Graphs of SWMM Results

This is code to analyze the results from SWMM and create figures

Eleonore Durand

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NOTE: Figures will be be hidden from knitted markdown.

Code setup - Load packages

```
library(tidyverse) #For data wrangling
library(stargazer) #For creating nice tables
library(kableExtra) #For creating nice tables
library(hydroGOF)
```

Analysis of dry storm results

```
subcatch<- read_csv("subcatchments_all.csv") %>%
  mutate(subcatchment= OBJECTID_1) %>%
  select(subcatchment, Curve_Number, Slope, percent_imp, Area_sqft)

swm_results_dry<-read_csv("wailupe10_dry_summary.csv")

#Characterize results by urbanization level
results_dry<- merge(subcatch, swm_results_dry, by = "subcatchment") %>%
  mutate(runoff_normalized=
           total_runoff_in/Area_sqft) %>%
  mutate(Urbanization_level=
           case_when(
             percent_imp <15 |percent_imp == 15 ~ "Natural (less than 15 % Impervious)",
             percent_imp >15 & percent_imp <45 ~ "Urbanized (Between 15 and 45 % Impervious)",
             percent_imp >44.9999 ~ "Very urbanized (More than 45 % Impervious)"
             )
           )

write.csv(results_dry, file = "results_dry.csv") ##Export as .csv for use with graph maps

#Perform a linear regression for the SWMM dry storm results
results_regression_dry<- lm(total_runoff_in ~Curve_Number + Slope + percent_imp +
                              Area_sqft, data = results_dry)

#Graph the relationship bw simulated runoff and impervious cover by urbanization level
runoff_imp_graph_dry<- results_dry %>%
  ggplot(aes(x=percent_imp, y=total_runoff_in))+
  geom_point(aes(color=Urbanization_level))+
  labs(x= "Percent Impervious of Subcatchment", y= "Total Simulated Runoff (inches)")+
```

```r
  scale_y_continuous(limits= c(0,7), breaks= seq(0,7, by= 1),expand= c(0,0.08))+
  scale_x_continuous(limits= c(0,80), breaks= seq(0,80, by= 10),expand= c(0,0))+
  scale_color_manual(name= "Urbanization Level", values= c("darkgreen", "darkseagreen",
                                                            "darkgoldenrod1"))+
  theme_classic()
runoff_imp_graph_dry
```

```r
#Save runoff vs. impervious graph
ggsave("runoff_imp_dry.pdf", width = 8, height =4)
ggsave("runoff_imp_dry.png", width = 8, height =4)

#Create a table for the regression results
regress_table_dry<- stargazer(results_regression_dry, type ="html", digits= 2,
                          dep.var.labels = "Total Runoff (Inches)",
                       covariate.labels = c("Curve Number", "Slope", "Percent Impervious",
                                            "Area (sqft)", "Y-Intercept"),
                       omit.stat = c("rsq"))
regress_table_dry
```

Analysis of wet storm results

```r
swm_results_wet<-read_csv("Wailupe10_wet_summary.csv")

#Characterize results by urbanization level
results_wet<- merge(subcatch, swm_results_wet, by = "subcatchment") %>%
  mutate(runoff_normalized=
           total_runoff_in/Area_sqft) %>%
  mutate(Urbanization_level=
           case_when(
             percent_imp <15 |percent_imp == 15 ~ "Natural (less than 15 % Impervious)",
             percent_imp >15 & percent_imp <45 ~ "Urbanized (Between 15 and 45 % Impervious)",
             percent_imp >44.9999 ~ "Very urbanized (More than 45 % Impervious)"
             )
           )

write.csv(results_wet, file = "results_wet.csv") ##save for use with graph maps

#Perform a linear regression for the SWMM wet storm results
results_regression_wet<- lm(total_runoff_in ~Curve_Number + Slope + percent_imp + Area_sqft,
                            data = results_wet)

#Graph the relationship bw simulated runoff and impervious cover
runoff_imp_graph_wet<- results_wet %>%
  ggplot(aes(x=percent_imp, y=total_runoff_in))+
  geom_point(aes(color=Urbanization_level))+
  labs(x= "Percent Impervious of Subcatchment", y= "Total Simulated Runoff (inches)")+
  scale_y_continuous(limits= c(0,3), breaks= seq(0,2.5, by= 0.5),expand= c(0,0.08))+
  scale_x_continuous(limits= c(0,80), breaks= seq(0,80, by= 10),expand= c(0,0))+
  scale_color_manual(name= "Urbanization Level", values= c("darkgreen", "darkseagreen",
                                                            "darkgoldenrod1"))+
  theme_classic()

#Create a graph of the relationship vw simulated runof and impervious cover normalized by area
```

```r
runoff_norm_wet<- results_wet %>%
  ggplot(aes(x=percent_imp, y=runoff_normalized))+
  geom_point(aes(color=Urbanization_level))+
  labs(x= "Percent Impervious of Subcatchment",
       y= "Total Simulated Runoff Normalized by Area (inches/sqft)")+
  scale_y_continuous(expand= c(0,0))+
  scale_x_continuous(limits= c(0,80), breaks= seq(0,80, by= 10),expand= c(0,0))+
  scale_color_manual(name= "Urbanization Level", values= c("darkgreen", "darkseagreen",
                                                           "darkgoldenrod1"))+
  theme_classic()

runoff_norm_wet
```

```r
runoff_imp_graph_wet
```

```r
#Save runoff vs. impervious graph
ggsave("runoff_imp_wet.pdf", width = 8, height =4)
ggsave("runoff_imp_wet.png", width = 8, height =4)

#Create a table of the regression results
regress_table_wet<- stargazer(results_regression_wet, type ="html", digits= 2,
                          dep.var.labels = "Total Runoff (Inches)",
                       covariate.labels = c("Curve Number", "Slope", "Percent Impervious",
                                            "Area (sqft)", "Y-Intercept"),
                       omit.stat = c("rsq"))
regress_table_wet
```

Analysis of simulated vs observed runoff

```r
#Graph observed vs simulated runoff

observed<- read_csv("c35_observed.csv")
simulated <- read_csv("C35_simulated_adj_cn25.csv")

discharge<- merge(observed, simulated, by = "time_step")

summary(discharge)


dischargettest<- t.test(discharge$discharge_obs_cfs, discharge$simulated_flow_cfs)

regress<- lm(discharge_obs_cfs ~ simulated_flow_cfs, data = discharge)

regress

sim<- discharge$simulated_flow_cfs
obs<- discharge$discharge_obs_cfs


sutcliffe<- NSE(sim, obs, na.rm=TRUE, FUN=NULL, epsilon=c("Pushpalatha2012"))

sutcliffe
```

```r
write.csv(discharge,file = "discharge_obv_sim1.csv", row.names = FALSE)

graph<- ggplot(discharge, aes(x=discharge_obs_cfs, simulated_flow_cfs))+
  geom_point()

graph
```

```r
calibrate_graph<- discharge %>%
  ggplot()+
  geom_line(aes(x=time_step, y=discharge_obs_cfs), color="darkseagreen")+
  geom_line(aes(x=time_step, y=simulated_flow_cfs), color= "darkgoldenrod1")+
  theme_classic()+
  labs(x="Time (hours)", y="Discharge (cfs)")+
  scale_y_continuous(limits= c(0,275), breaks= seq(0,250, by= 25),expand= c(0,0))+
  scale_x_continuous(limits= c(0,22), breaks= seq(0,22, by= 2),expand= c(0,0))+
  annotate("text", label= "Observed", x=19.5, y=65, size=3.5)+
  annotate("text", label= "Simulated", x=19.5, y=25, size=3.5)


calibrate_graph
```

```r
#Save discharge graphs from the 2010 "dry" storm
ggsave("discharge10.pdf", width = 8, height =4)
ggsave("dischage10.png", width = 8, height =4)

results_table<- results_wet %>%
  group_by(Urbanization_level) %>%
  summarize(
    number_of_subcatch=length(subcatchment),
    runoff_coefficient=round(mean(runoff_coeff),2),
    total_runoff_inches=round(mean(total_runoff_in),2),
    impervious_runoff_inches=round(mean(imperv_runoff_in),2),
    pervious_runoff_inches=round(mean(perv_runoff_in), 2),
    total_infiltration_inches= round(mean(total_infil_in),2),
    peak_runoff_cubicfs=round(mean(peak_runoff_cfs),2)

  )

results_table

table_pretty<-results_table %>%
              kable(col.names=c("Urbanization Level","Number of Subcatchments",
                                "Runoff Coefficient", "Total Runoff (in)",
                                "Impervious Runoff (in)", "Pervious Runoff (in)",
                                "Total Infiltration (in)", "Peak Runoff (cfs)")) %>%
  kable_styling(bootstrap_options = "striped")

table_pretty

results_table_dry<- results_dry %>%
  group_by(Urbanization_level) %>%
  summarize(
    number_of_subcatch=length(subcatchment),
    runoff_coefficient=round(mean(runoff_coeff),2),
```

```r
    total_runoff_inches=round(mean(total_runoff_in),2),
    impervious_runoff_inches=round(mean(imperv_runoff_in),2),
    pervious_runoff_inches=round(mean(perv_runoff_in), 2),
    total_infiltration_inches= round(mean(total_infil_in),2),
    peak_runoff_cubicfs=round(mean(peak_runoff_cfs),2)

  )

min_range_runoff_table_dry<- results_dry %>%
  summarize(
  min_runoff_coeff = min(runoff_coeff),
  max_runoff_coeff = max(runoff_coeff),
  median_runoff_coeff = median(runoff_coeff),
  min_imp_runoff= min(imperv_runoff_in),
  max_imp_runoff= max(imperv_runoff_in),
  med_imp_runoff=median(imperv_runoff_in),
  min_per_runoff=min(perv_runoff_in),
  max_per_runoff=max(perv_runoff_in),
  med_per_runoff=median(perv_runoff_in)
  ) %>%
  kable(col.names=c("Minimum Runoff Coefficient", "Maximum Runoff Coefficient",
                    "Median Runoff Coefficient", "Minimum Impervious Runoff (in)",
                    "Maximum Impervious Runoff (in)", "Median Impervious Runoff (In)",
                    "Minimum Pervious Runoff (in)", "Maximum Pervious Runoff (in)",
                    "Median Pervious Runoff (in)")) %>%
  kable_styling(bootstrap_options = "striped")

min_range_runoff_table_dry

results_table_dry

table_pretty_dry<-results_table_dry %>%
              kable(col.names=c("Urbanization Level","Number of Subcatchments",
                                "Runoff Coefficient", "Total Runoff (in)",
                                "Impervious Runoff (in)", "Pervious Runoff (in)",
                                "Total Infiltration (in)", "Peak Runoff (cfs)")) %>%
  kable_styling(bootstrap_options = "striped")

table_pretty_dry

min_range_runoff_table_wet<- results_wet %>%
  summarize(
  min_runoff_coeff = min(runoff_coeff),
  max_runoff_coeff = max(runoff_coeff),
  median_runoff_coeff = median(runoff_coeff),
  min_imp_runoff= min(imperv_runoff_in),
  max_imp_runoff= max(imperv_runoff_in),
  med_imp_runoff=median(imperv_runoff_in),
  min_per_runoff=min(perv_runoff_in),
  max_per_runoff=max(perv_runoff_in),
  med_per_runoff=median(perv_runoff_in)
  ) %>%
  kable(col.names=c("Minimum Runoff Coefficient", "Maximum Runoff Coefficient",
```

```
                    "Median Runoff Coefficient", "Minimum Impervious Runoff (in)",
                    "Maximum Impervious Runoff (in)", "Median Impervious Runoff (In)",
                    "Minimum Pervious Runoff (in)", "Maximum Pervious Runoff (in)",
                    "Median Pervious Runoff (in)")) %>%
  kable_styling(bootstrap_options = "striped")

min_range_runoff_table_wet
```

Analysis of observed vs simulated runoff for 2009 storm

```
observed09<- read_csv("c35_observed_09.csv")
simulated09 <- read_csv("C35_simulated09.csv")

discharge09<- merge(observed09, simulated09, by = "time_step")

summary(discharge09)

dischargettest09<- t.test(discharge09$discharge_obs_cfs, discharge09$simulated_flow_cfs)

regress09<- lm(discharge_obs_cfs ~ simulated_flow_cfs, data = discharge09)

regress09

sim09<- discharge09$simulated_flow_cfs
obs09<- discharge09$discharge_obs_cfs


sutcliffe09<- NSE(sim09, obs09, na.rm=TRUE, FUN=NULL, epsilon=c("Pushpalatha2012"))

sutcliffe09

write.csv(discharge09, file = "discharge_obv_sim09.csv", row.names = FALSE)

graph09<- ggplot(discharge09, aes(x=discharge_obs_cfs, simulated_flow_cfs))+
  geom_point()

graph
```

```
calibrate_graph09<- discharge09 %>%
  ggplot()+
  geom_line(aes(x=time_step, y=discharge_obs_cfs), color="darkseagreen")+
  geom_line(aes(x=time_step, y=simulated_flow_cfs), color= "darkgoldenrod1")+
  theme_classic()+
  labs(x="Time (hours)", y="Discharge (cfs)")+
  scale_y_continuous(limits= c(0,300), breaks= seq(0,300, by= 25),expand= c(0,0))+
  scale_x_continuous(limits= c(0,12), breaks= seq(0,12, by= 2),expand= c(0,0))+
  annotate("text", label= "Observed", x=8, y=150, size=3.5)+
  annotate("text", label= "Simulated", x=8, y=77, size=3.5)


calibrate_graph09
```

```r
##save discharge graphs from the 2009 "wet" storm
ggsave("discharge09_final.pdf", width = 8, height =4)
ggsave("dischage09_final.png", width = 8, height =4)
```

Top 15 subcatchments

```r
dry_runoff_coef_top_15 <- top_n(results_dry, 15, runoff_coeff)

dry_peak_top_15 <-top_n(results_dry, 15, peak_runoff_cfs)

wet_runoff_coef_top_15 <- top_n(results_wet, 15, runoff_coeff)

wet_peak_top_15 <- top_n(results_wet, 15, peak_runoff_cfs)

write.csv(dry_runoff_coef_top_15, file = "dry_runoff_top_15.csv", row.names = FALSE)

write.csv(wet_runoff_coef_top_15, file = "wet_runoff_top_15.csv", row.names = FALSE)

write.csv(dry_peak_top_15,file = "dry_peak_top_15.csv", row.names = FALSE)

write.csv(wet_peak_top_15, file = "wet_peak_top_15.csv", row.names = FALSE)
```

Visualizing the sediment data from 09

```r
sediment09<- read_csv("sediment_09_r.csv") %>%
  mutate(discharge_obs_cfs =
           case_when(time_step <0 ~ 0))

discharge_4_graph<- read_csv("c35_observed_09.csv") %>%
  mutate(susp_sed =
           case_when(time_step <0 ~ 0))

sedimentandflow<- rbind(sediment09, discharge_4_graph)

sediment_flow_graph <- sedimentandflow %>%
  ggplot()+
  geom_line(aes(x=time_step, y= discharge_obs_cfs), color= "blue")+
  geom_point(aes(x=time_step, y=susp_sed), color= "red")+
  theme_classic()

sediment_flow_graph
```

```r
obs_discharge_09<- discharge09 %>%
  ggplot(aes(x=time_step, y=discharge_obs_cfs)) +
  geom_line(color= "darkseagreen")+
  scale_x_continuous(expand = c(0,0), breaks= seq(0,11, by =1))+
  scale_y_continuous(expand = c(0,0), breaks= seq(0,300, by=50))+
  labs(x= "Time (hours)", y= "Observed Discharge (cfs)")+
  theme_classic()

obs_discharge_09
```

```
ggsave("observed_discharge_09.pdf", width = 8, height =4)
ggsave("observed_discharge_09_1.png", width = 8, height =4)

sediment_graph<- sediment09 %>%
  ggplot()+
  geom_point(aes(x=time_step, y=susp_sed), size= 5, color= "darkgoldenrod1")+
  geom_segment(aes(x=time_step, xend=time_step, y=0, yend=susp_sed), size=1.5,
             color="darkgoldenrod1")+
  scale_y_continuous(expand = c(0,0), breaks= seq(0,2500, by=250), limits= c(0, 2500))+
  scale_x_continuous(expand = c(0,0), breaks= seq(0,14, by =1), limits=c(0,14))+
  labs(x= "Time (hours)", y= "Suspended Sediments (mg/L)")+
  theme_classic()

sediment_graph
```

```
ggsave("observed_sediment_09.pdf", width = 8, height =4)
ggsave("observed_sediment_09_gold.png", width = 8, height =4)
```