Fruita 1W, September

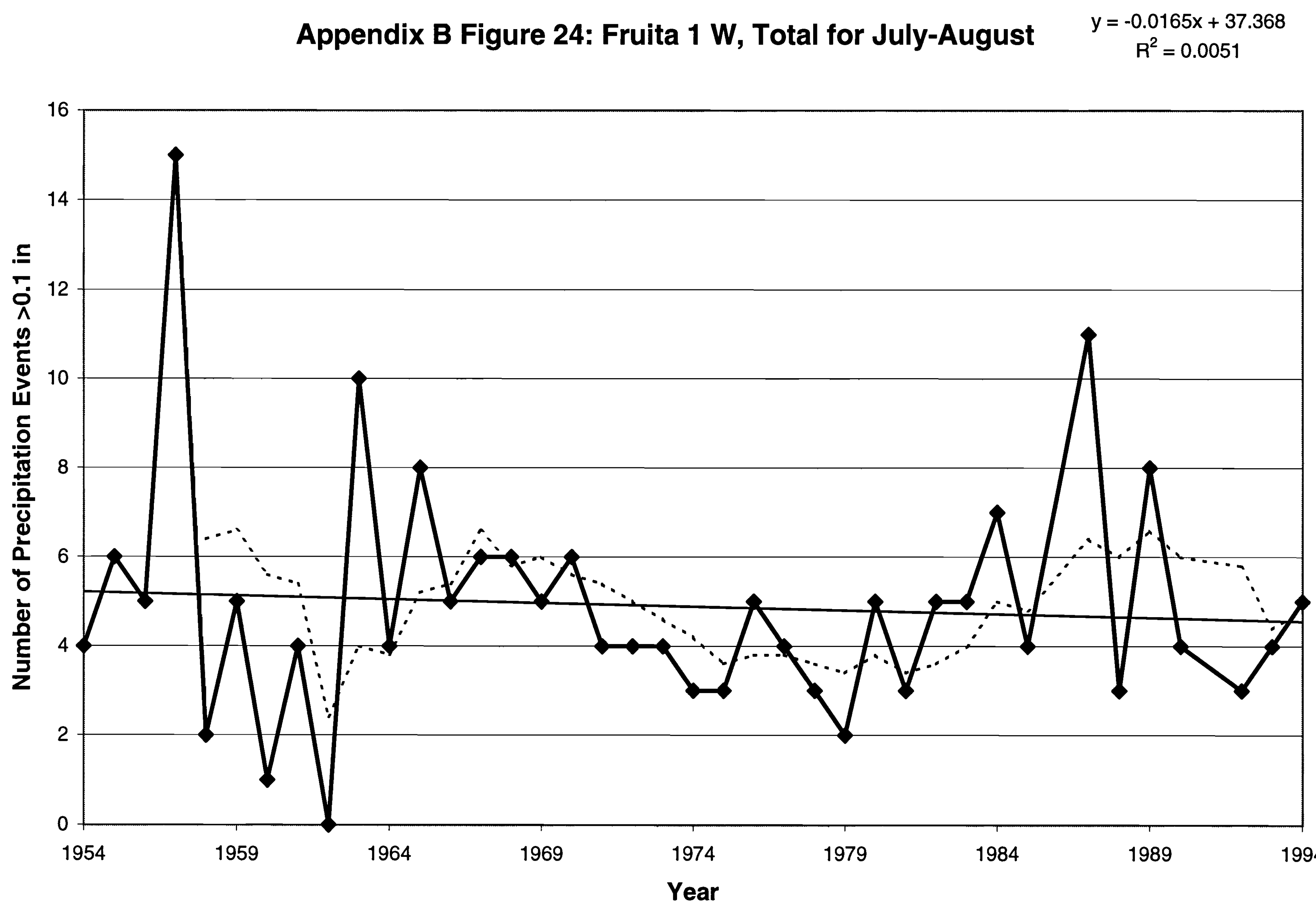


Appendix B Figure 22: Fruita 1W, Total May-September



Appendix B Figure 23: Fruita 1W, Total for July-September



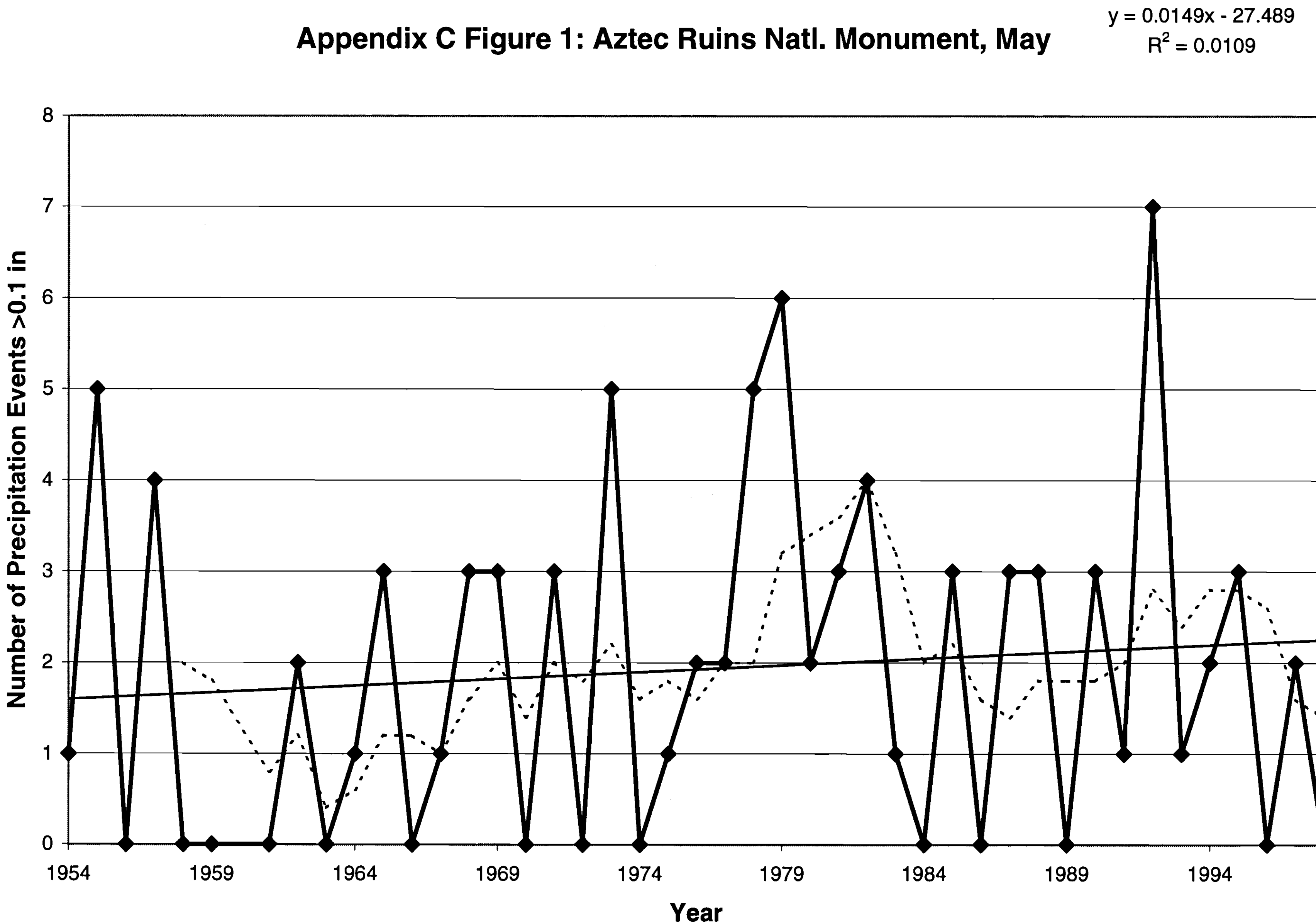


Appendix B Figure 24: Fruita 1 W, Total for July-August
y = -0.0165x + 37.368
R2 = 0.0051
Number of Precipitation Events >0.1 in
Year
0
2
4
6
8
10
12
14
16
1954
1959
1964
1969
1974
1979
1984
1989
1994

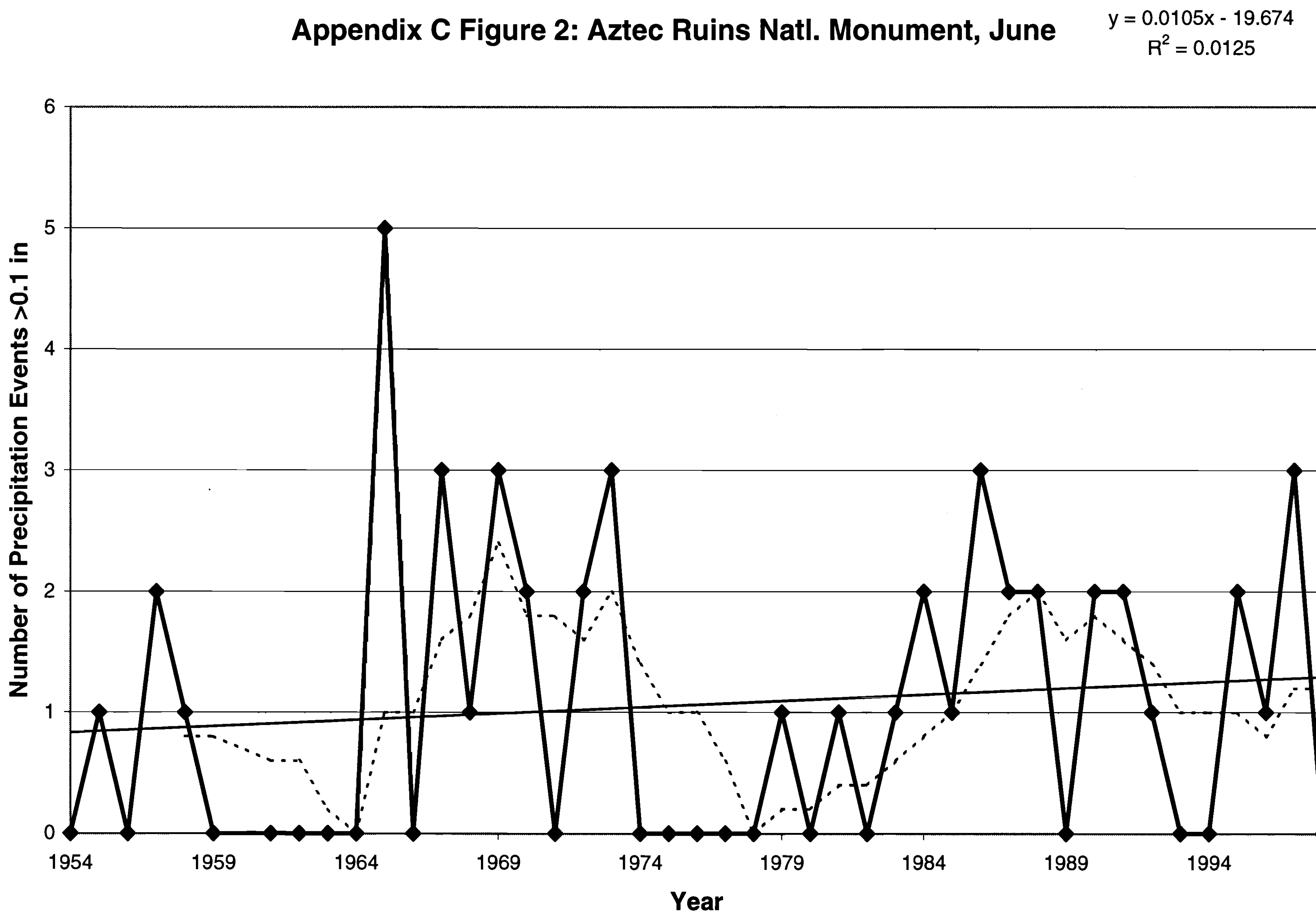
Appendix C Table 1: Number of Precipitation Events >0.1 in, Aztec Ruins Natl. Monument, New Mexico, 1954-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1954	1	0	7	5	6	19	18	12
1955	5	1	3	5	1	15	9	8
1956	0	0	4	2	0	6	6	6
1957	4	2	7	4	0	17	11	11
1958	0	1	2	3	5	11	10	5
1959	0	0	2	6	3	11	11	8
1961	0	0	3	5	3	11	11	8
1962	2	0	1	0	4	7	5	1
1963	0	0	2	6	4	12	12	8
1964	1	0	2	6	6	15	14	8
1965	3	5	5	2	4	19	11	7
1966	0	0	1	6	1	8	8	7
1967	1	3	2	3	3	12	8	5
1968	3	1	4	2	0	10	6	6
1969	3	3	2	4	4	16	10	6
1970	0	2	1	1	6	10	8	2
1971	3	0	2	4	4	13	10	6
1972	0	2	0	3	0	5	3	3
1973	5	3	1	1	3	13	5	2
1974	0	0	4	2	1	7	7	6
1975	1	0	2	0	4	7	6	2
1976	2	0	3	1	3	9	7	4
1977	2	0	7	5	2	16	14	12
1978	5	0	0	1	2	8	3	1
1979	6	1	2	3	0	12	5	5
1980	2	0	2	2	3	9	7	4
1981	3	1	4	0	0	8	4	4
1982	4	0	3	4	4	15	11	7
1983	1	1	4	6	4	16	14	10
1984	0	2	2	2	2	8	6	4
1985	3	1	1	1	5	11	7	2
1986	0	3	7	5	8	23	20	12
1987	3	2	2	7	0	14	9	9
1988	3	2	3	6	0	14	9	9
1989	0	0	5	3	1	9	9	8
1990	3	2	3	7	6	21	16	10
1991	1	2	1	4	3	11	8	5
1992	7	1	3	3	2	16	8	6
1993	1	0	0	7	1	9	8	7
1994	2	0	1	1	4	8	6	2
1995	3	2	1	2	3	11	6	3
1996	0	1	0	2	4	7	6	2
1997	2	3	2	6	5	18	13	8
1998	0	0	8	3	2	13	13	11
Ave.	**1.93**	**1.07**	**2.75**	**3.43**	**2.86**	**12.05**	**9.05**	**6.18**
S.D.	**1.86**	**1.23**	**2.05**	**2.08**	**2.04**	**4.25**	**3.80**	**3.13**
Max	**7**	**5**	**8**	**7**	**8**	**23**	**20**	**12**
Min	**0**	**0**	**0**	**0**	**0**	**5**	**3**	**1**

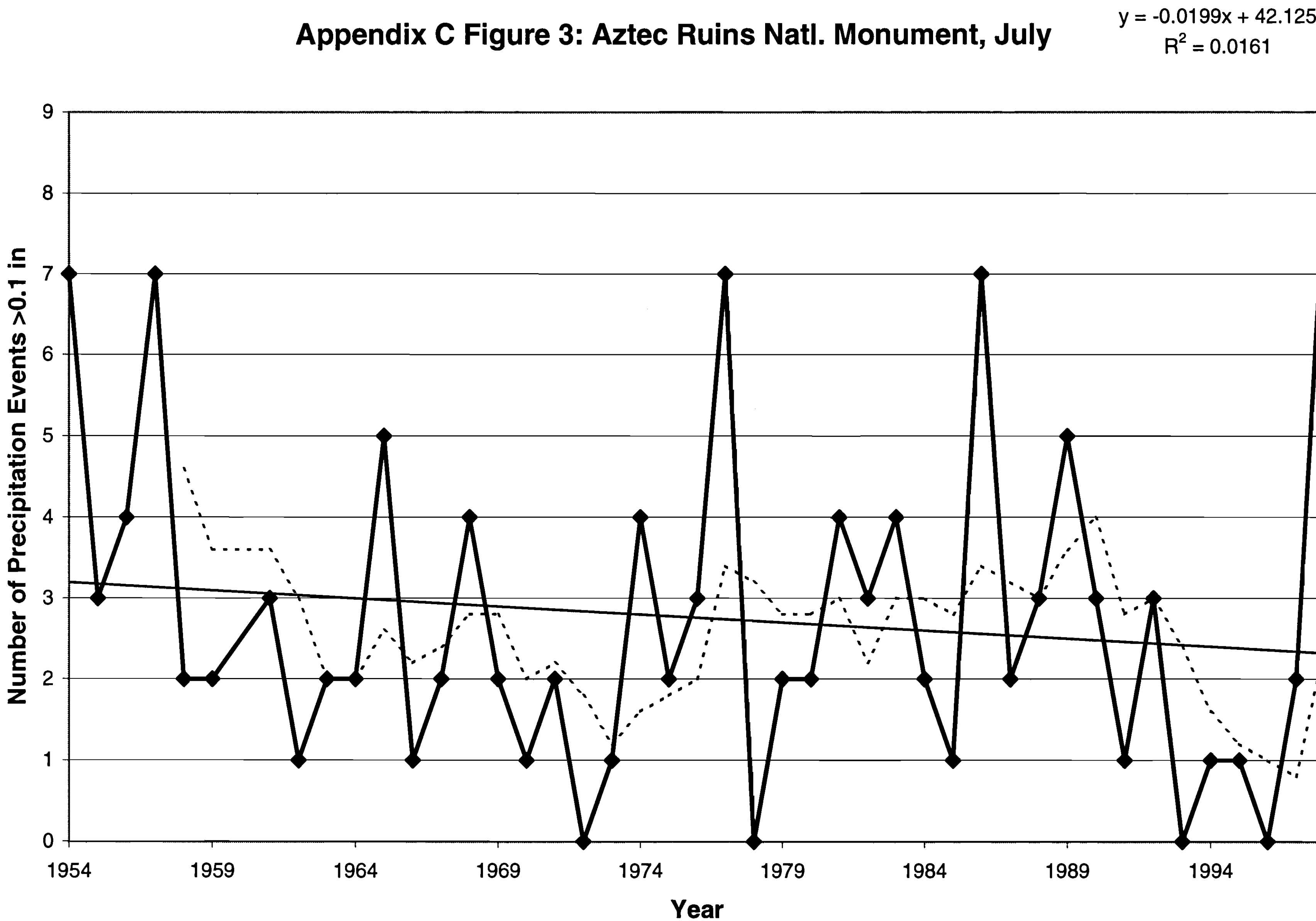
Appendix C Figure 1: Aztec Ruins Natl. Monument, May



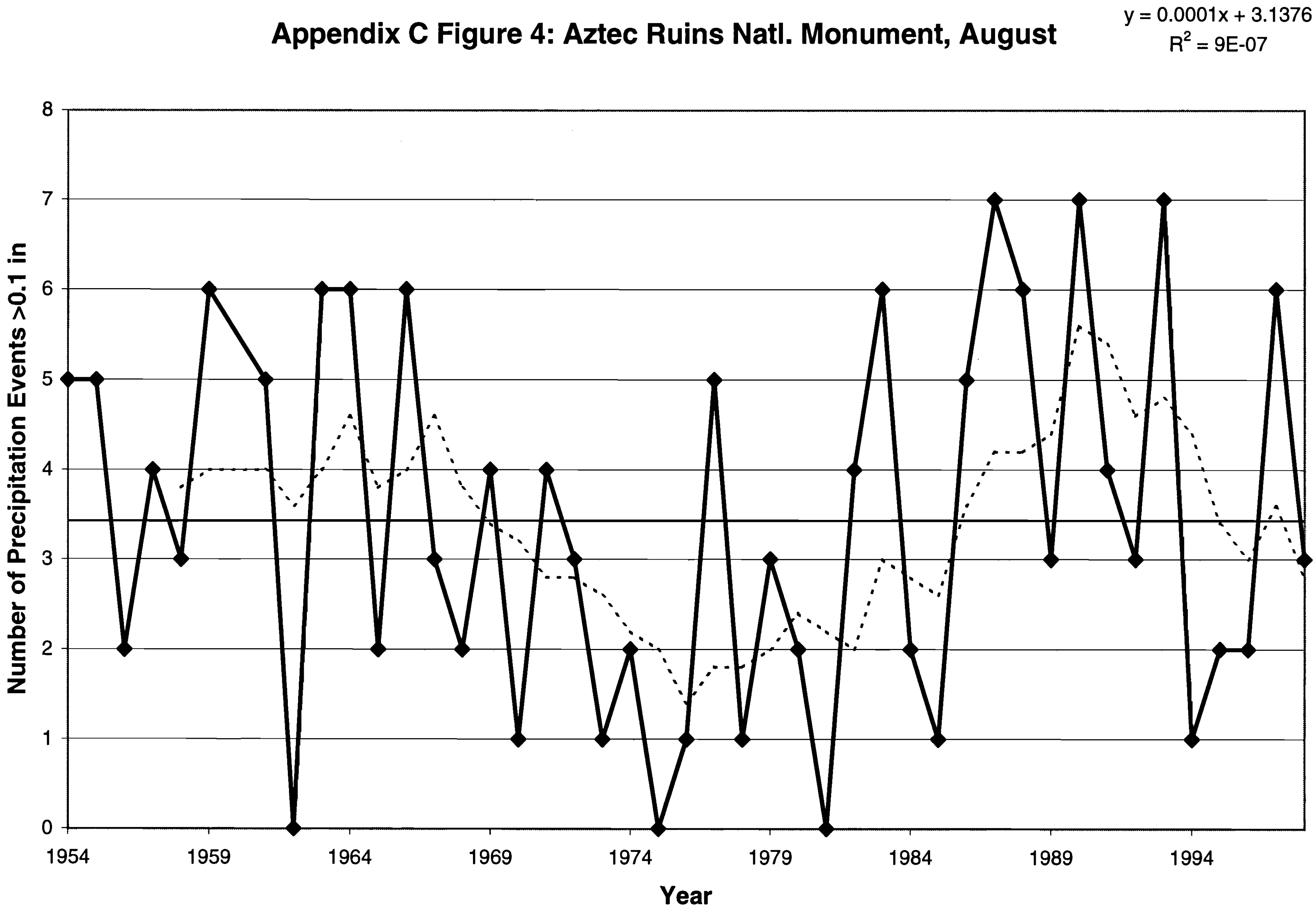
Appendix C Figure 2: Aztec Ruins Natl. Monument, June



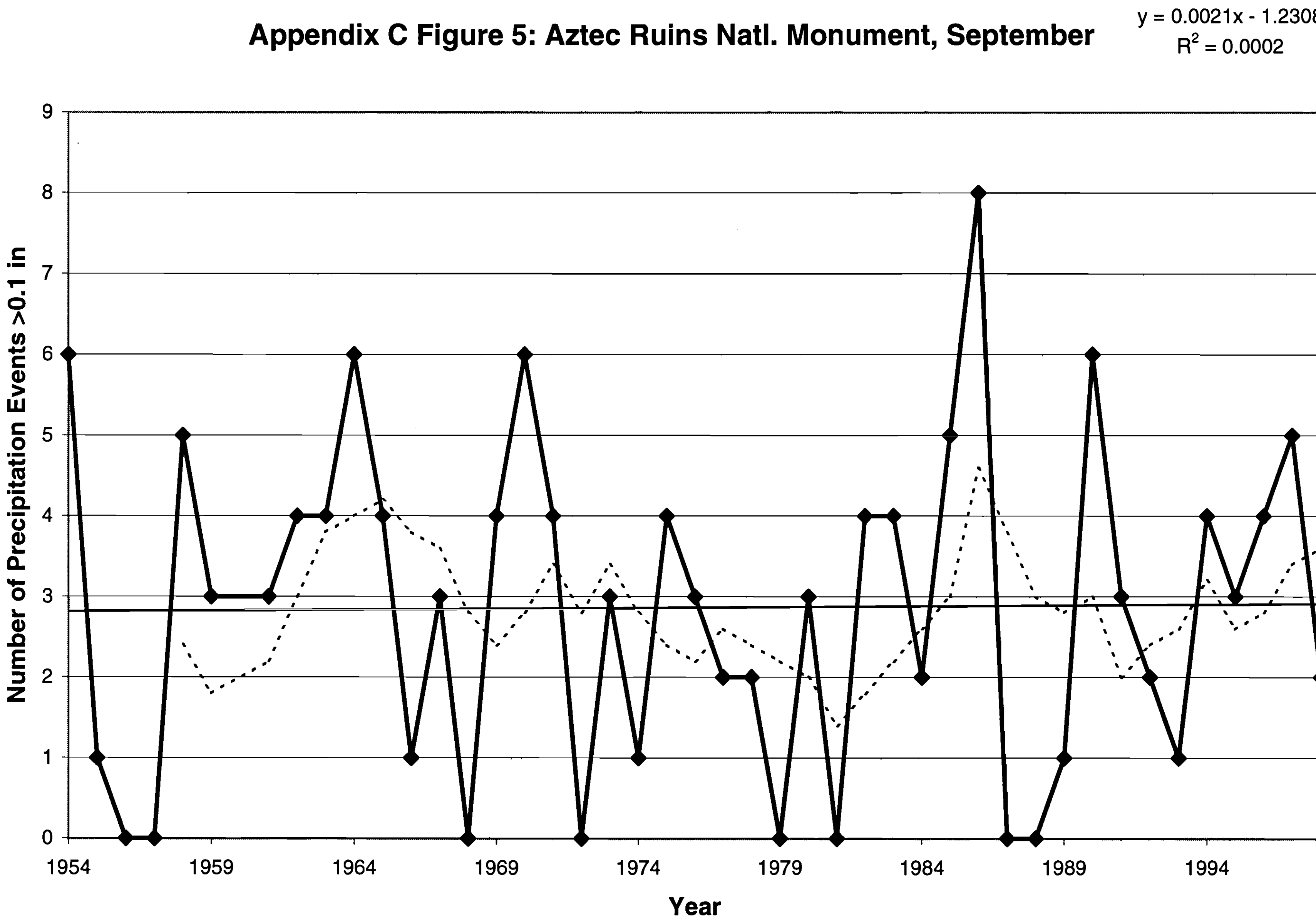
Appendix C Figure 3: Aztec Ruins Natl. Monument, July



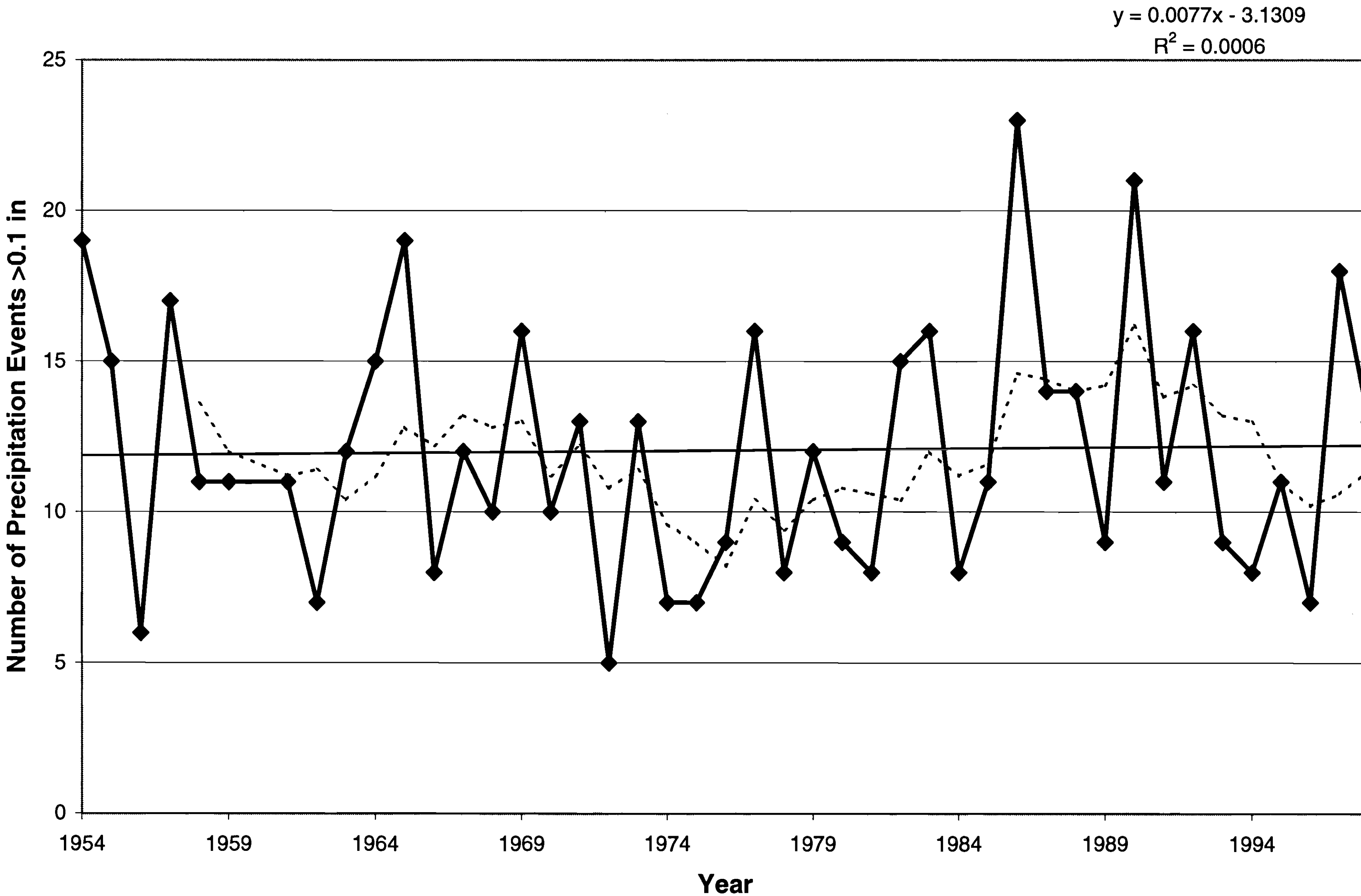
Appendix C Figure 4: Aztec Ruins Natl. Monument, August



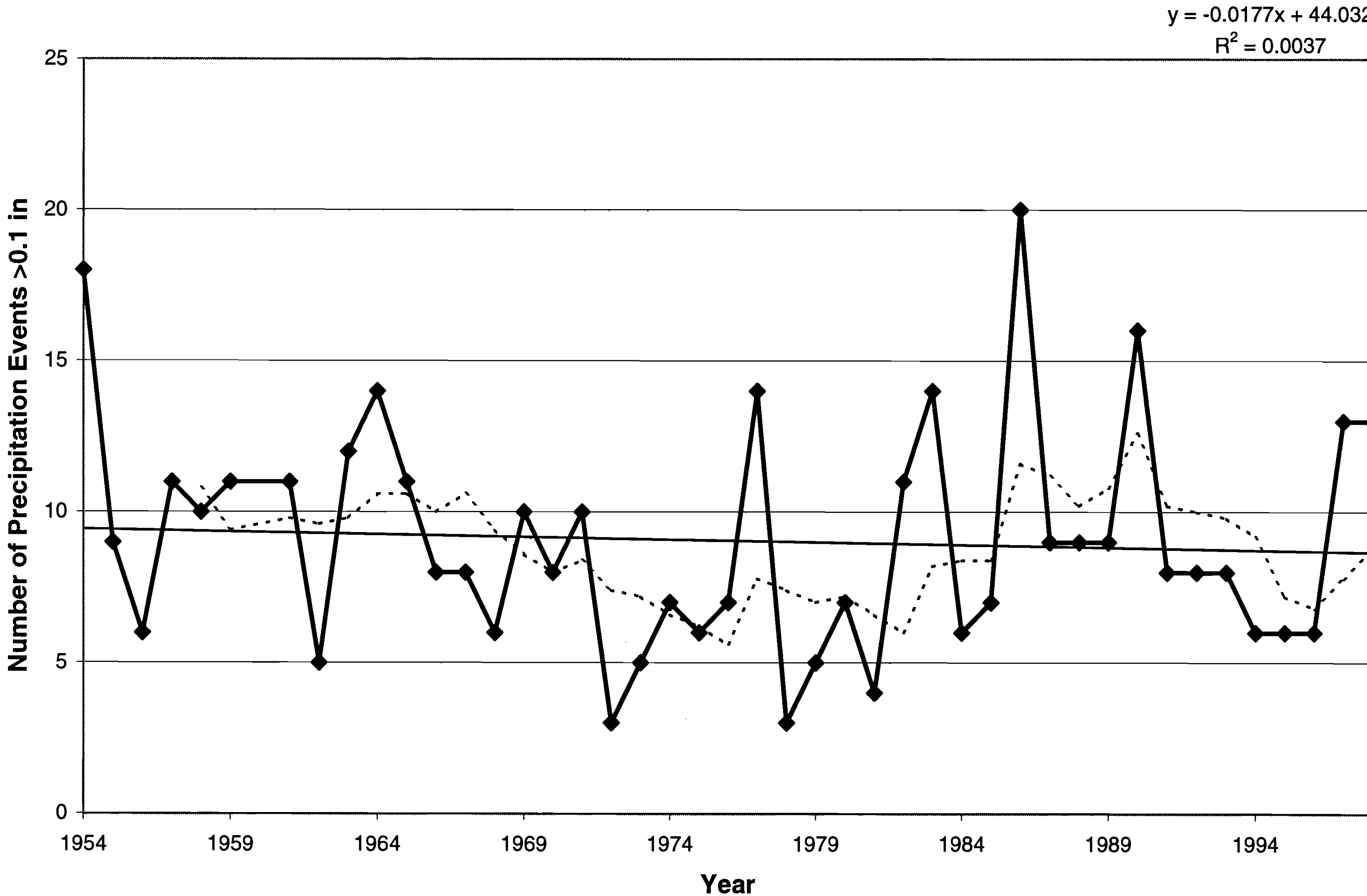
Appendix C Figure 5: Aztec Ruins Natl. Monument, September



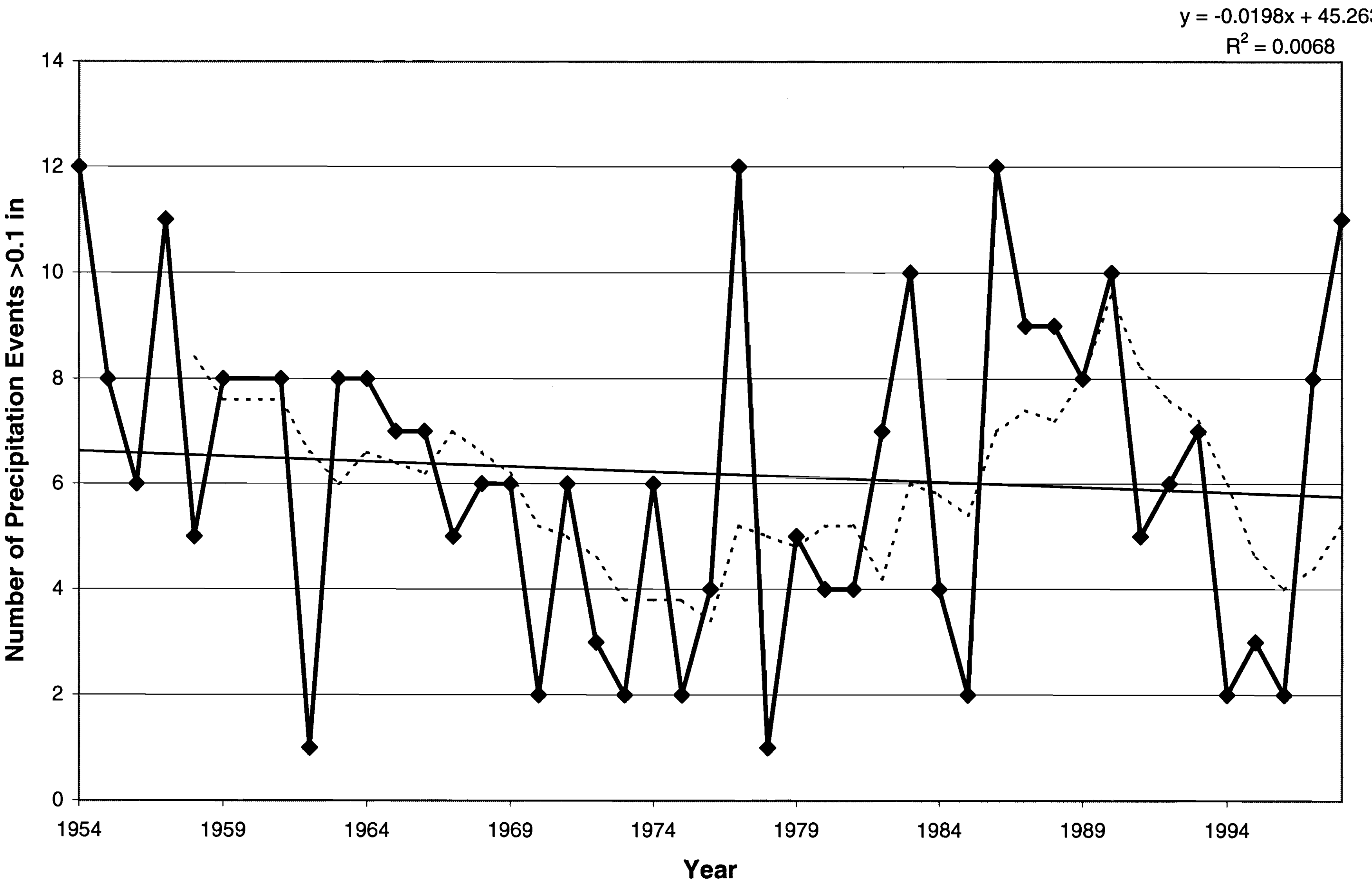
Appendix C Figure 6: Aztec Ruins Natl. Monument, Total May-September



Appendix C Figure 7: Aztec Ruins Natl Monument, Total for July-September

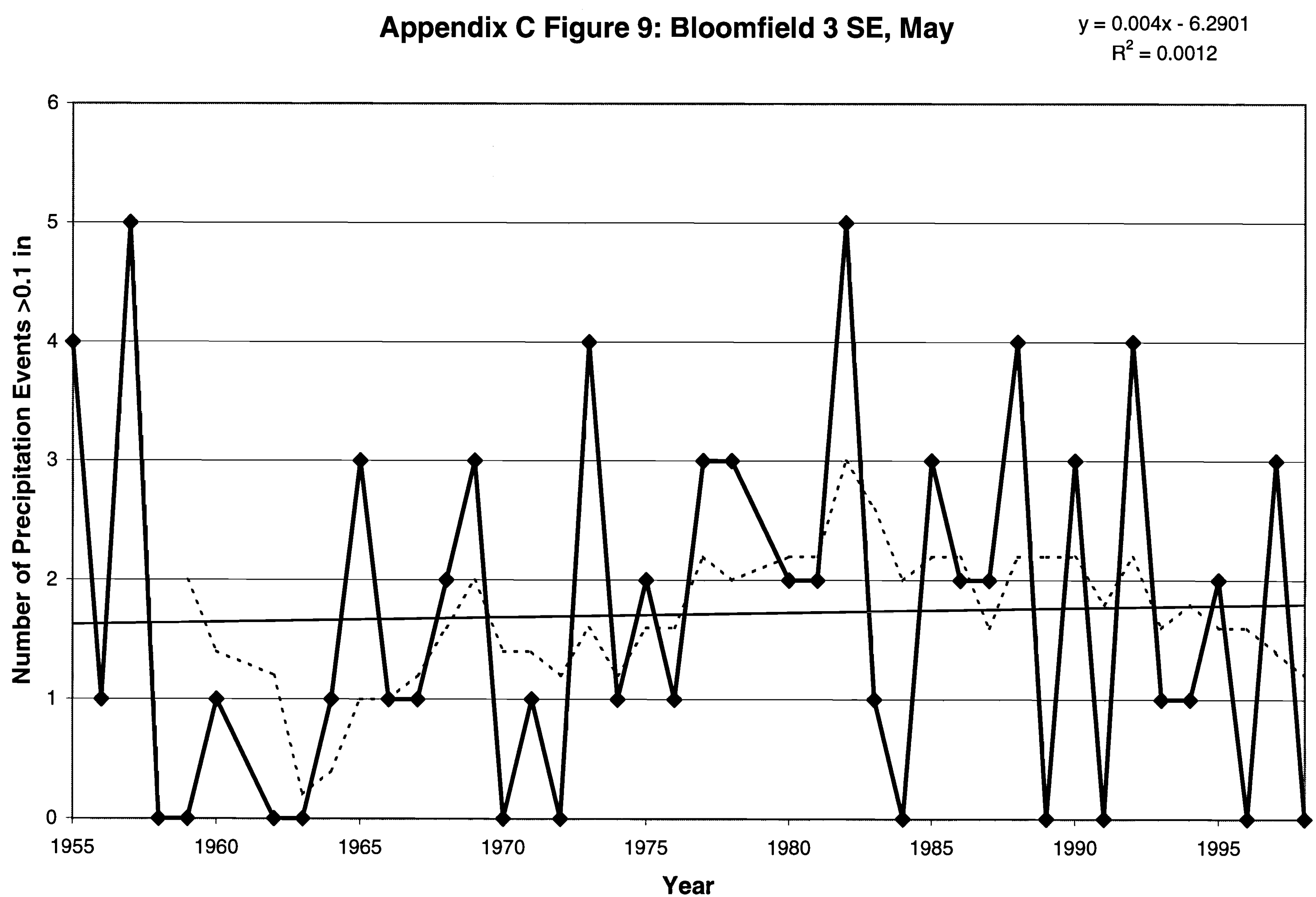


Appendix C Figure 8: Aztec Ruins Natl Monument, Total for July-August

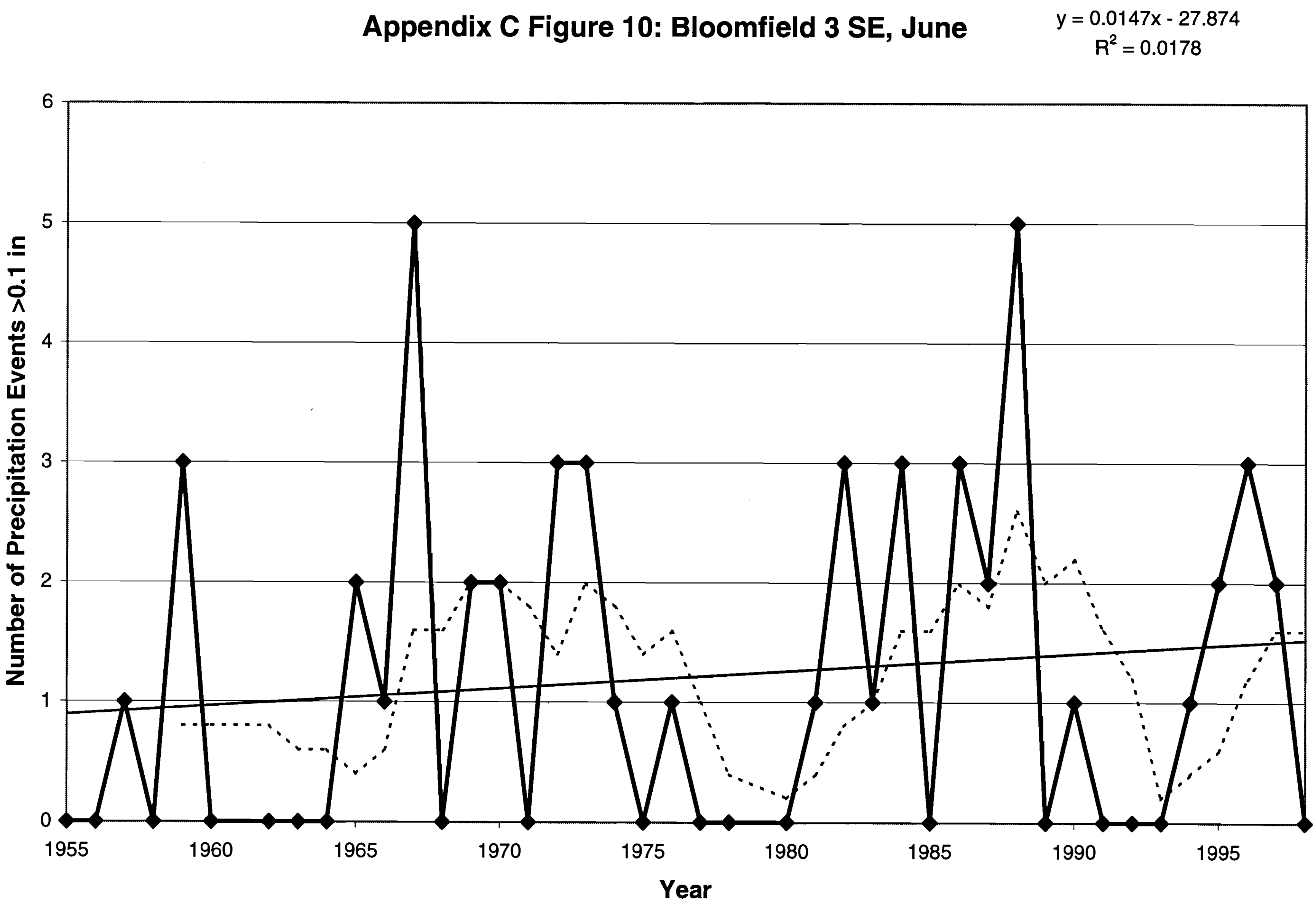


Appendix C Table 2: Number of Precipitation Events >0.1 in, Bloomfield, New Mexico, 1955-1998

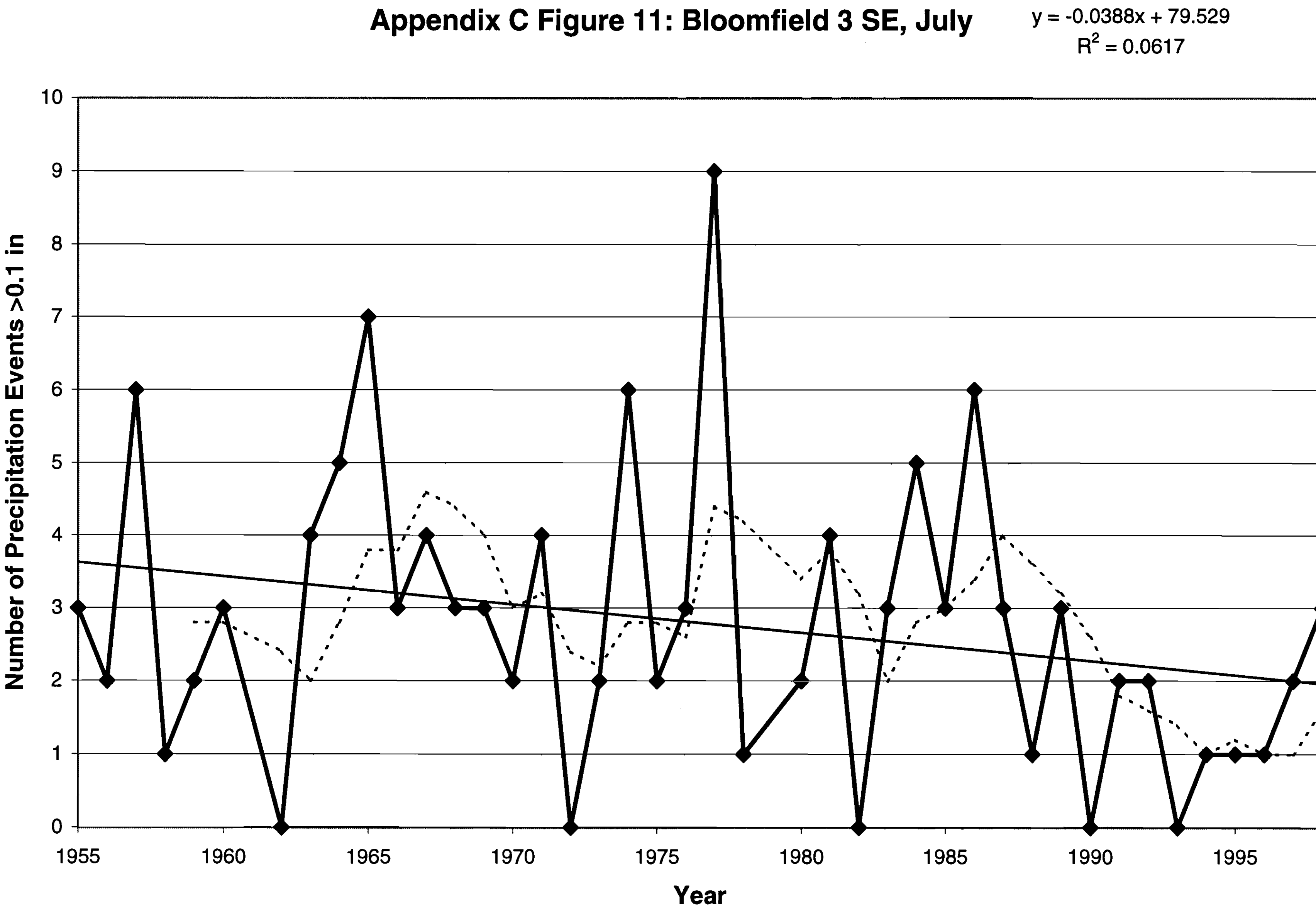
	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1955	4	0	3	2	0	9	5	5
1956	1	0	2	2	0	5	4	4
1957	5	1	6	8	0	20	14	14
1958	0	0	1	5	2	8	8	6
1959	0	3	2	5	2	12	9	7
1960	1	0	3	0	0	4	3	3
1962	0	0	0	0	3	3	3	0
1963	0	0	4	7	3	14	14	11
1964	1	0	5	5	4	15	14	10
1965	3	2	7	3	6	21	16	10
1966	1	1	3	5	3	13	11	8
1967	1	5	4	6	4	20	14	10
1968	2	0	3	1	0	6	4	4
1969	3	2	3	3	4	15	10	6
1970	0	2	2	2	5	11	9	4
1971	1	0	4	7	3	15	14	11
1972	0	3	0	6	1	10	7	6
1973	4	3	2	2	3	14	7	4
1974	1	1	6	1	1	10	8	7
1975	2	0	2	1	4	9	7	3
1976	1	1	3	2	6	13	11	5
1977	3	0	9	4	2	18	15	13
1978	3	0	1	1	2	7	4	2
1980	2	0	2	3	4	11	9	5
1981	2	1	4	1	2	10	7	5
1982	5	3	0	9	4	21	13	9
1983	1	1	3	1	3	9	7	4
1984	0	3	5	7	3	18	15	12
1985	3	0	3	0	4	10	7	3
1986	2	3	6	5	3	19	14	11
1987	2	2	3	2	0	9	5	5
1988	4	5	1	7	2	19	10	8
1989	0	0	3	3	1	7	7	6
1990	3	1	0	4	5	13	9	4
1991	0	0	2	3	0	5	5	5
1992	4	0	2	4	1	11	7	6
1993	1	0	0	2	1	4	3	2
1994	1	1	1	1	2	6	4	2
1995	2	2	1	3	2	10	6	4
1996	0	3	1	2	4	10	7	3
1997	3	2	2	4	1	12	7	6
1998	0	0	3	4	1	8	8	7
Ave.	**1.71**	**1.21**	**2.79**	**3.40**	**2.40**	**11.52**	**8.60**	**6.19**
S.D.	**1.50**	**1.42**	**2.02**	**2.34**	**1.70**	**4.97**	**3.82**	**3.29**
Max	**5**	**5**	**9**	**9**	**6**	**21**	**16**	**14**
Min	**0**	**0**	**0**	**0**	**0**	**3**	**3**	**0**

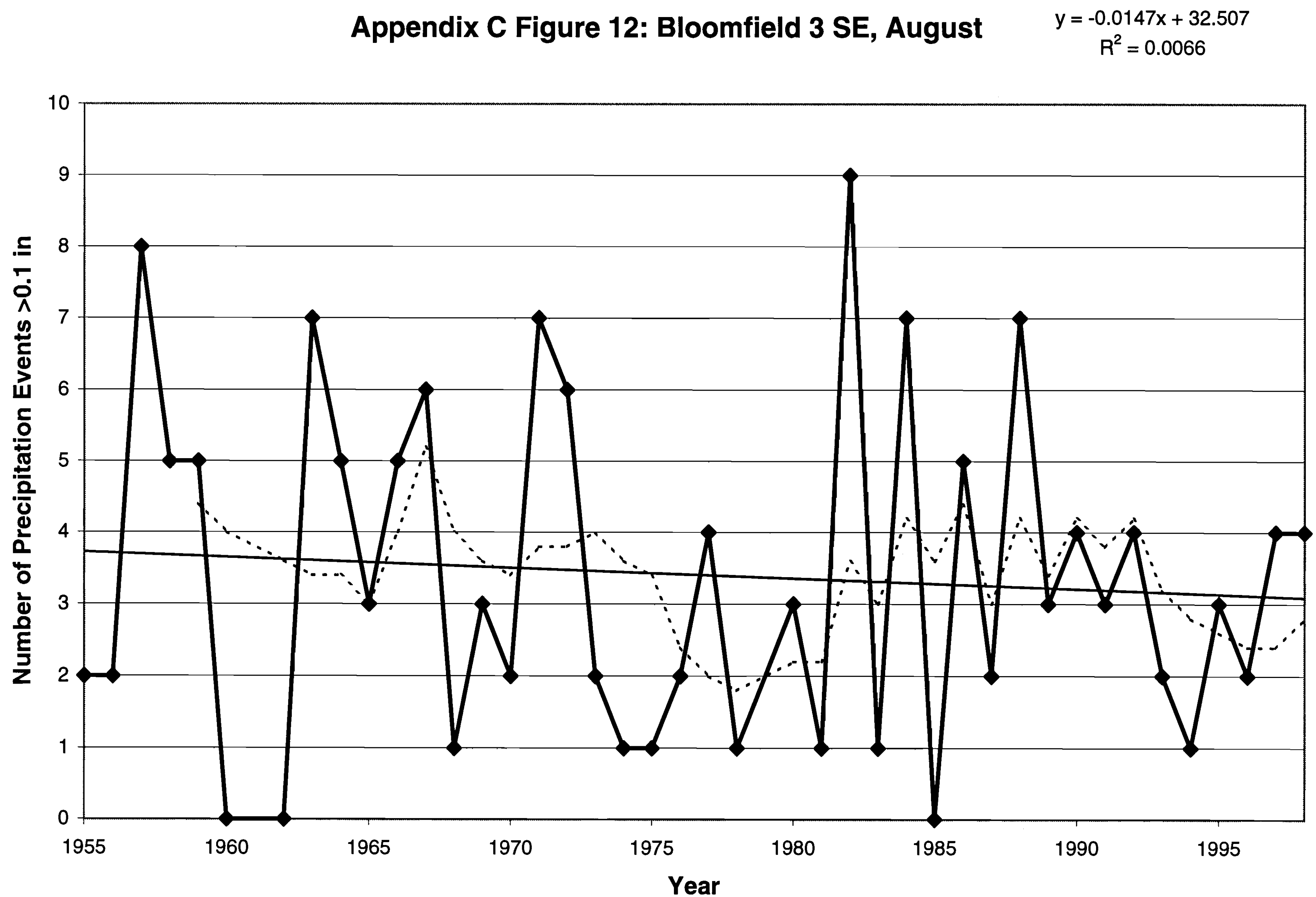

Appendix C Figure 9: Bloomfield 3 SE, May
y = 0.004x - 6.2901
R^2 = 0.0012
Number of Precipitation Events >0.1 in
0
1
2
3
4
5
6
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

Appendix C Figure 10: Bloomfield 3 SE, June

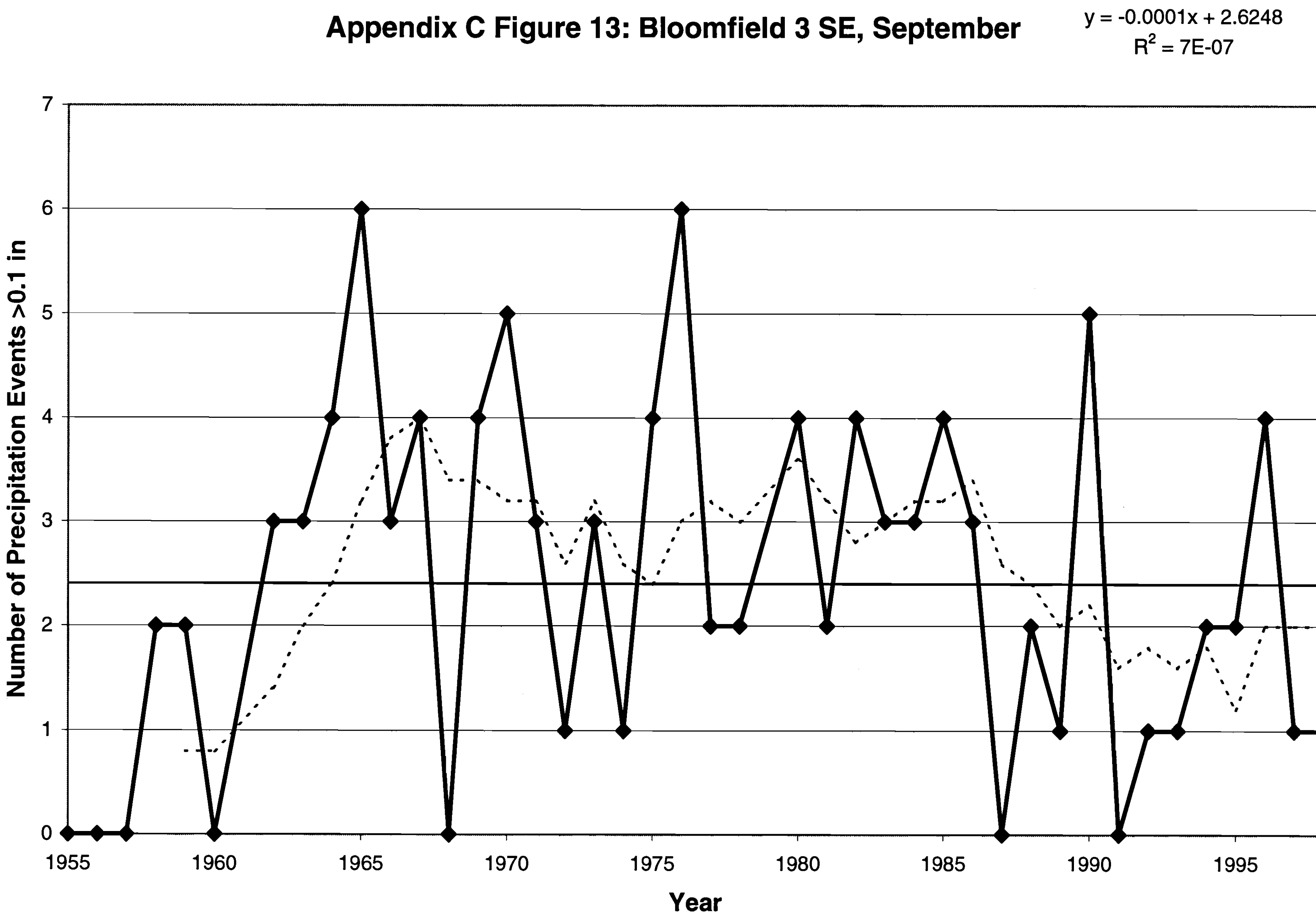


Appendix C Figure 11: Bloomfield 3 SE, July

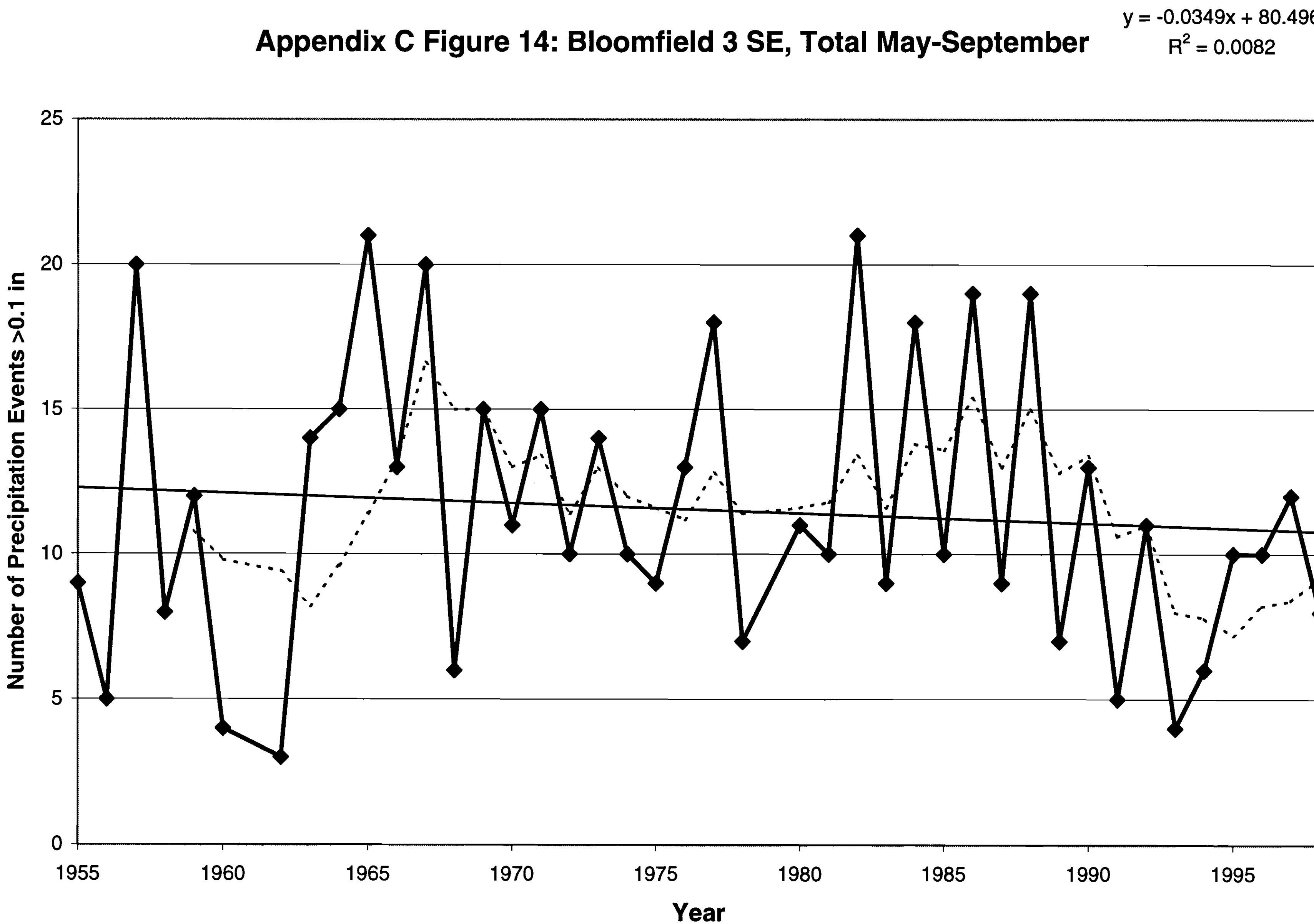



Appendix C Figure 12: Bloomfield 3 SE, August
y = -0.0147x + 32.507
R2 = 0.0066
Number of Precipitation Events >0.1 in
10
9
8
7
6
5
4
3
2
1
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

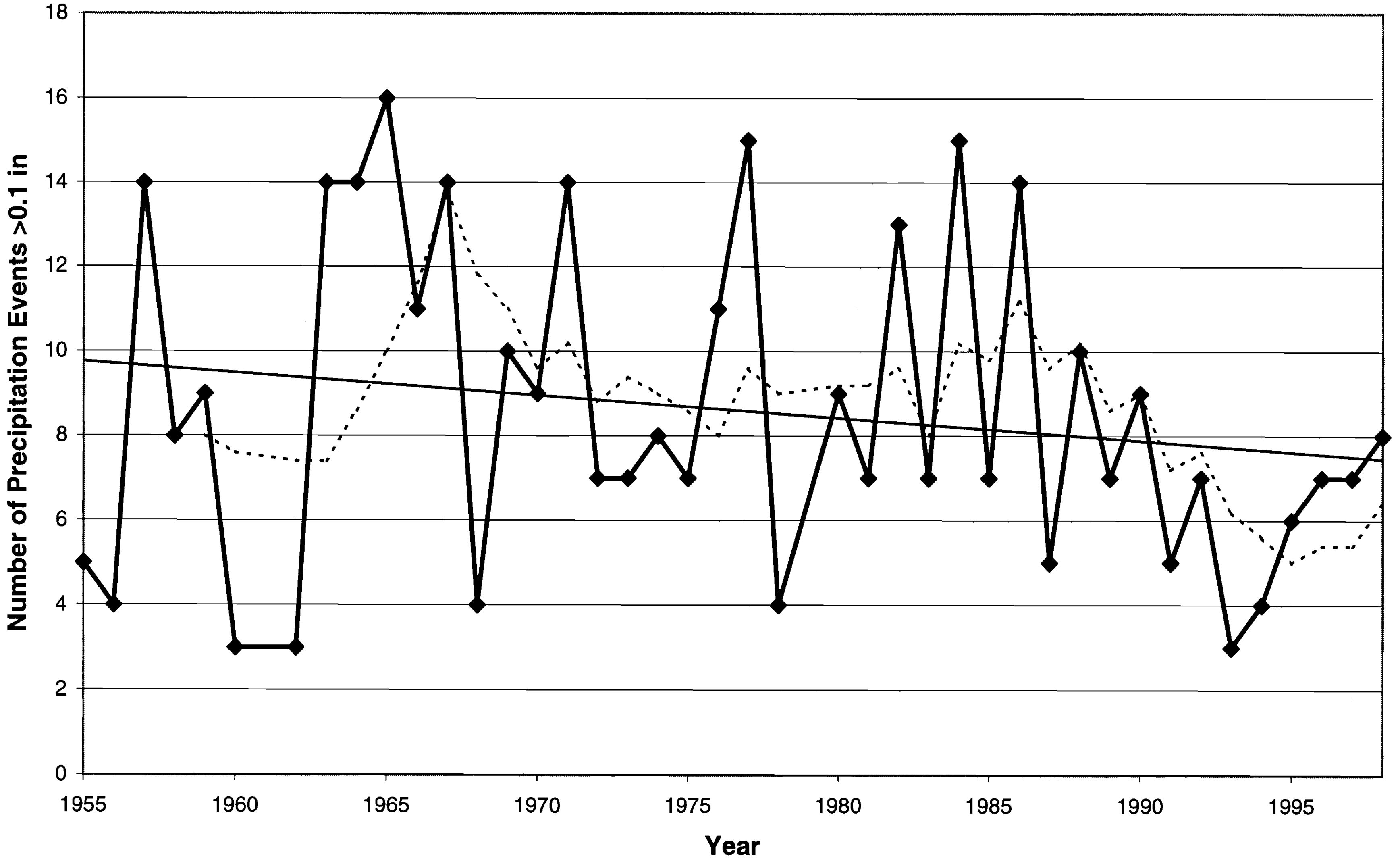
Appendix C Figure 13: Bloomfield 3 SE, September

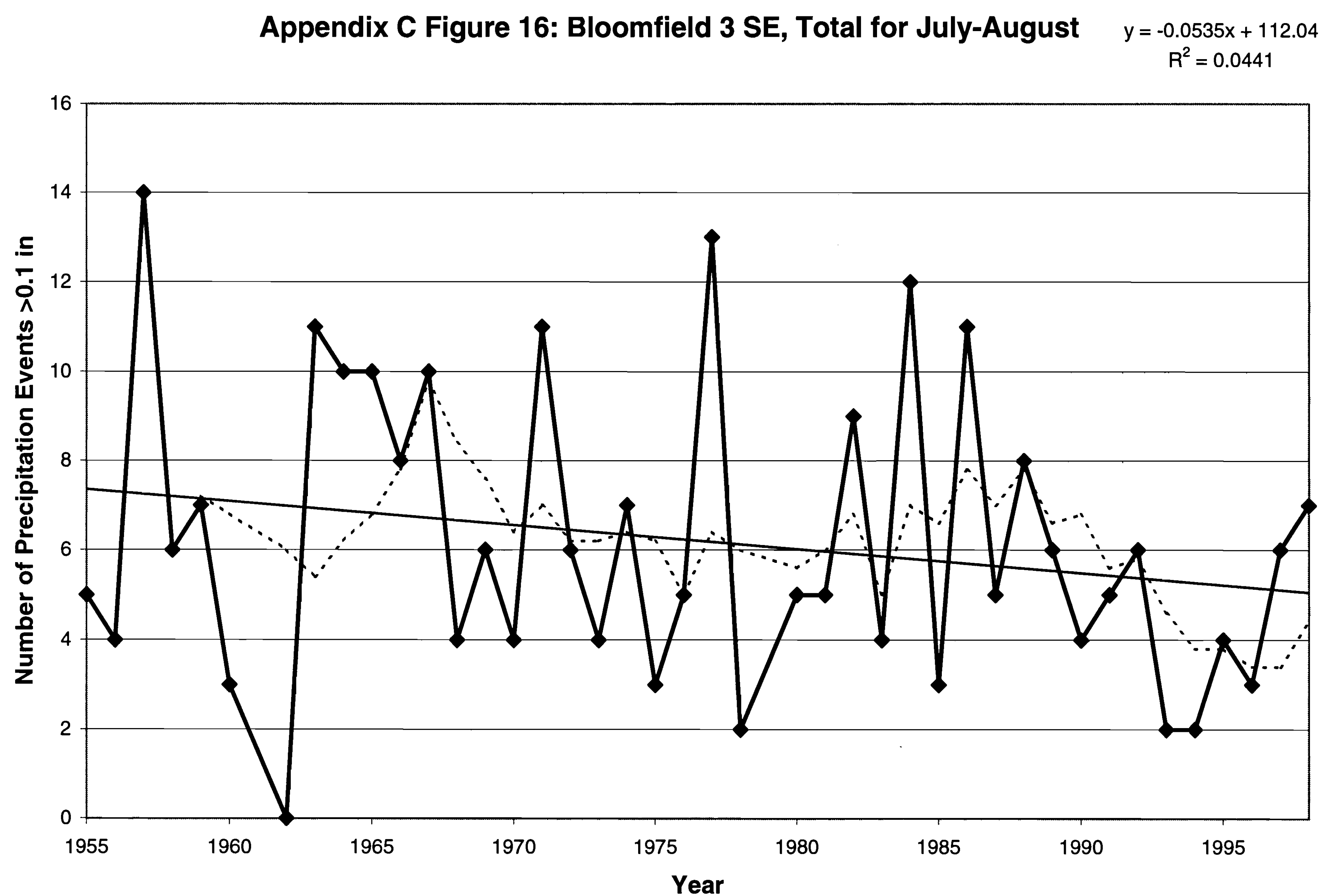


Appendix C Figure 14: Bloomfield 3 SE, Total May-September



Appendix C Figure 15: Bloomfield 3 SE, Total for July-September



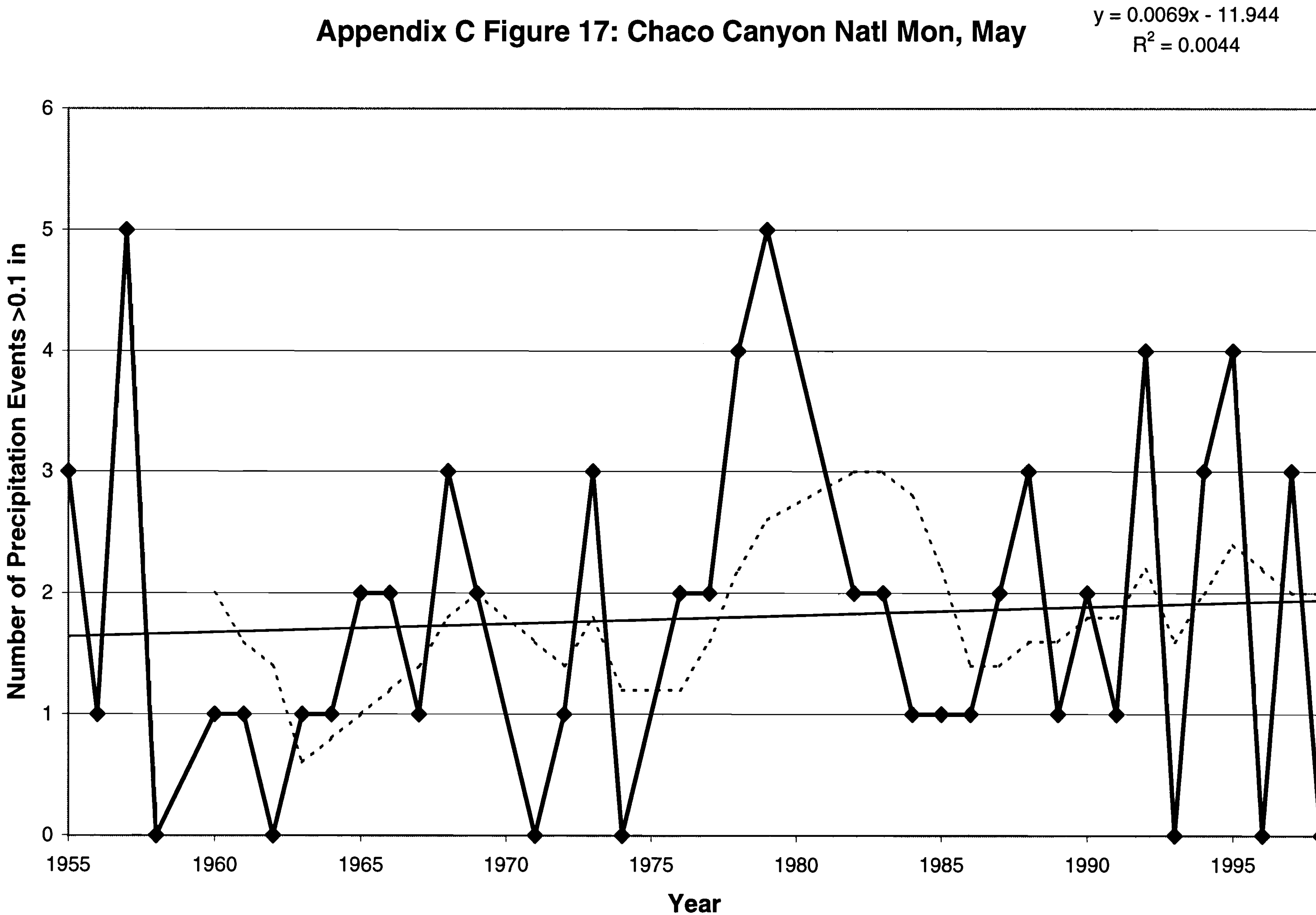


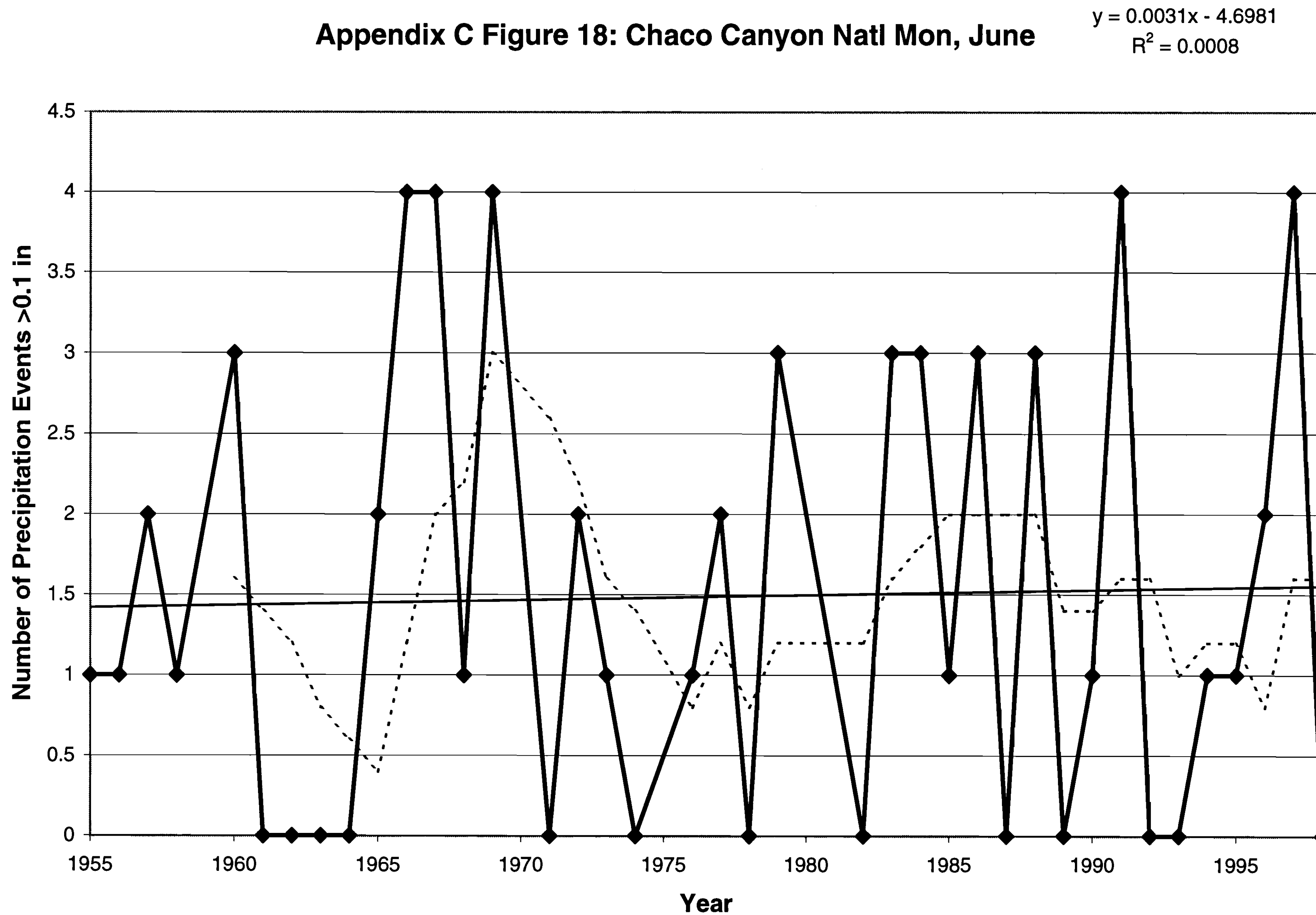
Appendix C Figure 16: Bloomfield 3 SE, Total for July-August
y = -0.0535x + 112.04
R2 = 0.0441
Number of Precipitation Events >0.1 in
Year
0
2
4
6
8
10
12
14
16
1955
1960
1965
1970
1975
1980
1985
1990
1995

Appendix C Table 3: Number of Precipitation Events >0.1 in, Chaco Canyon Natl Mon, New Mexico, 1955-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1955	3	1	2	8	0	14	10	10
1956	1	1	1	2	0	5	3	3
1957	5	2	3	9	0	19	12	12
1958	0	1	2	5	5	13	12	7
1960	1	3	4	1	2	11	7	5
1961	1	0	3	7	4	15	14	10
1962	0	0	2	2	5	9	9	4
1963	1	0	1	5	5	12	11	6
1964	1	0	3	5	2	11	10	8
1965	2	2	5	5	5	19	15	10
1966	2	4	3	5	4	18	12	8
1967	1	4	9	5	4	23	18	14
1968	3	1	4	4	0	12	8	8
1969	2	4	6	5	7	24	18	11
1971	0	0	5	7	5	17	17	12
1972	1	2	1	4	4	12	9	5
1973	3	1	6	2	2	14	10	8
1974	0	0	5	3	2	10	10	8
1976	2	1	3	4	3	13	10	7
1977	2	2	2	4	4	14	10	6
1978	4	0	1	4	4	13	9	5
1979	5	3	3	5	0	16	8	8
1982	2	0	1	4	4	11	9	5
1983	2	3	2	2	3	12	7	4
1984	1	3	4	5	4	17	13	9
1985	1	1	7	2	5	16	14	9
1986	1	3	7	4	6	21	17	11
1987	2	0	3	1	2	8	6	4
1988	3	3	1	8	1	16	10	9
1989	1	0	6	3	1	11	10	9
1990	2	1	5	1	3	12	9	6
1991	1	4	4	5	3	17	12	9
1992	4	0	4	3	2	13	9	7
1993	0	0	0	7	2	9	9	7
1994	3	1	3	2	4	13	9	5
1995	4	1	0	3	4	12	7	3
1996	0	2	2	4	6	14	12	6
1997	3	4	3	8	3	21	14	11
1998	0	0	6	6	3	15	15	12
Ave.	**1.79**	**1.49**	**3.38**	**4.33**	**3.15**	**14.15**	**10.87**	**7.72**
S.D.	**1.40**	**1.43**	**2.10**	**2.08**	**1.83**	**4.08**	**3.37**	**2.75**
Max	**5**	**4**	**9**	**9**	**7**	**24**	**18**	**14**
Min	**0**	**0**	**0**	**1**	**0**	**5**	**3**	**3**

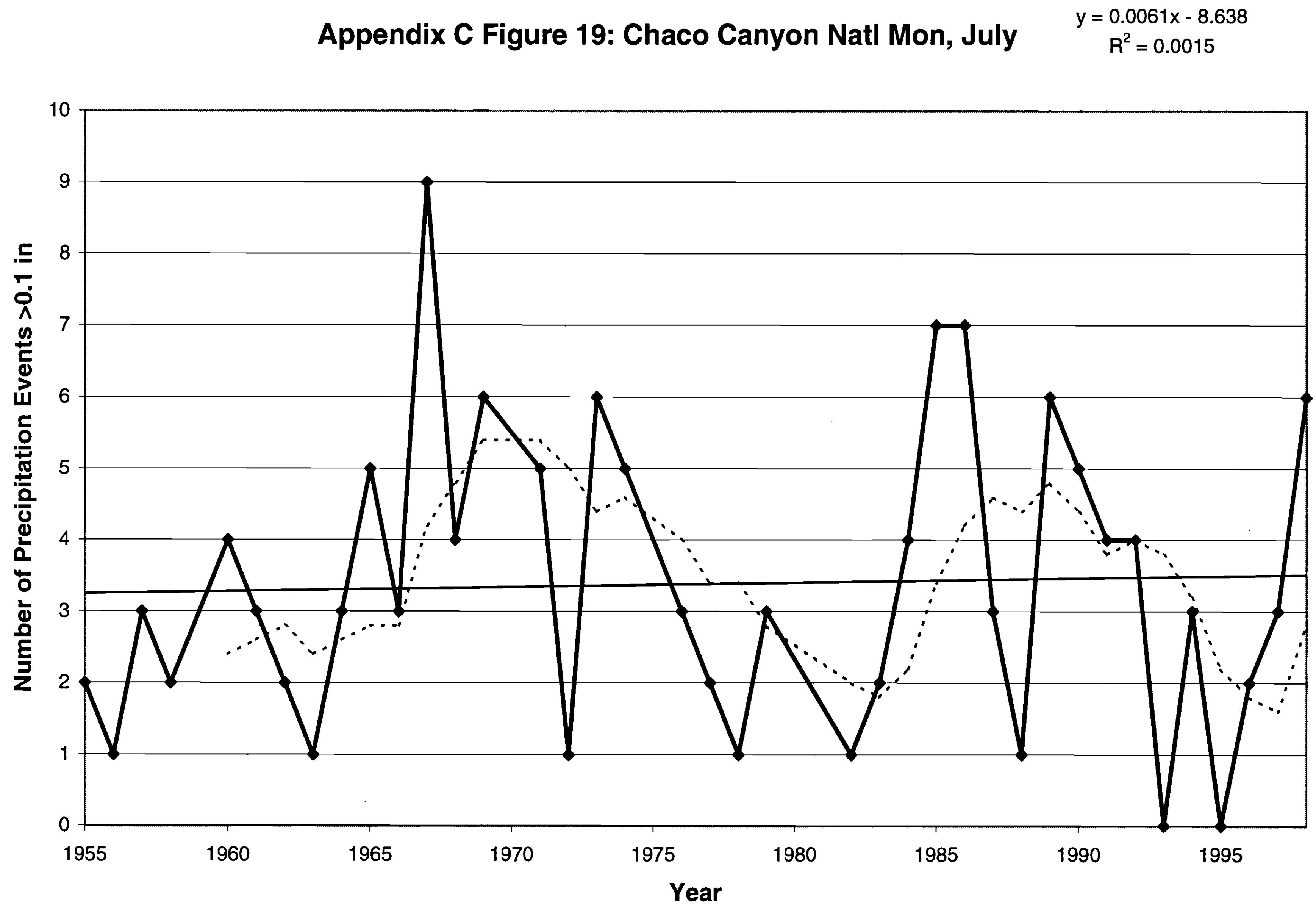
Appendix C Figure 17: Chaco Canyon Natl Mon, May



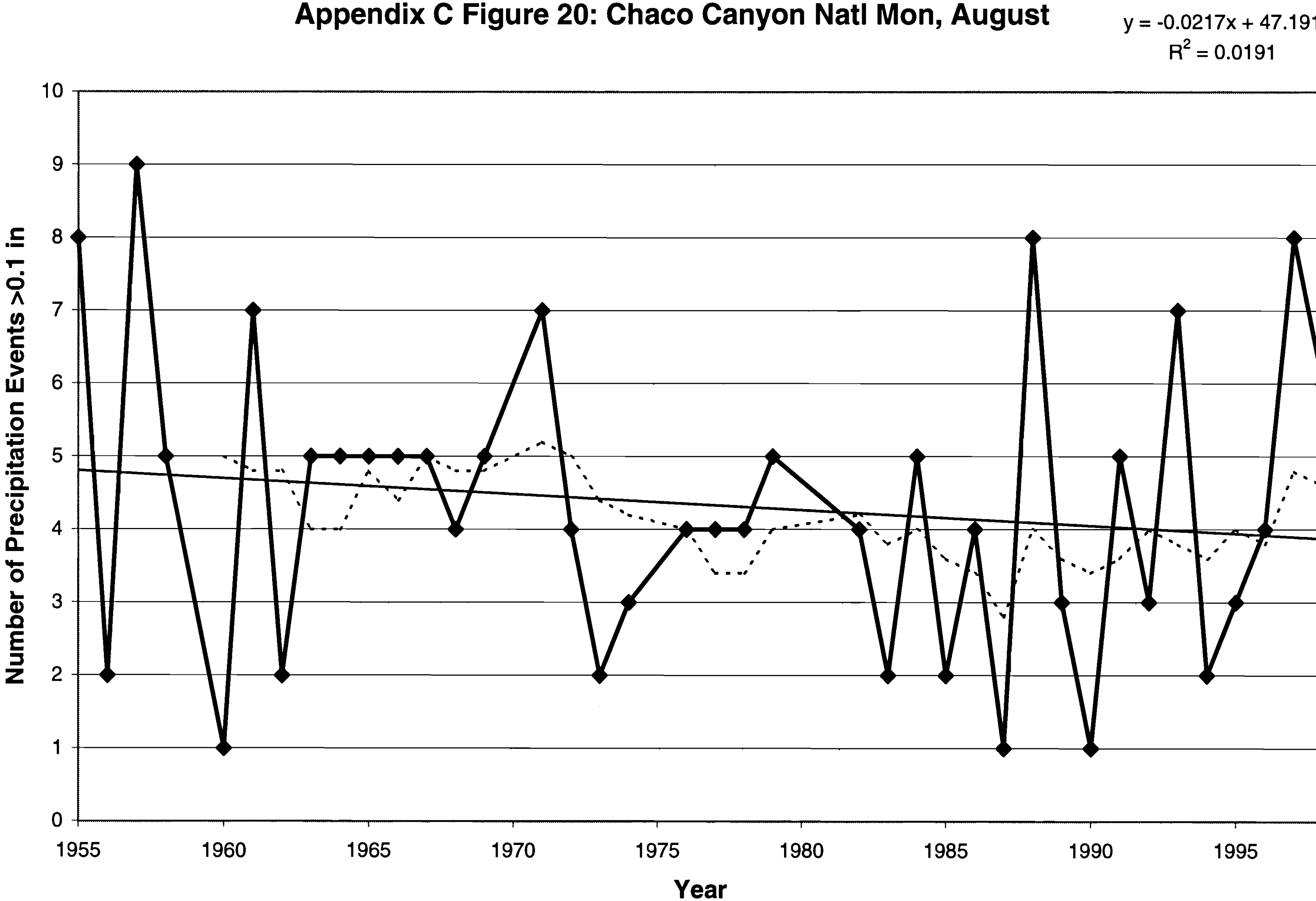


Appendix C Figure 18: Chaco Canyon Natl Mon, June
y = 0.0031x - 4.6981
R2 = 0.0008
Number of Precipitation Events >0.1 in
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

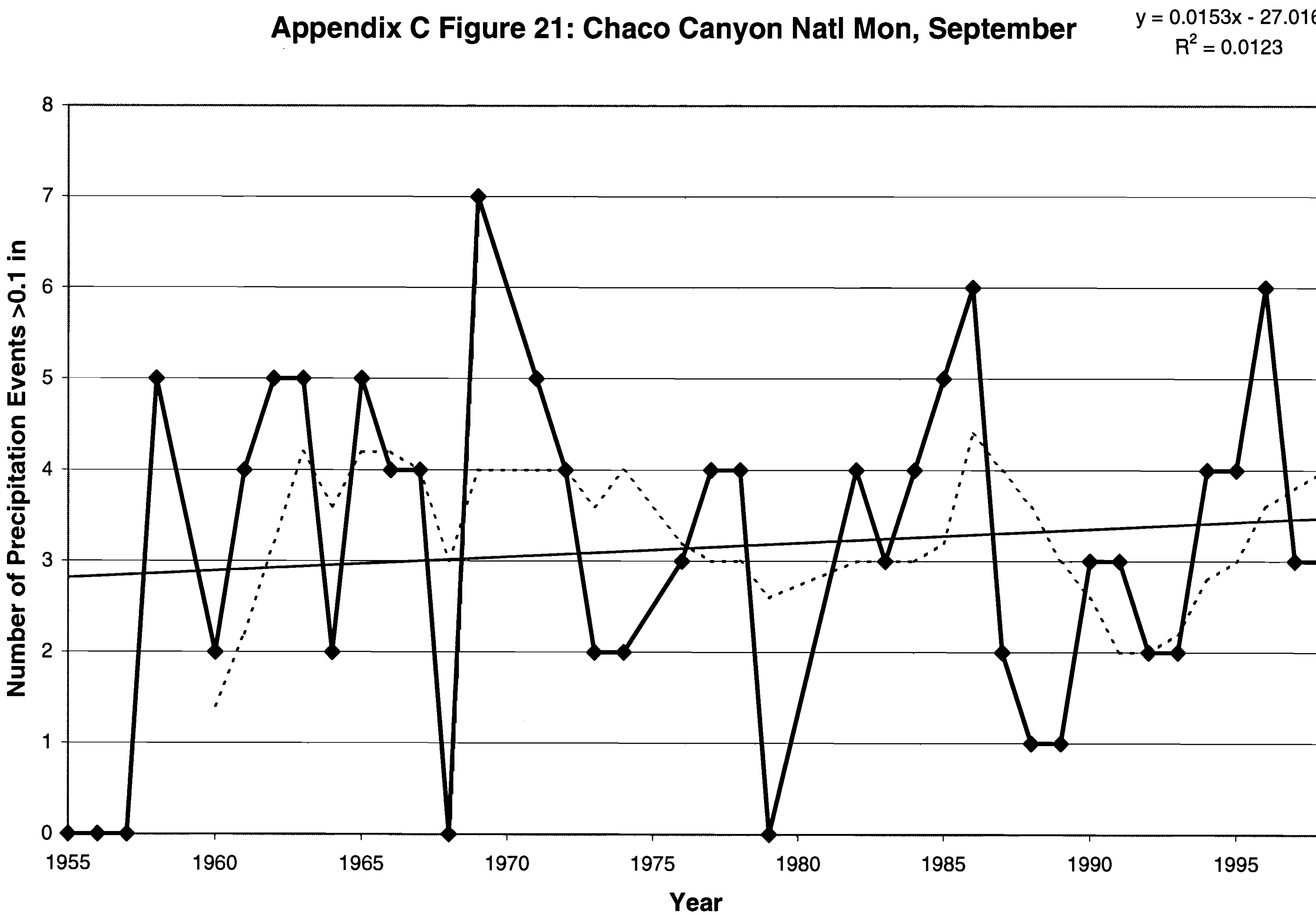
Appendix C Figure 19: Chaco Canyon Natl Mon, July



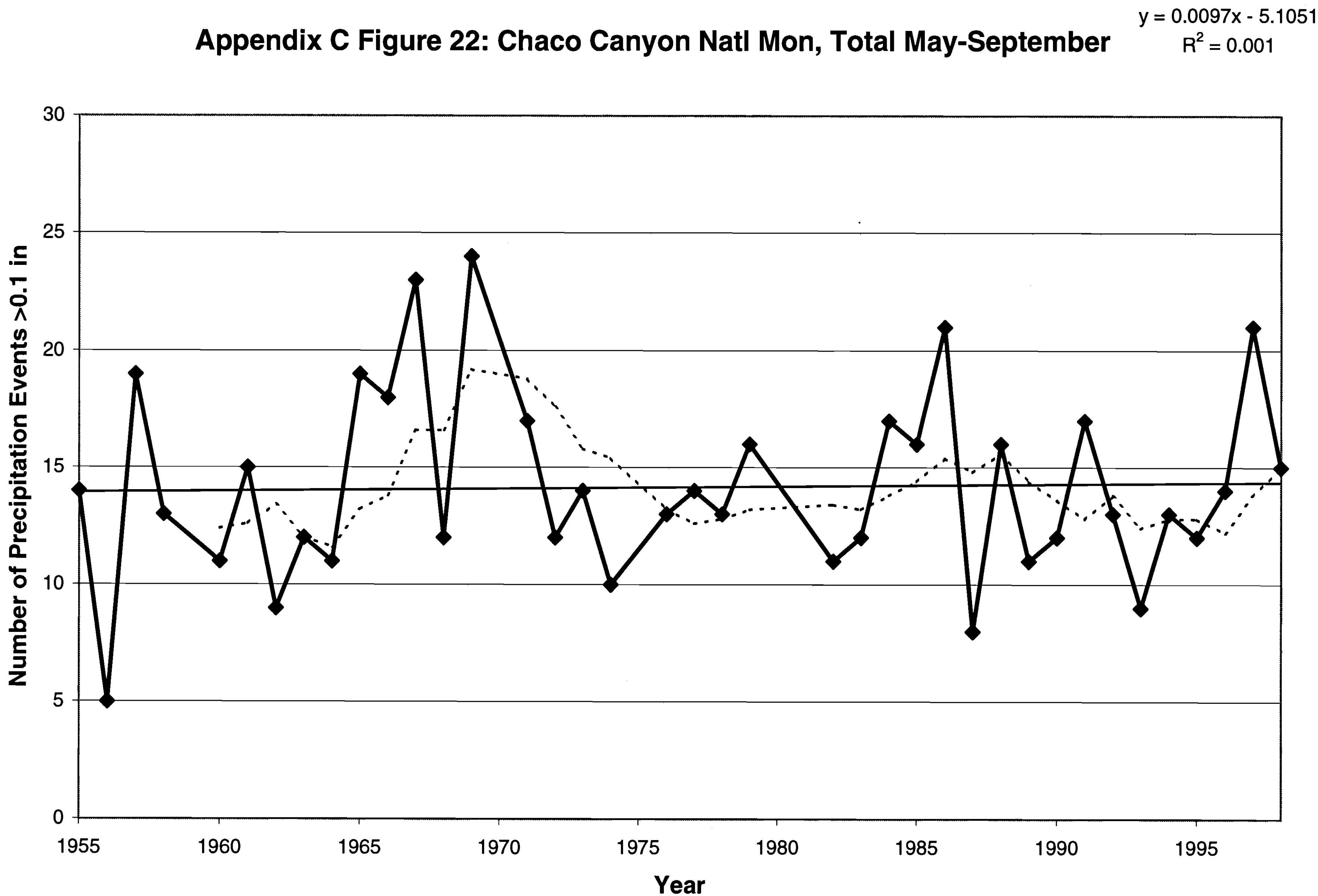
Appendix C Figure 20: Chaco Canyon Natl Mon, August

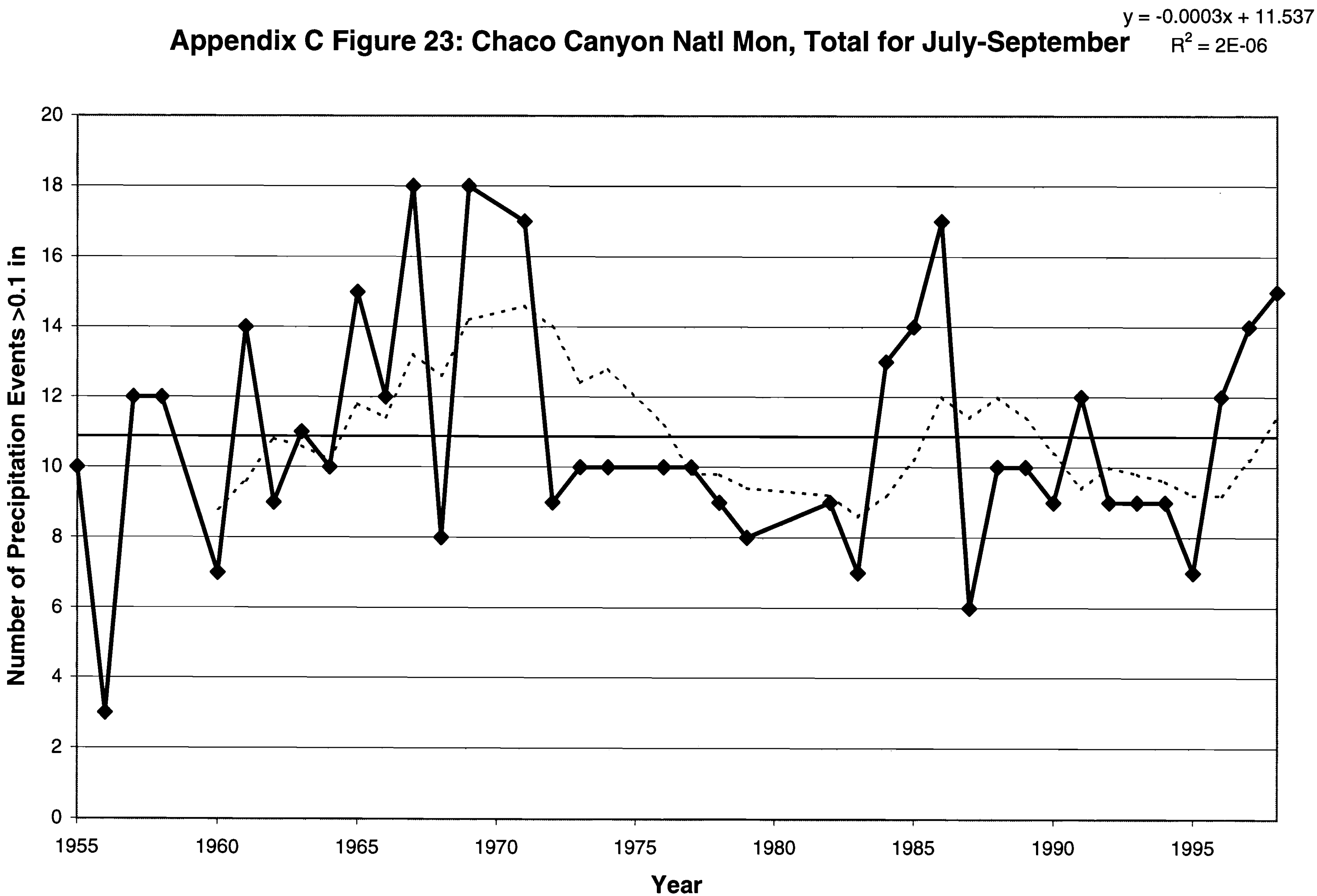


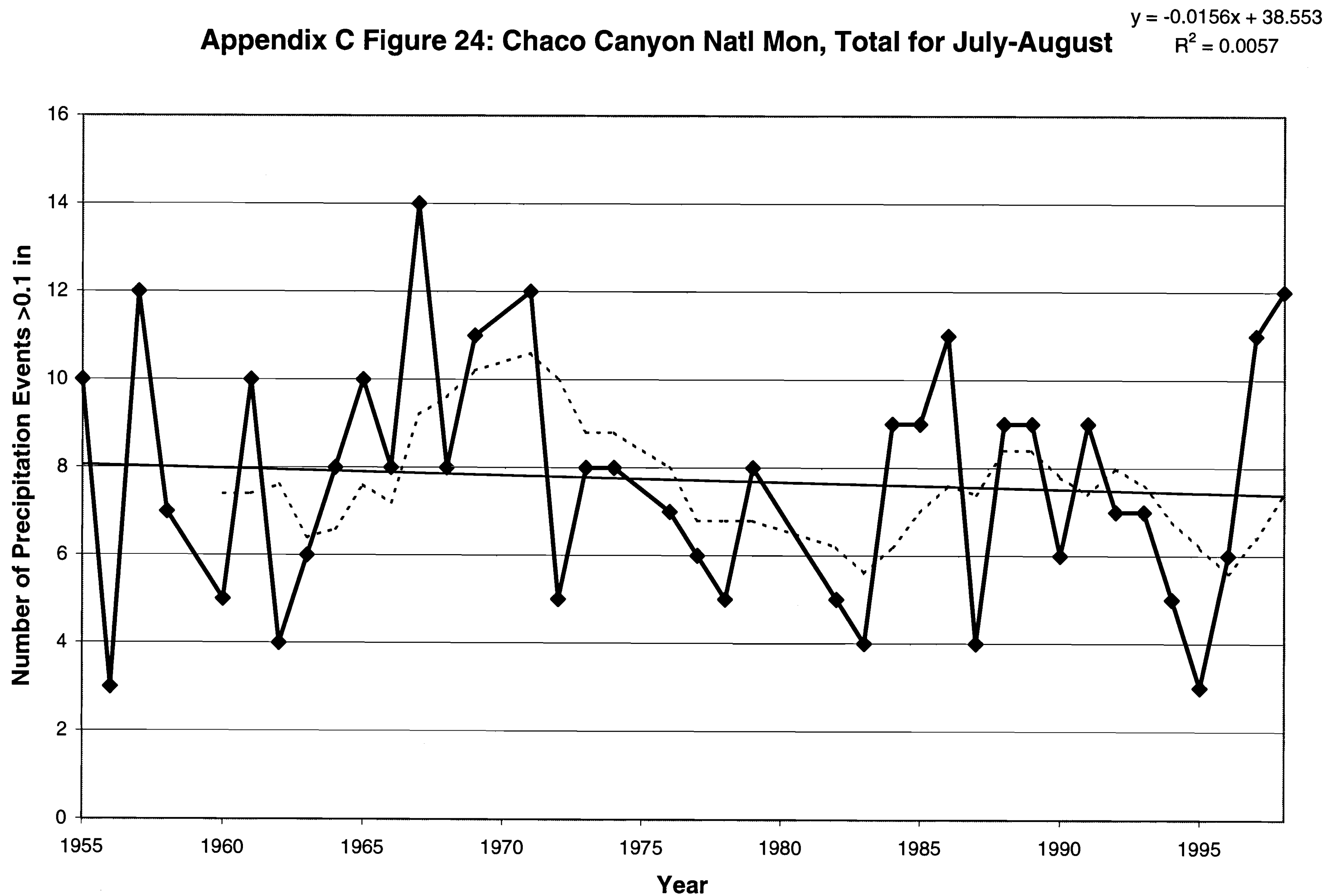
Appendix C Figure 21: Chaco Canyon Natl Mon, September



Appendix C Figure 22: Chaco Canyon Natl Mon, Total May-September




y = -0.0003x + 11.537
R2 = 2E-06
Appendix C Figure 23: Chaco Canyon Natl Mon, Total for July-September
Number of Precipitation Events >0.1 in
0
2
4
6
8
10
12
14
16
18
20
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

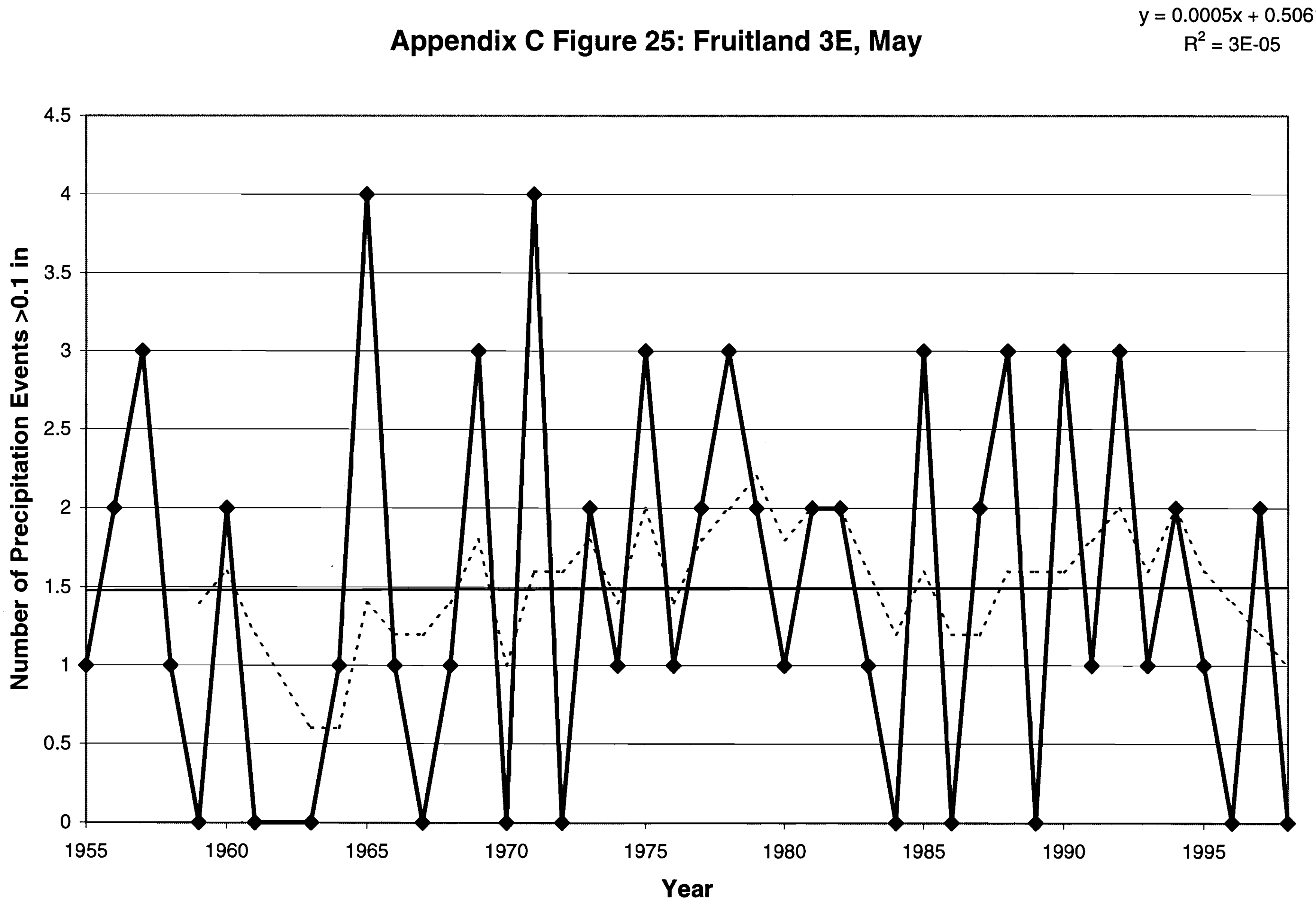


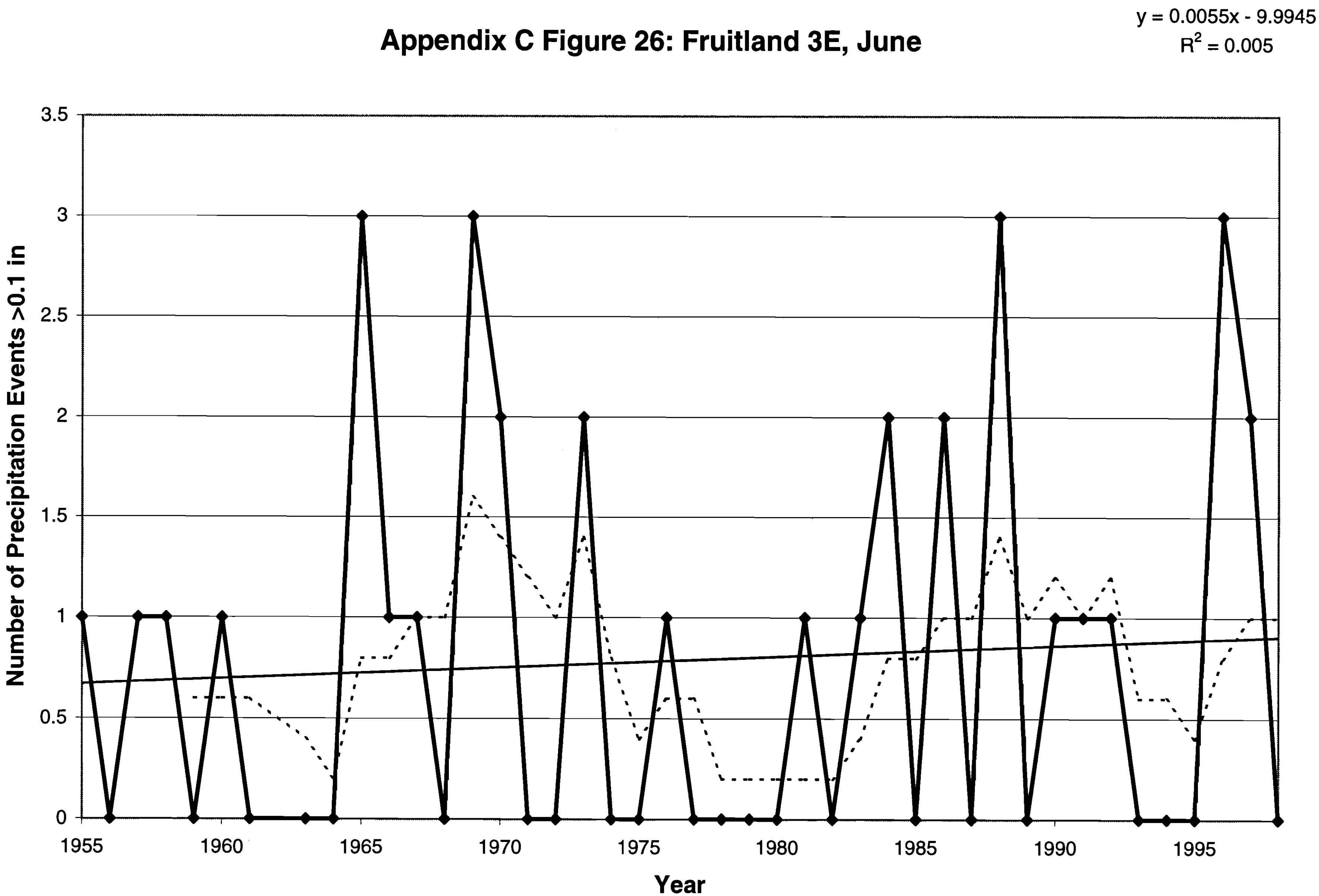
Appendix C Figure 24: Chaco Canyon Natl Mon, Total for July-August
y = -0.0156x + 38.553
R2 = 0.0057
16
14
12
10
8
6
4
2
0
Number of Precipitation Events >0.1 in
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

Appendix C Table 4: Number of Precipitation Events >0.1 in, Fruitland 3 E, New Mexico, 1955-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1955	1	1	2	4	1	9	7	6
1956	2	0	2	1	0	5	3	3
1957	3	1	7	6	0	17	13	13
1958	1	1	1	3	4	10	8	4
1959	0	0	0	6	1	7	7	6
1960	2	1	2	1	2	8	5	3
1961	0	0	0	6	1	7	7	6
1963	0	0	1	4	2	7	7	5
1964	1	0	0	0	5	6	5	0
1965	4	3	4	1	3	15	8	5
1966	1	1	2	1	1	6	4	3
1967	0	1	4	6	2	13	12	10
1968	1	0	2	3	0	6	5	5
1969	3	3	5	3	4	18	12	8
1970	0	2	3	0	3	8	6	3
1971	4	0	3	6	3	16	12	9
1972	0	0	0	4	3	7	7	4
1973	2	2	2	3	5	14	10	5
1974	1	0	6	2	1	10	9	8
1975	3	0	3	2	4	12	9	5
1976	1	1	5	3	3	13	11	8
1977	2	0	4	1	2	9	7	5
1978	3	0	0	0	2	5	2	0
1979	2	0	1	0	0	3	1	1
1980	1	0	0	3	3	7	6	3
1981	2	1	2	2	1	8	5	4
1982	2	0	3	7	2	14	12	10
1983	1	1	3	3	3	11	9	6
1984	0	2	1	4	2	9	7	5
1985	3	0	3	2	5	13	10	5
1986	0	2	6	1	5	14	12	7
1987	2	0	1	4	1	8	6	5
1988	3	3	0	6	2	14	8	6
1989	0	0	1	2	1	4	4	3
1990	3	1	1	4	8	17	13	5
1991	1	1	2	2	3	9	7	4
1992	3	1	3	4	1	12	8	7
1993	1	0	0	4	2	7	6	4
1994	2	0	0	1	3	6	4	1
1995	1	0	0	2	3	6	5	2
1996	0	3	1	2	1	7	4	3
1997	2	2	5	3	5	17	13	8
1998	0	0	4	1	2	7	7	5
Ave.	**1.49**	**0.79**	**2.21**	**2.86**	**2.44**	**9.79**	**7.51**	**5.07**
S.D.	**1.20**	**0.99**	**1.91**	**1.91**	**1.69**	**4.02**	**3.12**	**2.69**
Max	**4**	**3**	**7**	**7**	**8**	**18**	**13**	**13**
Min	**0**	**0**	**0**	**0**	**0**	**3**	**1**	**0**

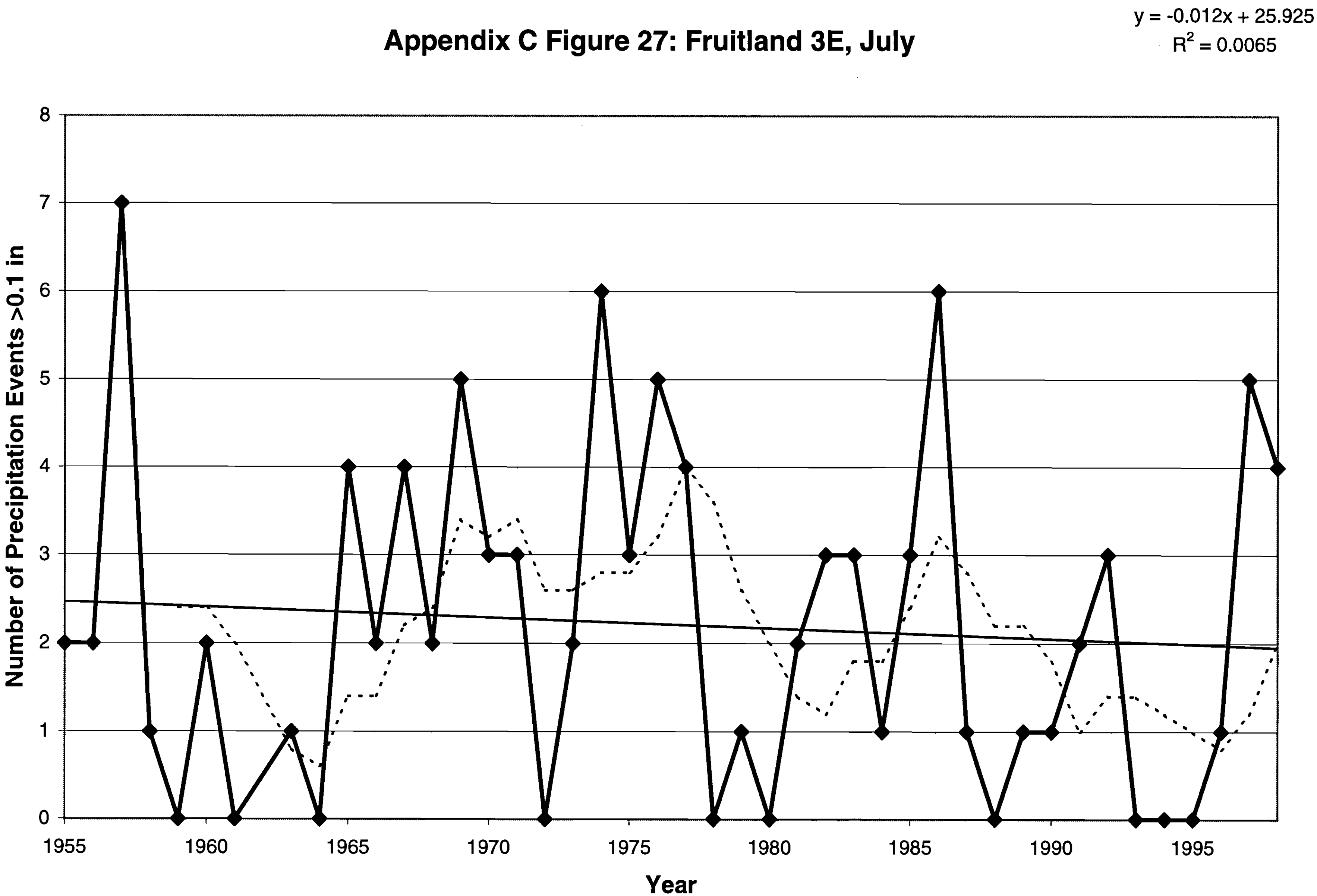
Appendix C Figure 25: Fruitland 3E, May



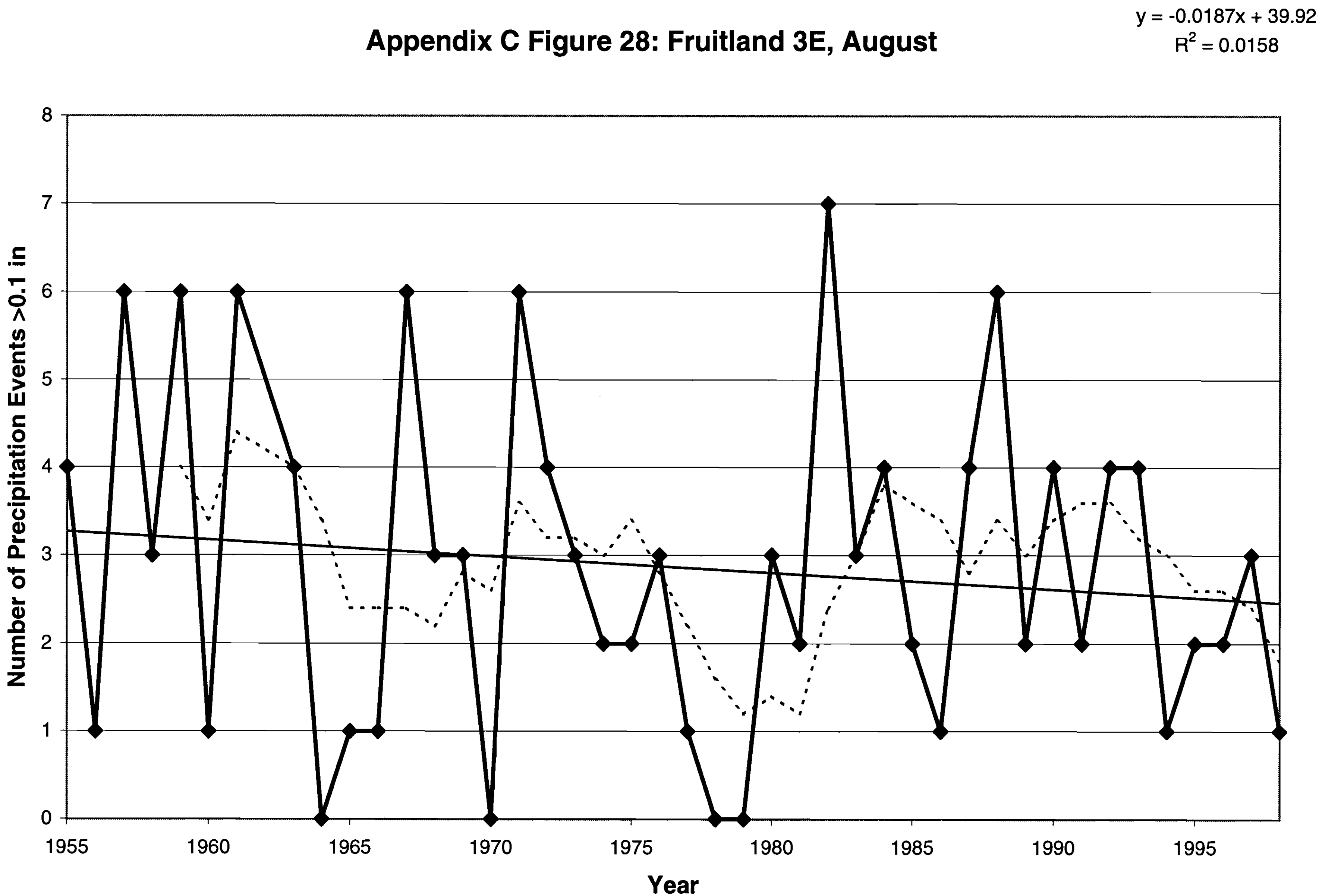


y = 0.0055x - 9.9945
R^2 = 0.005
Appendix C Figure 26: Fruitland 3E, June
Number of Precipitation Events >0.1 in
3.5
3
2.5
2
1.5
1
0.5
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

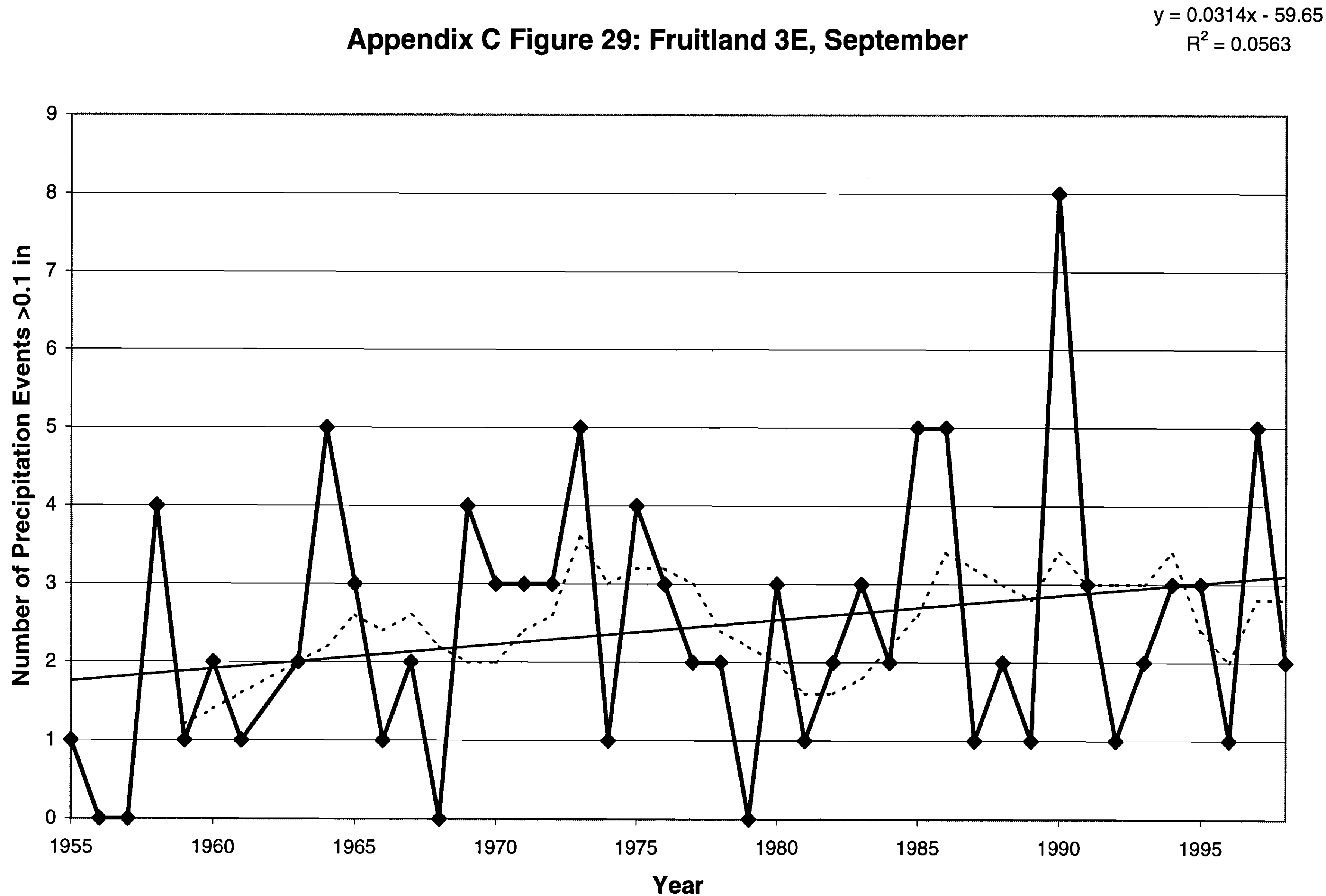
Appendix C Figure 27: Fruitland 3E, July



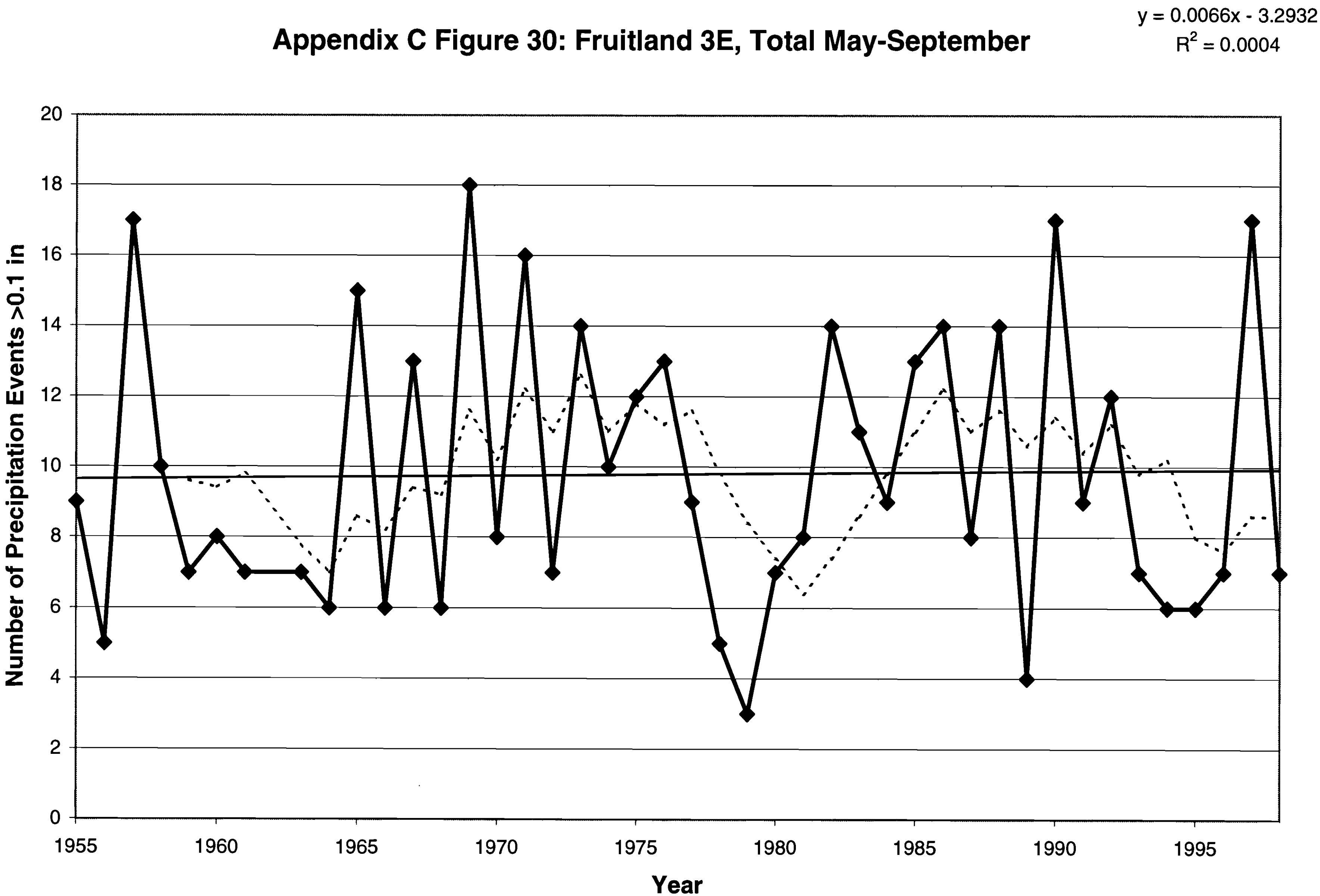
Appendix C Figure 28: Fruitland 3E, August



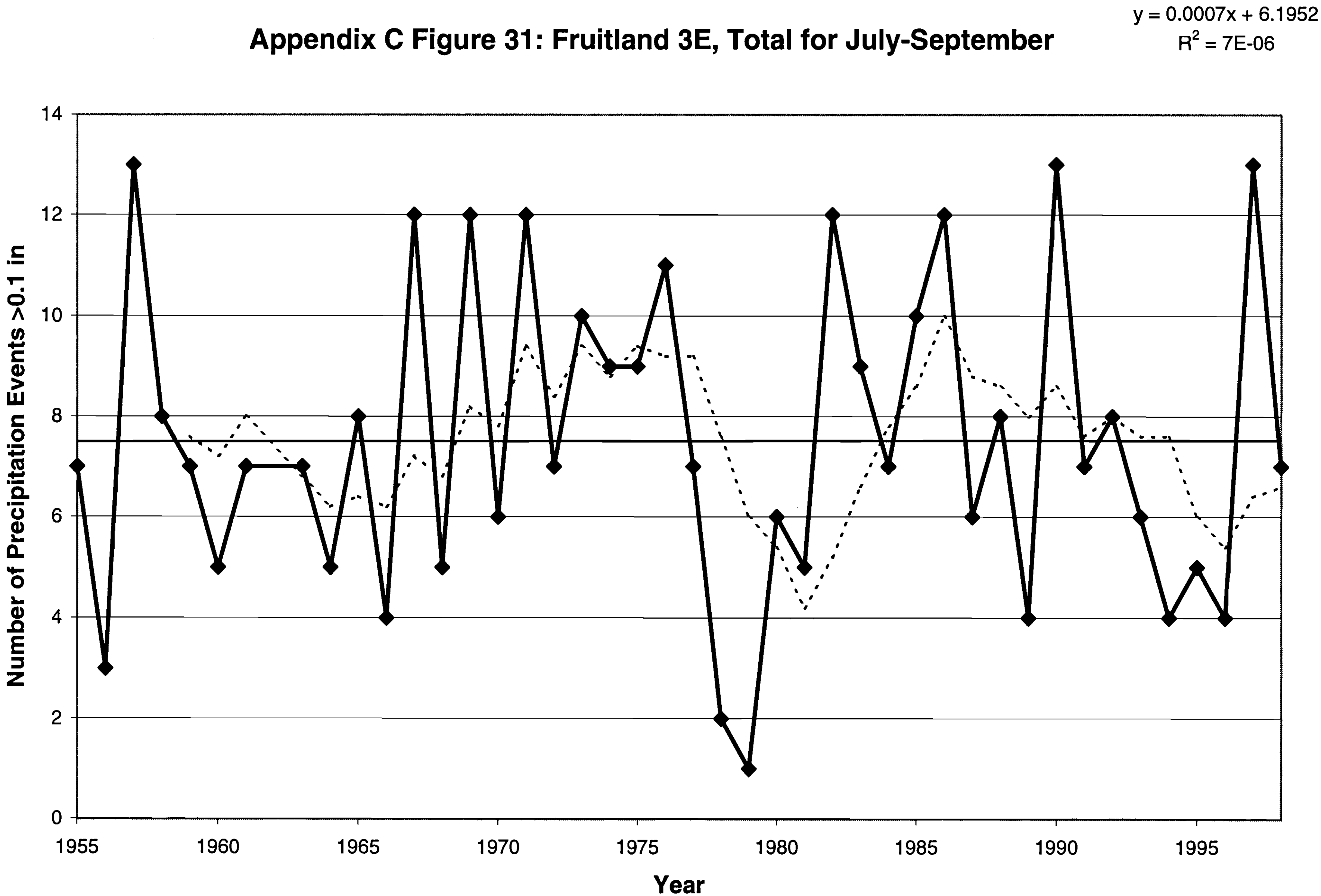
Appendix C Figure 29: Fruitland 3E, September

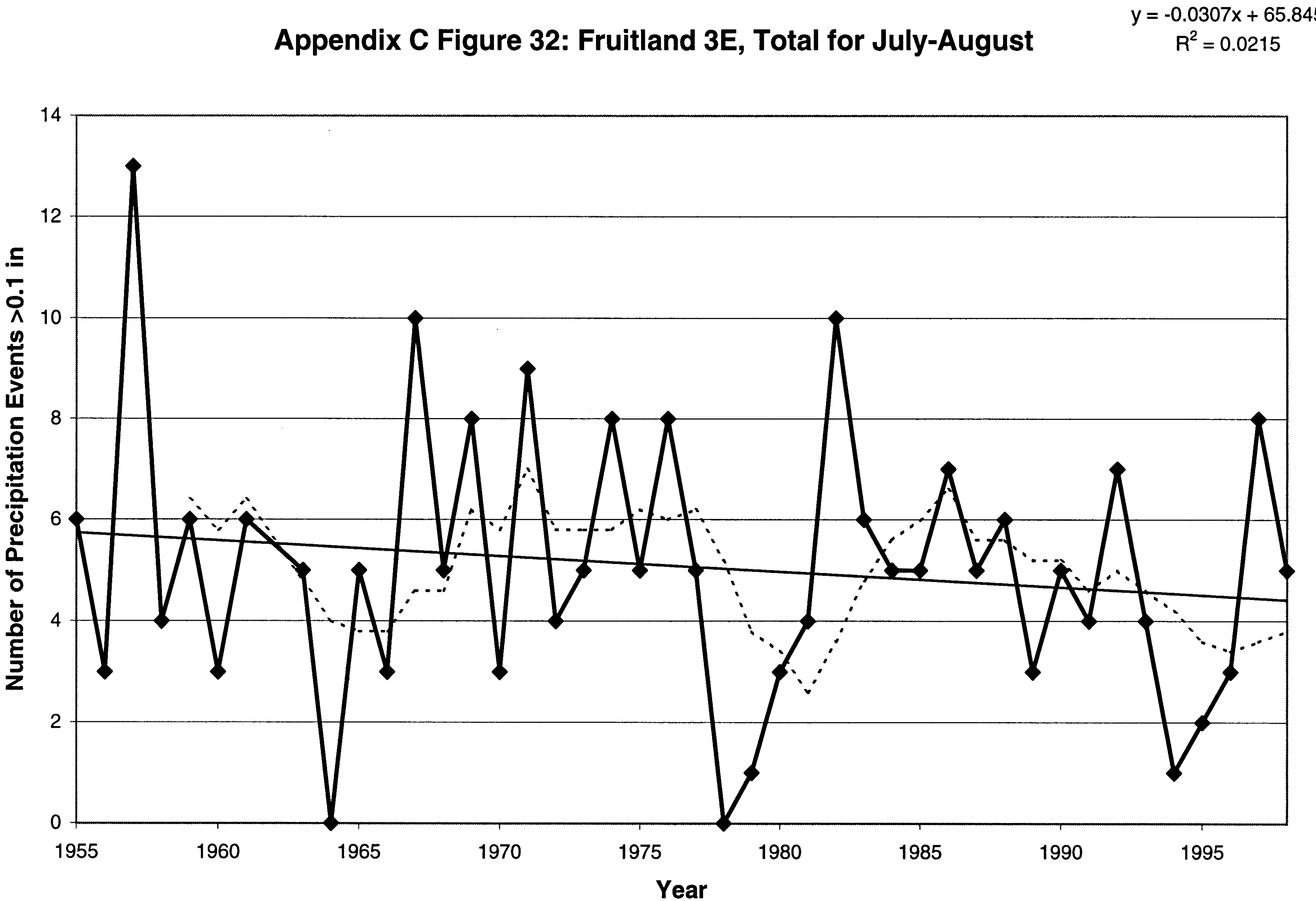


Appendix C Figure 30: Fruitland 3E, Total May-September



Appendix C Figure 31: Fruitland 3E, Total for July-September



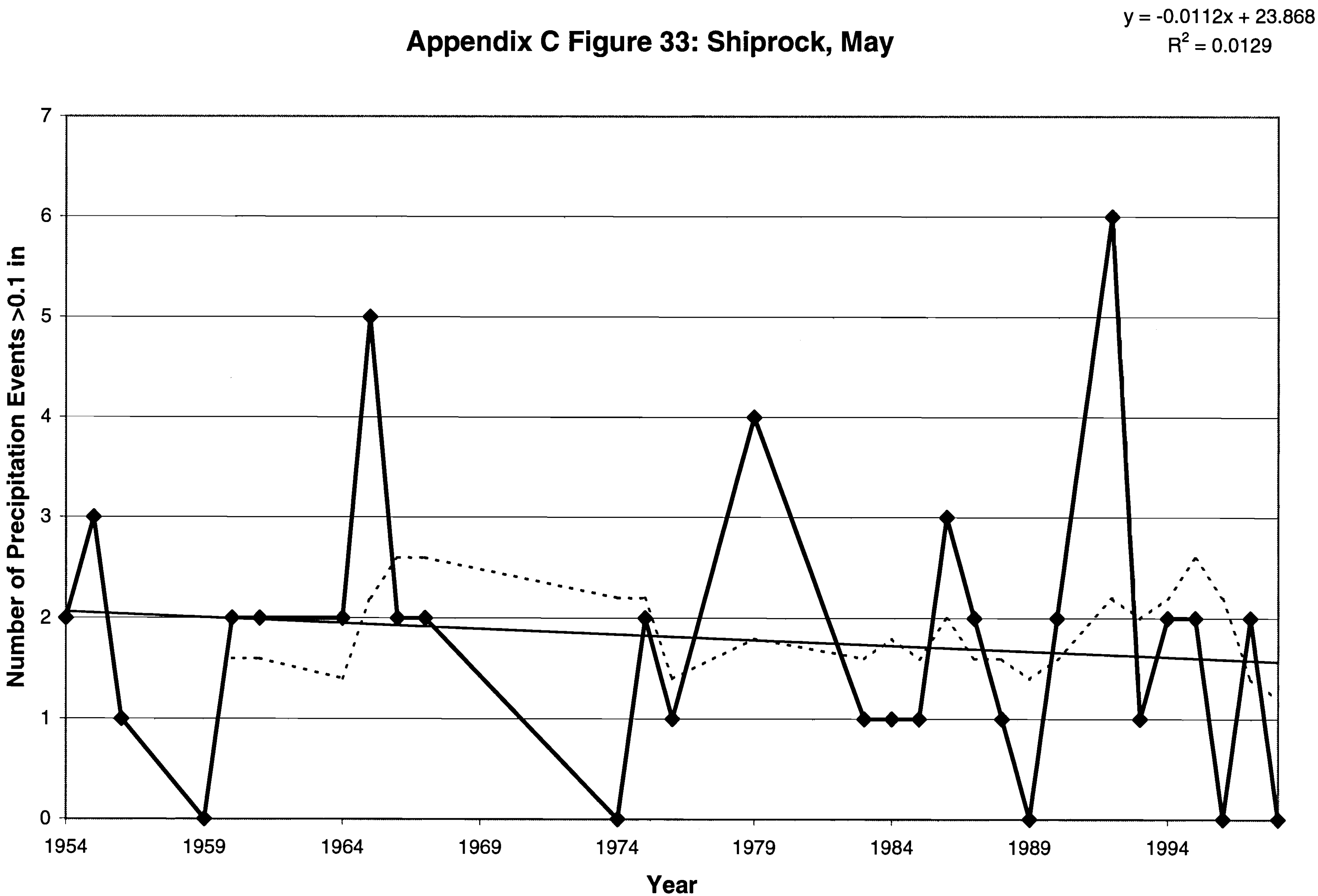

y = -0.0307x + 65.845
R^2 = 0.0215
Appendix C Figure 32: Fruitland 3E, Total for July-August
Number of Precipitation Events >0.1 in
0
2
4
6
8
10
12
14
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

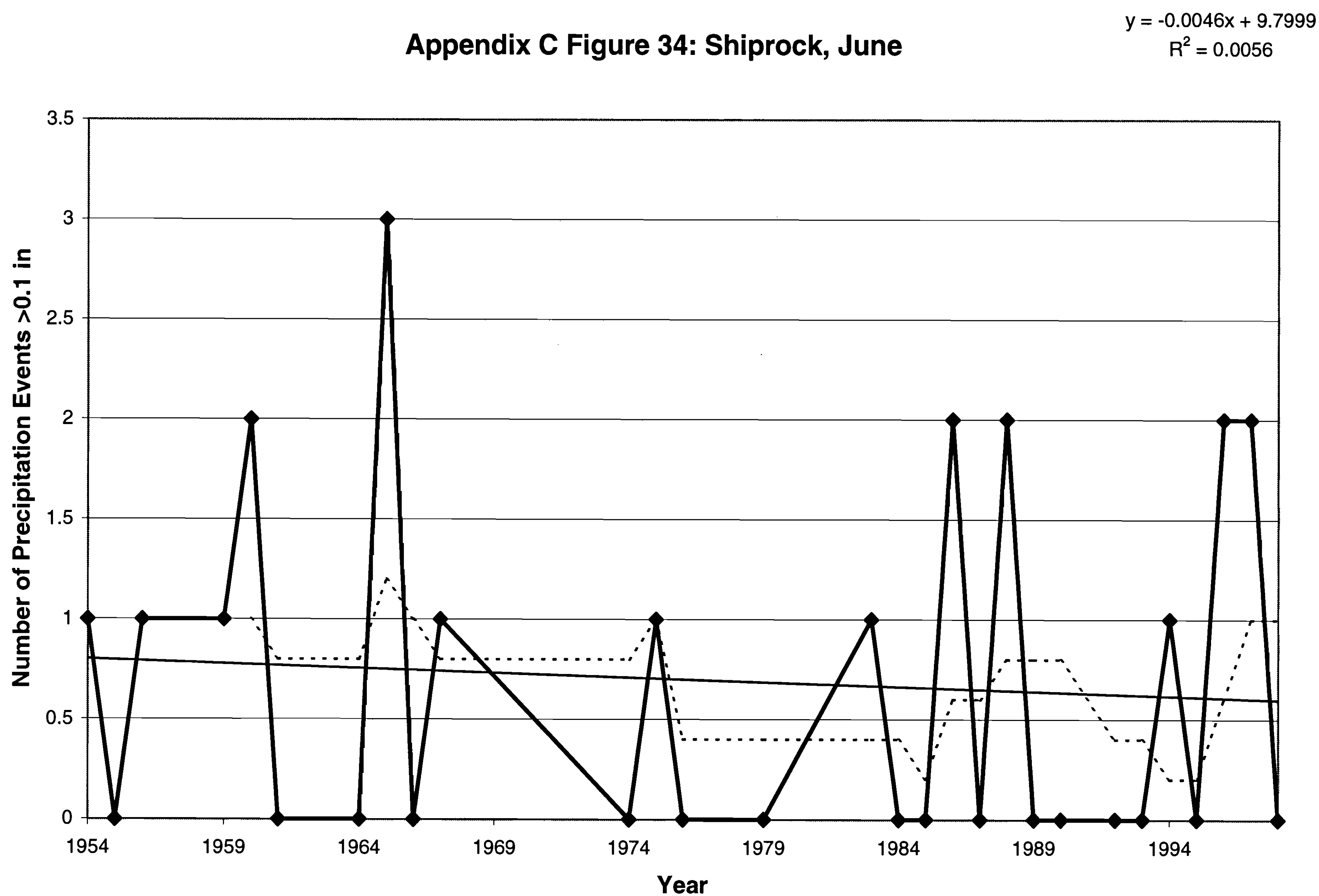
Appendix C Table 5: Number of Precipitation Events >0.1 in, Shiprock, New Mexico, 1954-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1954	2	1	6	2	3	14	11	8
1955	3	0	2	2	0	7	4	4
1956	1	1	1	2	0	5	3	3
1959	0	1	0	2	1	4	3	2
1960	2	2	1	1	1	7	3	2
1961	2	0	1	3	4	10	8	4
1964	2	0	3	2	3	10	8	5
1965	5	3	1	0	2	11	3	1
1966	2	0	3	2	0	7	5	5
1967	2	1	1	5	1	10	7	6
1974	0	0	0	1	0	1	1	1
1975	2	1	5	2	4	14	11	7
1976	1	0	0	2	3	6	5	2
1979	4	0	1	0	0	5	1	1
1983	1	1	2	1	2	7	5	3
1984	1	0	1	2	1	5	4	3
1985	1	0	2	0	0	3	2	2
1986	3	2	5	2	4	16	11	7
1987	2	0	1	3	0	6	4	4
1988	1	2	0	4	2	9	6	4
1989	0	0	2	2	0	4	4	4
1990	2	0	0	5	6	13	11	5
1992	6	0	4	6	1	17	11	10
1993	1	0	1	10	1	13	12	11
1994	2	1	0	3	1	7	4	3
1995	2	0	0	1	5	8	6	1
1996	0	2	1	2	1	6	4	3
1997	2	2	4	3	5	16	12	7
1998	0	0	4	1	1	6	6	5
Ave.	**1.79**	**0.69**	**1.79**	**2.45**	**1.79**	**8.52**	**6.03**	**4.24**
S.D.	**1.42**	**0.89**	**1.74**	**2.05**	**1.78**	**4.22**	**3.46**	**2.61**
Max	**6**	**3**	**6**	**10**	**6**	**17**	**12**	**11**
Min	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**

Note: 16 years were removed due to loss of data so error may be to high.

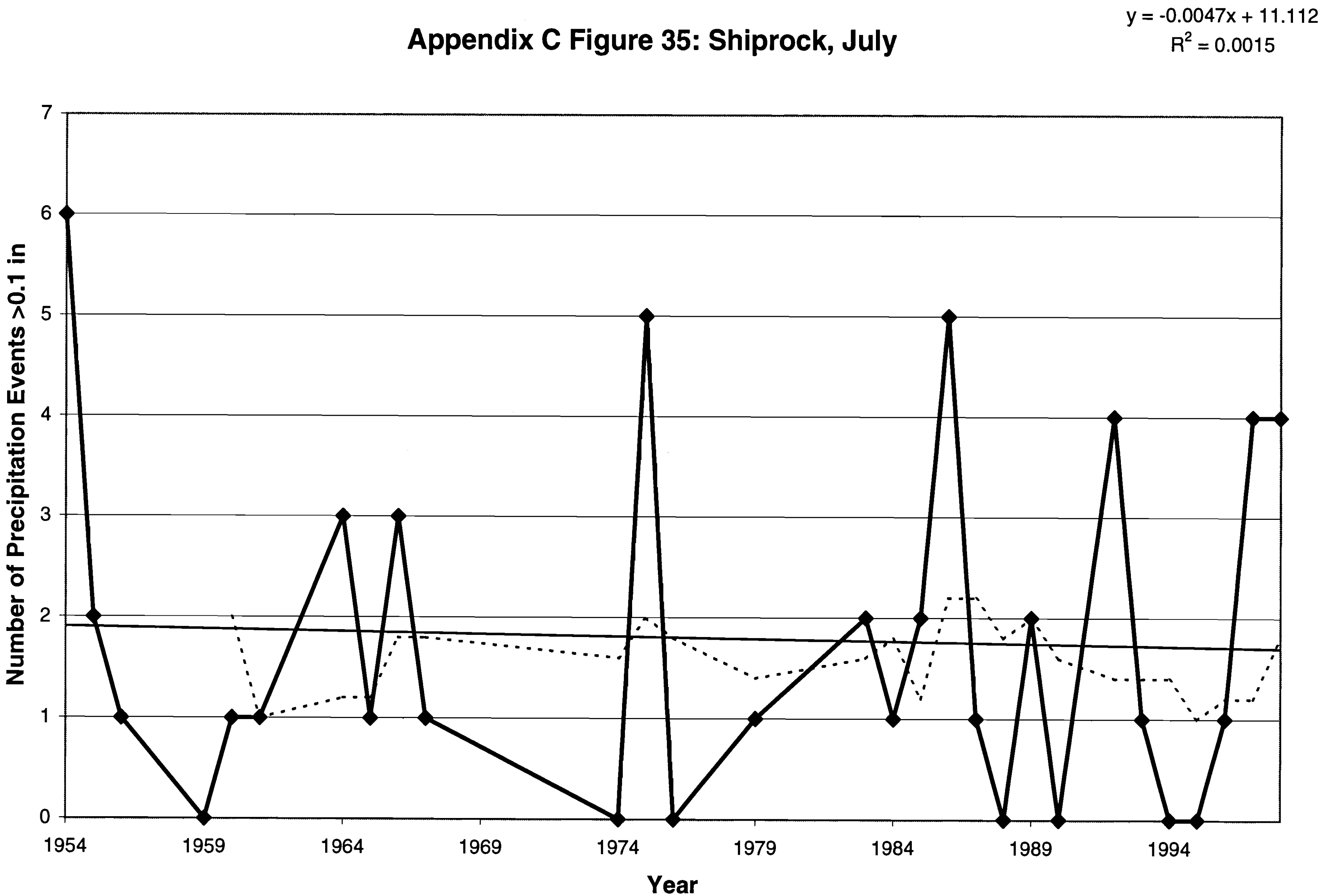
Appendix C Figure 33: Shiprock, May



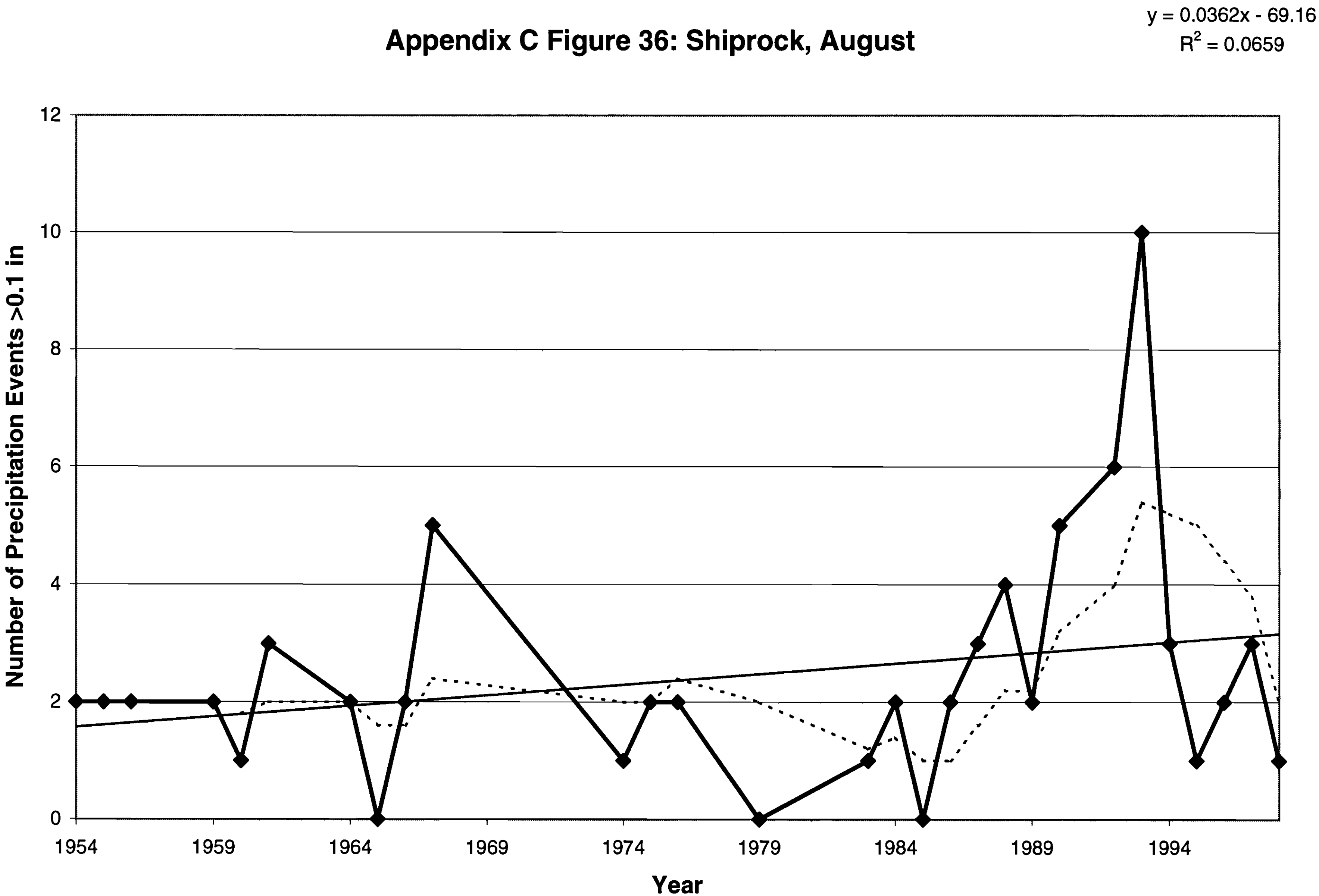


Appendix C Figure 34: Shiprock, June
y = -0.0046x + 9.7999
R2 = 0.0056
3.5
3
2.5
2
1.5
1
0.5
0
Number of Precipitation Events >0.1 in
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

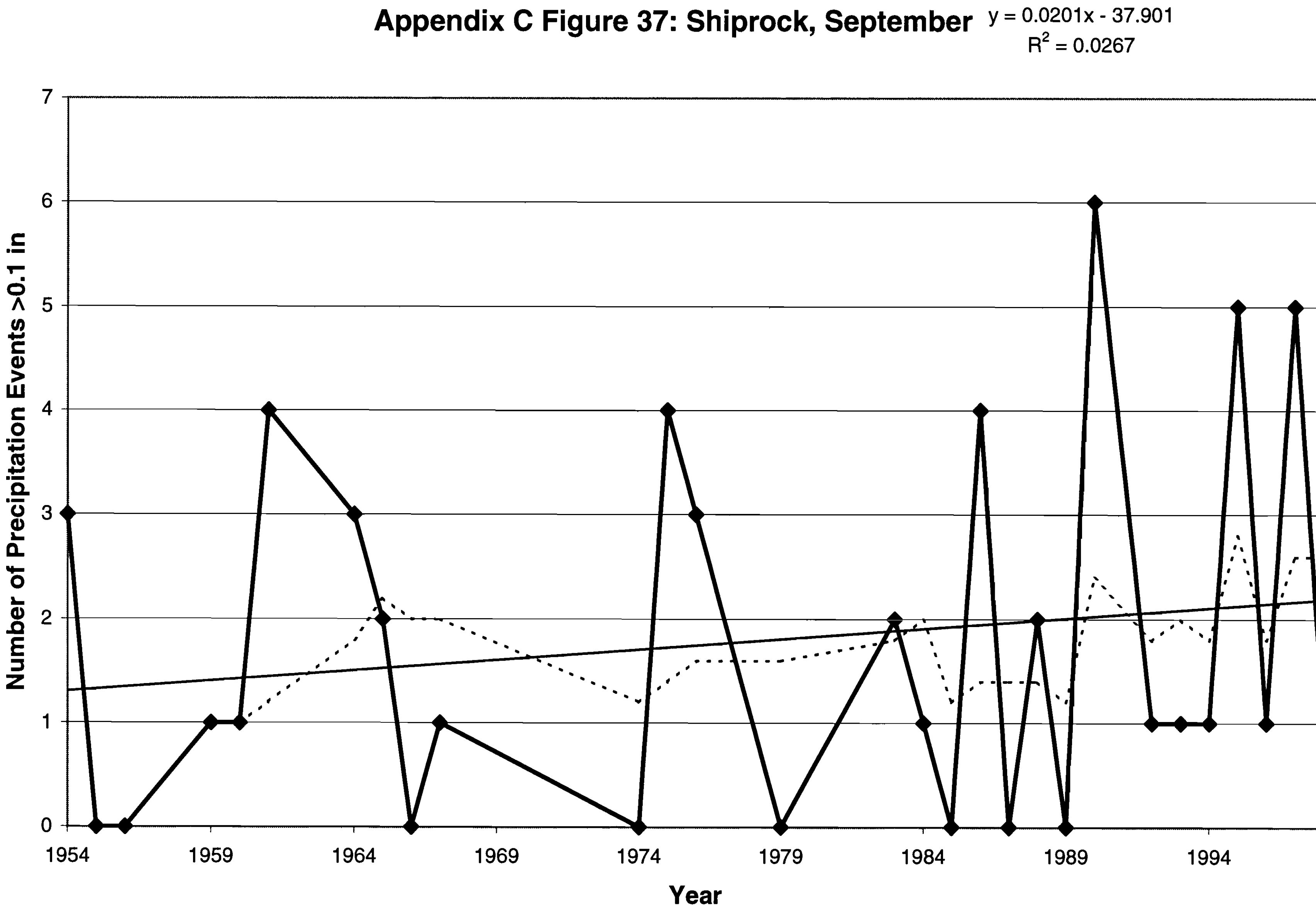
Appendix C Figure 35: Shiprock, July



Appendix C Figure 36: Shiprock, August

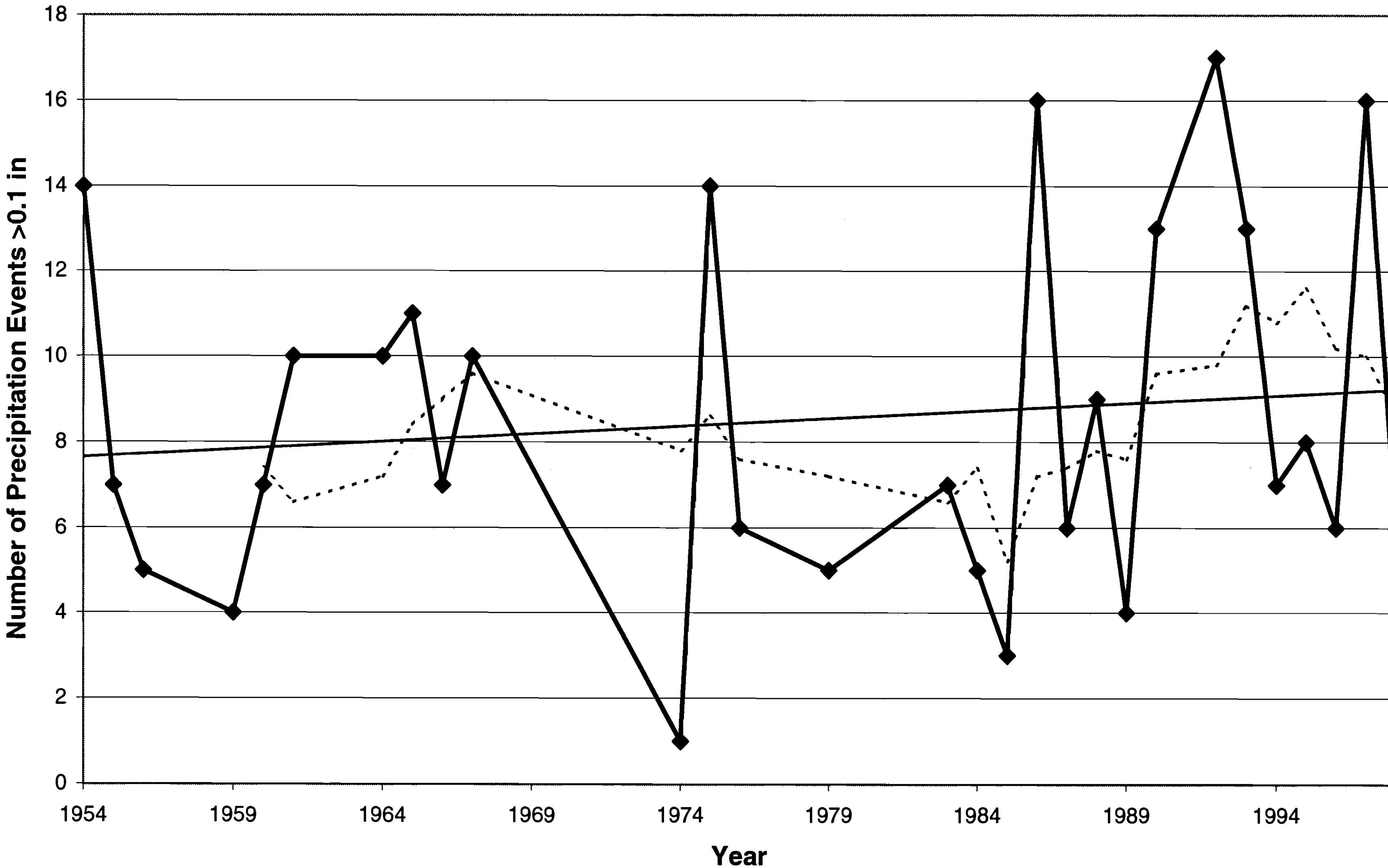


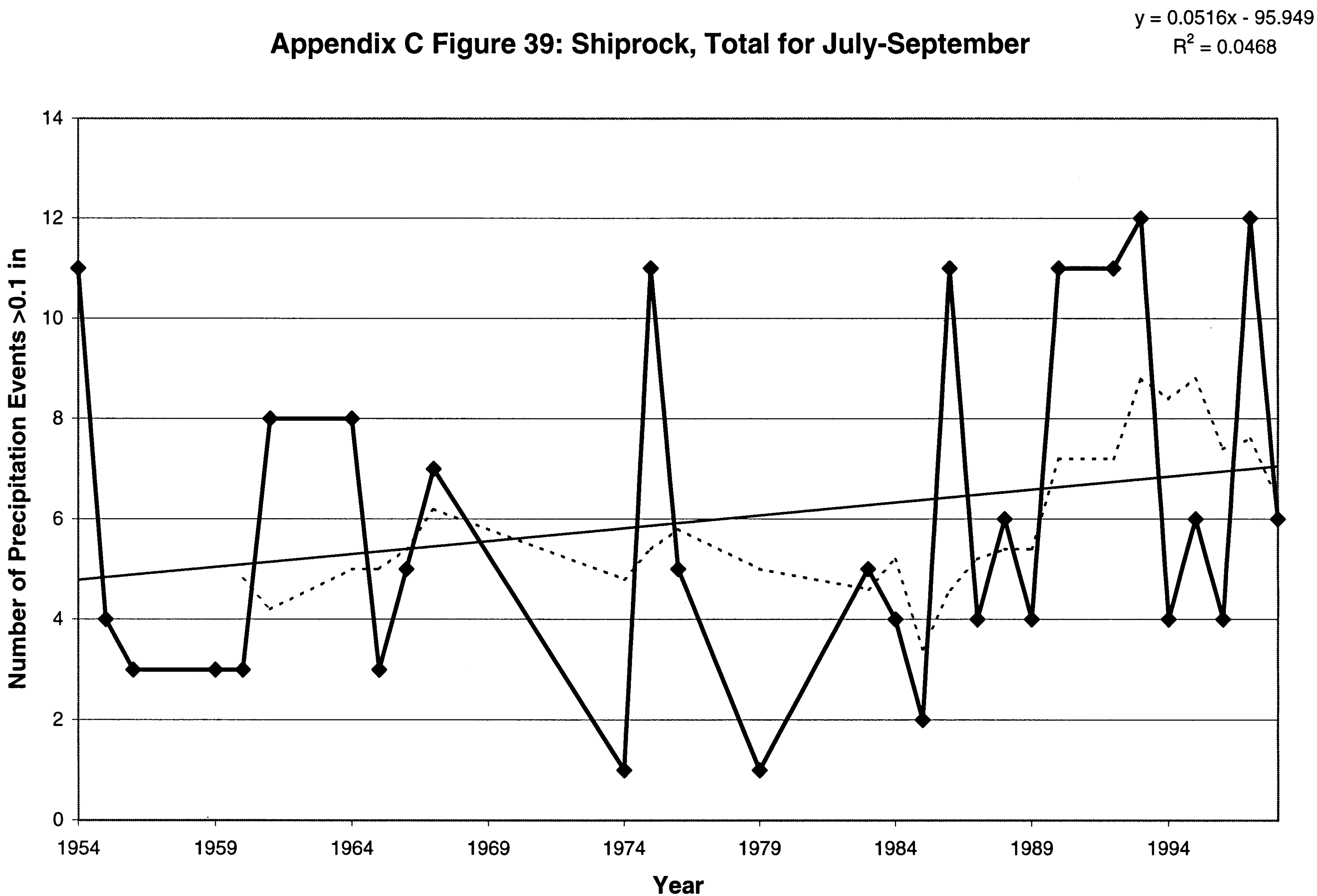
Appendix C Figure 37: Shiprock, September



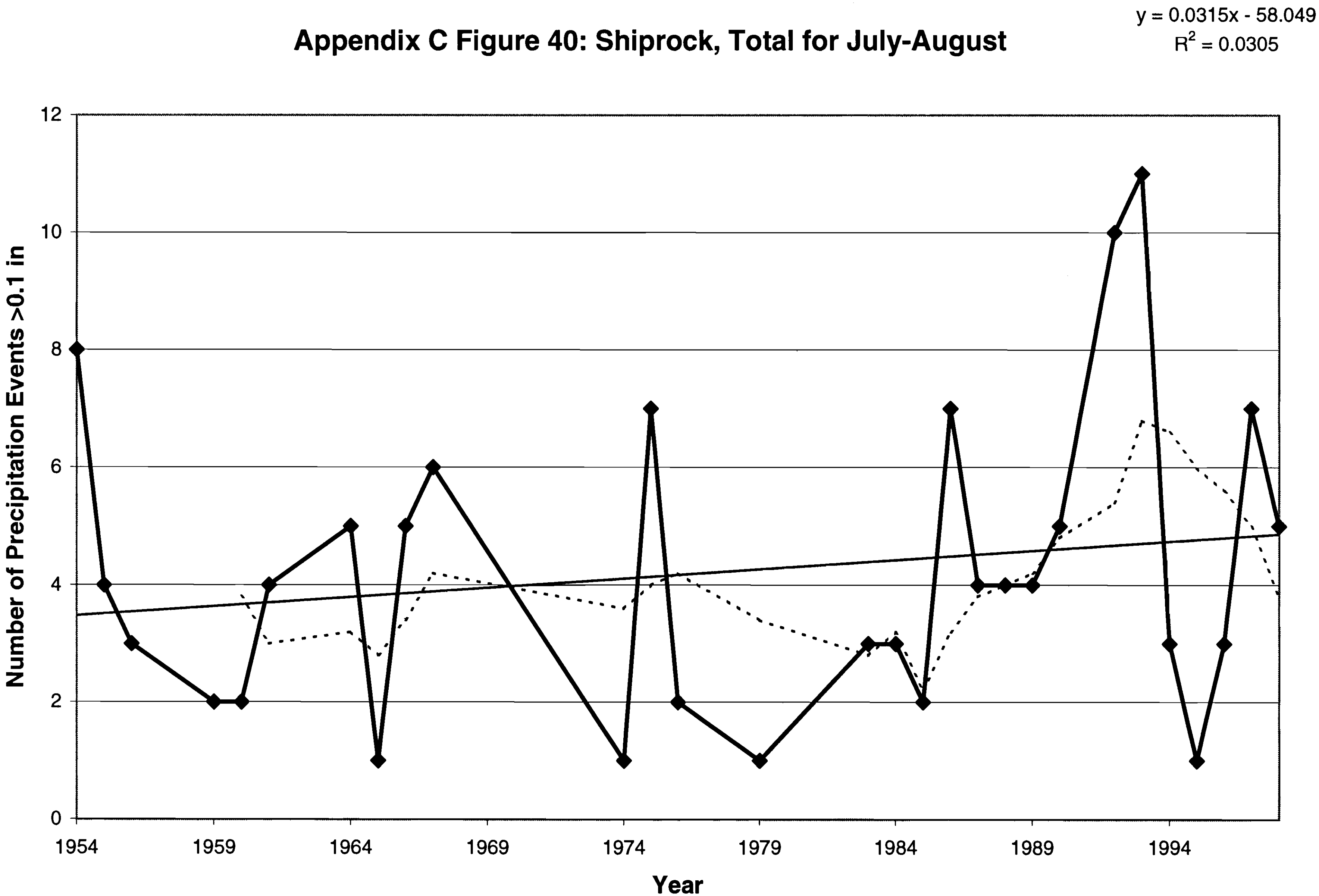
$y = 0.0358x - 62.281$
$R^2 = 0.0151$

Appendix C Figure 38: Shiprock, Total May-September




Appendix C Figure 39: Shiprock, Total for July-September
y = 0.0516x - 95.949
R2 = 0.0468
Number of Precipitation Events >0.1 in
0
2
4
6
8
10
12
14
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

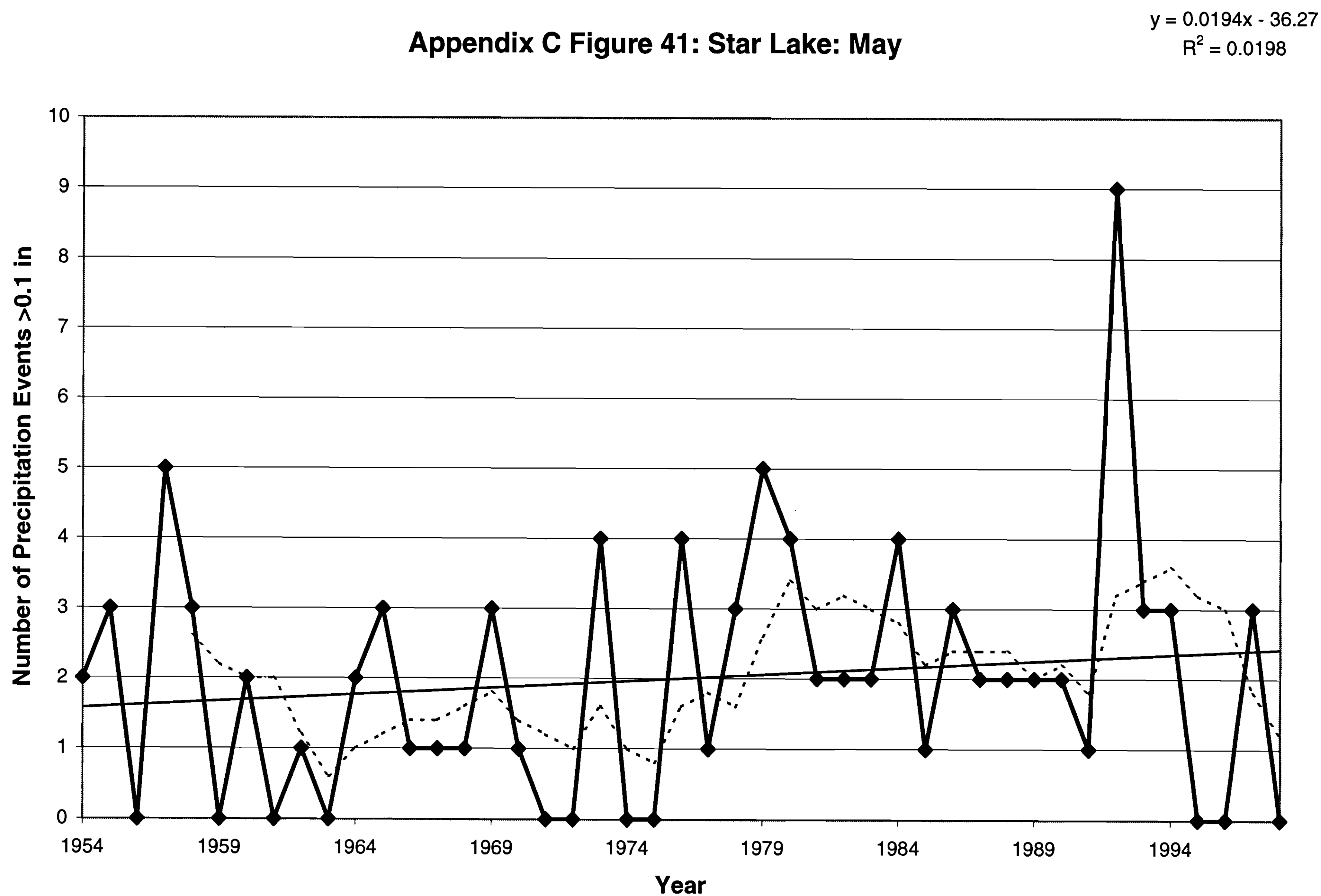
Appendix C Figure 40: Shiprock, Total for July-August



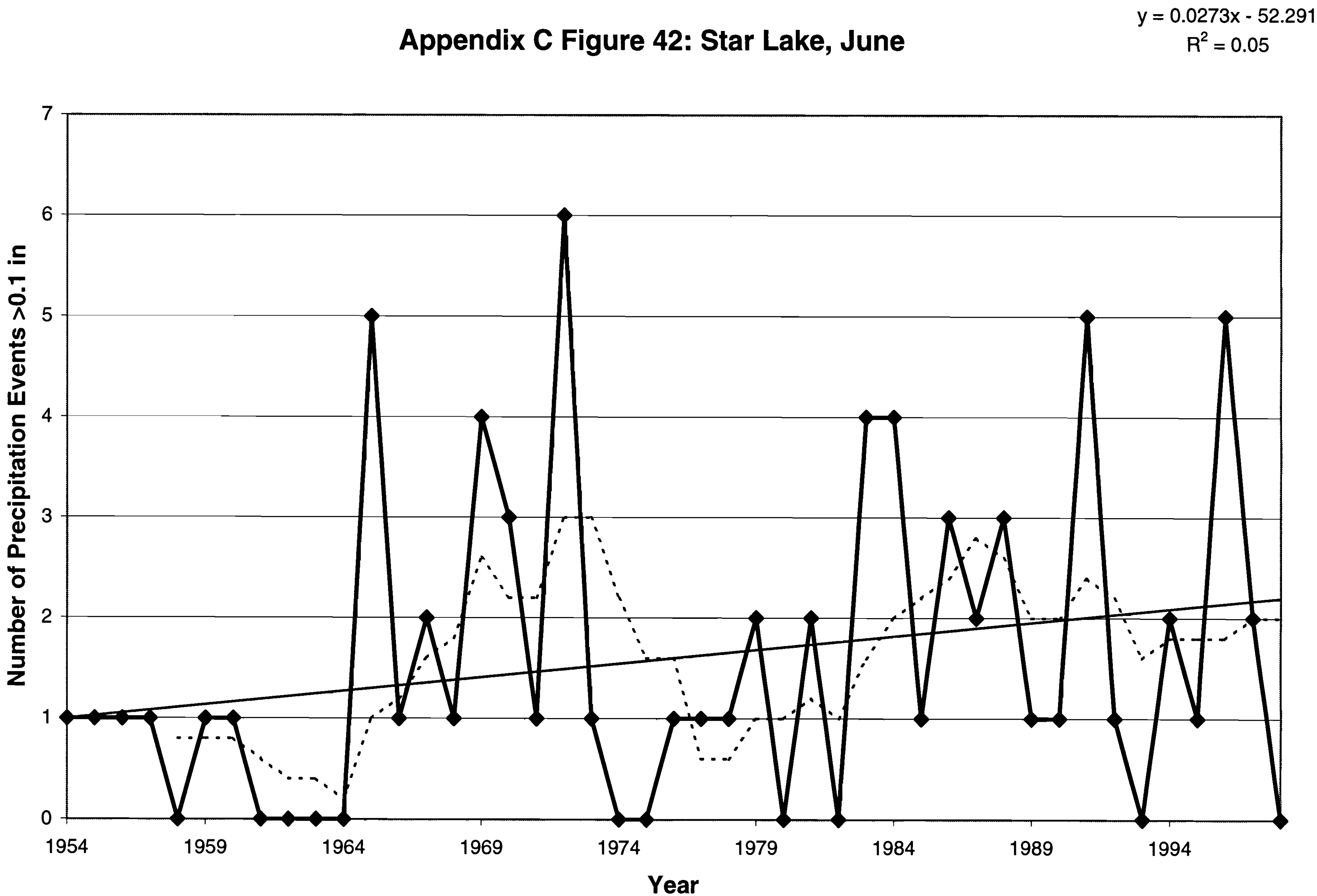
Appendix C Table 6: Number of Precipitation Events >0.1 in, Star Lake, New Mexico, 1954-1998.

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1954	2	1	3	5	5	16	13	8
1955	3	1	4	9	2	19	15	13
1956	0	1	4	2	0	7	6	6
1957	5	1	6	8	0	20	14	14
1958	3	0	4	8	3	18	15	12
1959	0	1	3	10	1	15	14	13
1960	2	1	2	5	1	11	8	7
1961	0	0	2	4	5	11	11	6
1962	1	0	1	2	5	9	8	3
1963	0	0	4	6	7	17	17	10
1964	2	0	3	4	3	12	10	7
1965	3	5	8	5	4	25	17	13
1966	1	1	8	5	1	16	14	13
1967	1	2	5	6	4	18	15	11
1968	1	1	6	5	0	13	11	11
1969	3	4	3	5	6	21	14	8
1970	1	3	4	5	4	17	13	9
1971	0	1	6	6	5	18	17	12
1972	0	6	4	4	3	17	11	8
1973	4	1	7	5	2	19	14	12
1974	0	0	3	5	2	10	10	8
1975	0	0	7	3	8	18	18	10
1976	4	1	1	5	4	15	10	6
1977	1	1	2	4	2	10	8	6
1978	3	1	4	2	3	13	9	6
1979	5	2	4	3	0	14	7	7
1980	4	0	4	4	3	15	11	8
1981	2	2	5	8	2	19	15	13
1982	2	0	3	9	4	18	16	12
1983	2	4	1	7	4	18	12	8
1984	4	4	3	3	4	18	10	6
1985	1	1	7	2	6	17	15	9
1986	3	3	6	4	5	21	15	10
1987	2	2	2	3	1	10	6	5
1988	2	3	3	4	2	14	9	7
1989	2	1	2	4	1	10	7	6
1990	2	1	4	4	2	13	10	8
1991	1	5	4	6	6	22	16	10
1992	9	1	2	8	3	23	13	10
1993	3	0	0	4	1	8	5	4
1994	3	2	5	9	3	22	17	14
1995	0	1	6	6	4	17	16	12
1996	0	5	5	4	6	20	15	9
1997	3	2	4	2	8	19	14	6
1998	0	0	6	3	2	11	11	9
Ave.	**2.00**	**1.60**	**4.00**	**5.00**	**3.27**	**15.87**	**12.27**	**9.00**
S.D.	**1.81**	**1.60**	**1.92**	**2.10**	**2.10**	**4.31**	**3.48**	**2.86**
Max	**9**	**6**	**8**	**10**	**8**	**25**	**18**	**14**
Min	**0**	**0**	**0**	**2**	**0**	**7**	**5**	**3**

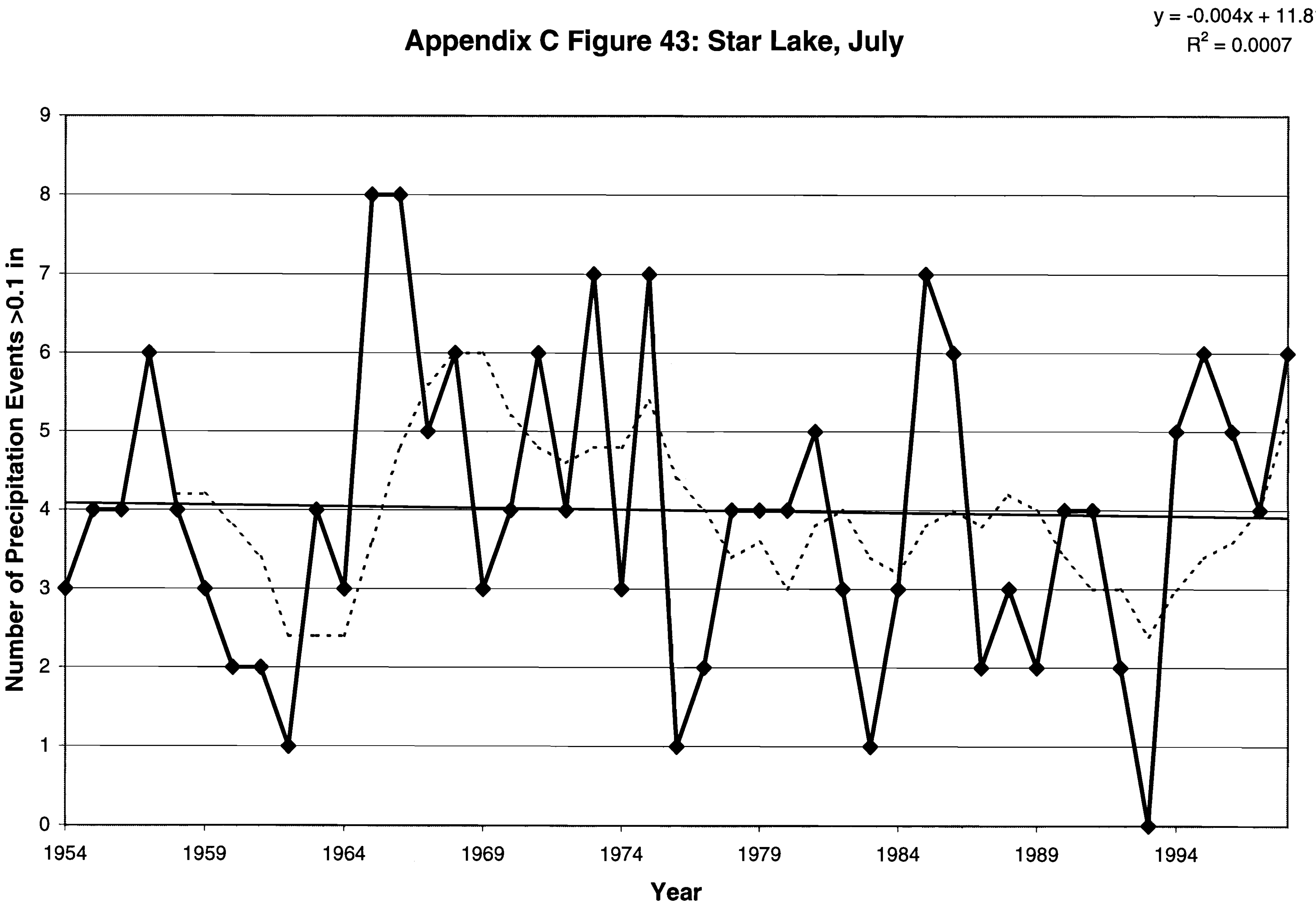
Appendix C Figure 41: Star Lake: May



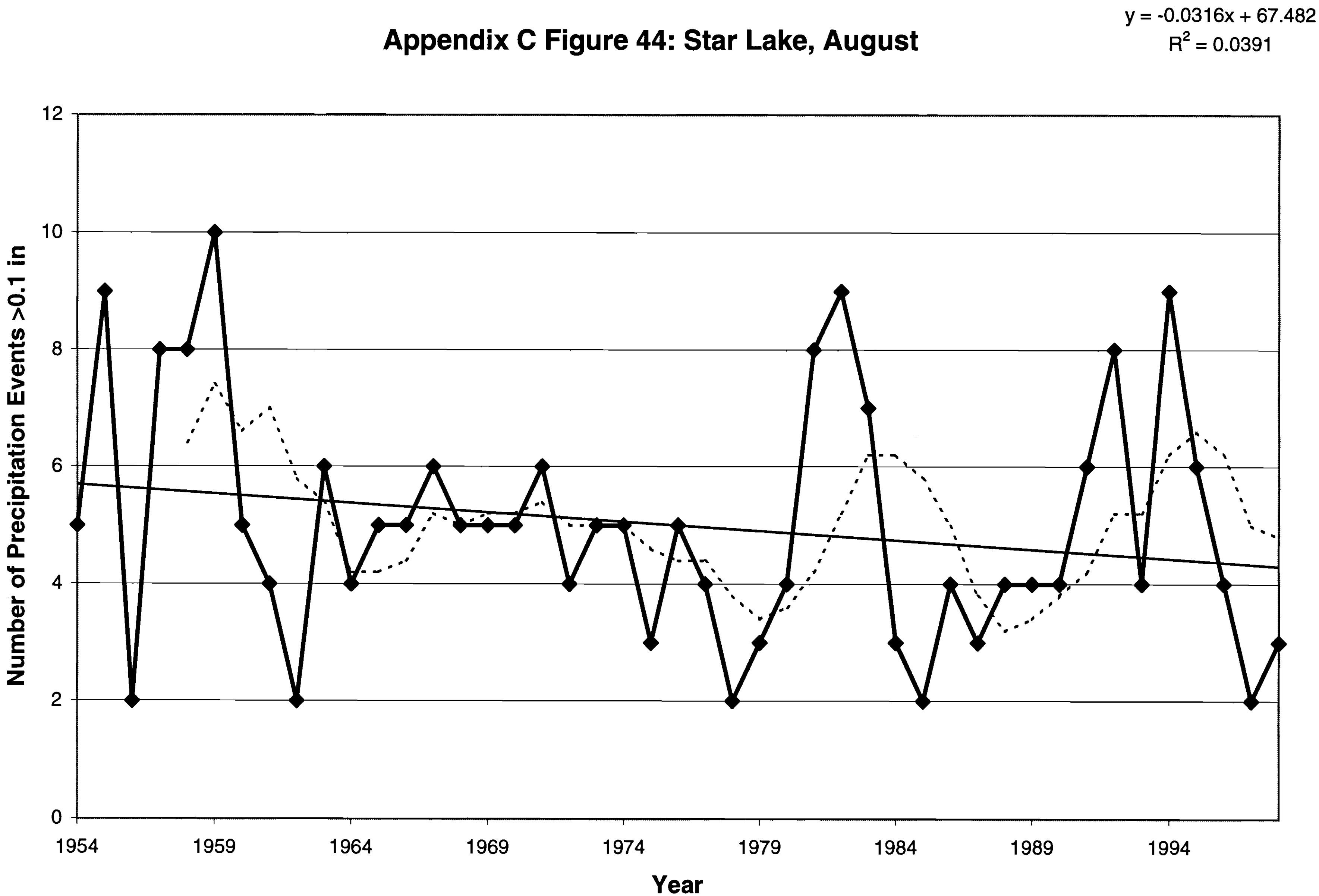
Appendix C Figure 42: Star Lake, June



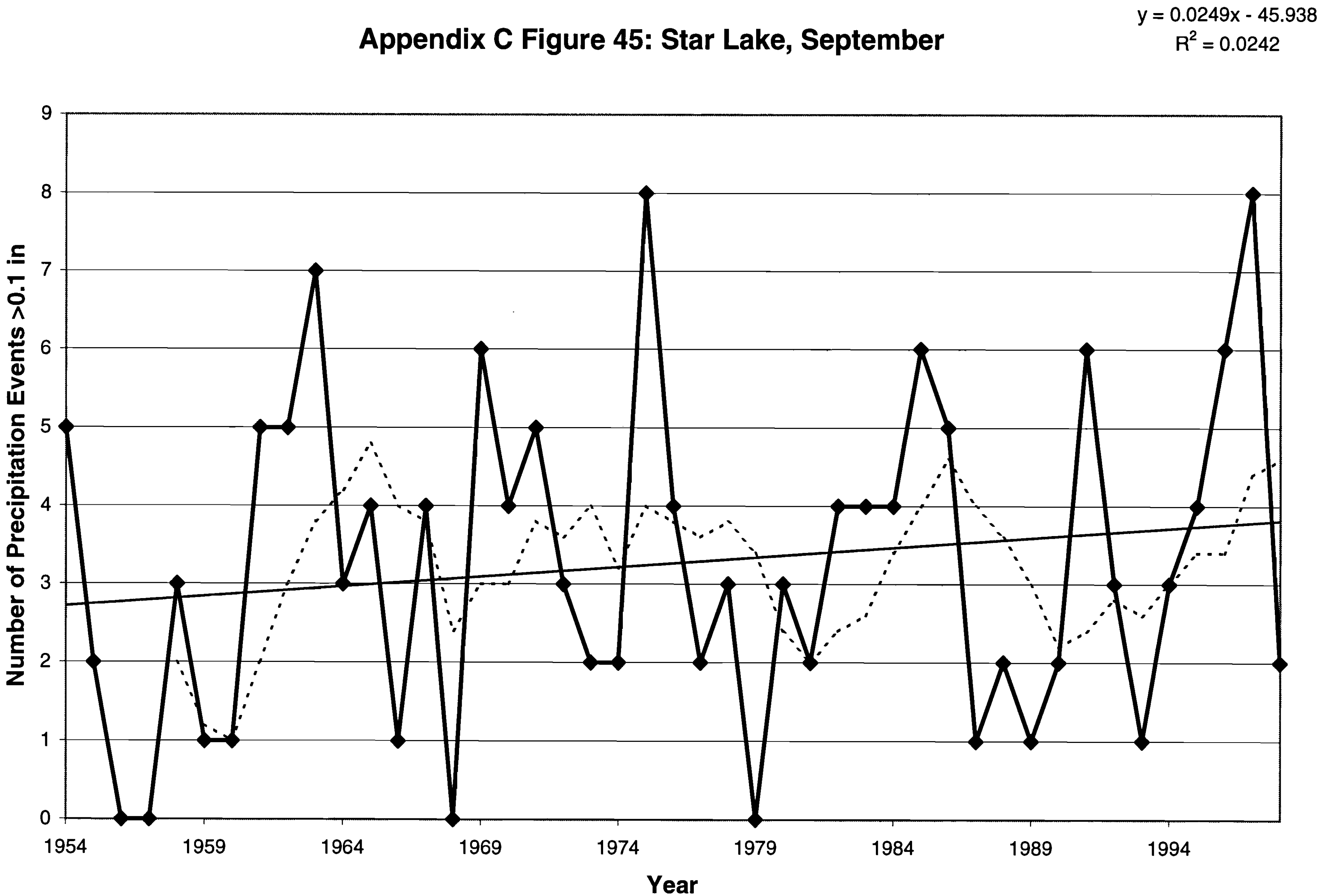
Appendix C Figure 43: Star Lake, July



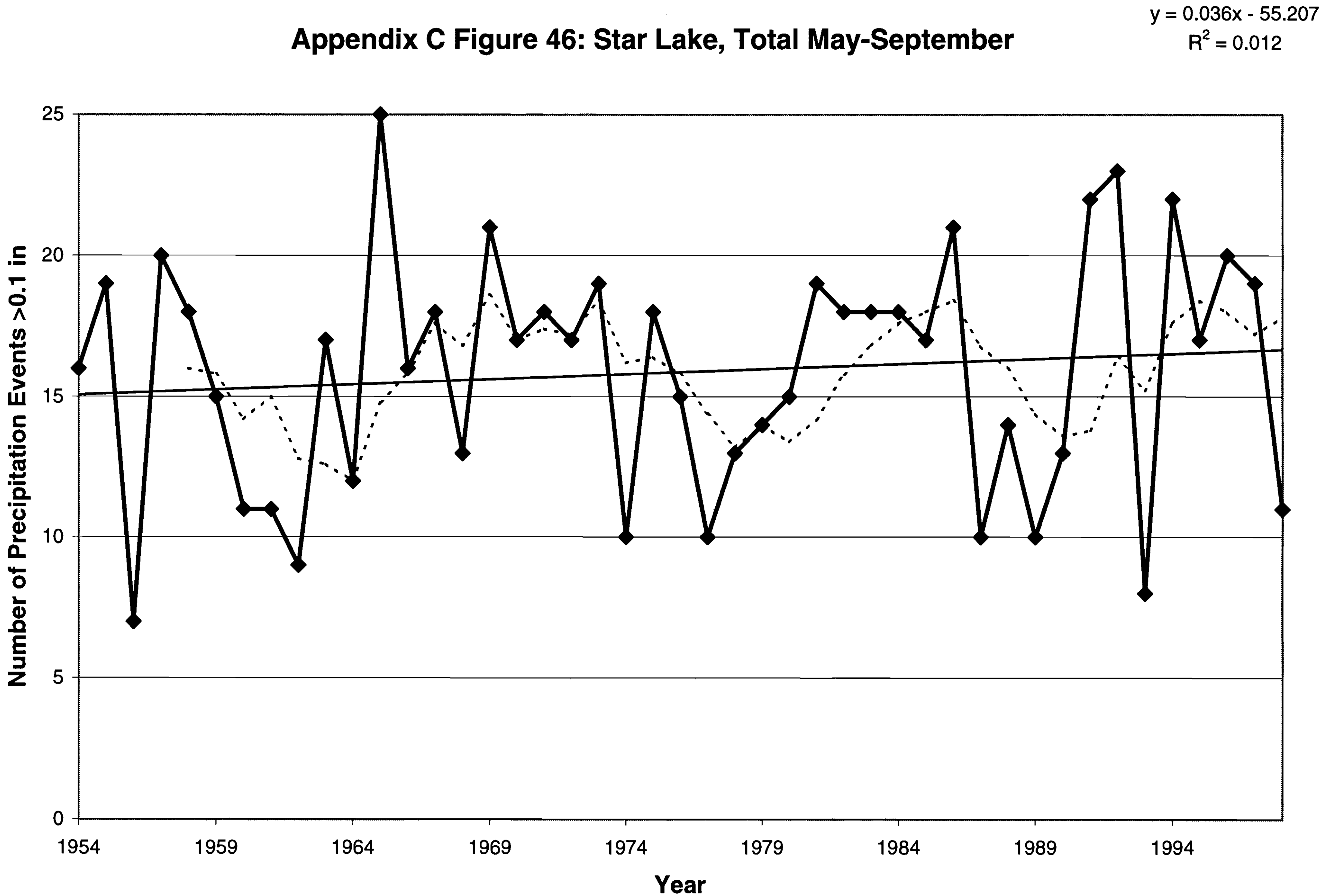
Appendix C Figure 44: Star Lake, August



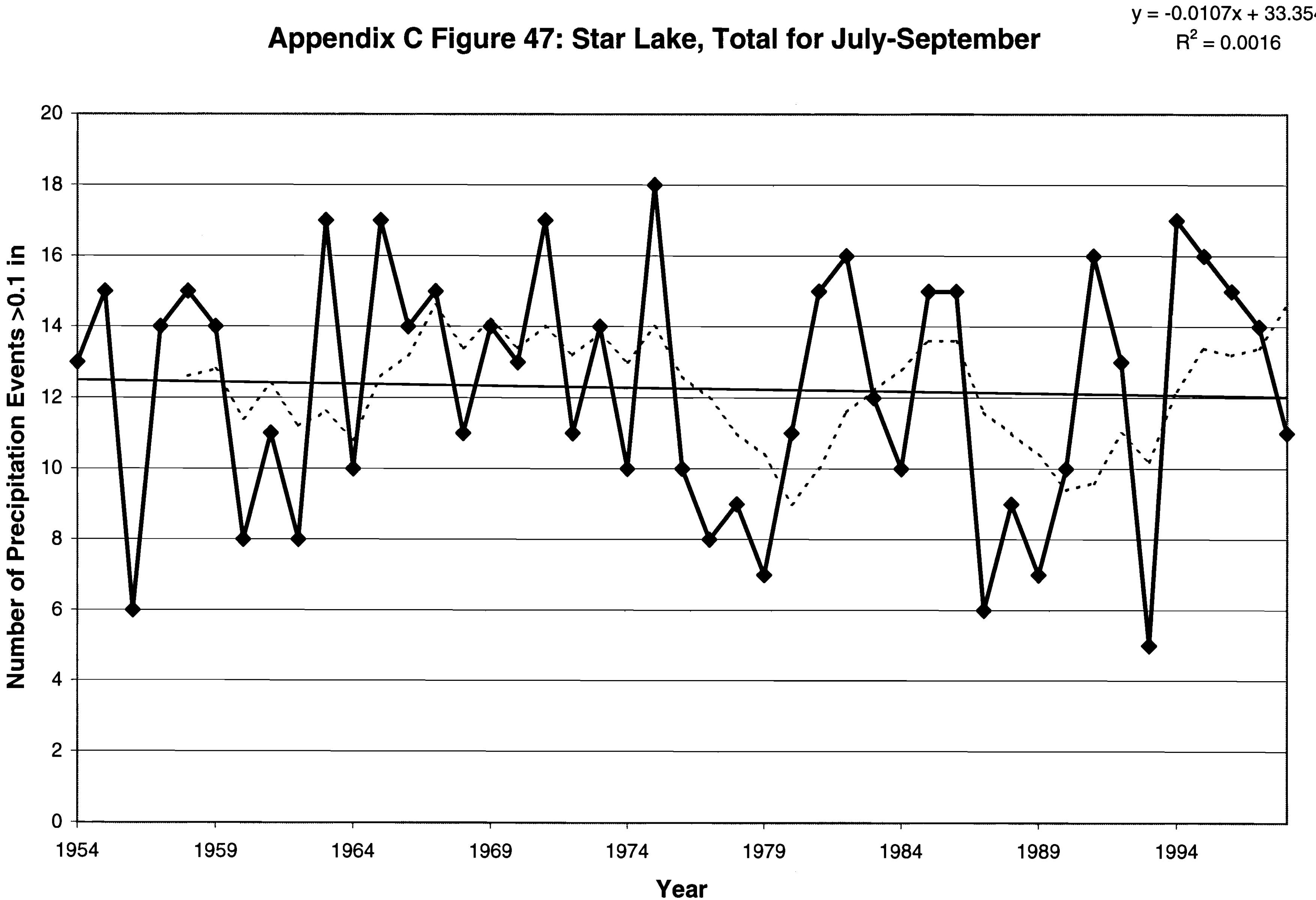
Appendix C Figure 45: Star Lake, September

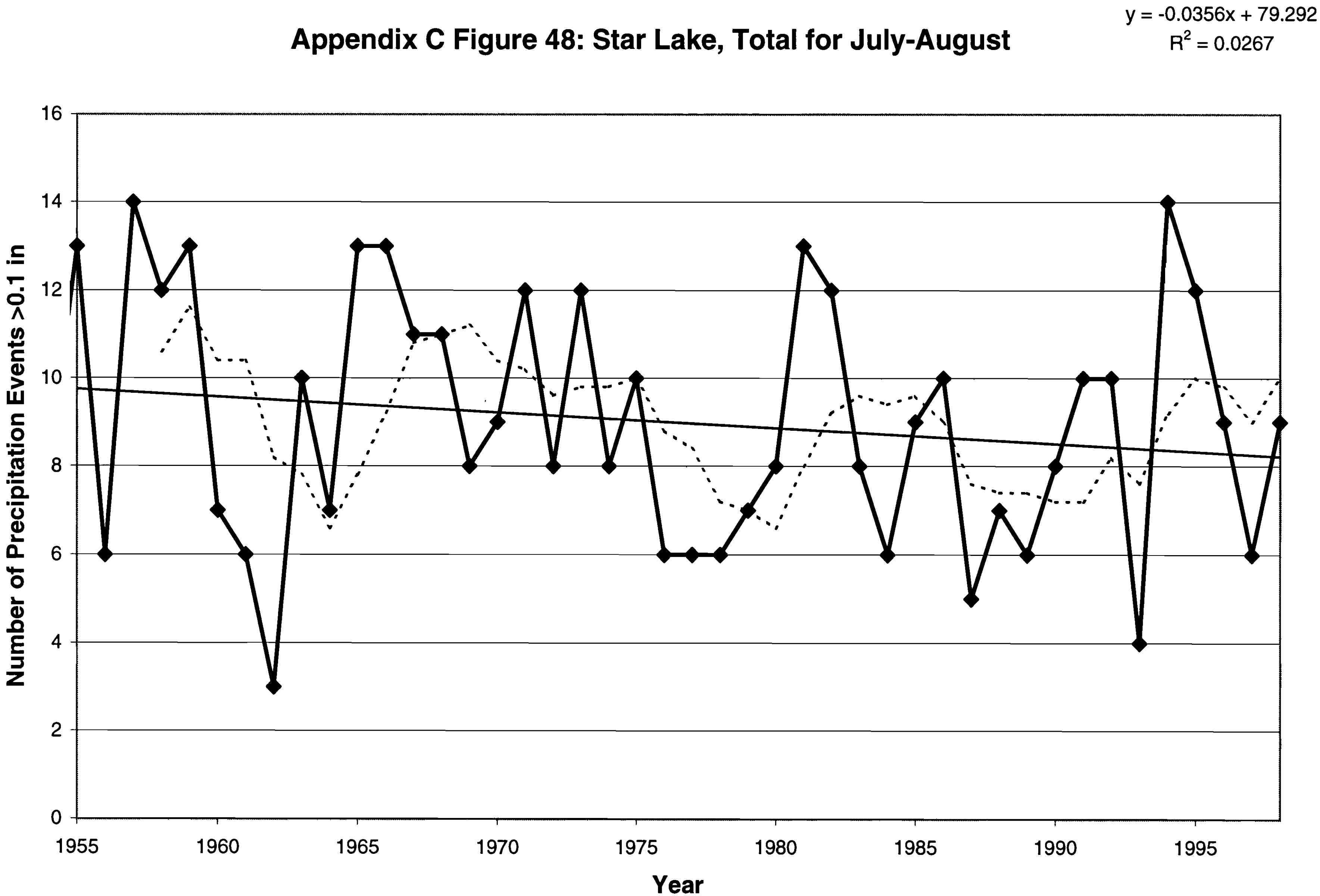


Appendix C Figure 46: Star Lake, Total May-September



Appendix C Figure 47: Star Lake, Total for July-September



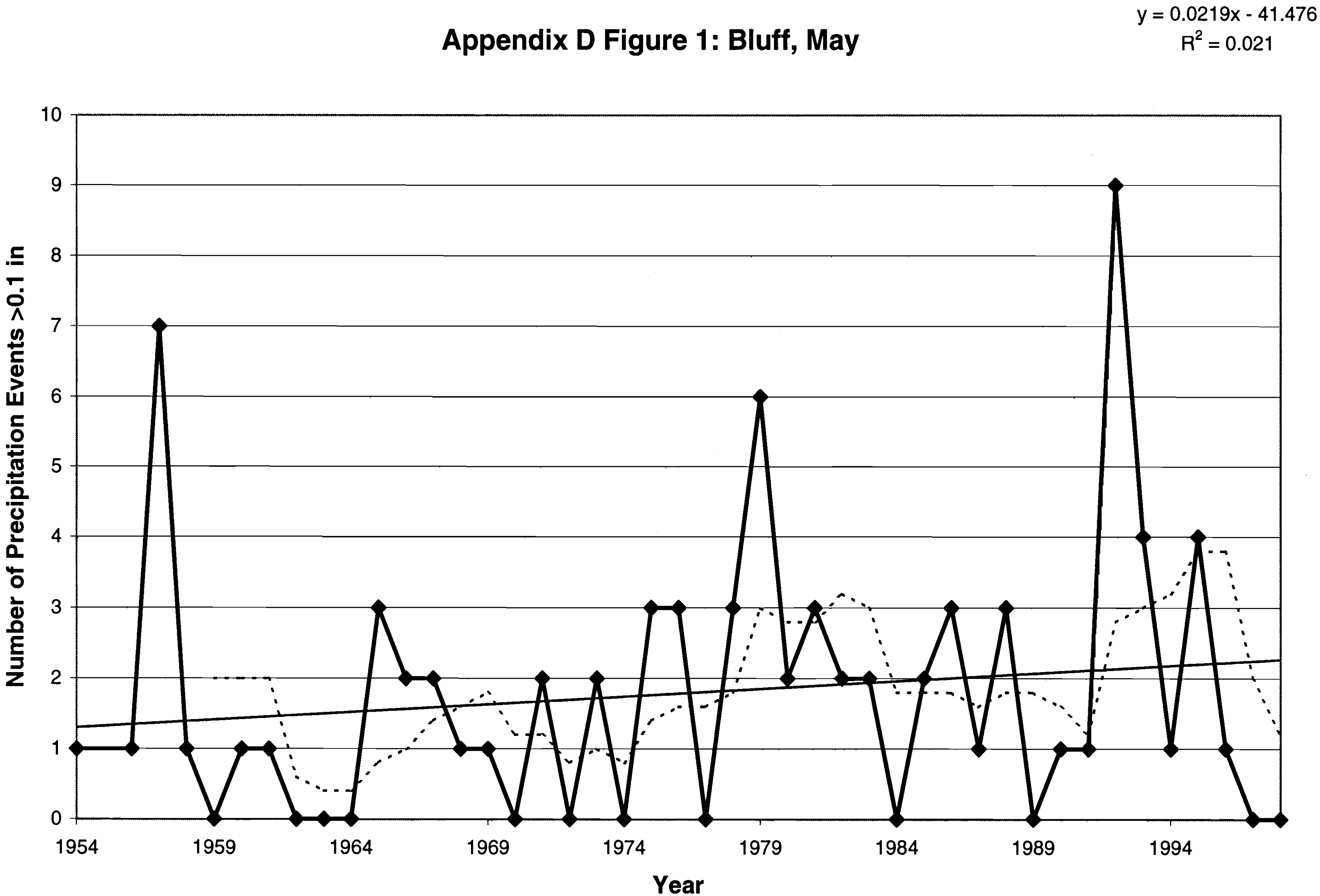


Appendix C Figure 48: Star Lake, Total for July-August
y = -0.0356x + 79.292
R2 = 0.0267
Number of Precipitation Events >0.1 in
Year
0
2
4
6
8
10
12
14
16
1955
1960
1965
1970
1975
1980
1985
1990
1995

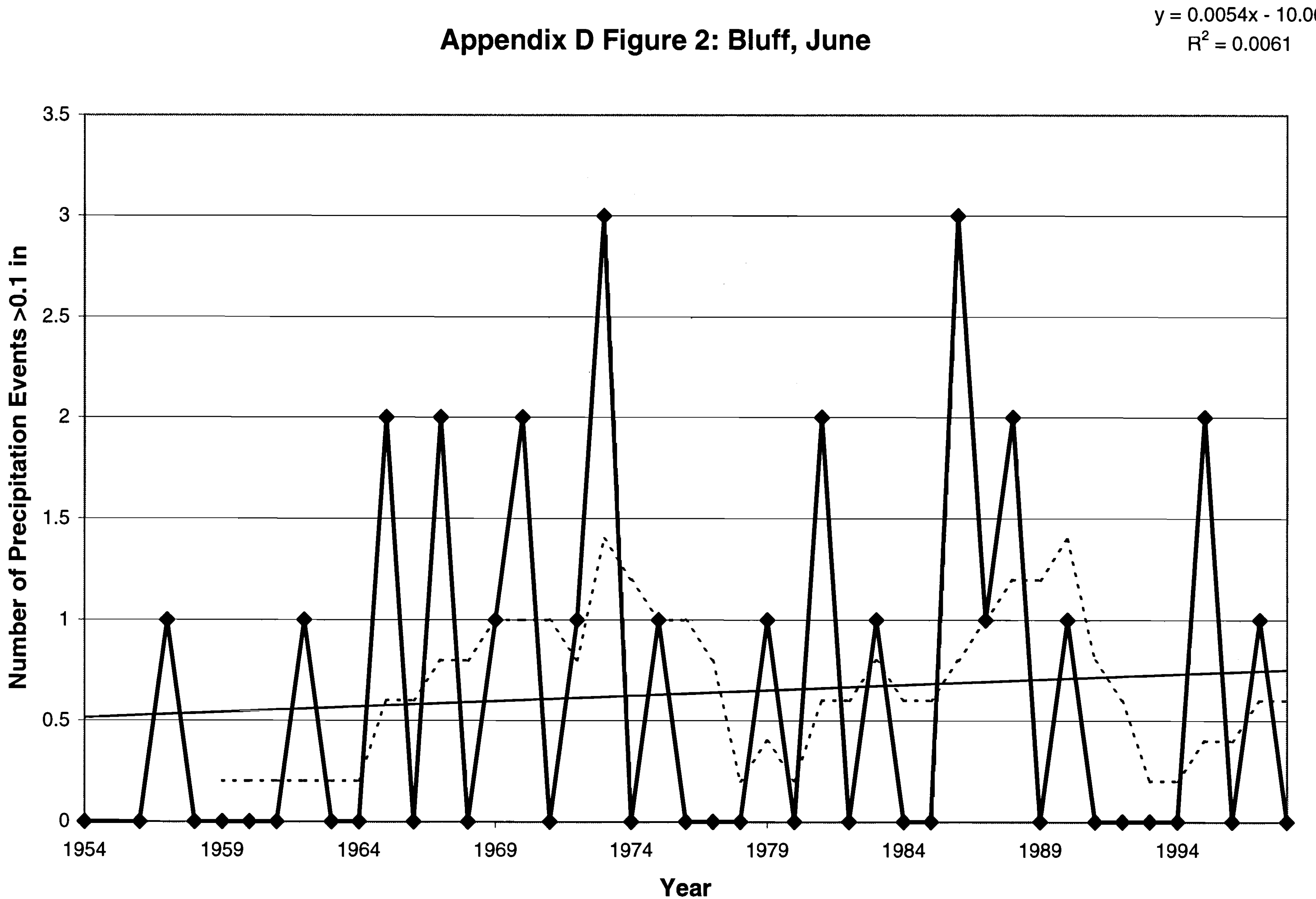
Appendix D Table 1: Number of Precipitation Events >0.1 in, Bluff, Utah, 1954-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1954	1	0	1	1	3	6	5	2
1956	1	0	2	3	0	6	5	5
1957	7	1	3	5	0	16	8	8
1958	1	0	1	1	0	3	2	2
1959	0	0	0	0	1	1	1	0
1960	1	0	0	0	2	3	2	0
1961	1	0	2	3	3	9	8	5
1962	0	1	0	0	3	4	3	0
1963	0	0	0	7	2	9	9	7
1964	0	0	2	4	2	8	8	6
1965	3	2	2	3	4	14	9	5
1966	2	0	3	3	2	10	8	6
1967	2	2	3	4	2	13	9	7
1968	1	0	5	4	0	10	9	9
1969	1	1	1	2	1	6	4	3
1970	0	2	1	3	3	9	7	4
1971	2	0	2	3	1	8	6	5
1972	0	1	2	0	3	6	5	2
1973	2	3	3	3	1	12	7	6
1974	0	0	0	0	0	0	0	0
1975	3	1	5	0	2	11	7	5
1976	3	0	2	2	3	10	7	4
1977	0	0	5	5	0	10	10	10
1978	3	0	0	1	2	6	3	1
1979	6	1	2	2	0	11	4	4
1980	2	0	0	1	1	4	2	1
1981	3	2	3	3	4	15	10	6
1982	2	0	6	6	4	18	16	12
1983	2	1	3	3	3	12	9	6
1984	0	0	1	1	1	3	3	2
1985	2	0	4	0	3	9	7	4
1986	3	3	4	4	4	18	12	8
1987	1	1	2	4	1	9	7	6
1988	3	2	0	3	2	10	5	3
1989	0	0	3	3	0	6	6	6
1990	1	1	2	0	3	7	5	2
1991	1	0	1	3	1	6	5	4
1992	9	0	3	3	1	16	7	6
1993	4	0	0	5	2	11	7	5
1994	1	0	0	1	1	3	2	1
1995	4	2	0	1	1	8	2	1
1996	1	0	2	0	3	6	5	2
1997	0	1	3	3	5	12	11	6
1998	0	0	1	1	1	3	3	2
Ave.	**1.80**	**0.64**	**1.93**	**2.36**	**1.84**	**8.57**	**6.14**	**4.30**
S.D.	**1.95**	**0.89**	**1.61**	**1.81**	**1.35**	**4.38**	**3.25**	**2.82**
Max	**9**	**3**	**6**	**7**	**5**	**18**	**16**	**12**
Min	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

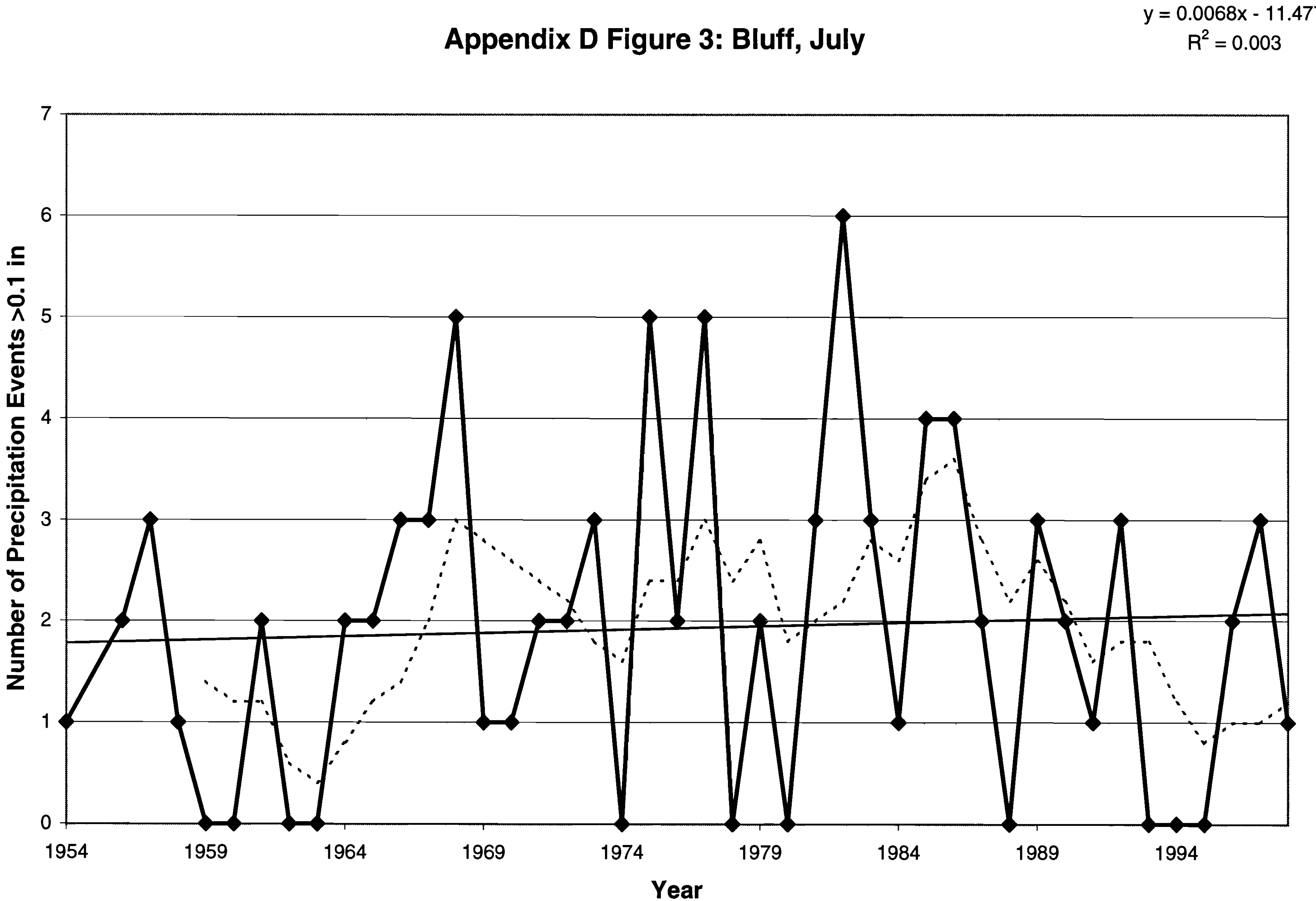
Appendix D Figure 1: Bluff, May



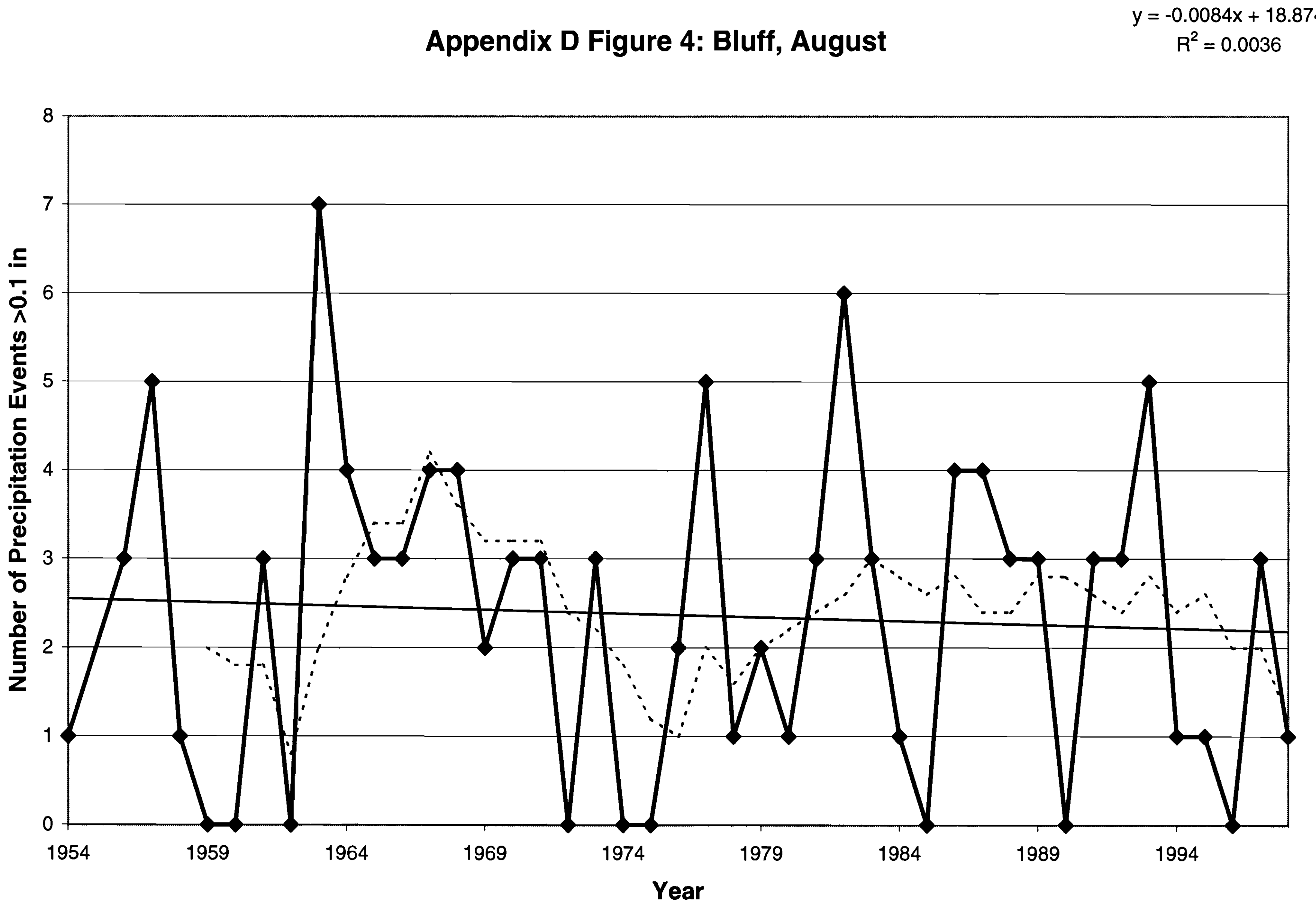
Appendix D Figure 2: Bluff, June



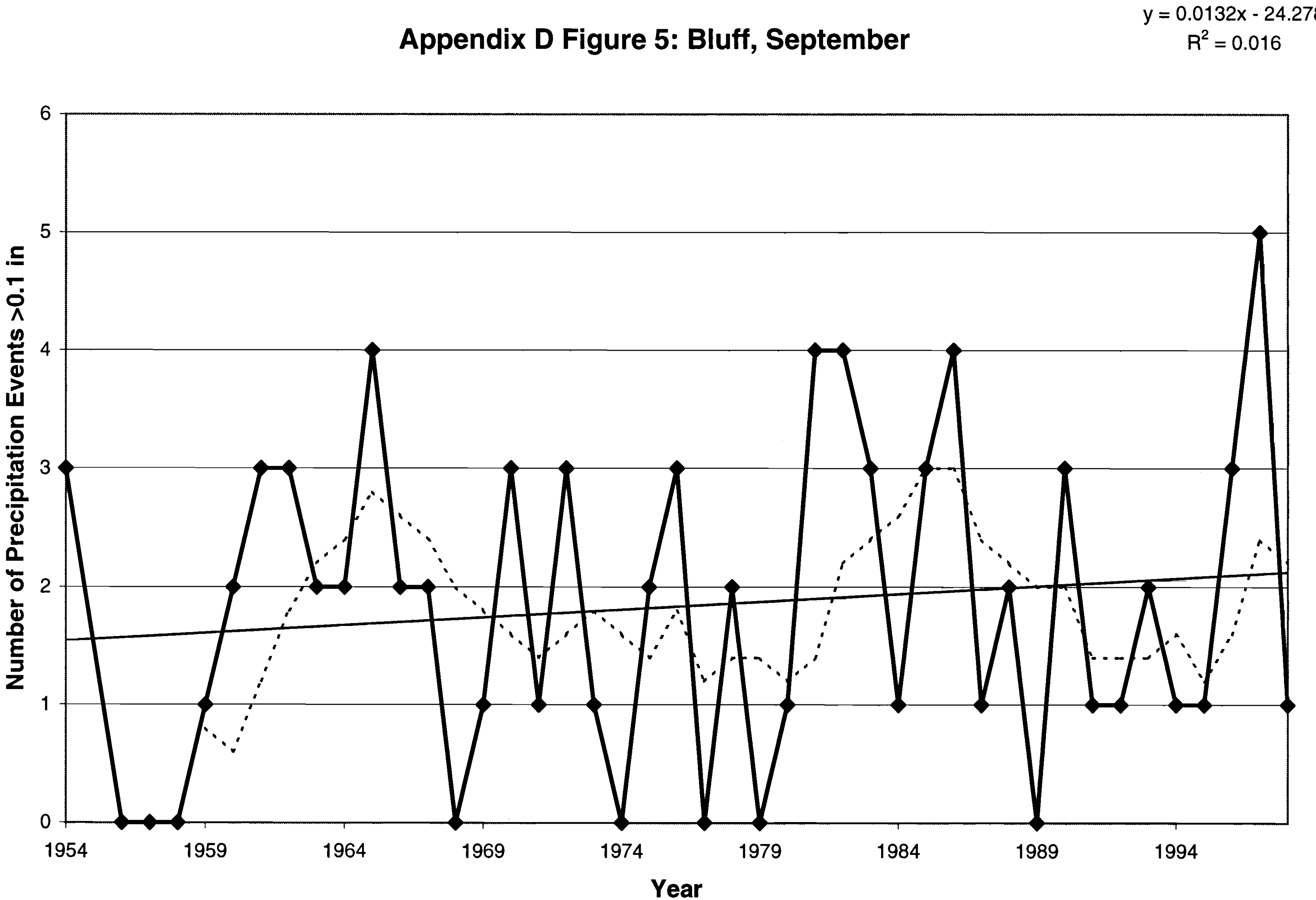
Appendix D Figure 3: Bluff, July

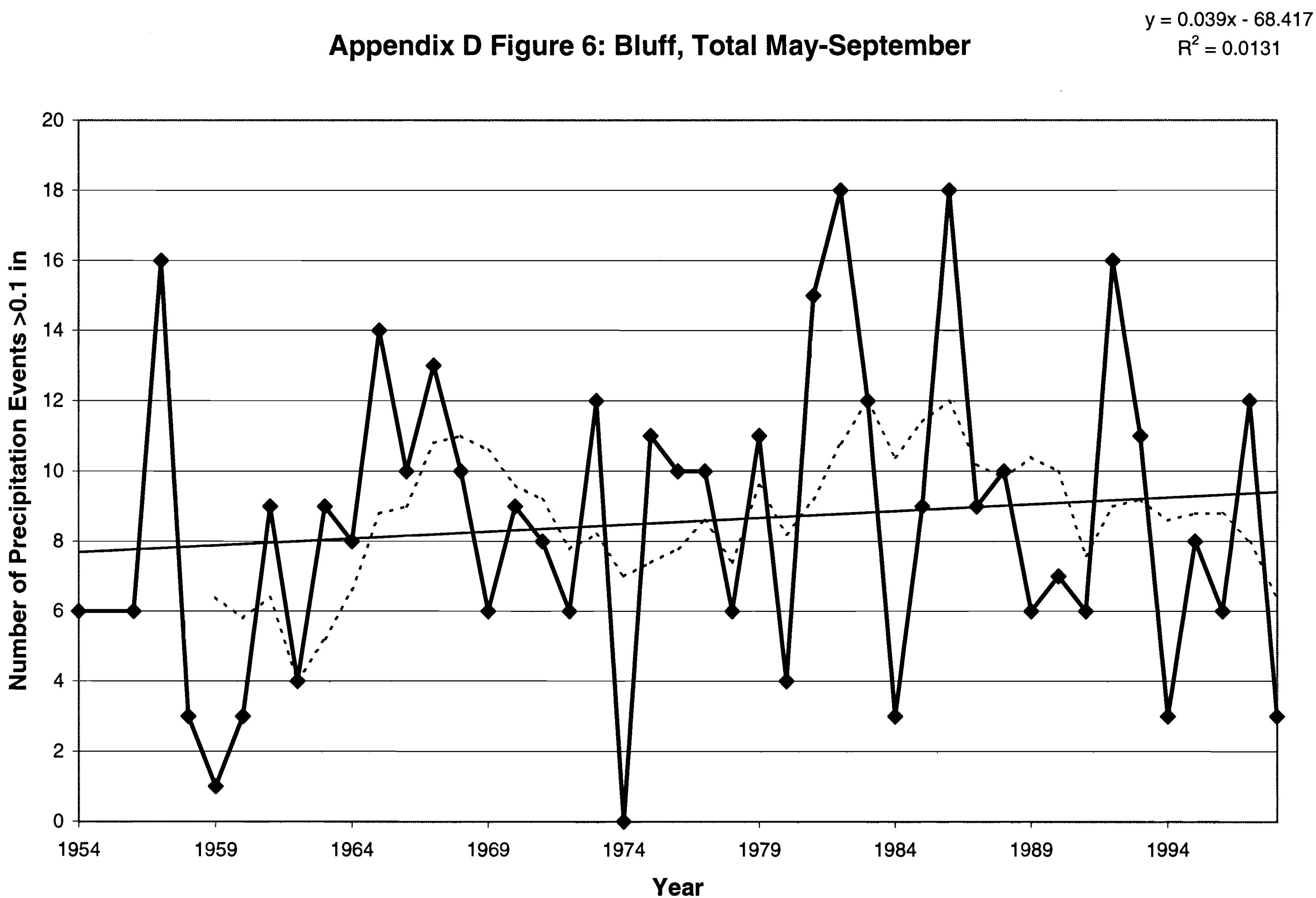


Appendix D Figure 4: Bluff, August



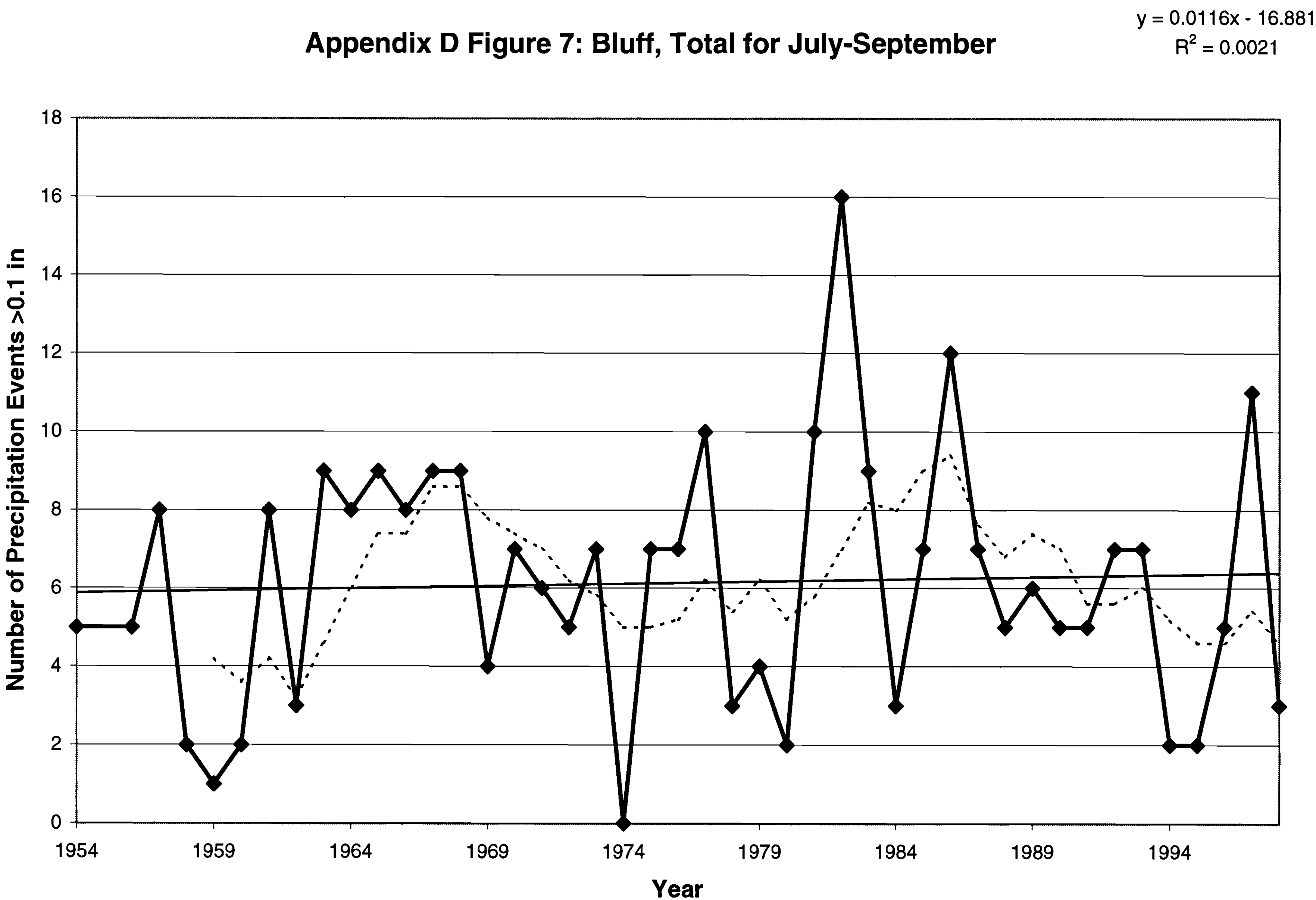
Appendix D Figure 5: Bluff, September



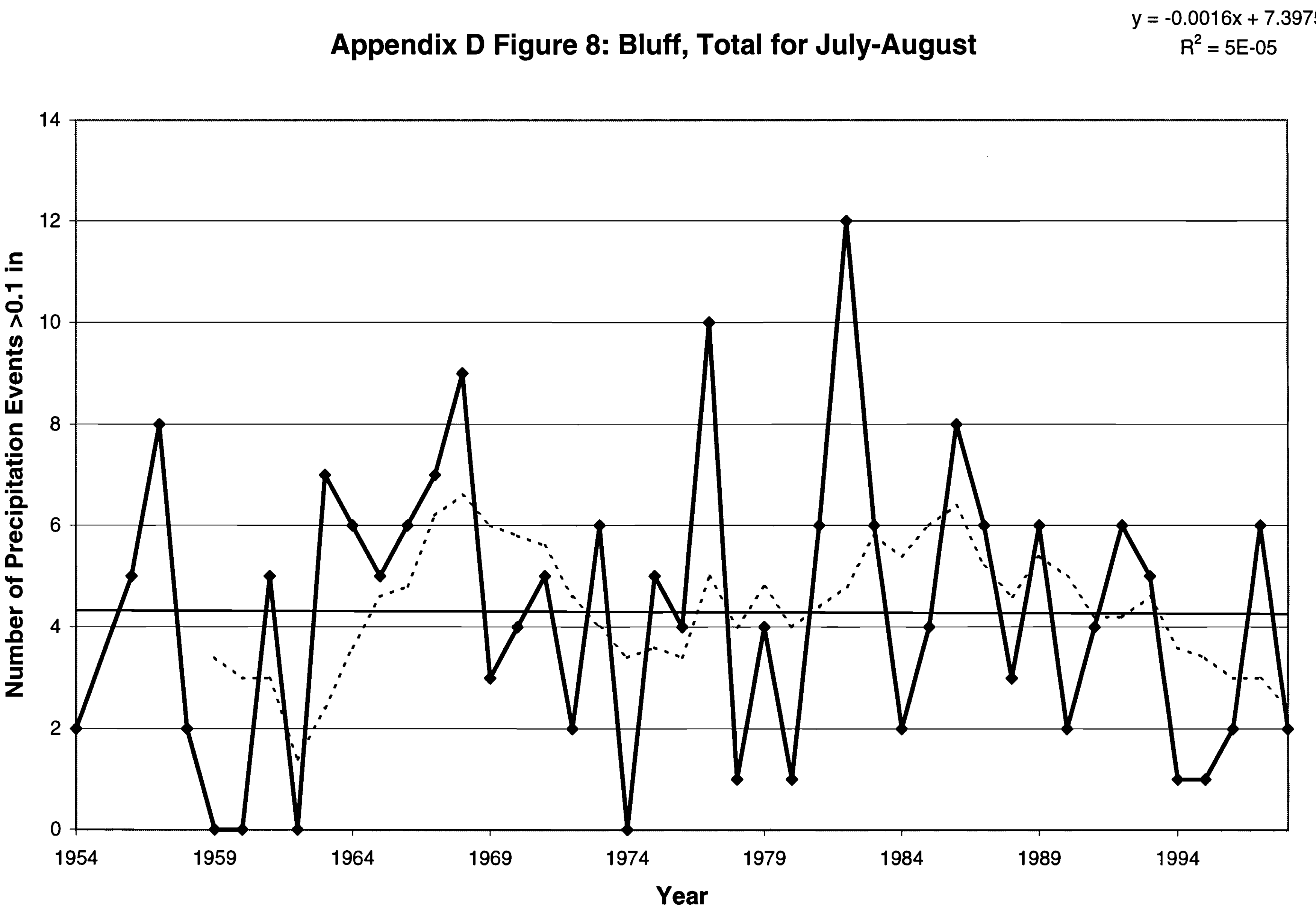


Appendix D Figure 6: Bluff, Total May-September
y = 0.039x - 68.417
R^2 = 0.0131
Number of Precipitation Events >0.1 in
Year
0
2
4
6
8
10
12
14
16
18
20
1954
1959
1964
1969
1974
1979
1984
1989
1994

Appendix D Figure 7: Bluff, Total for July-September



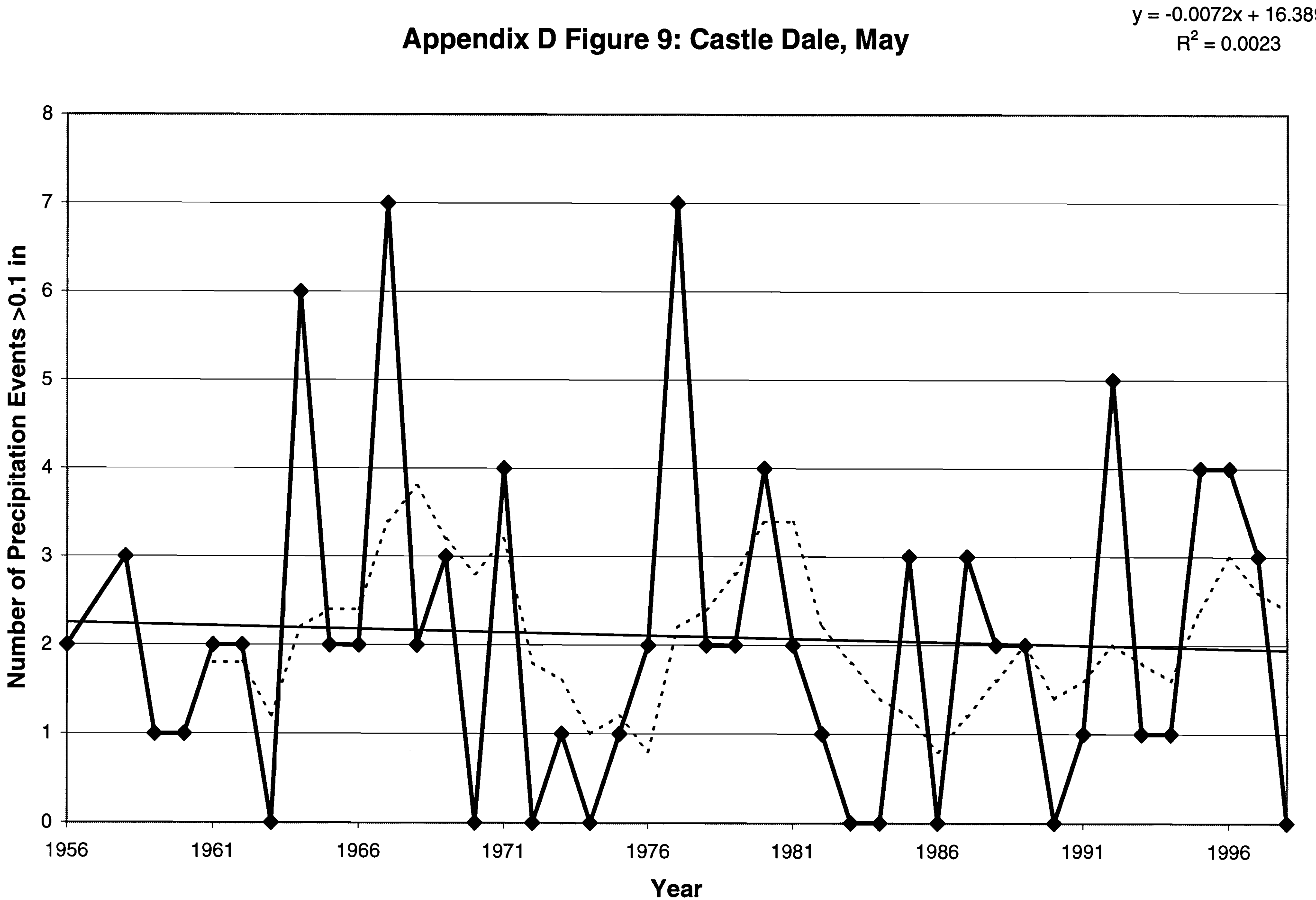
Appendix D Figure 8: Bluff, Total for July-August



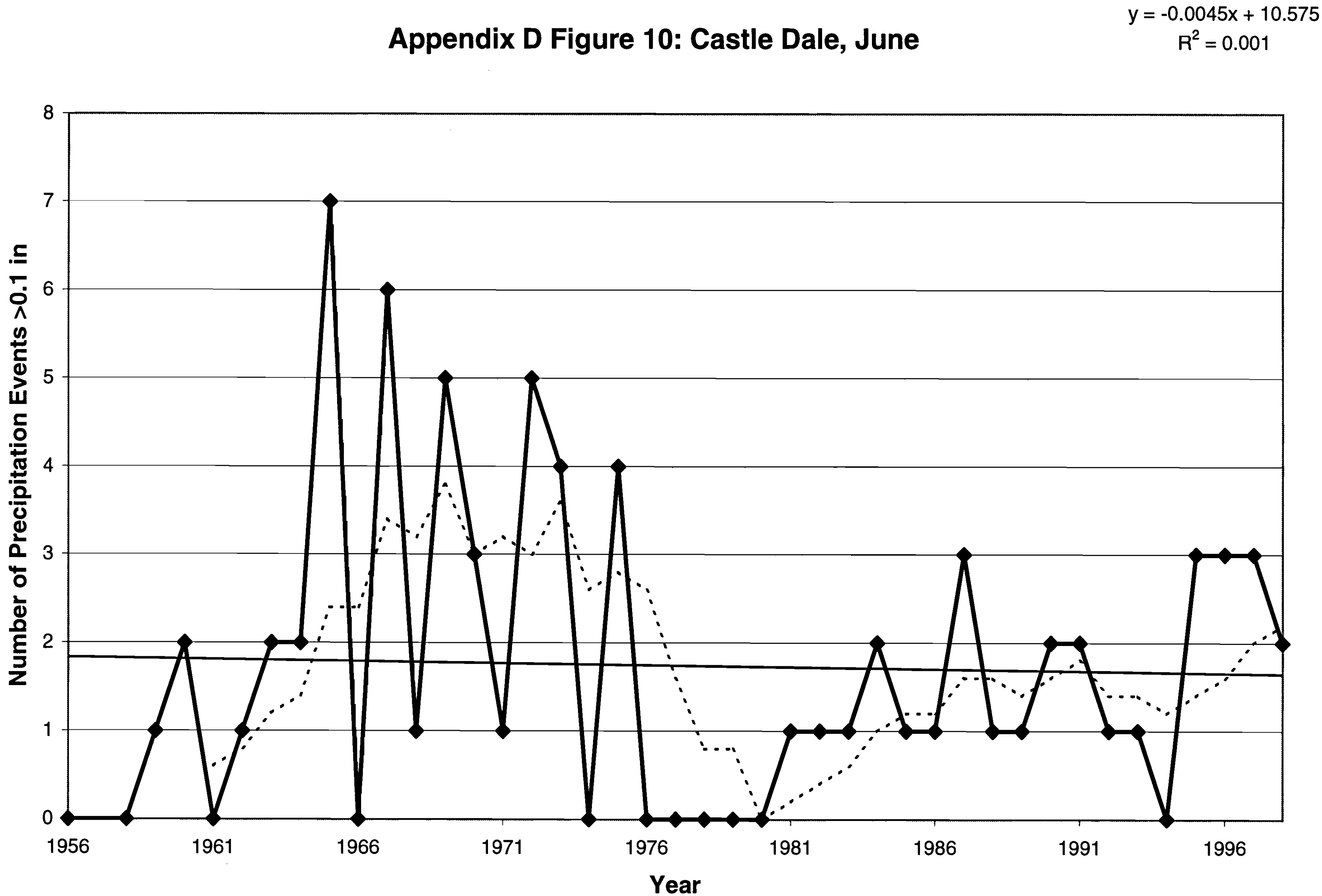
Appendix D Table 2: Number of Precipitation Events >0.1 in, Castle Dale, Utah, 1956-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1956	2	0	0	0	1	3	1	0
1958	3	0	1	2	3	9	6	3
1959	1	1	3	3	4	12	10	6
1960	1	2	0	1	5	9	6	1
1961	2	0	4	10	6	22	20	14
1962	2	1	3	1	3	10	7	4
1963	0	2	0	7	3	12	10	7
1964	6	2	2	1	1	12	4	3
1965	2	7	7	5	4	25	16	12
1966	2	0	5	4	1	12	10	9
1967	7	6	1	1	3	18	5	2
1968	2	1	3	3	1	10	7	6
1969	3	5	1	4	2	15	7	5
1970	0	3	3	1	1	8	5	4
1971	4	1	0	2	0	7	2	2
1972	0	5	0	2	1	8	3	2
1973	1	4	4	2	0	11	6	6
1974	0	0	4	0	1	5	5	4
1975	1	4	5	0	2	12	7	5
1976	2	0	2	0	3	7	5	2
1977	7	0	3	3	1	14	7	6
1978	2	0	0	0	1	3	1	0
1979	2	0	0	4	0	6	4	4
1980	4	0	3	3	4	14	10	6
1981	2	1	2	2	5	12	9	4
1982	1	1	2	6	5	15	13	8
1983	0	1	3	1	2	7	6	4
1984	0	2	3	5	1	11	9	8
1985	3	1	4	0	3	11	7	4
1986	0	1	1	4	2	8	7	5
1987	3	3	7	4	0	17	11	11
1988	2	1	1	3	2	9	6	4
1989	2	1	3	6	1	13	10	9
1990	0	2	2	3	8	15	13	5
1991	1	2	5	6	2	16	13	11
1992	5	1	0	2	2	10	4	2
1993	1	1	0	1	1	4	2	1
1994	1	0	0	3	2	6	5	3
1995	4	3	3	5	2	17	10	8
1996	4	3	2	0	3	12	5	2
1997	3	3	3	7	8	24	18	10
1998	0	2	2	3	3	10	8	5
Ave.	**2.10**	**1.74**	**2.31**	**2.86**	**2.45**	**11.45**	**7.62**	**5.17**
S.D.	**1.85**	**1.75**	**1.88**	**2.32**	**1.94**	**5.07**	**4.24**	**3.31**
Max	**7**	**7**	**7**	**10**	**8**	**25**	**20**	**14**
Min	**0**	**0**	**0**	**0**	**0**	**3**	**1**	**0**

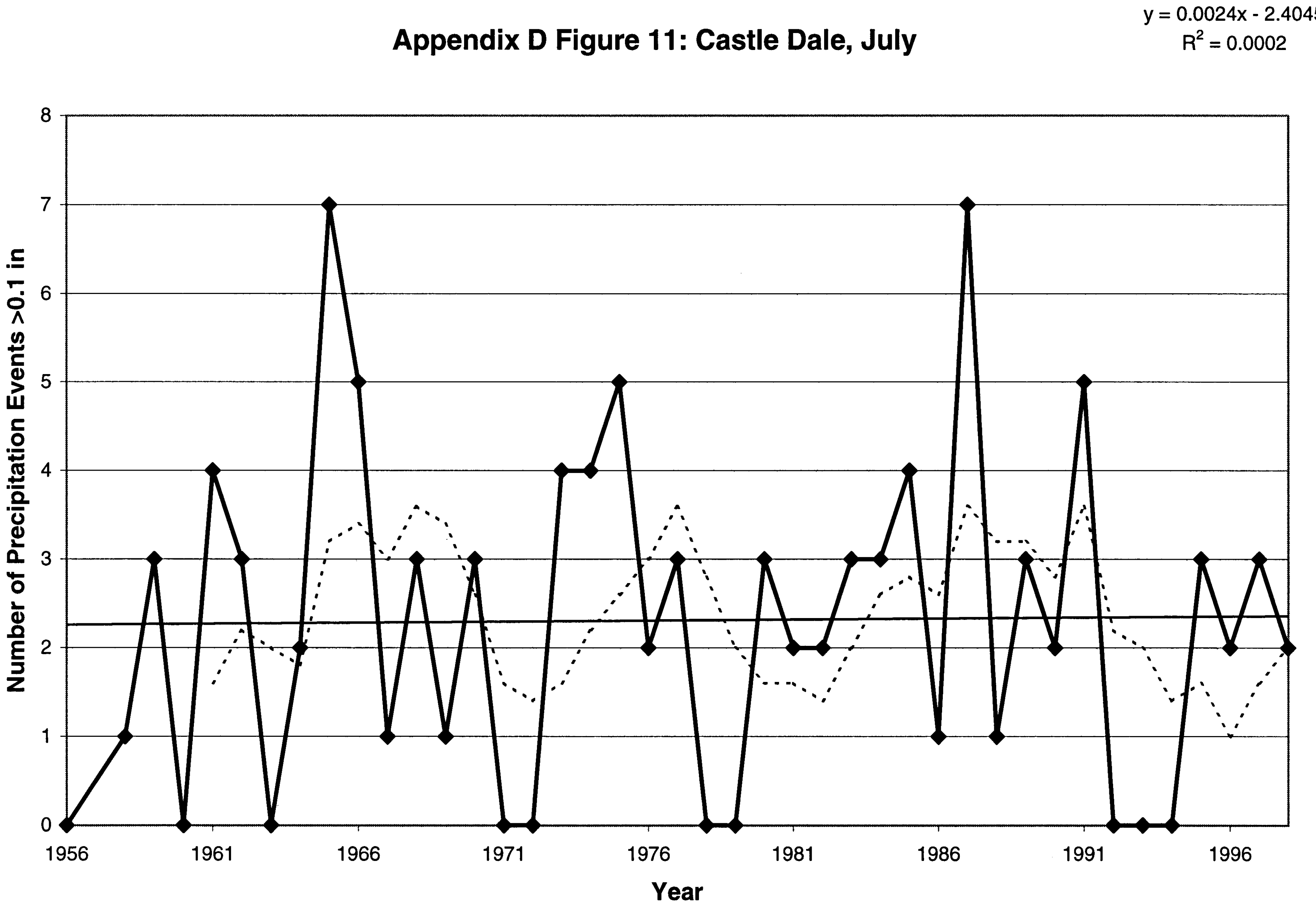
Appendix D Figure 9: Castle Dale, May

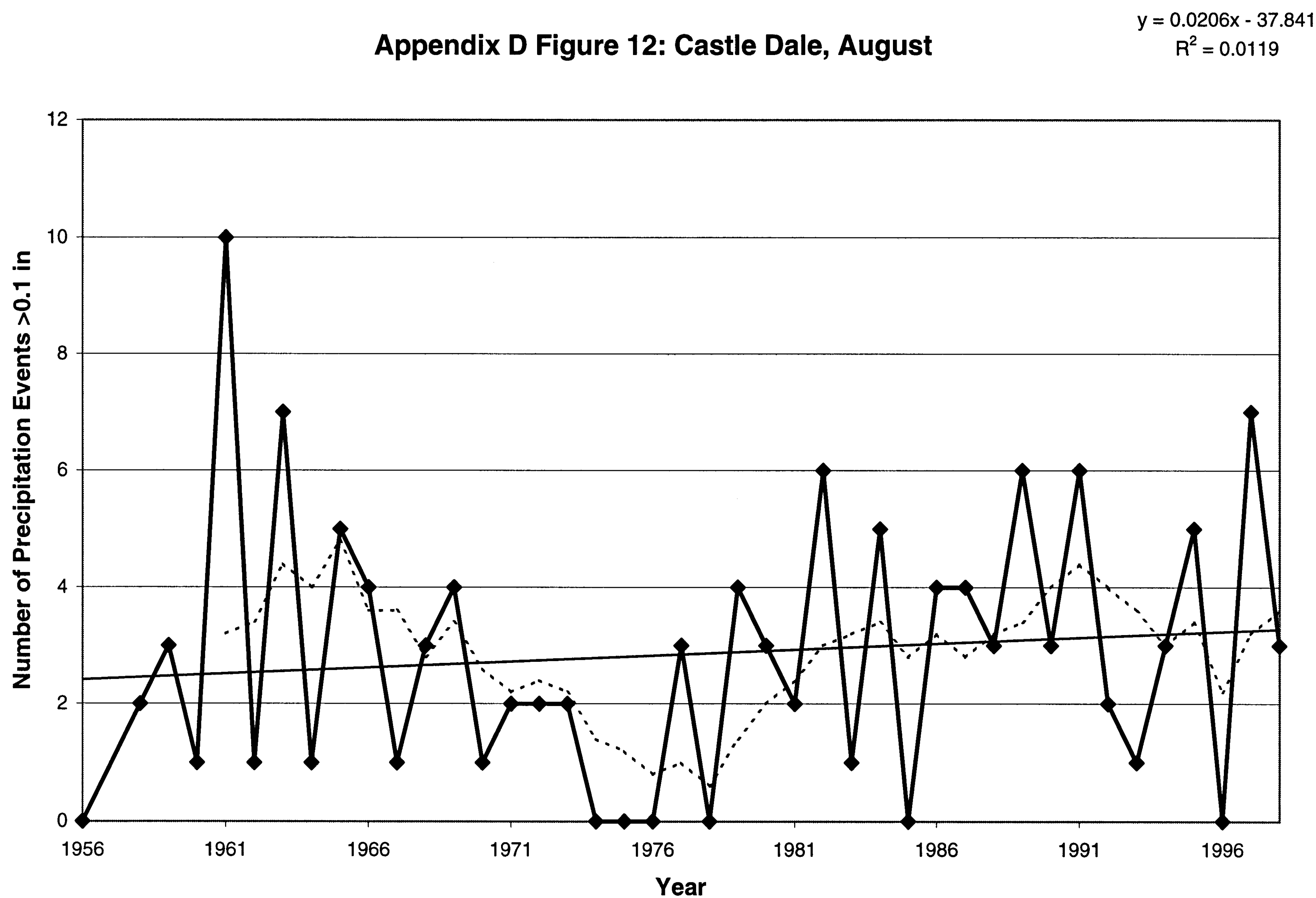


Appendix D Figure 10: Castle Dale, June



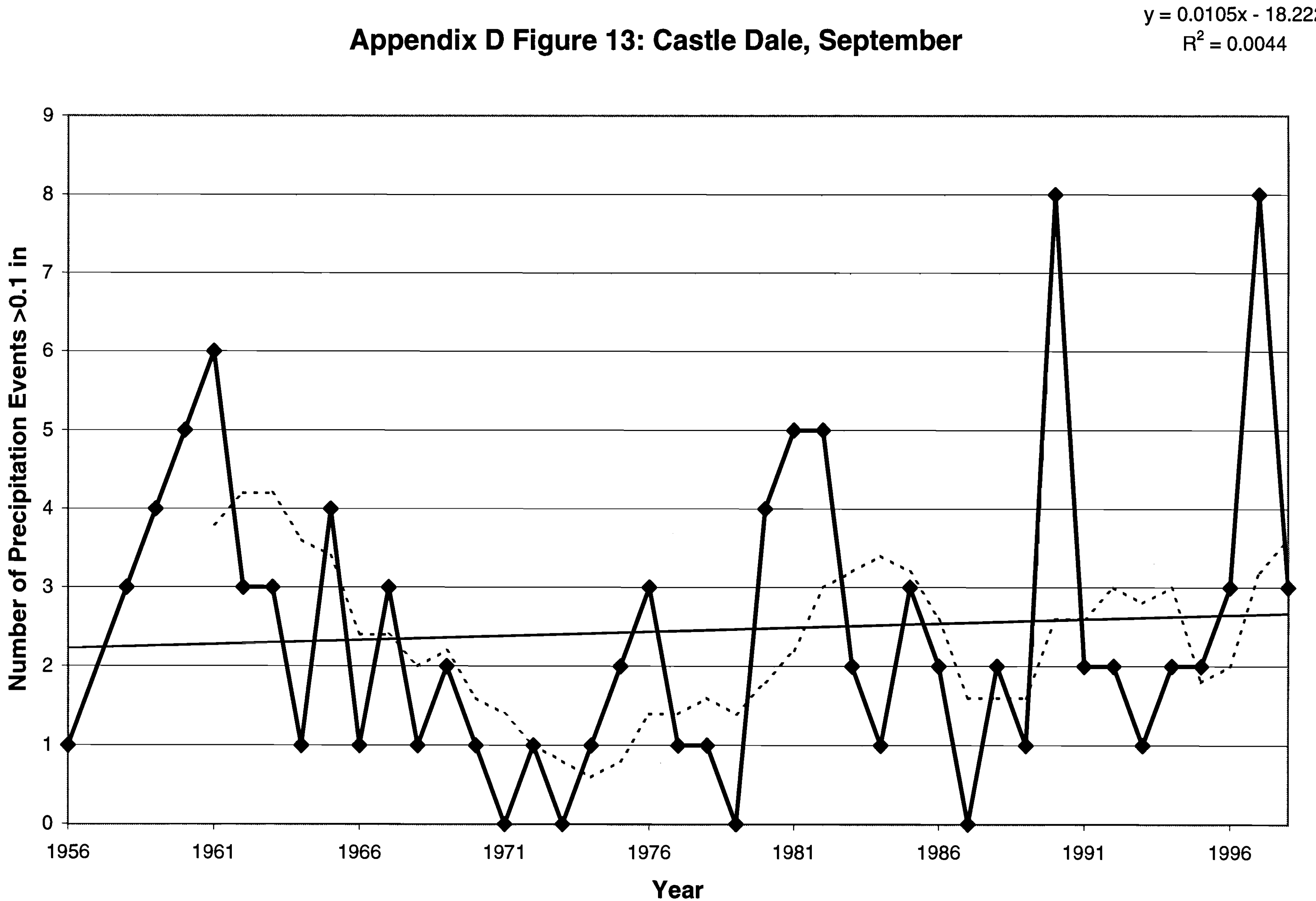
Appendix D Figure 11: Castle Dale, July

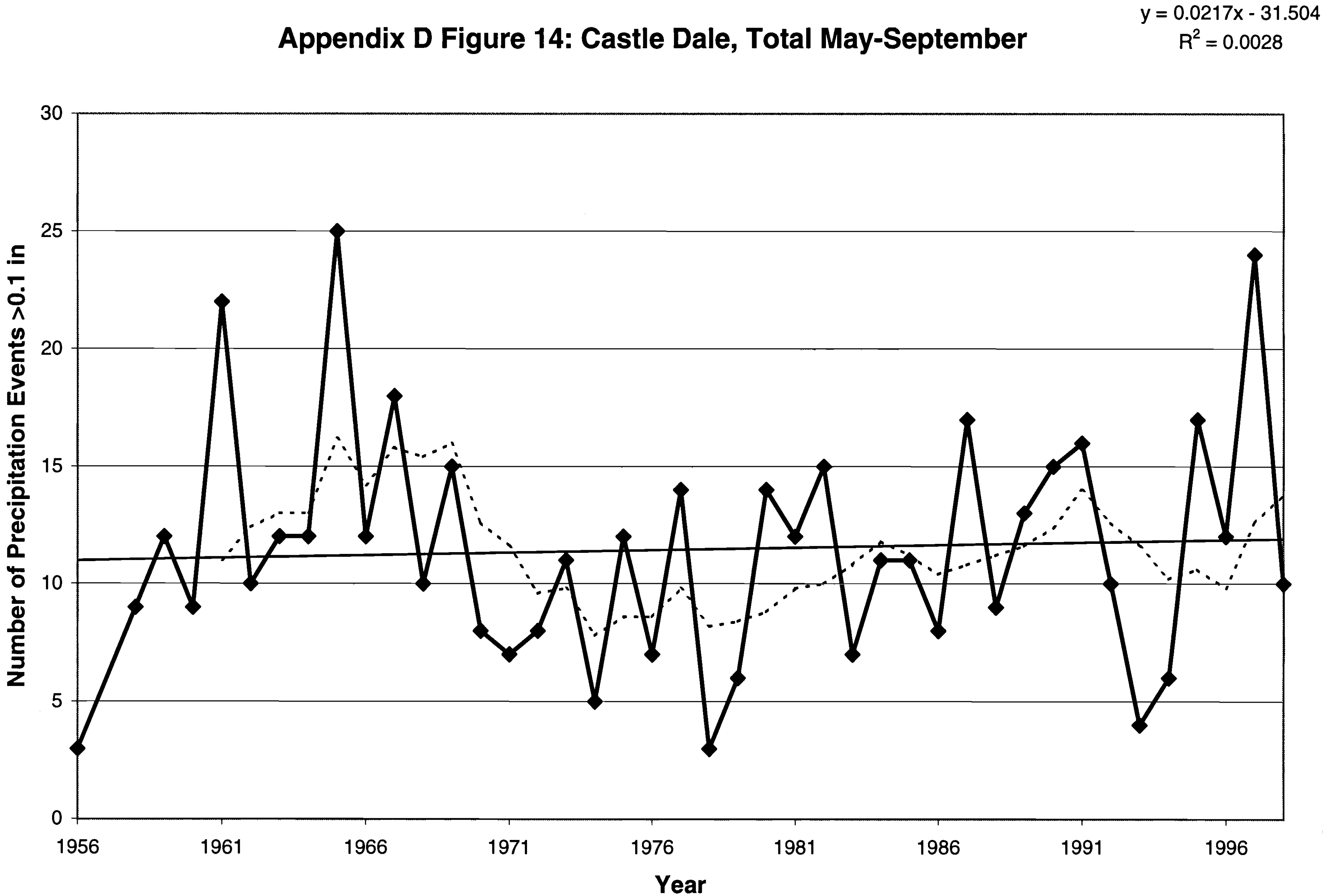




y = 0.0206x - 37.841
R2 = 0.0119
Appendix D Figure 12: Castle Dale, August
Number of Precipitation Events >0.1 in
12
10
8
6
4
2
0
1956
1961
1966
1971
1976
1981
1986
1991
1996
Year

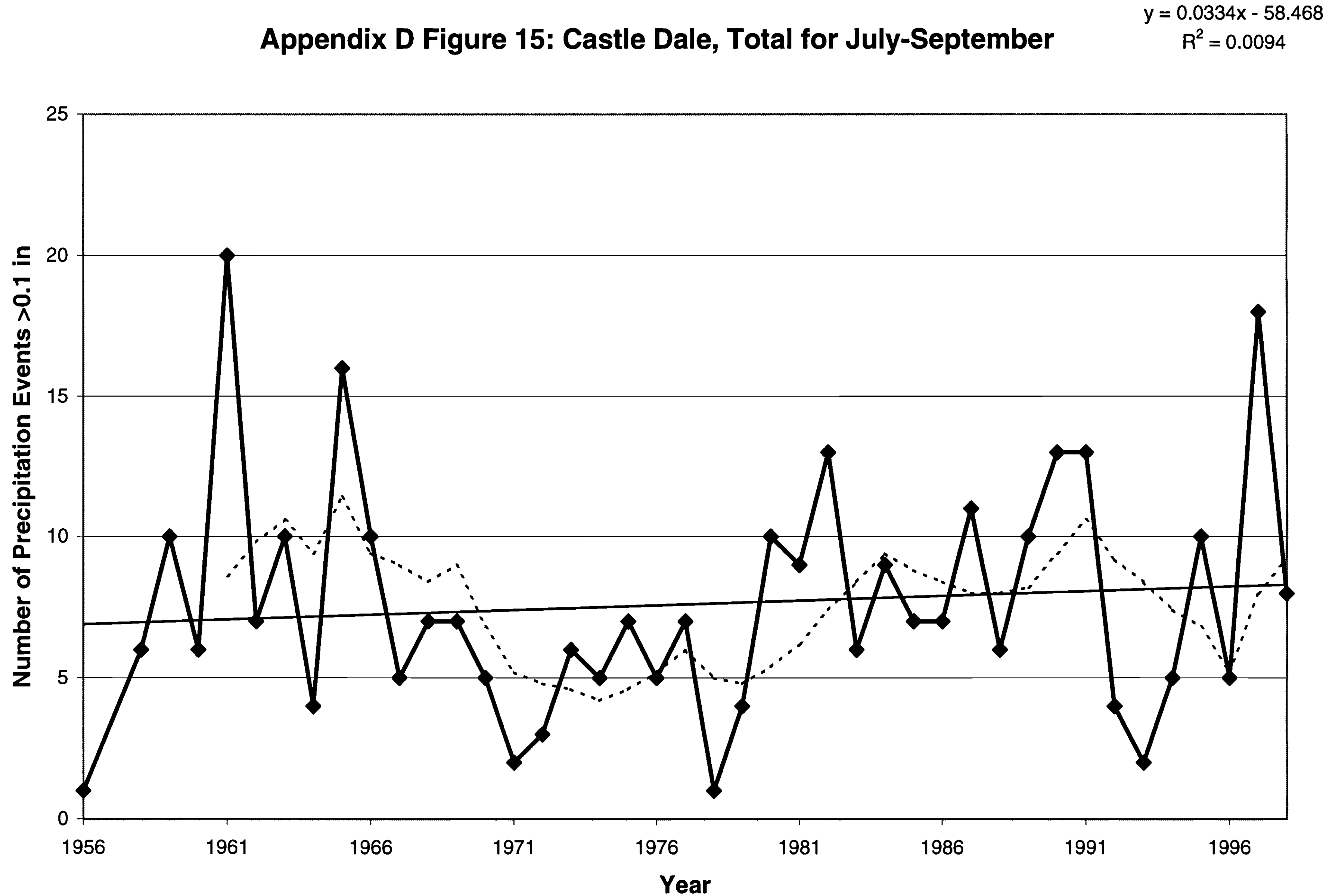
Appendix D Figure 13: Castle Dale, September



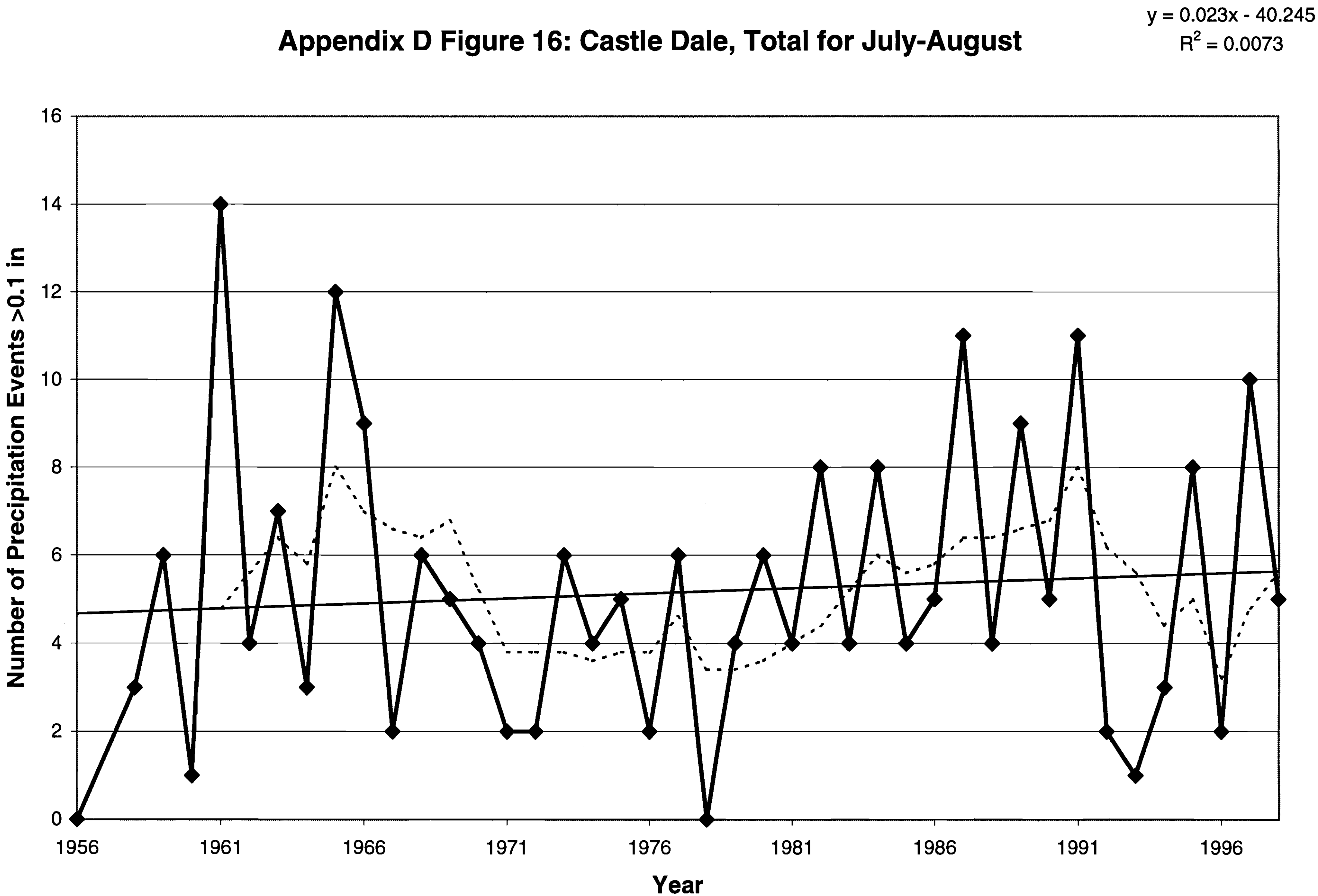


Appendix D Figure 14: Castle Dale, Total May-September
y = 0.0217x - 31.504
R2 = 0.0028
Number of Precipitation Events >0.1 in
Year
0
5
10
15
20
25
30
1956
1961
1966
1971
1976
1981
1986
1991
1996

Appendix D Figure 15: Castle Dale, Total for July-September



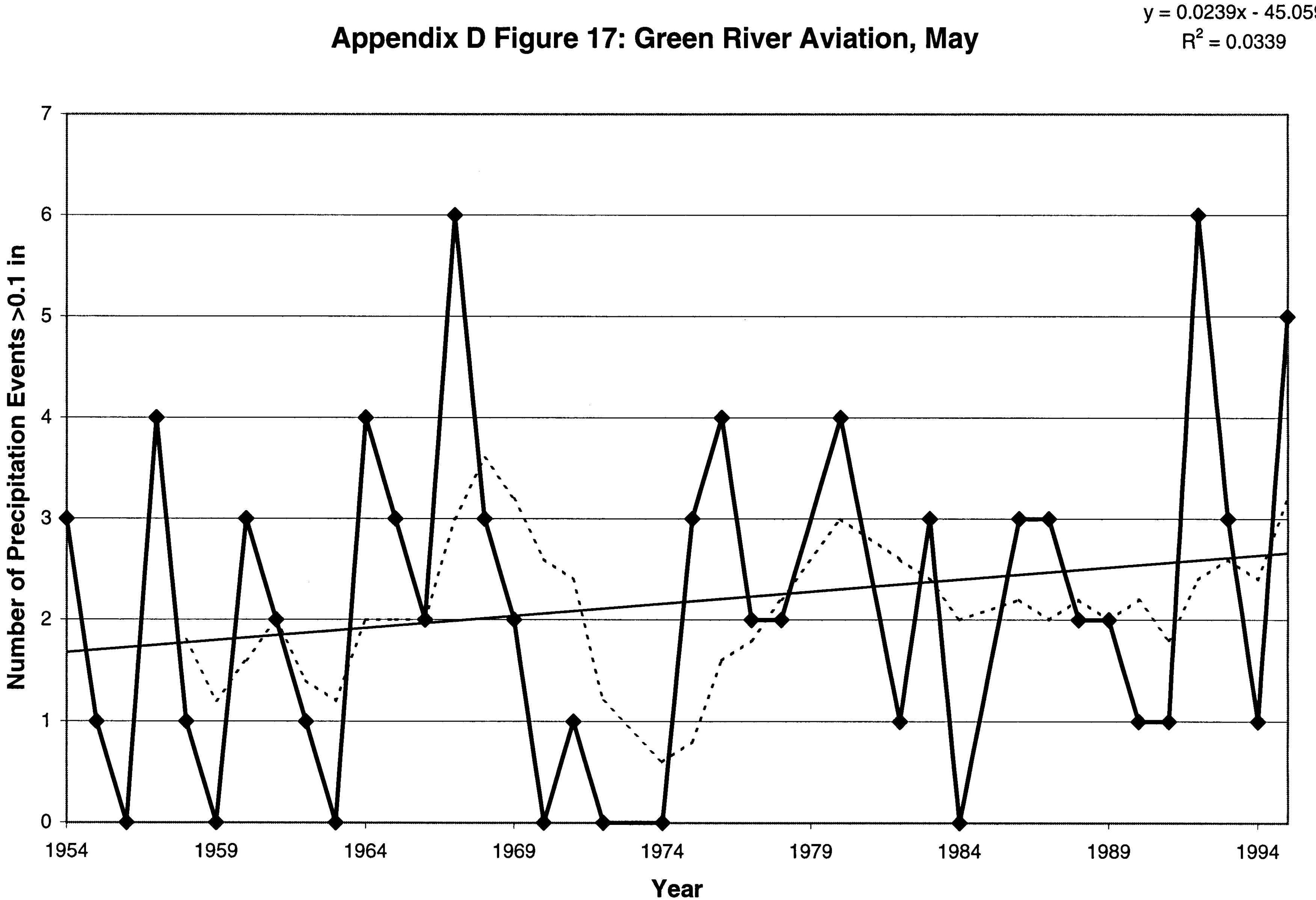
Appendix D Figure 16: Castle Dale, Total for July-August



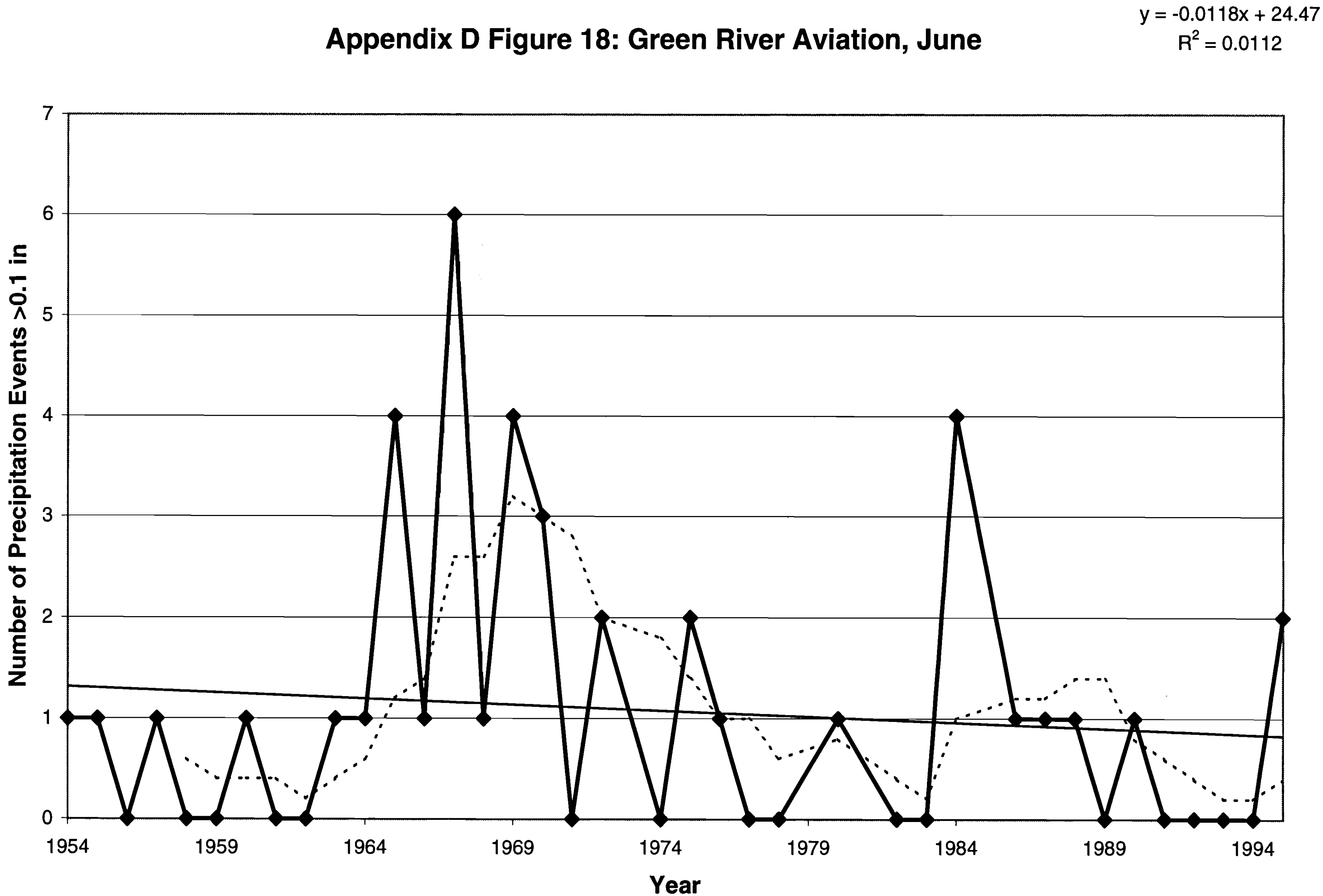
Appendix D Table 3: Number of Precipitation Events >0.1 in, Green River Aviation, Utah, 1954-1995

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1954	3	1	0	1	4	9	5	1
1955	1	1	0	2	1	5	3	2
1956	0	0	2	1	0	3	3	3
1957	4	1	4	5	1	15	10	9
1958	1	0	0	2	1	4	3	2
1959	0	0	0	3	3	6	6	3
1960	3	1	1	0	2	7	3	1
1961	2	0	1	6	6	15	13	7
1962	1	0	0	0	3	4	3	0
1963	0	1	0	5	3	9	8	5
1964	4	1	1	2	2	10	5	3
1965	3	4	5	2	3	17	10	7
1966	2	1	1	1	1	6	3	2
1967	6	6	3	2	2	19	7	5
1968	3	1	2	2	1	9	5	4
1969	2	4	2	6	2	16	10	8
1970	0	3	0	2	1	6	3	2
1971	1	0	2	3	2	8	7	5
1972	0	2	0	1	2	5	3	1
1974	0	0	0	0	1	1	1	0
1975	3	2	2	0	2	9	4	2
1976	4	1	2	0	2	9	4	2
1977	2	0	3	3	1	9	7	6
1978	2	0	0	0	3	5	3	0
1980	4	1	0	2	3	10	5	2
1982	1	0	1	3	2	7	6	4
1983	3	0	3	2	2	10	7	5
1984	0	4	3	6	1	14	10	9
1986	3	1	6	2	3	15	11	8
1987	3	1	4	2	1	11	7	6
1988	2	1	0	4	2	9	6	4
1989	2	0	2	3	4	11	9	5
1990	1	1	2	0	4	8	6	2
1991	1	0	2	5	1	9	8	7
1992	6	0	2	1	0	9	3	3
1993	3	0	0	1	0	4	1	1
1994	1	0	0	5	2	8	7	5
1995	5	2	1	3	0	11	4	4
Ave.	**2.16**	**1.08**	**1.50**	**2.32**	**1.95**	**9.00**	**5.76**	**3.82**
S.D.	**1.65**	**1.42**	**1.56**	**1.83**	**1.29**	**4.10**	**2.92**	**2.56**
Max	**6**	**6**	**6**	**6**	**6**	**19**	**13**	**9**
Min	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**

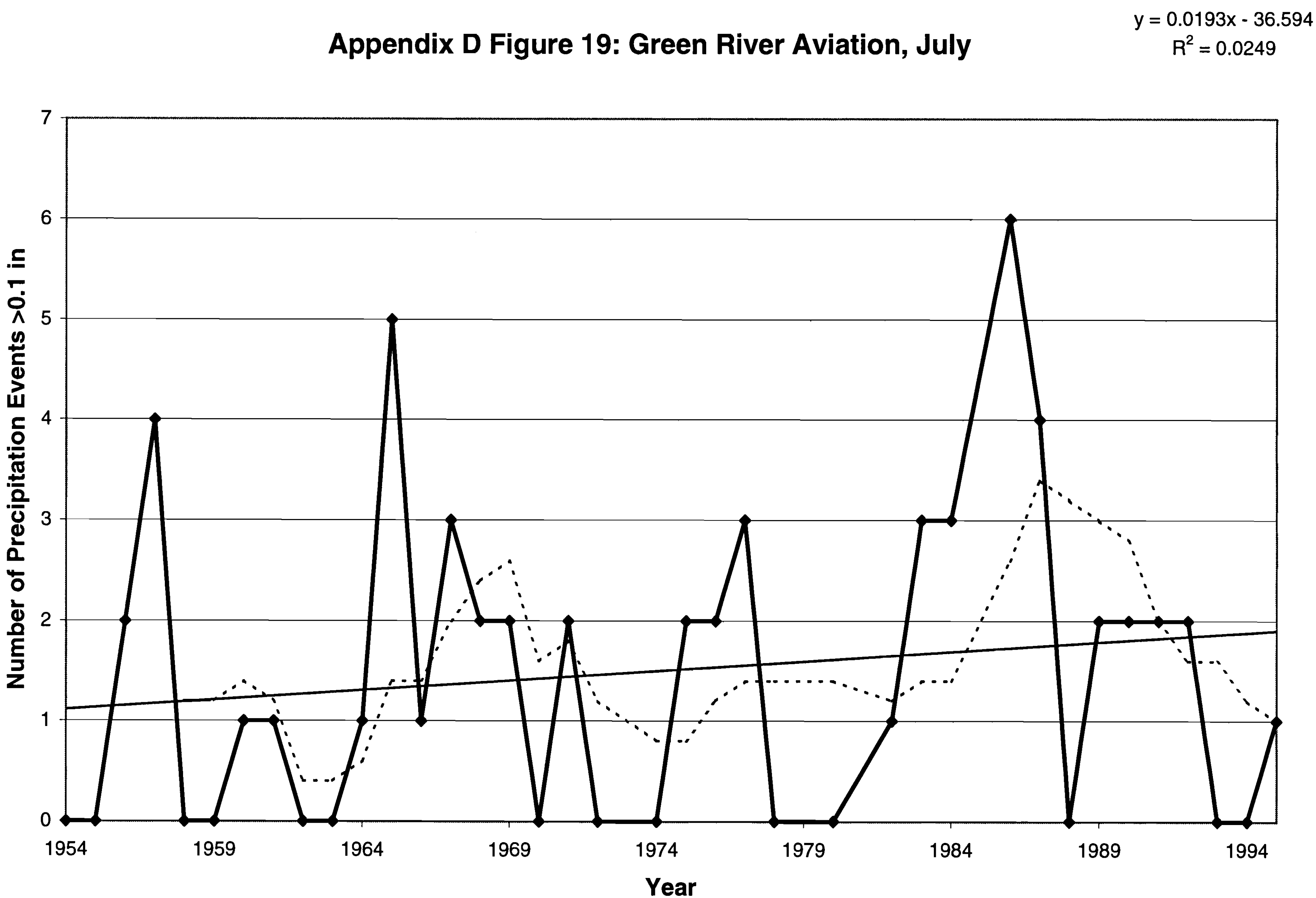
Appendix D Figure 17: Green River Aviation, May



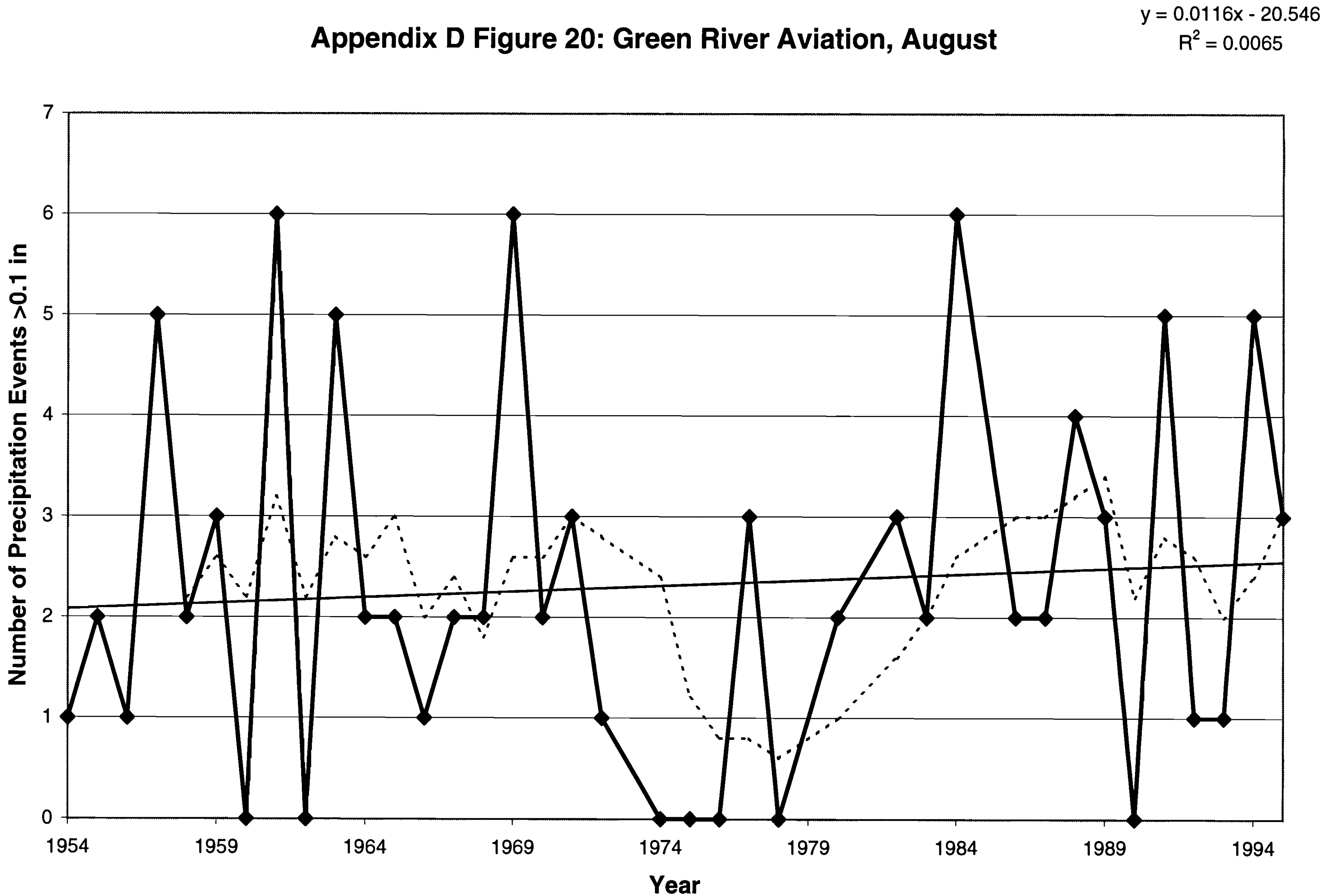
Appendix D Figure 18: Green River Aviation, June



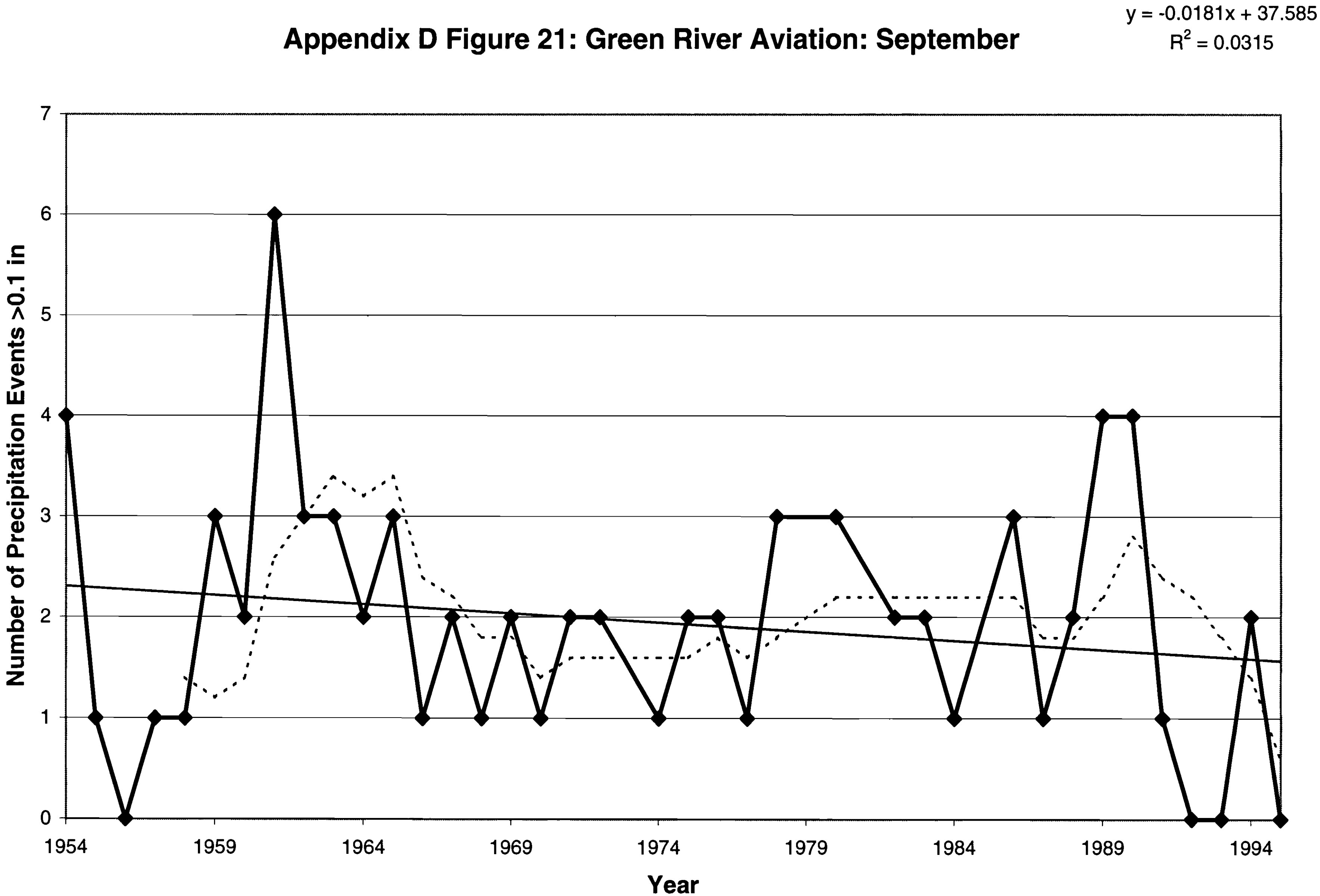
Appendix D Figure 19: Green River Aviation, July



Appendix D Figure 20: Green River Aviation, August

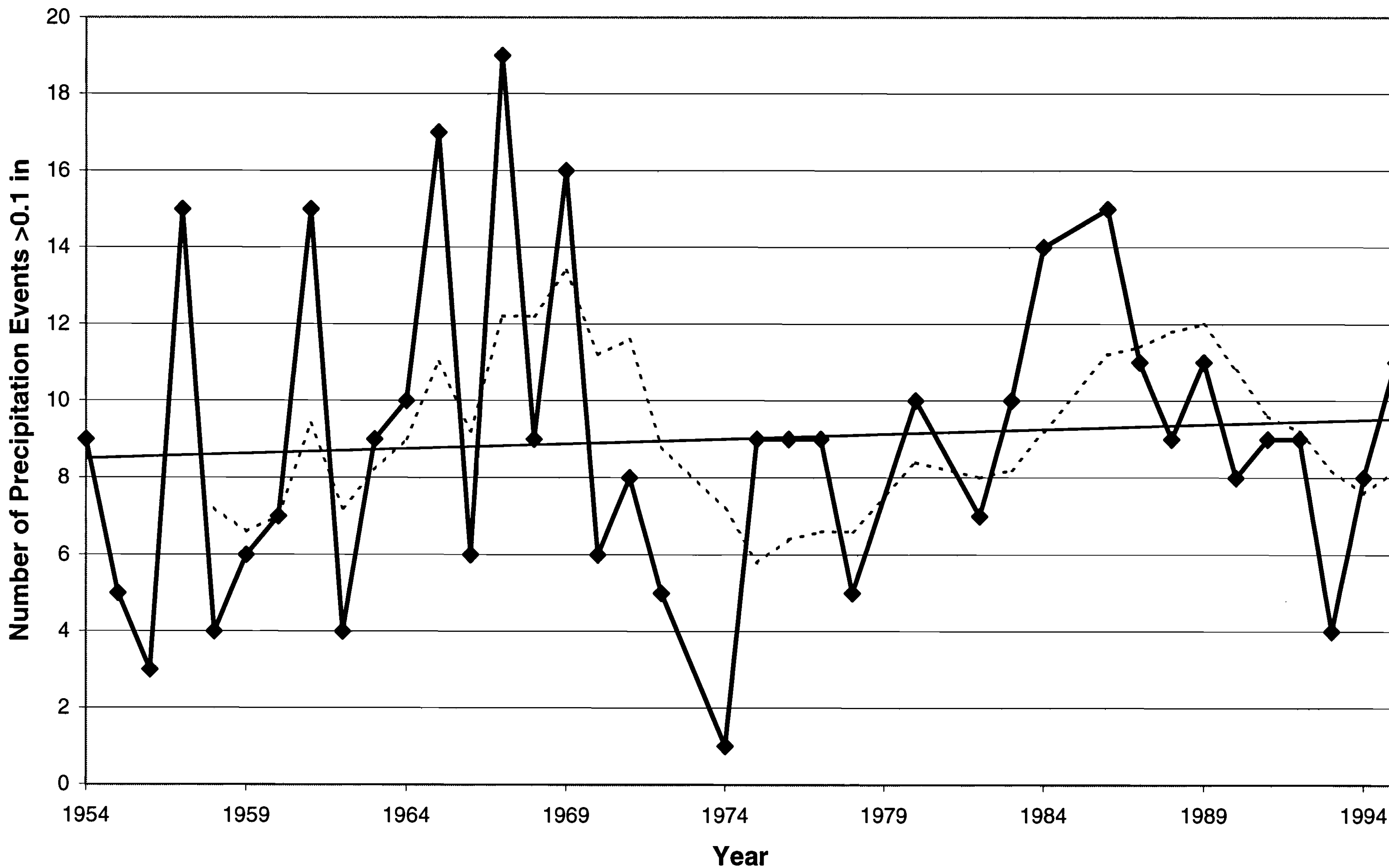


Appendix D Figure 21: Green River Aviation: September

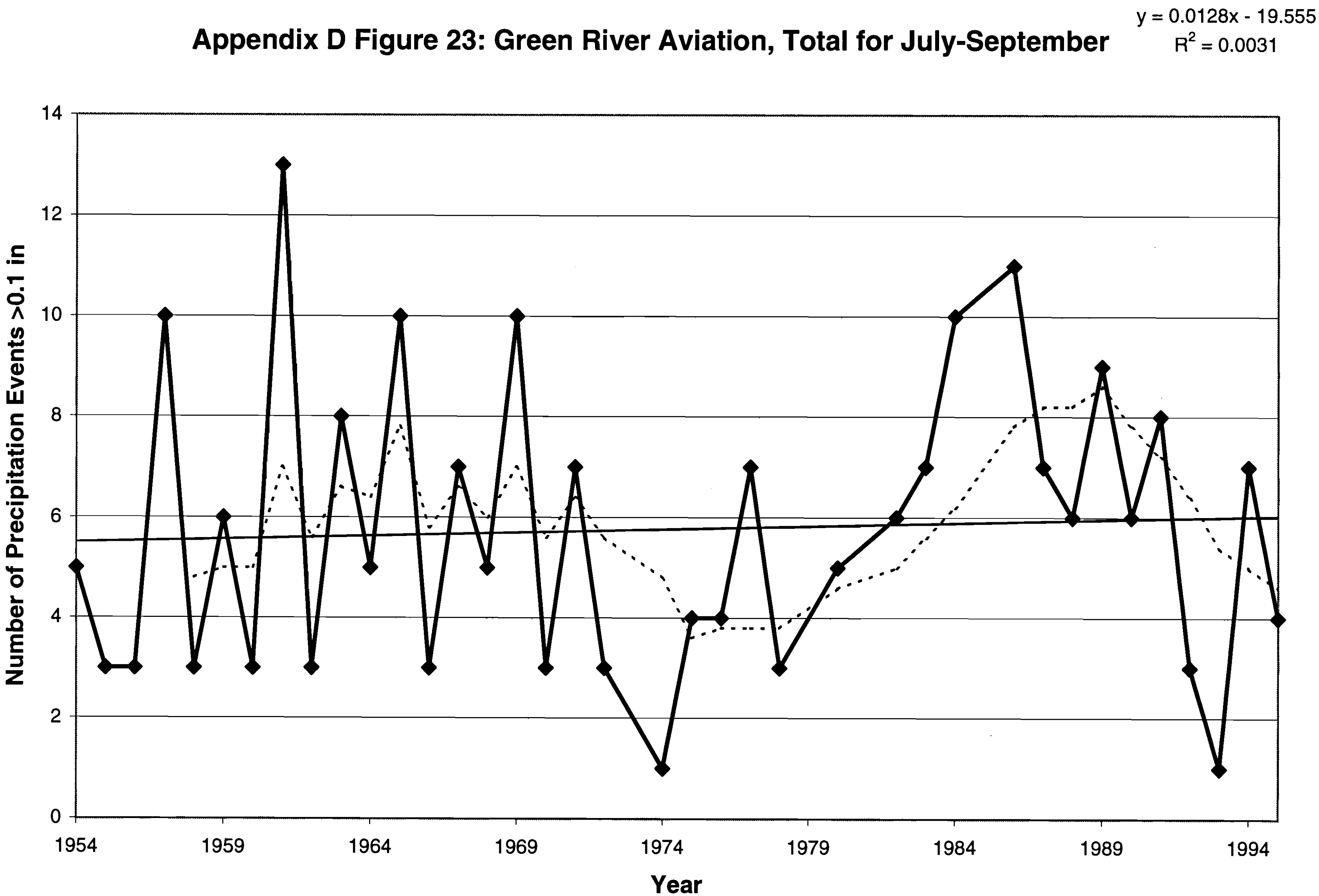


Appendix D Figure 22: Green River Aviation, Total May-September

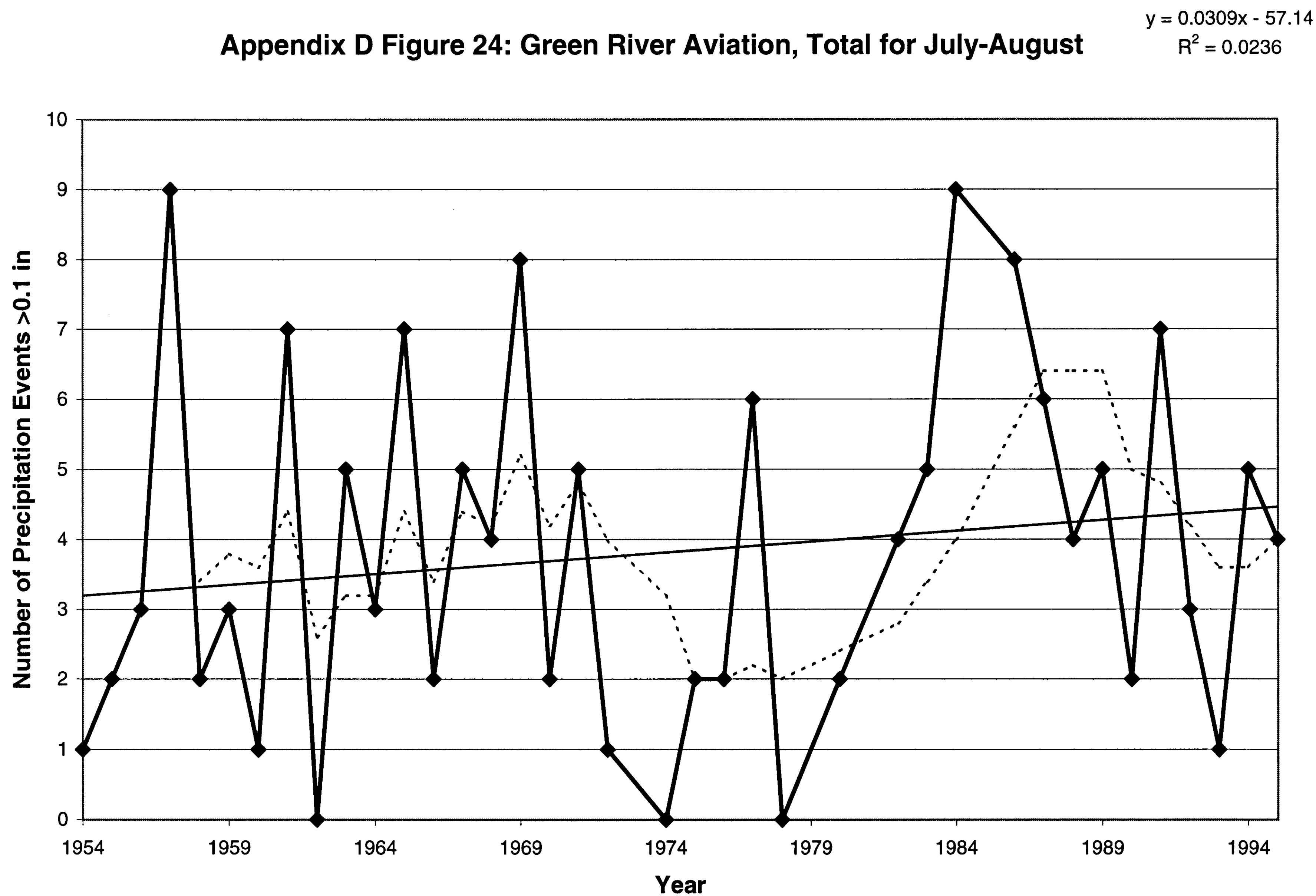
$y = 0.0249x - 40.143$
$R^2 = 0.006$



Appendix D Figure 23: Green River Aviation, Total for July-September



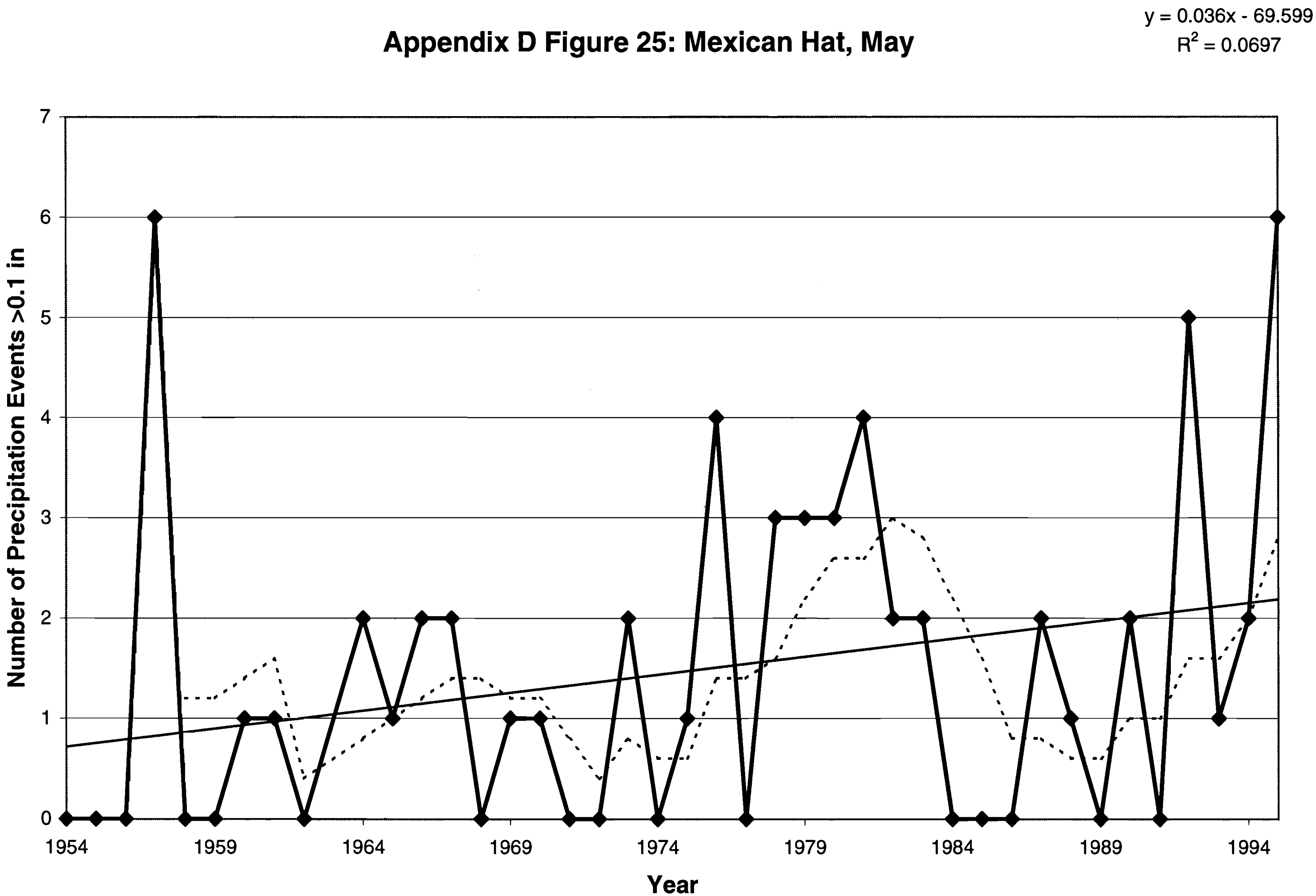
Appendix D Figure 24: Green River Aviation, Total for July-August



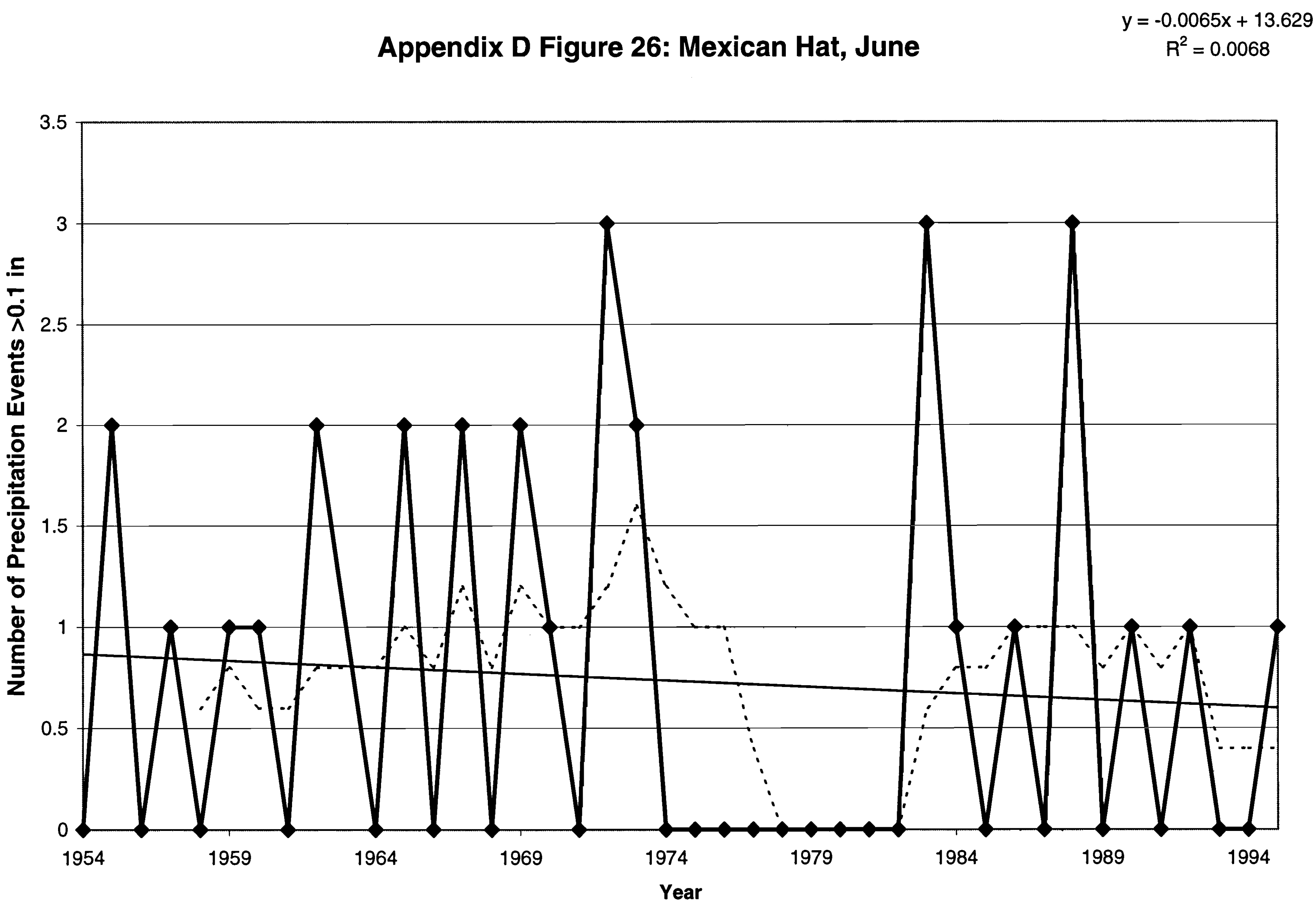
Appendix D Table 4: Number of Precipitation Events >0.1 in, Mexican Hat, Utah, 1954-1995

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	May	June	July	August	September	Total	Total	Total
1954	0	0	4	1	3	8	8	5
1955	0	2	0	4	0	6	4	4
1956	0	0	2	2	0	4	4	4
1957	6	1	0	3	0	10	3	3
1958	0	0	2	0	1	3	3	2
1959	0	1	0	3	0	4	3	3
1960	1	1	0	0	4	6	4	0
1961	1	0	2	3	3	9	8	5
1962	0	2	2	0	2	6	4	2
1964	2	0	4	2	0	8	6	6
1965	1	2	3	2	2	10	7	5
1966	2	0	3	3	1	9	7	6
1967	2	2	2	3	2	11	7	5
1968	0	0	4	3	0	7	7	7
1969	1	2	3	3	1	10	7	6
1970	1	1	0	4	3	9	7	4
1971	0	0	0	5	1	6	6	5
1972	0	3	2	1	1	7	4	3
1973	2	2	0	1	2	7	3	1
1974	0	0	4	0	1	5	5	4
1975	1	0	5	0	2	8	7	5
1976	4	0	1	0	3	8	4	1
1977	0	0	3	1	0	4	4	4
1978	3	0	0	0	1	4	1	0
1979	3	0	0	1	0	4	1	1
1980	3	0	1	1	1	6	3	2
1981	4	0	3	3	4	14	10	6
1982	2	0	1	4	4	11	9	5
1983	2	3	3	1	5	14	9	4
1984	0	1	6	2	1	10	9	8
1985	0	0	4	0	5	9	9	4
1986	0	1	5	4	2	12	11	9
1987	2	0	1	3	1	7	5	4
1988	1	3	1	4	3	12	8	5
1989	0	0	2	4	0	6	6	6
1990	2	1	0	1	5	9	6	1
1991	0	0	1	3	2	6	6	4
1992	5	1	5	3	2	16	10	8
1993	1	0	0	4	1	6	5	4
1994	2	0	0	1	4	7	5	1
1995	6	1	0	3	1	11	4	3
Ave.	**1.46**	**0.73**	**1.93**	**2.10**	**1.80**	**8.02**	**5.83**	**4.02**
S.D.	**1.67**	**0.98**	**1.78**	**1.50**	**1.54**	**3.03**	**2.46**	**2.16**
Max	**6**	**3**	**6**	**5**	**5**	**16**	**11**	**9**
Min	**0**	**0**	**0**	**0**	**0**	**3**	**1**	**0**

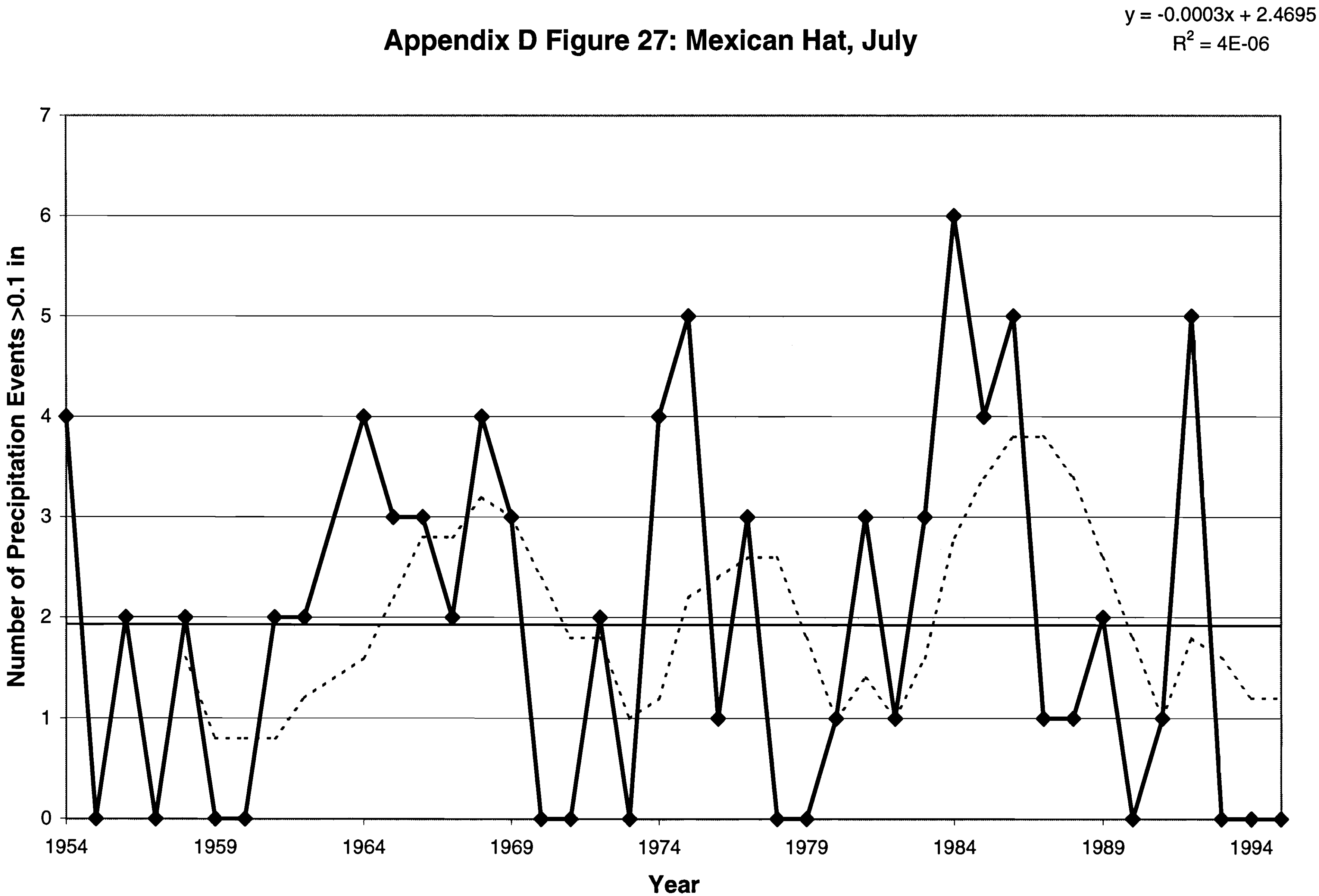
Appendix D Figure 25: Mexican Hat, May



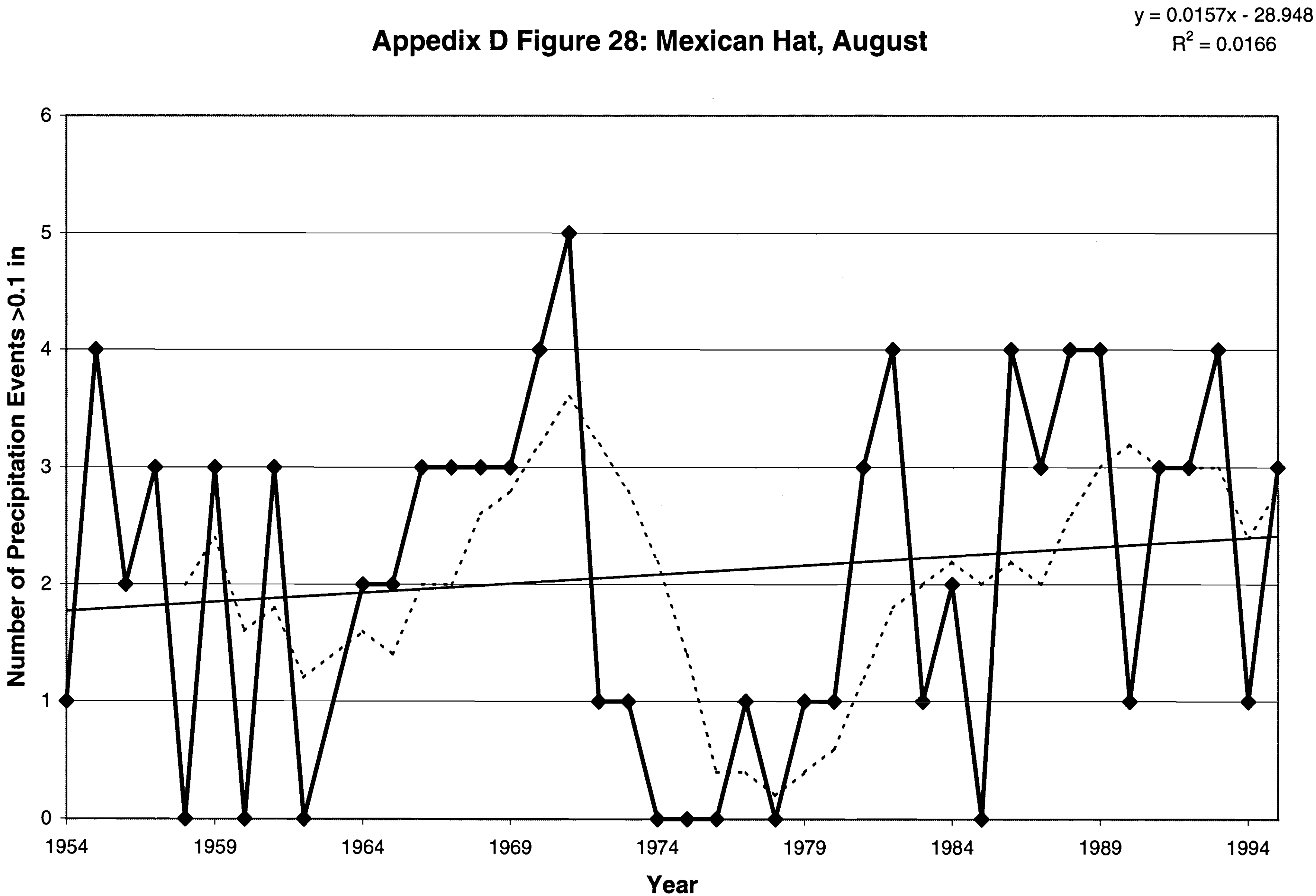
Appendix D Figure 26: Mexican Hat, June



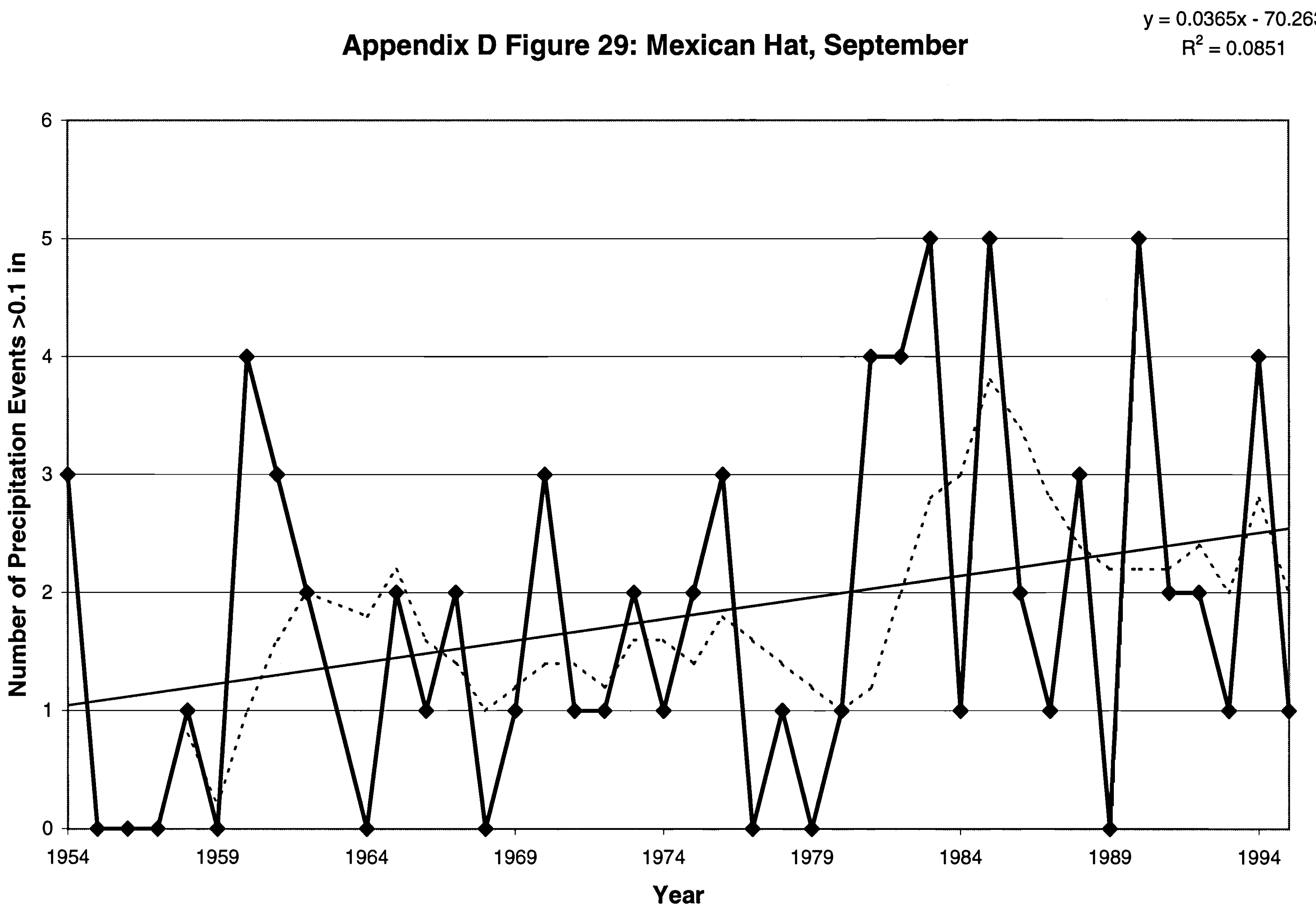
Appendix D Figure 27: Mexican Hat, July

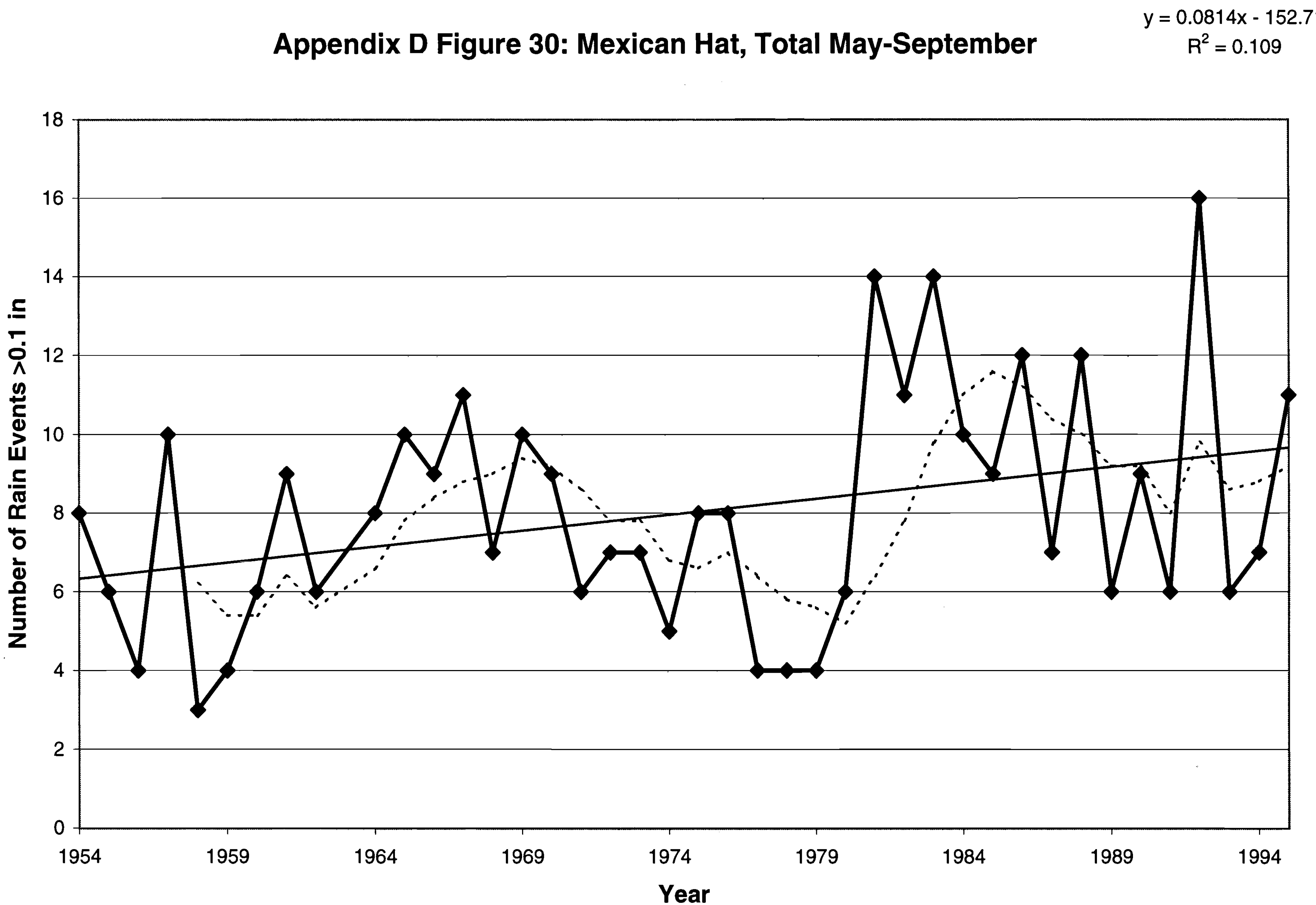


Appedix D Figure 28: Mexican Hat, August

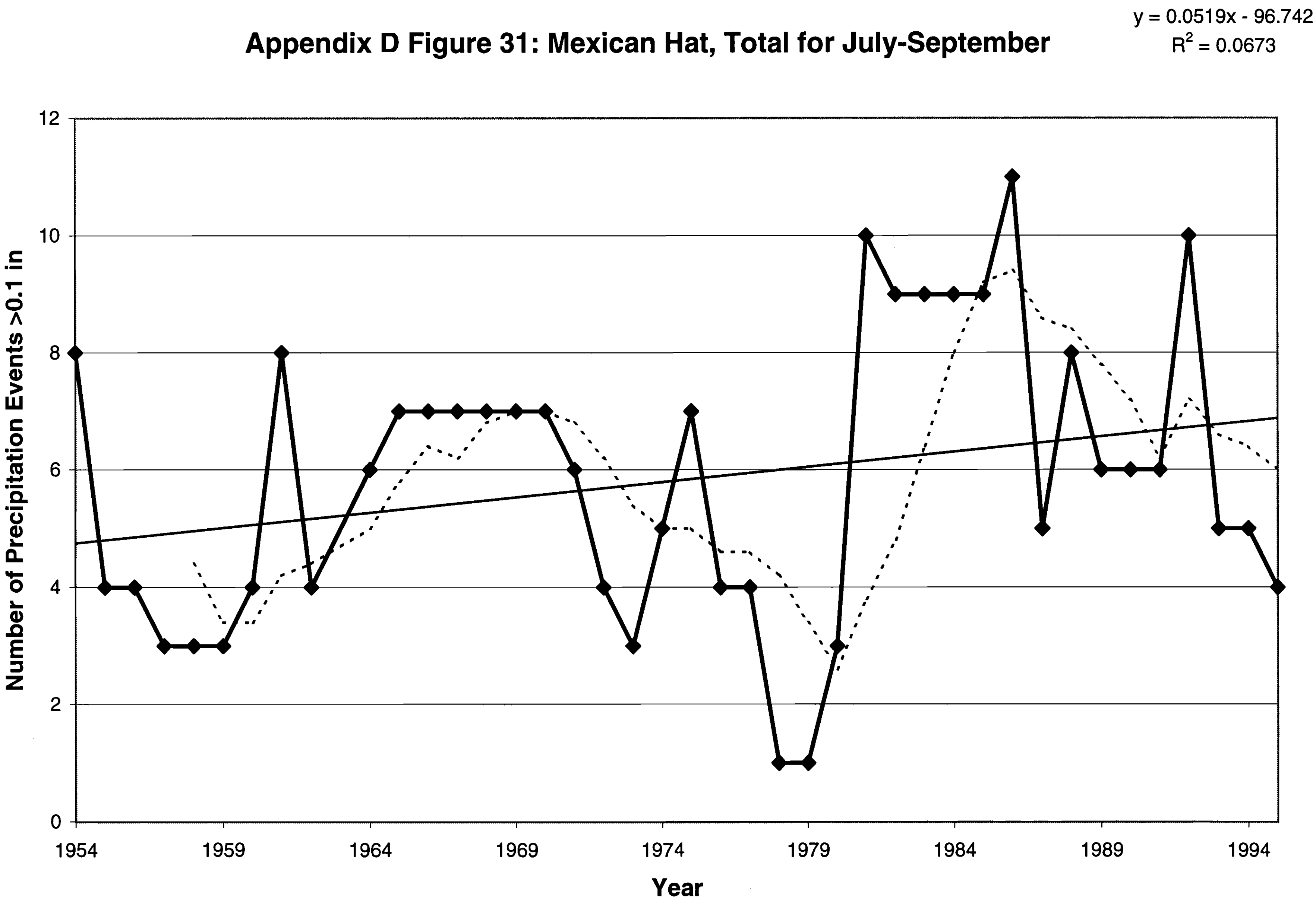


Appendix D Figure 29: Mexican Hat, September

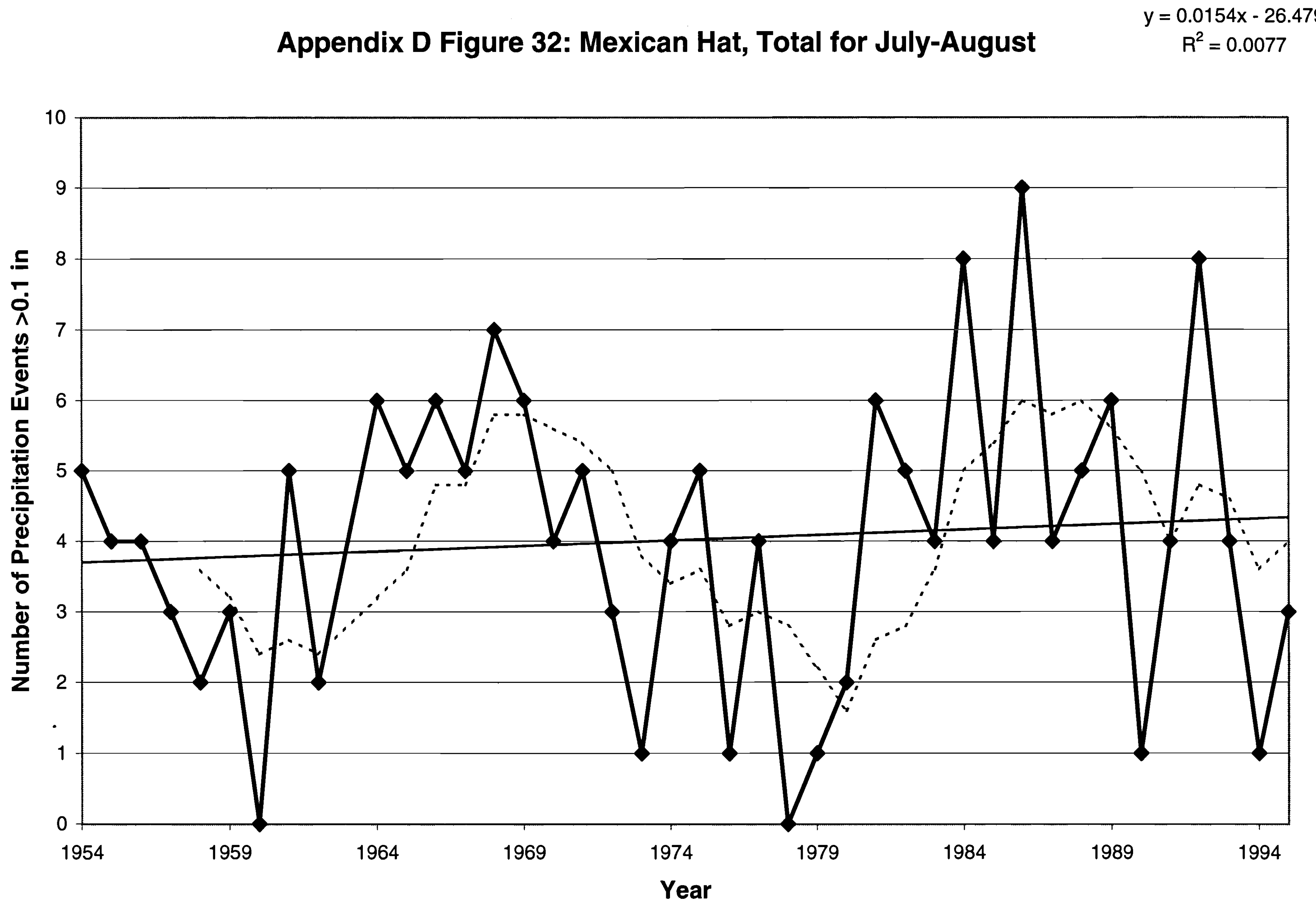



y = 0.0814x - 152.71
R^2 = 0.109
Appendix D Figure 30: Mexican Hat, Total May-September
Number of Rain Events >0.1 in
18
16
14
12
10
8
6
4
2
0
1954
1959
1964
1969
1974
1979
1984
1989
1994
Year

Appendix D Figure 31: Mexican Hat, Total for July-September



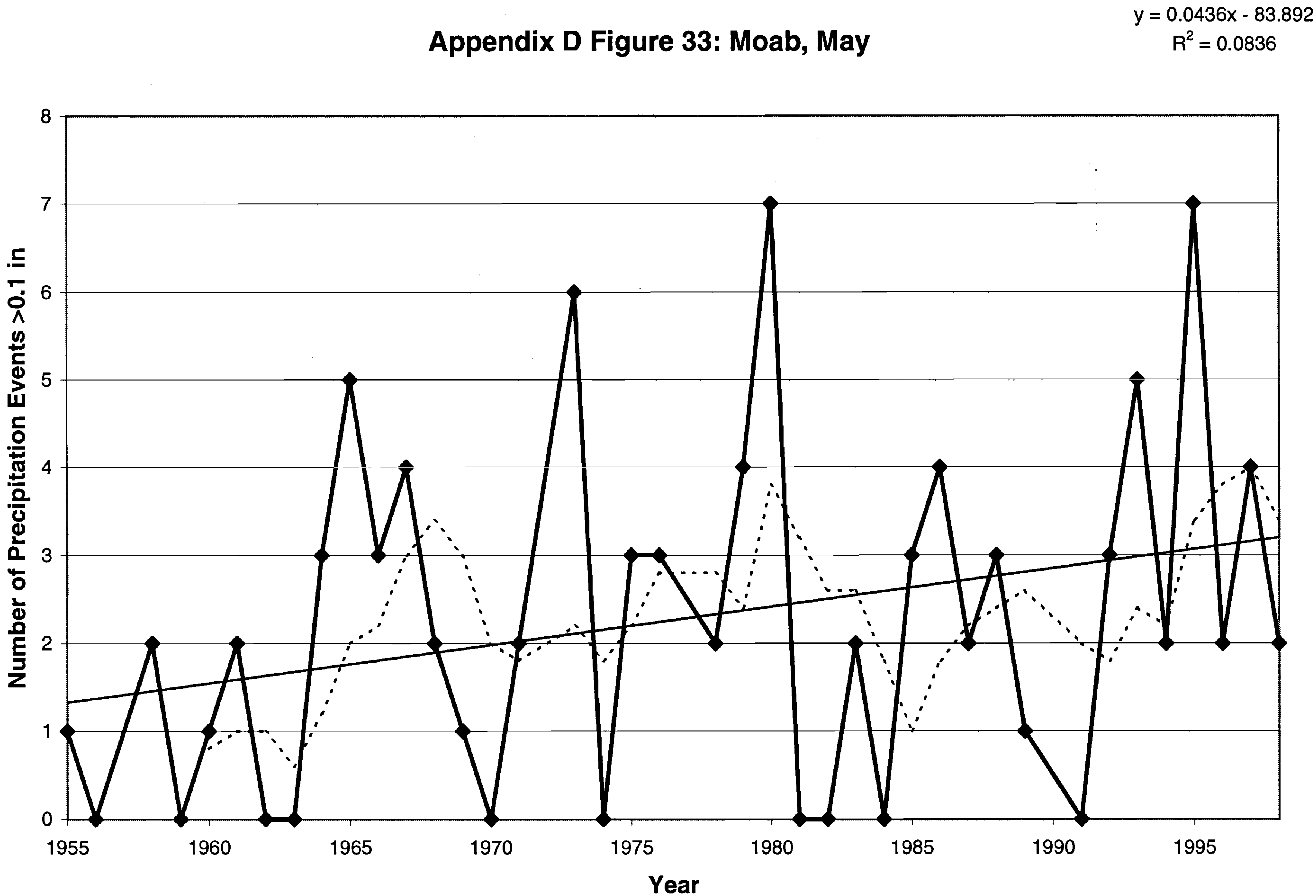
Appendix D Figure 32: Mexican Hat, Total for July-August



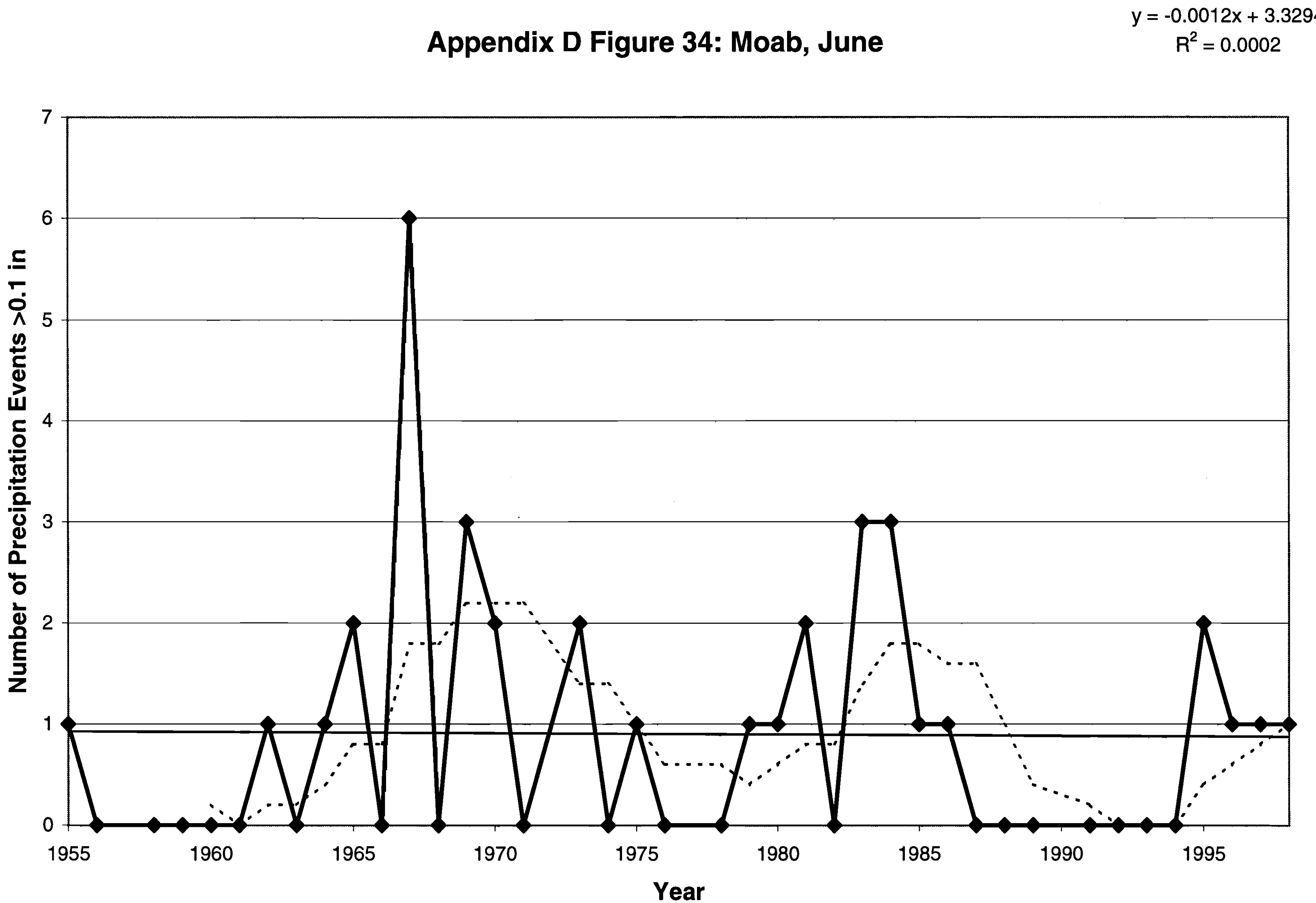
Appendix D Table 5: Number of Precipitation Events >0.1 in, Moab, Utah, 1955-1998

	Month 5	Month 6	Month 7	Month 8	Month 9	May-September	July-September	July-August
Year	**May**	**June**	**July**	**August**	**September**	**Total**	**Total**	**Total**
1955	1	1	1	2	0	5	3	3
1956	0	0	3	2	0	5	5	5
1958	2	0	0	3	3	8	6	3
1959	0	0	1	4	3	8	8	5
1960	1	0	1	1	2	5	4	2
1961	2	0	1	6	3	12	10	7
1962	0	1	2	0	4	7	6	2
1963	0	0	3	5	3	11	11	8
1964	3	1	0	1	2	7	3	1
1965	5	2	6	2	2	17	10	8
1966	3	0	2	2	2	9	6	4
1967	4	6	2	2	3	17	7	4
1968	2	0	4	3	0	9	7	7
1969	1	3	3	4	2	13	9	7
1970	0	2	0	1	1	4	2	1
1971	2	0	0	1	1	4	2	1
1973	6	2	0	3	2	13	5	3
1974	0	0	2	0	0	2	2	2
1975	3	1	2	0	2	8	4	2
1976	3	0	2	2	2	9	6	4
1978	2	0	0	1	0	3	1	1
1979	4	1	0	0	1	6	1	0
1980	7	1	3	2	3	16	8	5
1981	0	2	4	2	2	10	8	6
1982	0	0	1	2	3	6	6	3
1983	2	3	5	3	2	15	10	8
1984	0	3	3	3	1	10	7	6
1985	3	1	4	0	6	14	10	4
1986	4	1	3	1	2	11	6	4
1987	2	0	5	3	0	10	8	8
1988	3	0	0	3	2	8	5	3
1989	1	0	2	5	0	8	7	7
1991	0	0	2	5	3	10	10	7
1992	3	0	4	2	2	11	8	6
1993	5	0	0	4	0	9	4	4
1994	2	0	1	3	2	8	6	4
1995	7	2	1	4	1	15	6	5
1996	2	1	1	1	4	9	6	2
1997	4	1	3	5	10	23	18	8
1998	2	1	0	0	1	4	1	0
Ave.	**2.28**	**0.90**	**1.93**	**2.33**	**2.05**	**9.48**	**6.30**	**4.25**
S.D.	**1.95**	**1.26**	**1.64**	**1.62**	**1.85**	**4.41**	**3.34**	**2.44**
Max	**7**	**6**	**6**	**6**	**10**	**23**	**18**	**8**
Min	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**0**

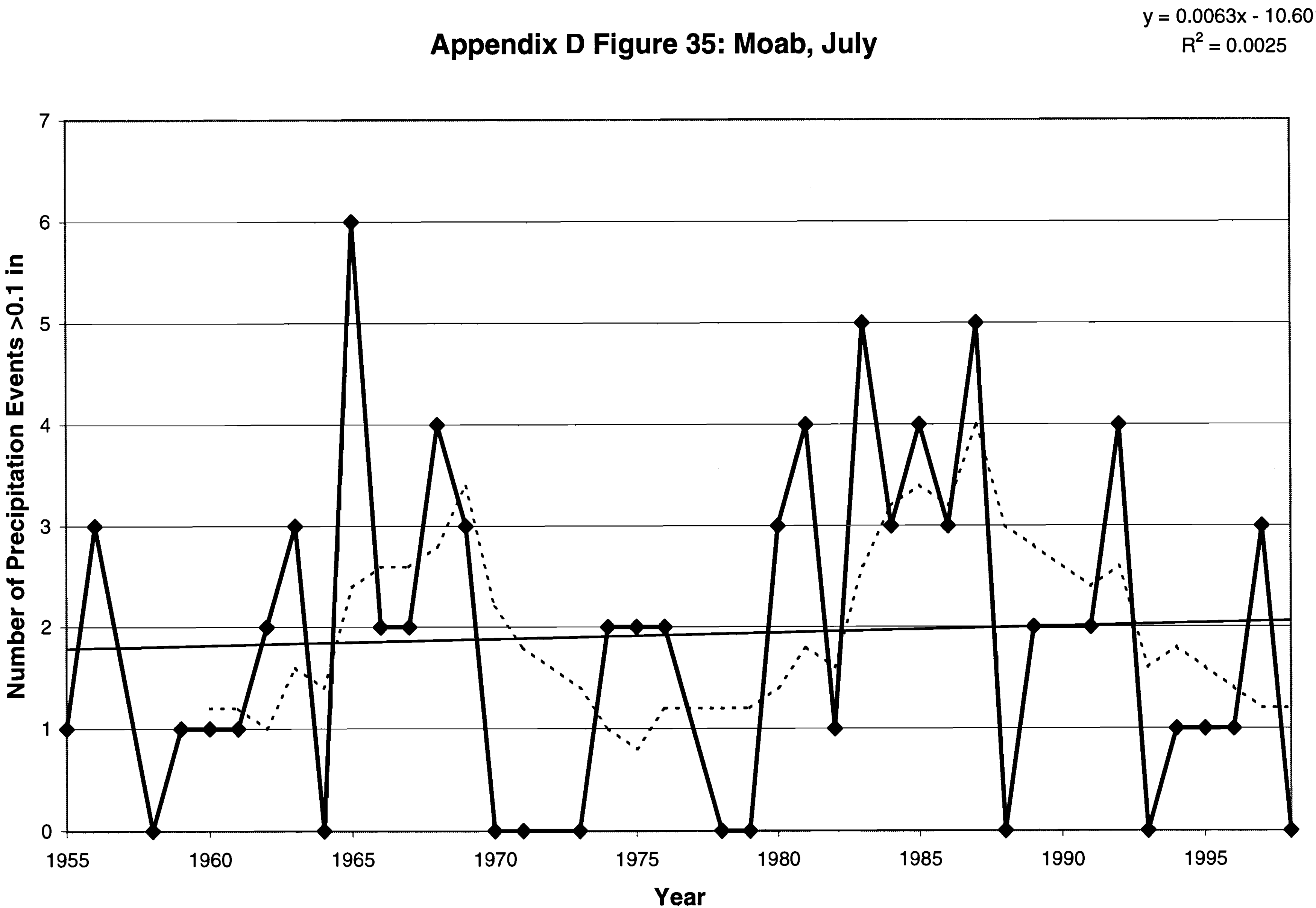
Appendix D Figure 33: Moab, May



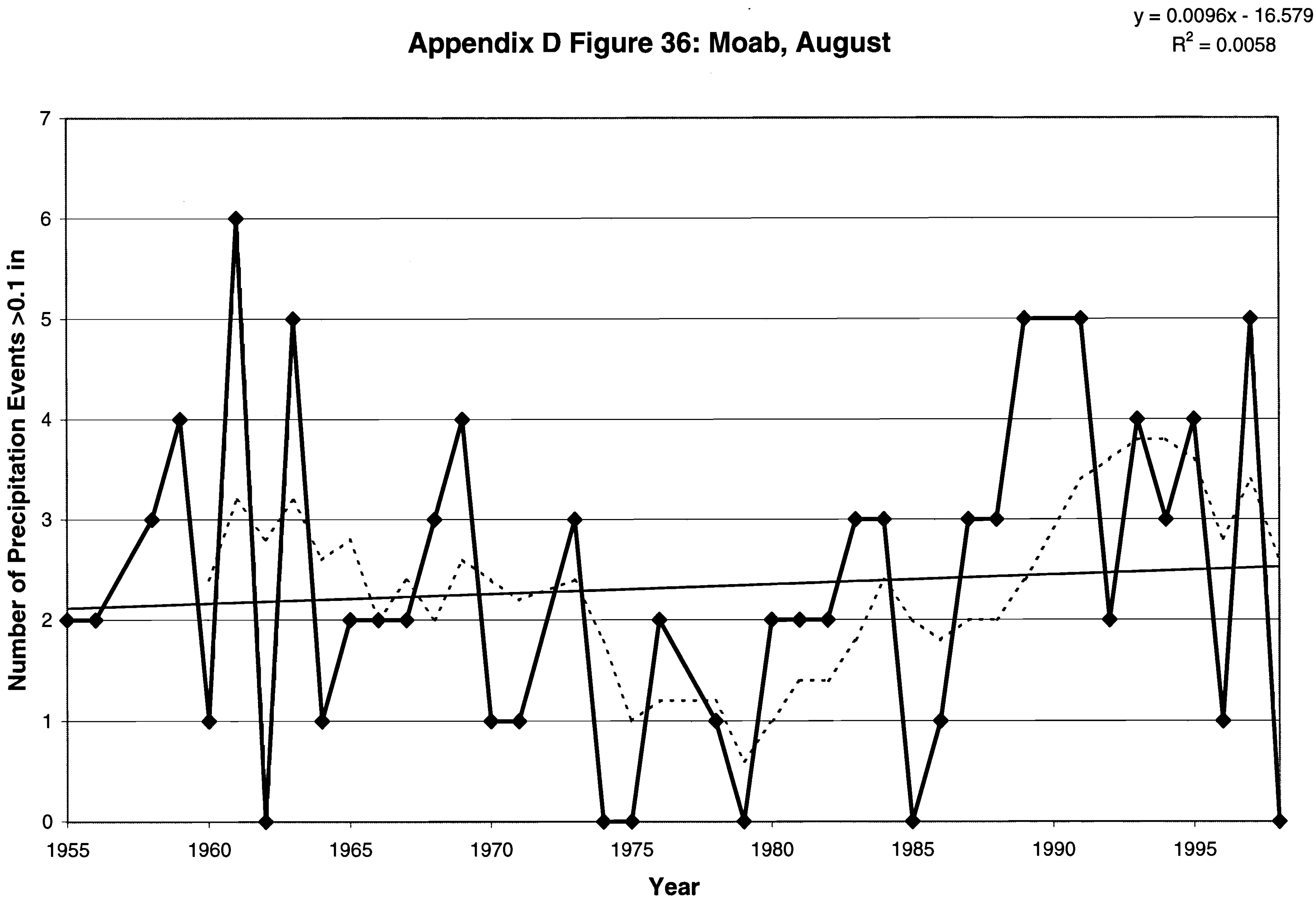
Appendix D Figure 34: Moab, June



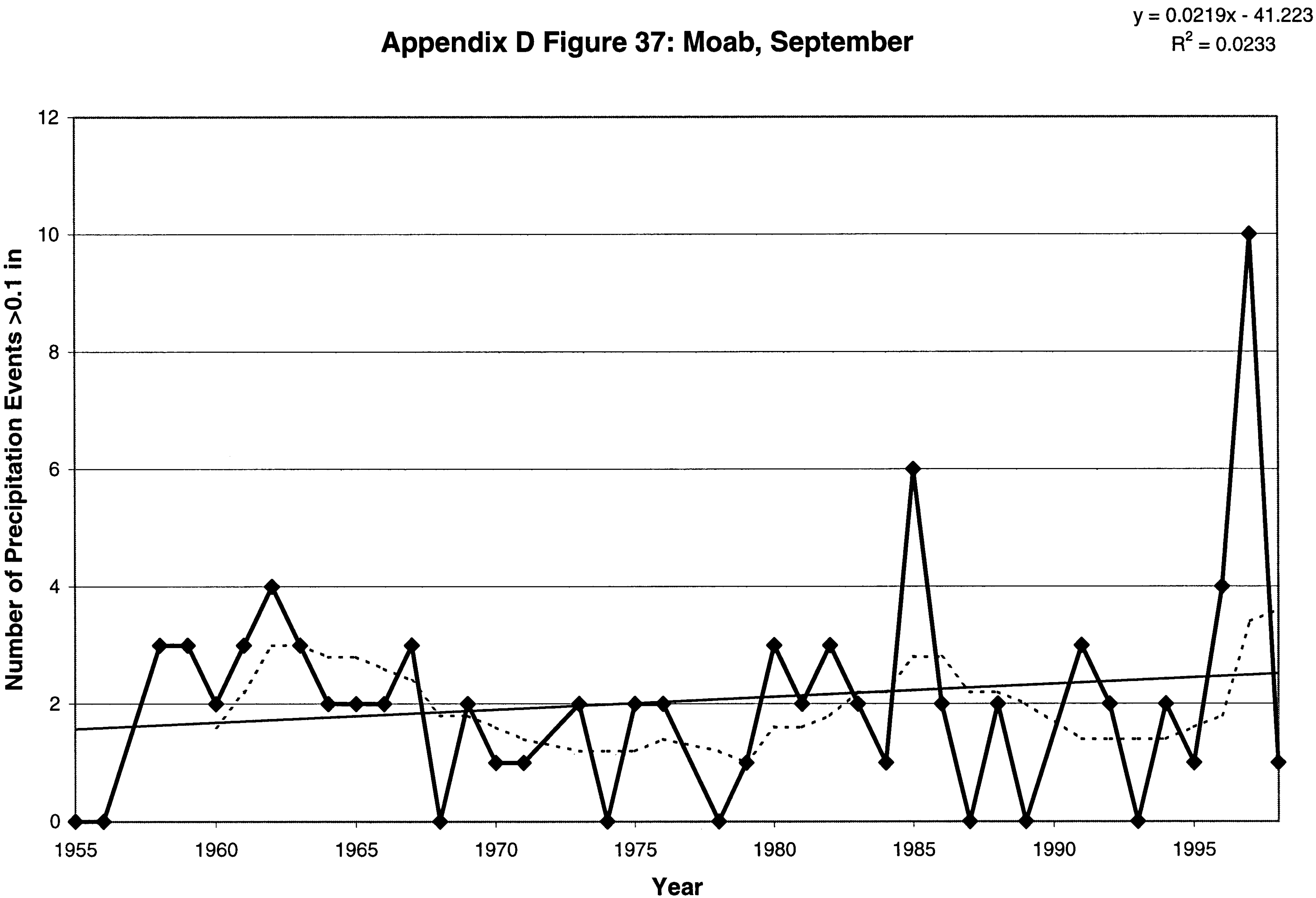
Appendix D Figure 35: Moab, July



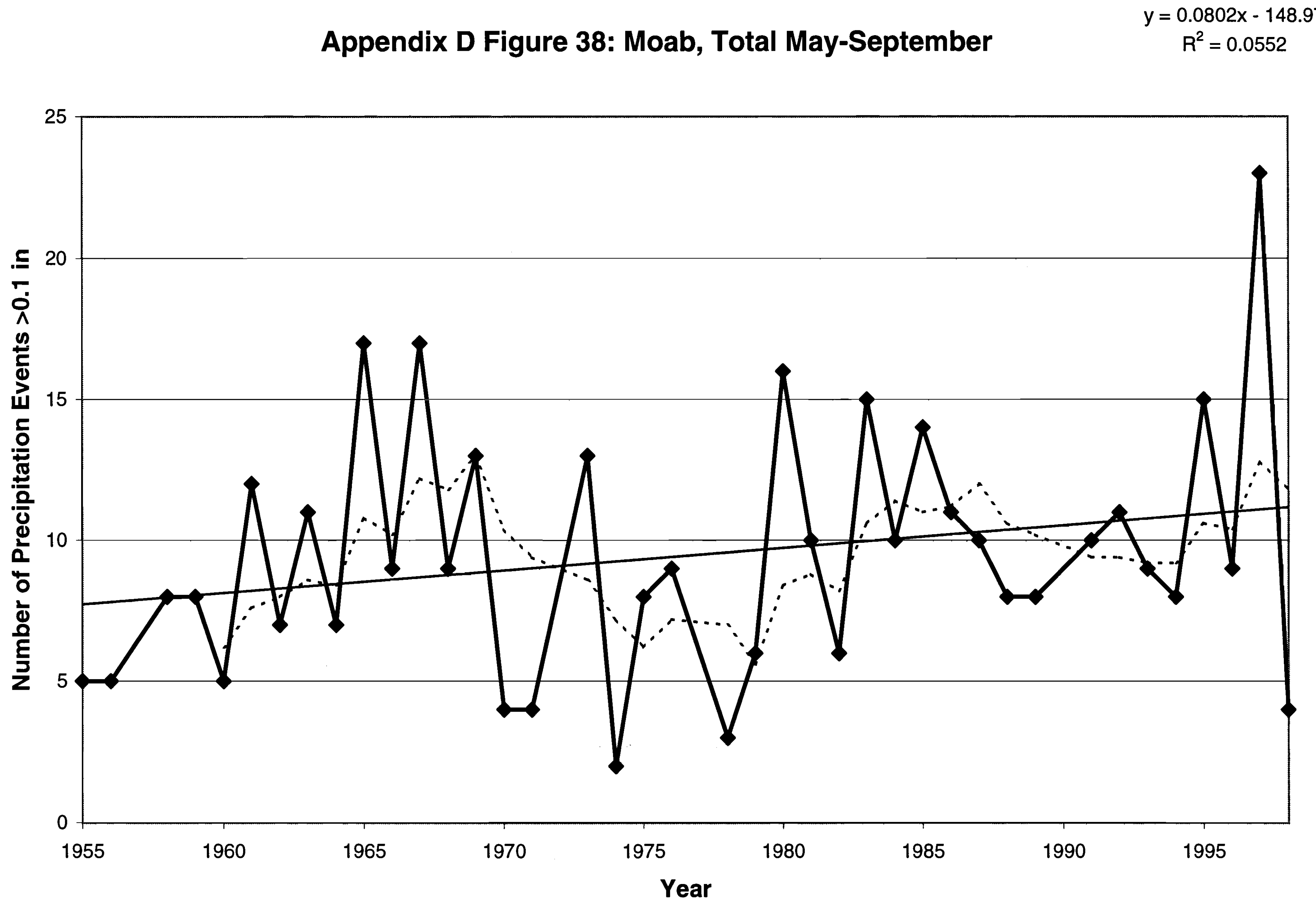
Appendix D Figure 36: Moab, August



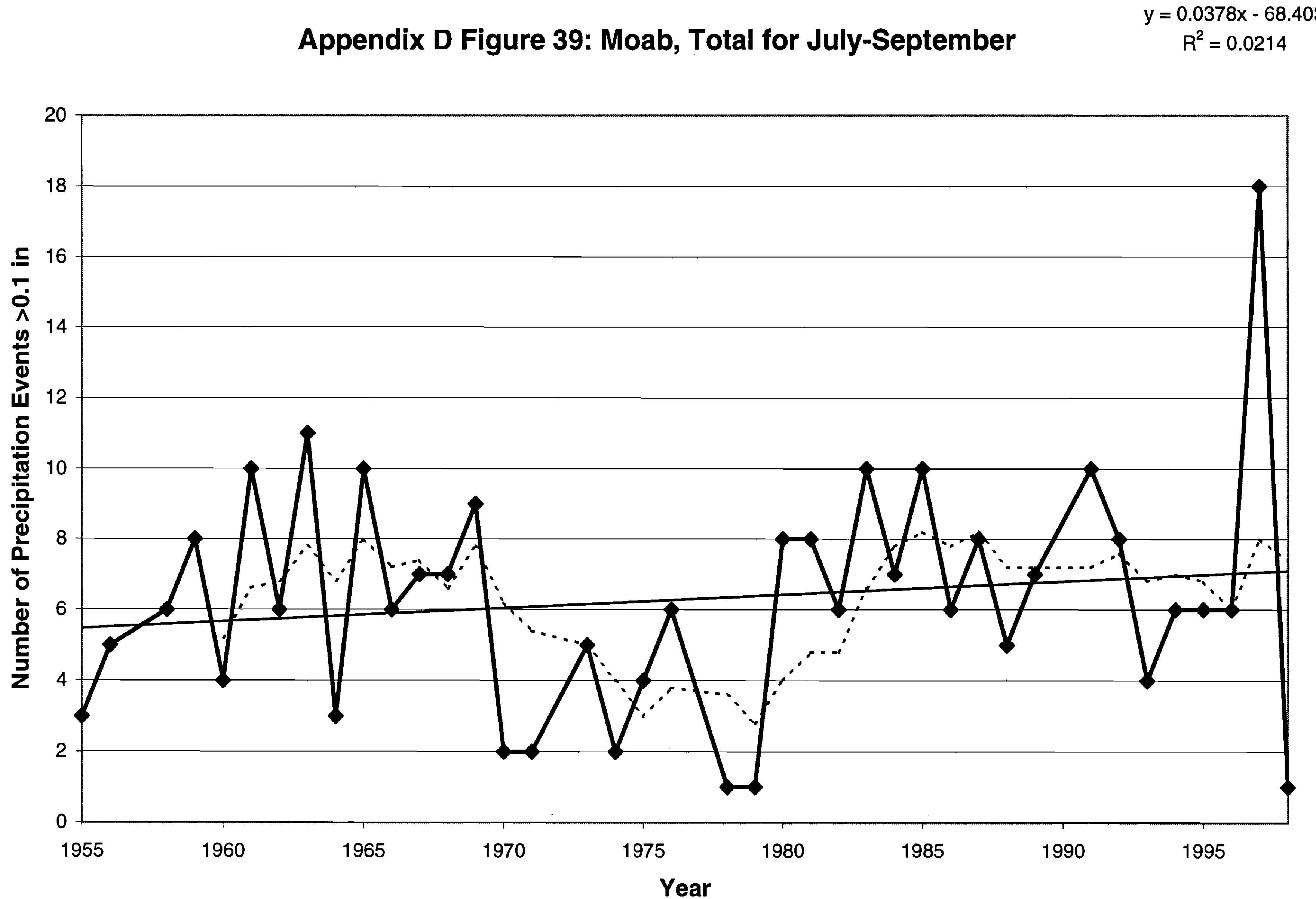
Appendix D Figure 37: Moab, September



Appendix D Figure 38: Moab, Total May-September



Appendix D Figure 39: Moab, Total for July-September



Appendix D Figure 40: Moab, Total for July-August