Storage characterization through gravity-meter experiments and stream flow analysis: Consequences for dry weather flow prediction

Chillara ReddyVaraprasad

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Declaration

I declare that this written submission represents my ideas in my own words, and where ideas or words of others have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources that have thus not been properly cited, or from whom proper permission has not been taken when needed.

(Signature)

(Chillara ReddyVaraprasad)

(Roll No.)

Approval Sheet

This Thesis entitled Storage characterization through gravity-meter experiments and stream flow analysis: Consequences for dry weather flow prediction by Chillara ReddyVaraprasad is approved for the degree of Master of Technology from IIT Hyderabad

(Dr. Chinthapenta R Viswanath) Examiner
Dept. of Mech and Aero Eng
IITH

(Dr.Basudev Biswal) Adviser
Dept. of Civil Eng
IITH

(Dr. KBVN Phanindra) Co-Adviser
Dept. of Civil Eng
IITH

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Dedication

To my adviser, father, mother, and brother

Abstract

Dry weather flow prediction is important as streamflow during dry or rain-less periods, i.e. water available for various usages, is generally very low. Generally hydrological models are employed to predict dry weather flow. However, they keep several parameters whose values need to be determined through calibration, which is a cumbersome process. Furthermore, models usually under perform during low flow periods. The main aim of this study is to predict low flow by utilizing as much less information as possible. We achieve this by exploiting the recent finding that dry weather flow characteristics are influenced by past discharge. In particular, the recession coefficient k (in $-dQ/dt = kQ^{\alpha}$) displays a power law relationship with past average discharge: $k \propto Q_N^{-\lambda}$, where Q_N is the average discharge during past N to 2 days before the recession event. The strength of the relationship can be measured in terms of coefficient of determination (R_N^2), and a higher R_N^2 implies that we can have prediction of k from Q_N. Generally R_N^2 decreases with N, although for some basins the opposite can happen, which indicating that there exists an optimal way of obtaining k from past discharge. In this study, we propose a novel algorithm that gives better performance of k in most of the cases. The consequence is that low flow discharge observed during dry weather periods can be predicted by integrating the power law equation for discharge, which can be achieved in several ways, each of them making a distinct approximation that requires different input information. Each of the method is evaluated by considering multiple indicators such as R^2 and NSE and PBIAS (percent bias). The performances are generally falling within acceptable ranges mentioned in the hydrologic literature. We also found that performances of the models can be explained by catchment characteristics. In summary, our study opens a new avenue of predicting low flow discharge by just considering past discharge.

In this study we also employed an experimental setup for observing the gravity variation at microscale for the purpose of detecting the effect of storage fluctuations on variability of gravity. For this we observed the gravity values at 12 stations in a roughly straight path at IIT Hyderabad in ODF campus. We noted down the weekly gravity values for a period of three months (August 2015 to December 2015). After applying the suitable corrections for various factors like latitude, elevation it was observed that the storage fluctuations has considerable effect on the variability of gravity values at micro scale. Our study proves that gravity variability at micro scale can be employed for hydrological modelling.

Contents

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C. Reddy Varaprasad

(Signature)

(Chillara ReddyVaraprasad)

CE14MTECH11023

(Roll No.)

APPROVAL SHEET

This thesis entitled by "Storage characterization through gravimeter experiments and streamflow analysis: Consequences for dry weather flow prediction" by C. Reddy Varaprasad is approved for the degree of Master of Technology from IIT Hyderabad.

Dr. Chintapenta R Viswanath
Assistant Professor,
Department of Mech. and Aero. Engg.,
IIT Hyderabad.

Dr. Basudev Biswal
Assistant Professor,
Department of Civil Engg.,
IIT Hyderabad.

Dr. Phanindra KBVN
Assistant Professor,
Department of Civil Engg.,
IIT Hyderabad.

Dr. Riddhi Singh
Assistant Professor,
Department of Civil Engg.,
IIT Hyderabad.

Chapter 1

Introduction

During the dry weather period, very little water will be available for various purposes like domestic water supply (see figure 1.1), hydro electric power generation, minimum flow to treat the discharged pollutants [1, 2, 3]. Unfortunately less number of successful attempts were made in the study of low prediction models compared to the flood forecasting models. So there is a huge need to focus on low flow forecasting, as a consequence predicted low flows will be very useful for effective water quality and quantity management. A number of rainfall runoff models like HBV, IHACRES are frequently used to predict daily stream flow with a considerable accuracy. These models are complex and are data demanding [4], so streamflow prediction with limited data is always a basic challenging task in the field of hydrology. Razavi et al. [4] gave an exhaustive review on the existing low flow prediction models and also about their necessary input data, validity and limitations.

Figure 1.1: The picture depicts the water crisis in India especially during summer. The Latur water train with 50 wagons (Each wagon with one lakh liters) brings water from Sangli which is 342 km away from Latur. (for full details see *http*: *//indianexpress.com/article/india/india-news-india/latur-water-train-maharashtra-marathwada-water-crisis-2756869/*)

The gradual diminution of discharge due to the evapotranspiration, interception (Which accounts 95% of precipitation in arid regions), during the low precipitation or no precipitation periods is termed as the recession flow. Analysis of recession flow provides significant information of storage characteristics of basin as it is mainly constitutes the subsurface flow and this can be done by ascertaining the patterns in the recession events and by connecting with the physical properties of the basin with the help of analytical models [5, 6, 7, 8, 9].

1.1 Objectives of the Thesis

The main objective of the research is to propose a novel algorithm for the better prediction of k that can be further used for the prediction of dry weather flow. The sub-objectives includes

1. Investigating the variability of recession constants (α, k) across each recession event

2. Identifying the dominant factors for the prediction of recession coefficient k from the literature

3. Studying the anomaly of relationship of recession coefficient k with past discharge for the California basins and investigating the reasons causing the anomaly

4. Proposing a novel algorithm for the improved prediction of recession coefficient k

5. Predicting the dry weather flow with the help of improved recession coefficient k

6. Evaluating the model performance for various prediction methods

7. Observing the spatial and temporal variation of relative gravity and investigating whether the micro study of gravity variation can be used for hydrologic study or not.

1.2 Organization of Thesis

This Thesis is organized as six chapters. The brief description of each chapter is given below.

Chapter 1 deals with the motivation of research with brief description of study area along with the main and sub-objectives of research were discussed at the end.

Chapter 2 deals with comprehensive literature on some of the existing works in the field of hydrology with emphasis on behavior of recession parameters and their prediction. Various model evaluation parameters that has undertaken in this study along with their reportable values were also included in this chapter. Various factors affecting the relative gravity and their corrections was discussed at the end.

Study area and data used in this study was discussed in 3.

Chapter 4 deals with the novel approach for the better prediction of k compared to the existing literature and consequently dry weather flow by taking one basin as an example. It also includes the procedure involved in observing the relative gravity at the end.

Simulation results, the efficiency of model along with detailed figures and Corrected values of relative gravity and the factors causing variability were discussed in chapter 5.

Summary , limitations of work and the future scope of work was presented in chapter 6.

Code and the supplementary material was provided in chapter 7

Chapter 2

Literature review

2.1 Storage-Discharge relationship

Generally recession flow can be expressed as a function of time variable t as $Q = Q(t)$, where Q is the rate of flow at the outlet of the basin at time t. Most of the recession studies suffers from the fact that, there is no theory that gives the exact starting of recession flow. However it was eliminated by Brutsaert (1977), who expressed discharge rate ($\frac{dQ}{dt}$) as a function of discharge (Q) as given below .

$$-\frac{dQ}{dt} = kQ^{\alpha} \tag{2.1}$$

where α and k are the constants which depends on the recession characteristics. $\frac{dQ}{dt}$ and Q are computed as $-\frac{dQ}{dt} = \frac{(Q_{t+\Delta t} - Q_{t})}{2}$ and $Q = \frac{(Q_t + Q_{t+\Delta t})}{2}$ [5]. The above mentioned equation can be derived from Boussinesq's work who proposed a nonlinear differential equation governing unsteady flow from an unconfined aquifer to a stream channel which is valid under ideal conditions of no inflow and outflow like leakage, recharge, evapotranspiration. Hence the adaptation of the above expression may not yield good results if the basin has human abstractions like storage structures, dominant evapotranspiration losses, and involvement of overland flow, diversion head works [11, 6, 12, 13, 14].

2.2 Variability of recession constants (k and α)

Due to the high variation in the sub sequent segments of recession curve, α and k are expected to vary in the individual recession events. But Biswal and Kumar (2014) revealed that α is almost invariant across each recession event whereas k is highly variant and this emphasizes the dynamic behavior of storage-discharge relationship ($-\frac{dQ}{dt} = kQ^{\alpha}$).

Biswal and Kumar (2014) calculated α of each recession event and median of distribution (corresponding to all the recession events) was considered as representative of the whole basin. In our analysis the same kind of approach was replicated in fixing α of the basin and individual k values for each recession event were calculated to account the dynamic behavior of storage-discharge relationship.

Several models have been proposed to predict k for e.g. Biswal and Kumar (2014) found that k of recession curve is having a power law relation with the past characteristic discharge Q_N where Q_N is the average discharge of N days before the recession peak.

Power law relationship of k and past discharge Q_N

$$k = k_N^{'} {Q_N}^{-\lambda_N} \tag{2.2}$$

The variation of k from event to event is mainly because of fact that past storage of basin differs from event to event [10, 15]

2.3 Recession flow definition

Recession flow at any time t can be found out, if we can predict the k of recession event accurately. The following equations (mentioned in boxes) for the prediction of dry weather flow were proposed by [16]

From the recession governing equation

$$-\frac{dQ}{dt} = kQ^{\alpha} \tag{2.3}$$

Separating the variables

$$-\frac{dQ}{Q^{\alpha}} = kdt \tag{2.4}$$

Integrating on both sides and applying the limits

$$-\int_{Q_0}^{Q_t} \frac{dQ}{Q^{\alpha}} = k\int_{0}^{t} dt \tag{2.5}$$

$$-\Big[Q^{-\alpha+1}\Big]_{Q_0}^{Q_t} = k(1-\alpha)\Big[t\Big]_{0}^{t} \tag{2.6}$$

on applying the limits

$$Q_t^{-\alpha+1} - Q_0^{-\alpha+1} = kt(\alpha-1) \tag{2.7}$$

Dry weather flow at ant time t (Q_t) can be predicted by the following equation

$$Q_t = (kt(\alpha-1) + Q_0^{-\alpha+1})^{\frac{1}{-\alpha+1}} \tag{2.8}$$

Where k can be predicted by the power law relation 2.2. on further simplification

$$\boxed{Q_t = Q_0(1 + kt(\alpha-1)Q_0^{\alpha-1})^{\frac{1}{-\alpha+1}}} \tag{2.9}$$

According to Biswal and Kumar [2014] for large time span (t) $(ktQ_0^{1-\alpha}) >> 1$

so after substituting the expression for k and applying the above assumption, equation 2.9 becomes

$$\boxed{Q_t = (k^{'}Q_N^{-\lambda_N}t(\alpha-1))^{\frac{1}{-\alpha+1}}} \tag{2.10}$$

equations 2.9, 2.10 were derived from the study of [16] and can be used for the prediction of dry weather flows depending on the availability of beginning discharge of the recession event.

2.4 Anomaly of recession coefficient k and past discharge

Bart and Hope (2014) in their *Inter seasonal variability in base flow recession rates: the role of aquifer antecedent storage in the central California watersheds* expressed better power law relation of k with cumulative antecedent streamflow from the beginning of the water year (first October) to recession peak. They analyzed the recession events that occurred between first October to end of February (water season) in every year of available period to neglect ET losses.

In our study by investigating the above behavior a generalized algorithm is proposed for better prediction of k and consequently dry weather flow too (by using equations 2.9, 2.10). Our approach needs only past discharge and can be satisfactorily applicable to any basin that is free from human interventions.

2.5 Model Evaluation Statistics

In hydrological modelling, comparison of predicted and observed values is the most commonly used practice for evaluating the efficiency of the model. In hydrologic literature various model evaluation statistics (dimensionless) like Pearson coefficient (r), Coefficient of determination (R^2), Index of agreement (d), Prediction efficiency (P_e), Performance virtue statistic (PV_k), Logarithmic transformation variable (e) and also model evaluation statistics (error index type) like Nash sutcliffe efficiency (NSE), MAE (mean absolute error), MSE (mean square error), RMSE (root mean square error), Percentage bias (PBIAS), RMSE-observations standard deviation ratio (RSR), Daily root mean square (DRMS) are available. Out of the above mentioned statistics NSE, R^2, Index of agreement are mostly used for evaluating the efficiency of model. Better prediction of modelled values in terms of one model evaluation parameter may be showing poor prediction in terms of another model evaluation parameter. So even for an experienced scientists also it will be a difficult task to judge the superiority of statistics amongst each other. This is mainly because each model evaluation statistic may give different emphasis on different types of measured and modelled values[17].

1. **Pearson coefficient (r):**

It represents the collinearity of modelled and predicted values. If Q_m represents the predicted values and Q_o represents the observed value then Pearson coefficient is calculated by the following formula

$$r = \frac{\sum(Q_m - \bar{Q_m})(Q_o - \bar{Q_o})}{\sqrt{\sum(Q_m - \bar{Q_m})^2 \sum(Q_o - \bar{Q_o})^2}} \tag{2.11}$$

Where $\bar{Q_m}$, $\bar{Q_o}$ are mean of modelled and observed values respectively. It ranges from -1 to 1 respectively. r=0 represents no relationship, and -1, 1 for positive and negative relationship between observed and simulated values.

2. **Coefficient of determination (R^2):**

It represents the goodness of fit between predicted and observed values. It represents the proportion of variance of dependent variable (observed values)which can be predictable from dependent variables (predicted values). Its values varies from -1 to 1 with 0 indicates no correlation at all. -1 and +1 indicates that positive and negative relationship exist between observed and predicted values.

2.5.1 Model Evaluation Statistics (Dimensionless)

Strength of determination R^2

Its a standardized measure of error of prediction and varies from 0 to 1 with 0 being no relationship and 1 being a perfect relationship between the modelled and observed values. The strength of determination values are calculated by using the following formula

$$CorrelationCoefficient = \frac{(n\sum Q_oQ_m - \sum Q_o \sum Q_m)}{(\sqrt{\sum {Q_o}^2 - (\sum Q_o)^2}\sqrt{\sum {Q_m}^2 - (\sum Q_m)^2})} \tag{2.12}$$

Nash Sutcliffie Efficiency (NSE)

It determines the relative magnitude of residue of variance of measured and predicted values and variance of information (deviation of observed from their mean values)

Nash Sutcliffie Efficiency is defined as

$$NSE = 1 - \frac{\sum(Q_o - Q_m)^2)}{\sum(Q_o - \bar{Q_o})^2)} \tag{2.13}$$

NSE values varies from $-\infty$ to 1 with both the values as inclusive. NSE value of 1 indicates predicted and observed values are absolutely equal and 0 indicates that model is as accurate as the mean of the observed values. Negative NSE values indicates that mean of the observed values is better predictor than model predicted values.

2.5.2 Model Evaluation Statistics (Error Index)

Several model evaluation statistics of error indices like MAE (Mean Absolute Error), MSE (Mean Square Error), RMSE (Root Mean Square Error) are used for the model evaluation. An MAE, MSE, RMSE value of 0 indicates best fit. These model evaluation statistics can vary from 0 to ∞. Apart from the above statistics there are other evaluation statistics such as Percent Bias (PBIAS), RMSE-Observation Standard Deviation Ratio (RSR), Daily Root Mean Square Error (DRMSE) and the same are discussed below.

Percent Bias (PBIAS)

It represents the extent to which the predicted data to be larger or smaller than observed values. PBIAS is calculated as

$$PBIAS = \frac{\sum(Q_o - Q_m) * 100}{\sum(Q_o)} \tag{2.14}$$

It can vary from -∞ to $+\infty$ with 0 being an optimal value. Positive values of PBIAS indicates under performance of the model and negative value indicating the over performance of the model.

RMSE-Observation Standard Deviation Ratio(RSR)

RSR is calculated as the ratio of RMSE and standard deviation of observed data and is given by

$$RSR = \frac{\sqrt{\sum_{i=1}^{i=n-1}(Q_o - Q_m)^2}}{\sqrt{\sum_{i=1}^{i=n-1}(Q_o - \bar{Q_o})^2}} \tag{2.15}$$

It varies from 0 to ∞ with 0 indicating no residual error (perfect fit). Higher RSR value indicates poor model performance.

Table 2.1: General recommended performance ratings for streamflow prediction corresponding to monthly time step (*adapted from [18]*)

Performance rating	RSR	NSE	PBIAS (%)
Very good	$0.00 \leq RSR \leq 0.50$	$0.75 < NSE \leq 1$	$PBIAS < \pm 10$
Good	$0.50 < RSR \leq 0.60$	$0.65 < NSE \leq 0.75$	$\pm 10 \leq PBIAS < \pm 15$
Satisfactory	$0.60 < RSR \leq 0.70$	$0.5 < NSE \leq 0.65$	$\pm 15 \leq PBIAS < \pm 25$
Unsatisfactory	$RSR > 0.70$	$NSE \leq 0.50$	$PBIAS \geq \pm 25$

2.6 Gravity corrections

The factors that affects the values of gravity at micro scale and the respective corrections are explicitly discussed below.

2.6.1 Latitude correction

This accounts for earth's elliptical shape and rotation. This differs from the normal gravity which is gravity of earth if earth were a perfect, rotating ellipsoid. As the gravity value decreases from equator to pole, so correction for gravity increases if the latitude decreases (towards the equator). normal variation of gravity with latitude is given by

$$g_n = 978031.85\ [1.0 + 0.005278895 sin2(\phi) + 0.000023462 sin4(\phi)]\ (mGal) \tag{2.16}$$

where ϕ is latitude of the gravity observing place. Variation of gravity with latitude is given by

$$\Delta g_\phi = 0.000812 * sin(2\phi)\ mGal/m\ (N - S) \tag{2.17}$$

Differentiating the above equation w.r.t. latitude

$$\Delta g_\phi = \frac{dg}{d\phi} = 978.0318\ (0.0106048\ sin\phi\ cos\phi - 0.000235 sin2\phi\ cos2\phi) \tag{2.18}$$

The above equation 2.17 is valid for small scale survey in N-S plane.

2.6.2 Free air correction (Free-air gravity anomaly)

This is the gravity affected by the difference in the elevations between the observing station, base station and not due to the mass between the observing station and base station.

$$\Delta g_h = 0.3086h \ (mGal) \tag{2.19}$$

where h is elevation in meters. Correction is added if the station lies below the reference and subtracted if it lies above the reference station.

2.6.3 Bouguer slab correction

It accounts the effect of mass between the observing station and reference station. If the observing station lies above the reference, due to the presence of surplus mass the observed gravity will be more than observed gravity, so the correction will be negative and if the station lies below the reference point correction will be positive due to the deficiency of mass.
Magnitude of the correction is given by

$$\Delta g_b = -0.04193 \ \rho h \ (mGal) \tag{2.20}$$

where ρ is the average density of material overlying or underlying the survey area in $\frac{gm}{cc}$. Same kind of signs will be followed as free air correction.

2.6.4 Corrected Bouger gravity for terrain (Δg_{tb})

This correction is to account the variations in of terrain near the observing station. This correction is positive nevertheless of the presence of valley or mountain near the observing station due to the assumptions made in the Bouguer slab correction. It is computed by tables, templates or by the computers.
Apart from the above major corrections some minor corrections should be employed for change in

ground water level and for pressure variation. These should be accounted if their variation is large (especially for large scale studies).

2.6.5 Correction due to pressure

Change of atmospheric pressure will affect on micro gravimeter even in the order of $mGal$.

$$\Delta g_p = +3.6(P_1 - P_0)\ (mGals). \tag{2.21}$$

Where P_1= pressure at field station and P_0= pressure at base station.

So as per above formula if the pressure difference increases correction also increase.

2.6.6 Correction for ground water level change

These are seasonal variation i.e. given same for either dry or wet season. These can be considered by knowing the porosity of the soil and level of ground water at any one site. Magnitude of correction is given by

$$\Delta g_{GW} = -0.04192\ \Delta GWb\ (mGals). \tag{2.22}$$

Where ΔGW = variation in ground level water and b = porosity of the soil.

So corrected gravity is given by

$$\boxed{g_t = g_o \pm \Delta g_\phi \pm \Delta g_h \pm \Delta g_h \pm \Delta g_b \pm \Delta g_p \pm \Delta g_{GW} + \Delta g_{tb}} \tag{2.23}$$

where g_t is true gravity and g_o is observed gravity.

Chapter 3

Study area, data and preliminary processing

Daily average streamflow values (cusecs) were collected for 358 basins listed in USGS database (`http://usgswaterwatch.gov.in/`, 1^{st} column in supplementary material provides the basin ids). But finally 324 basins were finalized for analysis based on the number of recession events occurred (Baisn was selected if it has recession events ≥ 10 during the calibration period). Satellite images *(Courtesy: Google Earth)* were used to select the basins that were less or not influenced by human abstractions. Any streamflow series in which streamflow is observed to be decreased continuously for a period of more than 6 days was considered as a recession event [8, 10].

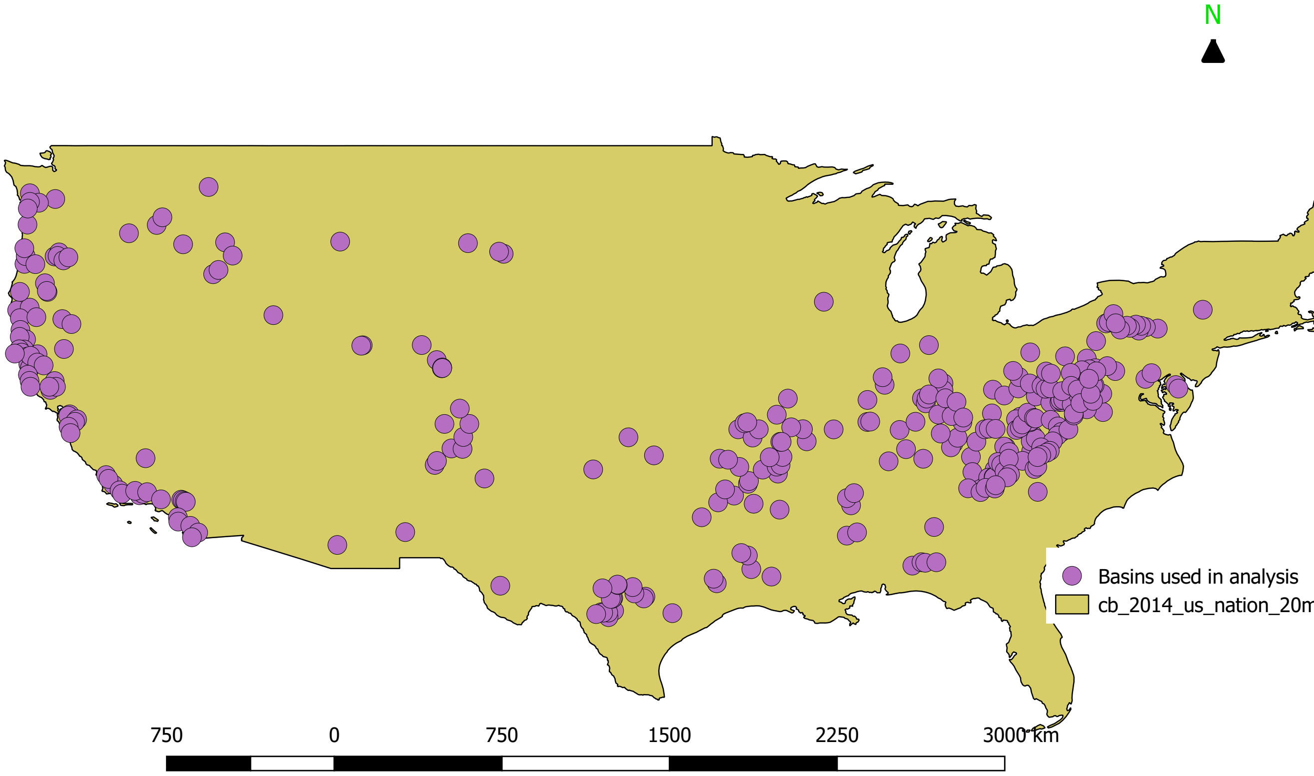

Figure 3.1: Spatial distribution of 324 USGS basins used in the study

Figure 3.2: Spatial distribution of 12 gravity observing stations used in the study

In this study a novel approach for the prediction of recession parameter was introduced and the same was implemented for the prediction of recession flows of 324 USGS listed basins (see figure 3.1). Half of the available data was used for calibration of recession parameters ($k_N^{'}$, λ_N) and the remaining data was used for validation. The predicted streamflows were in better agreement with the observed streamflows. To check the robustness of the model, the algorithm was tested for all basins individually with first half, second half of the data.

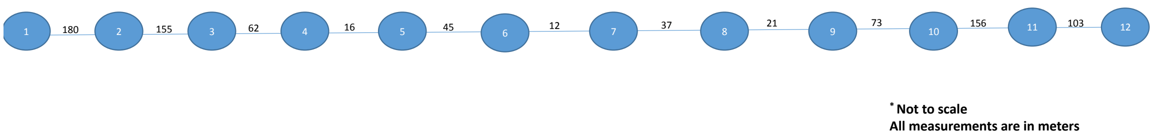

Figure 3.3: Spacing between the gravity observing stations

The study area for observing the relative gravity (Gravity residual compared to the base station) was selected nearer to IIT Hyderabad (ODF campus). The study area consists of a straight path of 880 m length with 12 gravity observing stations (see figure 3.2) with a small stream at the center of study area. The spacing between the stations varies inversely with their relative distance from the cross section of the intercepting stream. So the spacing between the stations (see figure 3.3) nearer to the stream was around 5 m in order to detect the effect of storage fluctuations in terms of gravity. The study area was chosen by considering the view of low traffic otherwise the gravity values will be affected due to the sensitivity of the instrument.

Chapter 4

Approach

Optimization of prediction of k and consequently dry weather flow prediction involves the following steps

1. Selection of basin and calculating α, k of individual recession events during calibration period by non linear regression analysis of $\frac{dQ}{dt}$ and Q

2. Fixing of α of basin as the median of the distribution of α values of individual recession events and back calculation of k

3. Collecting the past discharge of each recession event of N days during the calibration period (values of N used are 6,20,45,80,120 days) and k of individual recession events

4. Calculating the Q_{avg} by observing the trend of Q_N

5. Performing the linear regression analysis between k and Q_N and Q_{avg} for calculating the coefficients of regression

6. Selecting the coefficients of regression corresponding to high coefficient of determination (R^2) for the prediction of dry weather flow

7. Calculation of (Q_{avg}) for all the recession events during the validation period

8. Choosing the formula for the prediction dry weather period depending upon the consideration or not consideration of initial discharge

9. Calculation of dry weather flow and investigating the model performance through the model evaluation parameters

4.1 Optimizing the method of prediction of recession parameter k and the prediction of dry weather flow

4.1.1 Calculation of recession constants α and k

Recession parameters α, k were computed by the non-linear regression analysis between $\frac{dQ}{dt}$ and Q. The corresponding ln converted linear regression equations were given below.

$$\sum_{i=1}^{n-1} ln - (\frac{dQ}{dt})_i - nln(k) - \alpha \sum_{i=1}^{n-1} (ln(Q)_i) = 0 \tag{4.1}$$

$$\sum_{i=1}^{n-1} ln - (\frac{dQ}{dt})_i ln(Q)_i - \alpha \sum_{i=1}^{n-1} ln(Q)_i^2 - ln(k) \sum_{i=1}^{n-1} ln(Q) = 0 \tag{4.2}$$

the time step (dt) taken was in sec i.e. $24 \times 60 \times 60$. i, n indicates drop in the discharge and the length of the recession event. Calculation of α and k for first observed recession event of basin 03368000 is explained below.

Table 4.1: Daily streamflows of first recession event of basin 03368000

t (Days)	$Q(t)$ (ft^3/sec)	$-\frac{dQ}{dt}$ (ft^3/sec^2)	Q (ft^3/sec)	$ln(\frac{dQ}{dt})$	$ln(Q)$
1	6.6				
		1.04×10^{-5}	6.15	-11.47	1.82
2	5.7				
		1.27×10^{-5}	5.15	-11.27	1.64
3	4.6				
		4.63×10^{-6}	4.40	-12.28	1.48
4	4.2				
		8.10×10^{-6}	3.85	-11.72	1.35
5	3.5				
		2.31×10^{-6}	3.40	-12.98	1.22
6	3.3				
		2.31×10^{-6}	3.20	-12.98	1.16
7	3.1				
		2.31×10^{-6}	3.00	-12.98	1.10
8	2.9				
		2.31×10^{-6}	2.80	-12.98	1.03
9	2.7				

Table 4.2: Calculation of α and k

$ln(\frac{dQ}{dt})$	$ln(Q)$	$ln(Q)^2$	$ln(-\frac{dQ}{dt})ln(Q)$
-11.47	1.82	3.30	-20.84
-11.27	1.64	2.69	-18.47
-12.28	1.48	2.20	-18.20
-11.72	1.35	1.82	-15.80
-12.98	1.22	1.50	-15.88
-12.98	1.16	1.35	-15.09
-12.98	1.10	1.21	-14.26
-12.98	1.03	1.06	-13.36
$\sum ln(\frac{dQ}{dt}) = -98.66$	$\sum ln(Q) = 10.80$	$\sum ln(Q)^2 = 15.13$	$\sum ln(-\frac{dQ}{dt})ln(Q) = -131.90$

After substituting all the known values the equations 4.1, 4.2 becomes

$$-98.66 - 10.80\ \alpha - 8\ ln(k) = 0 \tag{4.3}$$

$$-131.90 - 15.13\ \alpha - 10.80\ ln(k) = 0 \tag{4.4}$$

Equations 4.3, 4.4 are solved for obtaining α, k of that recession event.

4.1.2 Calculation of k after fixing α

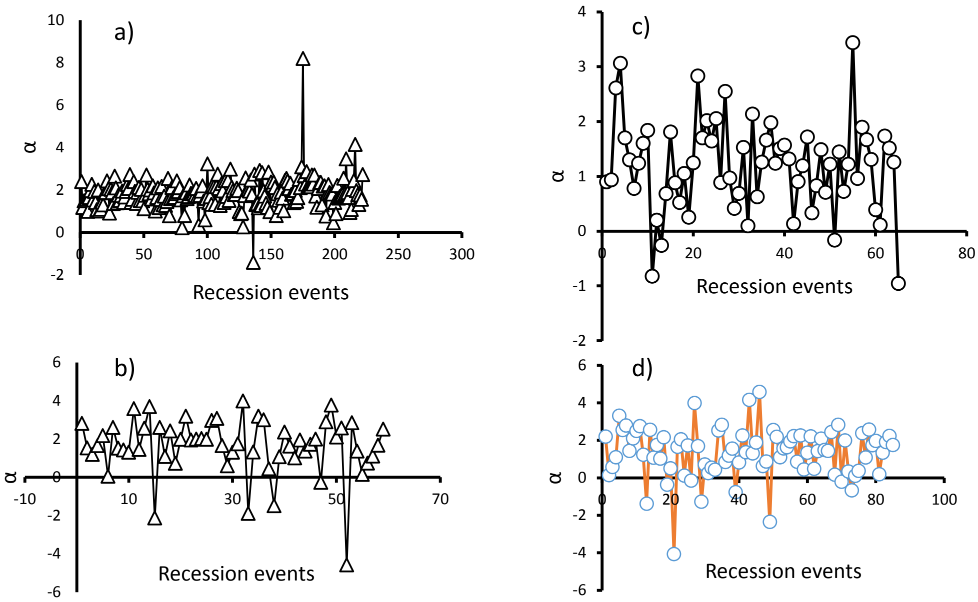

Figure 4.1: α distribution of the recession events during the first half of the avalaible data for the basins (a) 03368000 (b) 08227500 (c) 011063680 (d) 014034470

Since the α values of the individual recession events are exhibiting static behavior (for e.g. see the figure 4.1), to compare the variability of k across each recession events α of basin was fixed and k for each recession event was calculated from the following equation 4.5.

$$\sum_{i=1}^{n-1} ln - (\frac{dQ}{dt})_i - nln(k) - \alpha \sum_{i=1}^{n-1} (ln(Q)_i) = 0 \tag{4.5}$$

For the same basin 03368000 and for the first recession period (α of the basin is fixed as the median of α distribution of all the individual recession events and is observed as 1.83). So after fixing the α equation 4.5 becomes

$$-98.66 - 8\ ln(k) - 19.76 = 0 \tag{4.6}$$

Thus fixing of α enables to compare k of individual recession events.

4.1.3 Selecting of past discharge Q_N and k of each recession event

For each recession event for the prediction of k which is having power law relationship with past storage, past discharge of each recession event corresponding to 6,20,45,80,120 days by excluding two days from the peak were selected. For the same basin 03368000 the past discharge Q_N and k were shown in figure 4.2.

4.1.4 Calculating the Q_{avg} by observing the trend of Q_N

After selecting the values of Q_N, in order to account the past storage which is contributing to the recession event average of Q_N upto which Q_N has shown increasing trend was calculated and represented as Q_{avg}. k is function of past storage which is not a physical quantity, hence past discharge of basin was considered as a proxy for the past storage. The above condition helps in isolating the past discharge which is equivalent to the past storage that is contributing to the recession discharge. In other words if we blindly consider the past 120 days average discharge for the prediction of k, it may not contain all the past discharge that is contributing to the past storage (it may contains the surface flow).

		ft^3/sec			
Q_6	Q_{20}	Q_{45}	Q_{80}	Q_{120}	k (sec$^{0.17}$/ft$^{2.48}$)
16.55	24.535	25.76	34.7125	23.45667	3.75246E-07
4.283333	4.51	13.71556	25.37625	24.14167	4.29529E-07
149.0333	45.98	22.85556	23.58875	29.55167	1.13841E-06
10.56667	4.345	25.27111	17.3525	23.03	4.50787E-06
1.533333	4.175	7.173333	4.13125	4.580833	7.86067E-07
12.01667	20.98	12.5	10.61125	7.098333	4.52009E-07
2.9	18.435	17.32889	14.53	9.795833	5.58487E-07
149.1667	52.275	30.68222	26.48125	20.5775	4.33347E-07
48.65	15.52	33.66222	20.75625	25.67667	1.37632E-06
11.08333	3.325	1.477778	0.83125	0.788333	1.13791E-06
7.866667	17.27	17.72444	24.58125	16.97833	1.27822E-06
25.43333	9.795	5.455556	7.9925	17.32583	3.52704E-07
16.31667	14.64	8.22	9.30125	15.84583	4.1756E-07
13.11667	64.01	38.63778	25.72375	19.31833	1.02971E-06
2.65	7.85	38.34667	26.10625	18.47083	2.63034E-06
5.616667	22.7	13.94889	29.005	21.6275	2.24447E-06
20.93333	46.535	25.61556	20.77875	28.14	8.46996E-07
2.483333	4.825	5.577778	16.485	15.785	8.40644E-07
14.01667	10.185	4.951111	6.57625	5.759167	7.04773E-07
18.33333	21.4	26.66222	41.0275	31.04	3.09272E-07
8.833333	18.83	23.33778	43.96	32.59417	4.97131E-07
15.05	12.82	20.30222	42.69125	31.7625	3.74999E-07
2.333333	3.295	12.29111	19.9075	31.88	8.23638E-07
1.583333	3.135	6.957778	12.98	31.6075	7.55979E-07
2.116667	5.08	4.253333	10.99875	15.9275	2.02857E-06
90.53333	41.245	27.29556	16.41	11.21083	5.91417E-07
24.33333	19.335	10.32	23.00875	21.40083	4.96571E-07
8.25	5.68	3.68	8.7275	12.655	1.79026E-06
0.883333	7.13	5.135556	7.68875	7.401667	1.2607E-06
1.866667	1.27	0.744444	0.51125	0.43	1.61372E-06
26.26667	100.03	55.67556	32.425	21.7225	3.70972E-07
13.95	23.455	29.98	40.98625	28.07333	5.21091E-07
5.35	20.705	19.28667	42.7225	29.87083	4.03807E-07

Figure 4.2: Average past discharge Q_N and final k for first 33 recession events for the basin 03368000.

For separating the recession event and it's storage, the possible favorable conditions are as follows

1.$Q_6 > Q_{20} > Q_{45} > Q_{80} > Q_{120}$

2.$Q_6 > Q_{20} > Q_{45} > Q_{80}$

3.$Q_6 > Q_{20} > Q_{45}$

4.$Q_6 > Q_{20}$

5.$Q_6 < Q_{20}$

If it fails in the beginning (i.e.$Q_6 < Q_{20}$) Q_6 was considered as Q_{avg}.

For the basin 03368000, randomly selected values of past discharge satisfying above the conditions is shown in the table 4.3.

Table 4.3: For the basin 03368000 various possible conditions of past discharges that arises in contributing the past storage to the recession flow.

Recession event	Q_6	Q_{20}	Q_{45} $\frac{ft^3}{sec}$	Q_{80}	Q_{120}	Remarks
8	149.17	52.28	30.68	26.48	20.58	$Q_6 > Q_{20} > Q_{45} > Q_{80} > Q_{120}$
35	2.35	1.29	0.64	0.63	1.1	$Q_6 > Q_{20} > Q_{45} > Q_{80}$
13	16.32	14.64	8.22	9.30	15.85	$Q_6 > Q_{20} > Q_{45}$
9	48.65	15.52	33.66	20.76	25.68	$Q_6 > Q_{20}$
1	16.55	24.54	25.76	34.71	23.46	$Q_6 < Q_{20}$

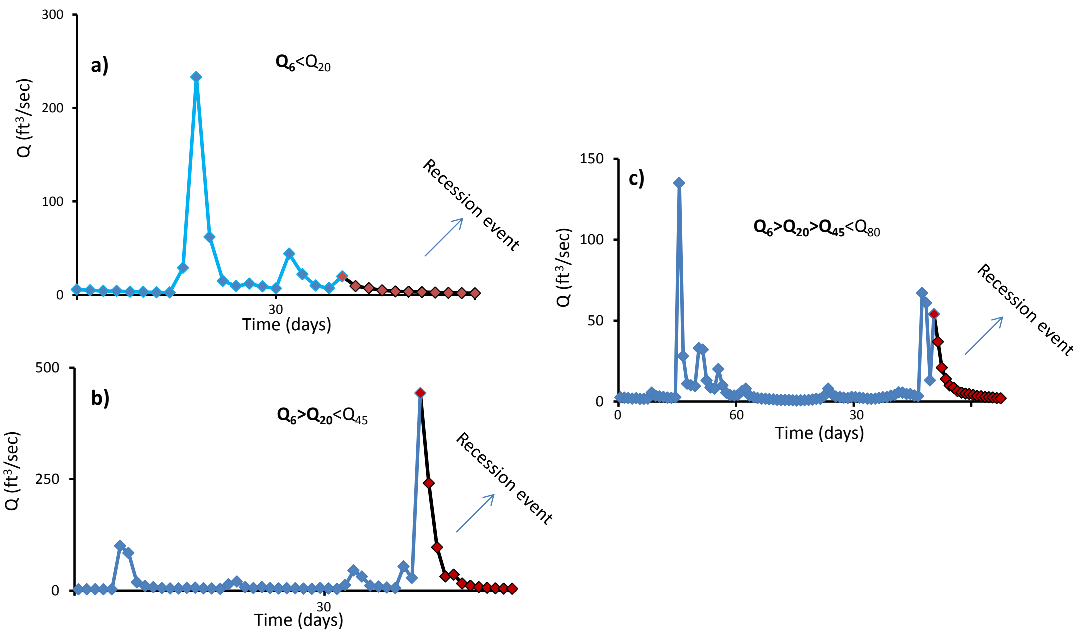

Figure 4.3: Involvement of surface flow after 6^{th}, 20^{th}, 45^{th} day of recession events 1, 9, 13 for the basin 03368000

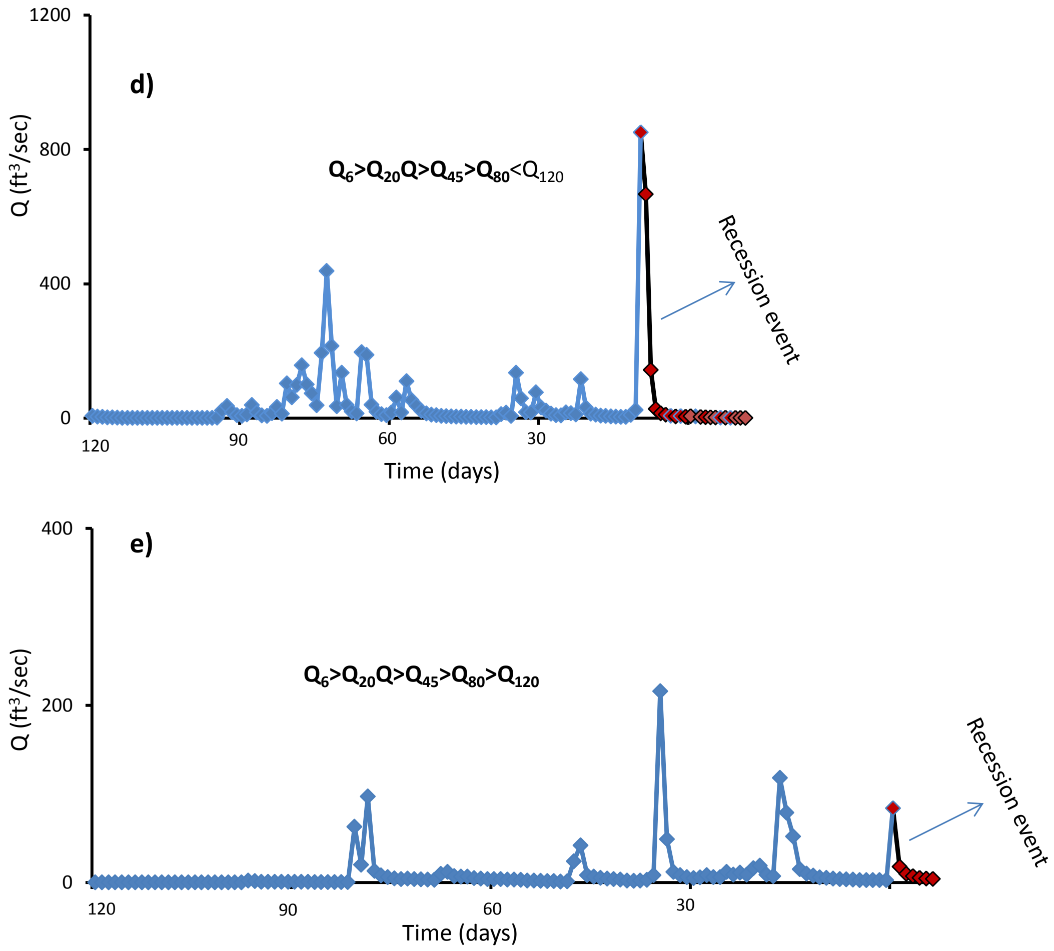

Figure 4.4: Involvement of surface flow after 80^{th}, 120^{th} day of recession events 35, 8 for the basin 03368000

$Q_6 > Q_{20} > Q_{45} > Q_{80} > Q_{120}$

It essentially indicates that there was no storm event or leakage from the surrounding aquifer that has a major contribution to the recession flow. It can be best visualized by the figure 4.4.(e). During the past discharge time series there was a sudden rise in the past flow at day 30 and 80 but their error causing probability is less due to their less lasting period. In such a case the past stream flow from day 2 to 120 contributes to the recession flow. So due to this average of Q_N (where

$N = 6, 20, 45, 80, 120$) was considered as Q_{avg}.

$Q_6 > Q_{20} > Q_{45} > Q_{80}$

It essentially indicates that there was no storm event or leakage from the surrounding aquifer that has a major contributes to the recession flow. It can be best visualized by the figure 4.4.(d). During the past discharge time series there was a sudden rise (upto 400 cusecs) in the past flow after day 80. so if their contribution after day 80 is considered, error causing probability will be more due to their high frequency nature. In such a case the past stream flow from day 2 to 80 contributes to the recession flow. So due to this average of Q_N (where $N = 6, 20, 45, 80$) was considered as Q_{avg}.

$Q_6 > Q_{20} > Q_{45}$

It essentially indicates that there was no storm event or leakage from the surrounding aquifer that has a major contributes to the recession flow. It can be best visualized by the figure 4.3.(c). During the past discharge time series there was a sudden rise (upto 140 cusecs) in the past flow after day 45. so if their contribution after day 45 is considered, error causing probability will be more due to the involvement of surface flow. In such a case the past stream flow from day 2 to 45 only contributes to the recession flow. So due to this average of Q_N (where $N = 6, 20, 45$) was considered as Q_{avg}.

$Q_6 > Q_{20}$

It essentially indicates that there was no storm event or leakage from the surrounding aquifer that has a major contributes to the recession flow. It can be best visualized by the figure 4.3.(b). During the past discharge time series there was a sudden rise (upto 100 cusecs for two consecutive days) in the past flow after day 20. so if their contribution after day 20 is considered, error causing probability will be more due to the involvement of surface flow. In such a case the past stream flow from day 2 to 20 only contributes to the recession flow. So due to this average of Q_N (where $N = 6, 20$) was considered as Q_{avg}.

$Q_6 < Q_{20}$

It essentially indicates that there was no storm event or leakage from the surrounding aquifer that has a major contributes to the recession flow. It can be best visualized by the figure 4.3.(a). During the past discharge time series there was a sudden rise (upto 220 and 80 cusecs for two consecutive days) in the past flow after day 6. so if their contribution after day 6 is considered, error causing probability will be more due to the involvement of surface flow. In such a case the past stream flow from day 2 to 6 only contributes to the recession flow. So due to this average of Q_N (where $N = 6$) was considered as Q_{avg}.

4.1.5 Performing the linear regression analysis (ln converted linear regression analysis) between k and past discharge

The constants between power law relation of k and past discharge, ($k^{'}_N$, λ_N) depends on N values for a given basin.

$$\sum_{i=1}^{n} ln(k)_i - n ln(k^{'}_N) + \lambda_N \sum_{i=1}^{n} ln(Q_N) = 0 \tag{4.7}$$

$$\sum_{i=1}^{n} ln(k)_i ln(Q_N)_i - n ln(k^{'}_N) \sum_{i=1}^{n} ln(Q_N) + \lambda_N \sum_{i=1}^{n} ln(Q_N)^2 = 0 \tag{4.8}$$

Table 4.4: For the same basin the prediction of k using the power law relation between k and past discharge Q_N is illustrated with the help of table given below.

Q_{avg}	$k(\frac{sec^{0.17}}{ft^{2.48}})$	$ln(Q_{avg})$	$ln(k)$	$ln(k)\ log(Q_{avg})$	$ln(Q_{avg})^2$
16.55	3.75×10^{-07}	2.81	-14.80	-41.59	7.90
4.283	4.29×10^{-07}	1.45	-14.66	-21.26	2.10
72.62	1.14×10^{-06}	4.29	-13.68	-58.69	18.40
7.46	4.51×10^{-06}	2.00	-12.31	-24.62	4.00
1.53	7.86×10^{-07}	0.43	-14.06	-6.05	0.18
12.02	4.52×10^{-07}	2.49	-14.61	-36.38	6.20
2.90	5.58×10^{-07}	1.06	-14.40	-15.26	1.12
55.84	4.33×10^{-07}	4.02	-14.65	-58.89	16.16
32.09	1.38×10^{-06}	3.47	-13.49	-46.81	12.04
3.50	1.14×10^{-06}	1.25	-13.68	-17.10	1.56

k values (after fixing the value of α) and past discharge for first 10 recession events were shown in the above table 4.4. Here only Q_{avg} was considered instead of Q_N. From the table 4.4

$\sum ln(Q_{avg}) = 23.27$

$\sum ln(k) = -140.34$

$\sum ln(Q_{avg})\ ln(k) = -326.65$

$\sum ln(Q_{avg})^2 = 69.66$

After replacing $(k_N^{'}, \lambda_N)$ by $(k_{avg}^{'}, \lambda_{avg})$, equations 4.7, 4.8 becomes

$$\sum_{i=1}^{n} ln(k)_i - n\ ln(k_{avg}^{'}) + \lambda_{avg} \sum_{i=1}^{n} ln(Q_{avg}) = 0 \tag{4.9}$$

$$\sum_{i=1}^{n} ln(k)_i\ ln(Q_{avg})_i - n\ ln(k_{avg}^{'}) \sum_{i=1}^{n} ln(Q_{avg})_i + \lambda_{avg} \sum_{i=1}^{n} ln(Q_{avg})^2 = 0 \tag{4.10}$$

Substituting the above values in equations 4.9, 4.10

$$-140.34 - 10\ ln(k_{avg}^{'}) + 23.27\ \lambda_{avg} = 0 \tag{4.11}$$

$$-326.65 - 232.7\ ln(k_{avg}^{'}) + 69.66\ \lambda_{avg} = 0 \tag{4.12}$$

By solving the above equations the values of $k_{avg}^{'}$, λ_{avg} are computed. So by using the power law relation between k and Q_{avg} the k value of any advance recession event can be found out.

4.1.6 Selection of regression coefficients corresponding to high strength of determination values

Generally due to the consideration of separated past discharge for each recession event, the strength of relationship between k and past discharge is larger when Q_{avg} is considered. This behavior was proved in 74% of the basins (see the R^2 values of $kVsQ_N$ and $kVsQ_{avg}$ shown in columns $2-7$ of the $SM-1$ provided at the end). Also in almost all of the remaining cases there exists only minute difference in the maximum value of strength of determination of k and Q_N when compared to strength of relationship of k and Q_{avg}. So for predicting the k of advancing recession event Q_{avg} was considered for correlating with k for all the basins. For all the basins $(\lambda_{avg}, k^{'}_{avg})$ during the calibration period were shown in $9-10$ columns of the $SM-1$ provided at the end.

4.1.7 Calculating the Q_{avg} for predicting the recession flow during the validation period

In the same way as the calibration period in order to calculate the recession flow, Q_{avg} was calculated by observing the trend of Q_N i.e. average of past average discharges upto which it has shown increasing trend was considered.

4.1.8 Choosing the formula for predicting the dry weather flow (recession flow)

Prediction of dry weather flow can be done by using as well as not using the initial discharge by using the following equations

Prediction of dry weather flow using the initial discharge

$$Q_t = Q_0(1 + k^{'}_N {Q_N}^{-\lambda_N} t(\alpha-1)Q_0^{\alpha-1})^{\frac{1}{1-\alpha}} \tag{4.13}$$

where Q_t is dry weather flow at time t
Q_0 is initial discharge at the beginning of the recession event
$(\lambda_N, k^{'}_N)$ are power law coefficient and constant between the power law relationship between k and Q_N.
α is the fixed value of α distribution of individual recession events of basin.
Due to high strength of determination between k and Q_{avg} $(\lambda_N, k^{'}_N)$ were replaced by $(\lambda_{avg}, k^{'}_{avg})$.
The Q_{avg} used in the above equation is belongs to validation period and should not be confused with Q_{avg} of validation period.

Prediction of dry weather flow without using the initial discharge

Suppose if the recession event or dry weather period lasts for larger time period, dry weather flow can be predicted even without using the initial discharge by the following formula. In our case due to the availability of initial discharge during the validation period (second half of the data) recession flows were predicted by using both the equations 5.2, 5.3. For each prediction case the model performance was checked individually.

$$Q_t = (k_N^{'} Q_N{}^{-\lambda_N} t(\alpha - 1))^{\frac{1}{1-\alpha}} \tag{4.14}$$

4.1.9 Evaluating the model performance after calculating the dry weather flow

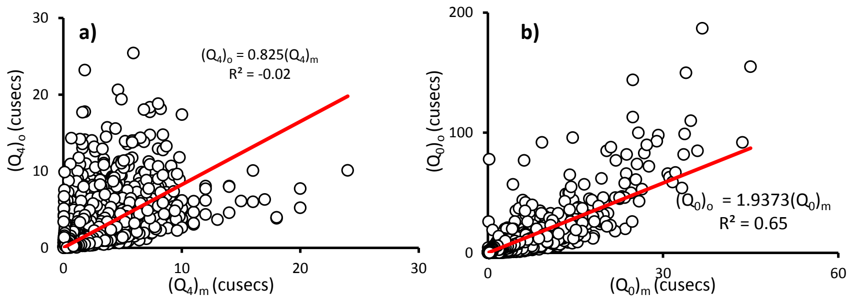

Figure 4.5: Linear regression passing through origin of both the cases of predicted and observed recession flows during second half of data

$(Q_4)_o$	$(Q_4)_m$	$(Q_4)_m$*0.825	$(Q_0)_o$	$(Q_0)_m$	$(Q_0)_m$*1.9373
4.2	8.884728	3.465	45	17.36897	33.64890843
3.5	6.780311	2.8875	11	10.26025	19.87717478
3.3	5.436649	2.7225	6.7	7.117409	13.78855678
3.1	4.510592	2.5575	4.7	5.376322	10.41554814
2.9	3.836926	2.3925	4.2	4.281798	8.295127878
2.7	3.326737	2.2275	3.4	3.535395	6.849120458
2	4.116452	1.65	2.5	2.996577	5.805267959
1.8	3.141438	1.485	7.1	4.931014	9.552853655
1.7	2.518896	1.4025	4.2	3.727358	7.221011071
1.6	2.089837	1.32	3.3	2.96989	5.753568701
4.6	20.61666	3.795	3	2.452972	4.75214177
3.7	15.73344	3.0525	2.7	2.079623	4.028853035
2.7	12.61553	2.2275	2.4	1.798409	3.484057713
2.2	10.46665	1.815	2.2	1.579631	3.06021995
1.8	8.903436	1.485	66	23.69518	45.90466469
1.4	7.719562	1.155	20	13.71235	26.56493944
1.3	6.794588	1.0725	13	9.420039	18.24944184
1.1	6.053701	0.9075	9.1	7.075457	13.70728262
0.9	5.448097	0.7425	7.1	5.614144	10.87628093
0.7	5.643313	0.5775	6.8	4.623361	8.956837782
0.6	4.306651	0.495	6.5	3.911107	7.576988059
0.5	3.453197	0.4125	6.3	3.376521	6.541333955
0.3	2.864993	0.2475	13	10.43514	20.21599424
1.1	2.293948	0.9075	11	8.664404	16.78555015
1	1.750609	0.825	8.2	7.374667	14.28694334
0.8	1.403689	0.66	6.7	6.39698	12.39286909
0.6	1.16459	0.495	5.8	5.63253	10.9118998
0.4	0.990656	0.33	5.4	5.01985	9.72495492
4.2	7.404903	3.465	5	4.518792	8.75425597

Figure 4.6: Observed and predicted recession flows for the basin 03368000 for both the cases of prediction with and without considering the bias error.

In the figure 4.5, $(Q_4)_o$=observed stream flows of each recession event from day 4 without considering the initial discharge; $(Q_4)_m$=predicted stream flows of each recession event from day 4 without considering the initial discharge; $(Q_0)_o$=observed stream flows of each recession event from day 2 with considering the initial discharge; $(Q_0)_m$=predicted stream flows of each recession event from day 2 with considering the initial discharge.

In this study dry weather flows were predicted by using the above formulae and the model performance was checked with the help of various model evaluation statistics like coefficient of determination (R^2), NSE, PBIAS (percent bias), RSR (RMSE - standardization ratio). Model evaluation parameters were also calculated from predicted and observed dry weather flows after removing the bias error. In other words if we fit the linear regression passing through the origin of predicted and observed values we can see whether the model under estimates or over estimates the observed values by a certain fixed value. In such case we can remove that bias error by multiplying the predicted values with the constant of proportionality between predicted and observed values. It can be better understand by the following example. For the 03368000 predicted stream flows both by using initial discharge and not by using the initial discharge along with the first 29 observed stream flows during the validation period (second half of the data) was shown figure 4.6. For that basin after fitting the observed and predicted for both the cases of prediction the regression constants passing through origin are given as 0.825 (for the prediction case without considering initial discharge), 1.9373 (for the prediction case with considering initial discharge respectively). In the first case of prediction the predicted recession flows indicates the over estimation of the model by a factor 0.825, so all the predicted flows were multiplied by the same factor in order to remove the bias error. For the later case the model under estimates the observed flows by a factor 1.9373 so all the predicted stream flows were multiplied by 1.9373 to remove the bias error. So in such way the performance of the model was evaluated by various model evaluation statistic parameters like coefficient of determination (R^2), NSE, PBIAS (percent bias), RSR (RMSE - standardization ratio) with the inclusive of bias error and after the elimination of bias error. For the above basin recession flows of around 2648 days were observed to be present during the validation period. The above mentioned constants 0.825, 1.9373 were obtained by the linear regression passing through origin of all the above mentioned 2648 days of stream flows and the corresponding predicted stream flows.

For reference purpose first 29 days observed and predicted stream flows only presented in the figure 4.6.

4.2 Relative gravity observing procedure

The following screens were edited prior to the gravity observation
In Survey screen, we have to specify the surveyor's identifier, station designation system, station grid reference parameter etc.. In autograv screen we can enable or disable the corrections due to various factors like tide, continuous tilt, terrain. Besides this it also contain option for saving or rejecting the raw data. In Options screen, we can specify the no.of cycles, starting delay (to attain stability before measurement), measurement type (numeric or alpha characteristic). Dump screen can be used for the transferring the data in text of alpha numeric format. Using Clock and Options screen, we can set the time and date of measurement, and for customer support and calibration issues options screen can be useful.

The following steps briefly explains the observations of gravity by Scientrix-CG5 gravimeter.
1. First level the instrument at the selected station with leveling screws provided at the bottom of tripod.
2. Choose the grid reference parameters like projection datum, enable/disable the corrections and other options like number of cycles and period of each cycle for observing the gravity.
3. Finally observe the gravity at that station and repeat the same procedure at remaining stations.
4. Finally dump the data with the USB.

4.3 Station topography details and magnitudes of corrections for elevation and latitude

Table 4.5: The following details of the stations were used in employing the major corrections. Due to lack of data, only two major corrections were employed.

Station No.	Latitude N (°)	Longitude E (°)	Elevation (m)	Δg_h $(mGal)$	Δg_ϕ $(mGal)$
1	17.492911	78.135361	599.2368	184.9244765	2865.145355
2	17.492677	78.136990	608.0760	187.6522536	2865.111296
3	17.492448	78.138389	600.4560	185.3007216	2865.077964
4	17.492369	78.138949	598.6272	184.7363539	2865.066466
5	17.492354	78.139124	598.6272	184.7363539	2865.064282
6	17.492275	78.139547	598.6272	184.7363539	2865.052784
7	17.492288	78.139628	598.6272	184.7363539	2865.054676
8	17.492208	78.139998	598.6272	184.7363539	2865.043031
9	17.492208	78.140195	611.7336	188.780989	2865.043031
10	17.492113	78.140944	599.8464	185.112599	2865.029204
11	17.491893	78.142418	599.2368	184.9244765	2864.997182
12	17.491769	78.143356	597.408	184.3601088	2864.979133

Chapter 5

Results and Discussions

5.1 Results for the calibration period

This study, emphasises the recession flows which are affected by subsurface properties only, by eliminating the peaks of all the recession events which are most likely due to the surface flow. From here on wards, recession event means, its exclusive of two days inclusive of the recession peak. The analysis was also performed by excluding the last element of recession curve to exclude the influence of next storm but the difference was found to be minimal. For each study basin all the recession events were selected and recession constants α and k were computed by non-linear regression analysis. α of the basin was taken as the median of α distribution of all the recession events. Due to its high variability in the individual segments of the recession, k was calculated individually for each recession event.

Prediction of the streamflow after t^{th} day of the peak of the recession curve is mainly influenced by k as variation of α of a basin is limited. According to Biswal and Kumar (2014) recession flow at any time can be obtained by integrating the recession equation and applying the limits and resulting equation is given below.

$$Q_t = Q_0(1 + kt(\alpha - 1)Q_0^{\alpha-1})^{\frac{1}{1-\alpha}} \tag{5.1}$$

substituting the expression of k, the above equation becomes

$$Q_t = Q_0(1 + k_N^{'} Q_N{}^{-\lambda_N} t(\alpha - 1) Q_0^{\alpha-1})^{\frac{1}{1-\alpha}} \tag{5.2}$$

where Q_0 is the initial discharge i.e. discharge at $t = 0$. But for large value of time (a minimum of 4 days in a general case), recession flow is independent of initial discharge [8] and the equation 5.2 becomes

$$Q_t = (k_N^{'} Q_N{}^{-\lambda_N} t(\alpha - 1))^{\frac{1}{1-\alpha}} \tag{5.3}$$

with better estimated k value for a recession event, equation 5.2 can be used for streamflow prediction provided the initial discharge of recession event is known. Even without knowing the initial discharge, advance forecasting of dry weather flow from fourth day of the recession event can be done by using equation 5.3. So to check the robustness of the model, streamflows were predicted from 4^{th} day, 2^{nd} day of each recession event during the validation period.

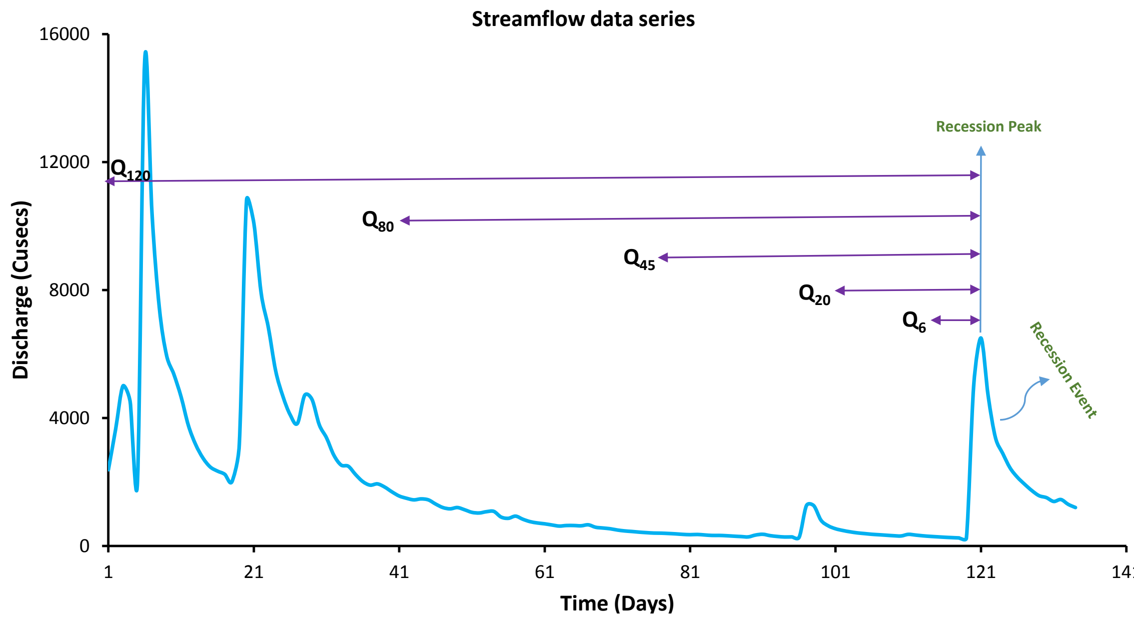

Figure 5.1: Illustrates the basic concept of the streamflow time series data in this study. The recession parameter k was examined with past streamflow (Q_N) by considering five N values ($N = 6, 20, 45, 80, 120$ days).

5.2 Anomaly of recession coefficient k with cumulative past discharge from a fixed reference

In Bart and Hope (2014), baseflow recession characteristics during water season for four basins (USGS ids :11143300, 1115200, 11148900, 11149900) of MCR (Mediterranean Climate Regions) were analyzed. The recession rate k is inversely proportional to antecedent storage which indicates that as the time span increases, the antecedent storage contribution towards the recession decreases [16, 8]. The difference between Biswal, Bart approach was in Biswal's approach the average past streamflows of 8, 28, 118 days were considered for each recession event whereas Bart and Hope (2014) investigated k of each recession event with antecedent cumulative streamflow from peak of each recession event to the beginning of corresponding water year. Similarly in our study antecedent discharge prior to the recession event was divided into five regions, with each region commencing from $N^{'}$ $[2, 10, 30, 60, 100]$ days to $N^{"}$ $[10, 30, 60, 100, 140]$ days respectively (for selecting the past streamflow for each recession event). In Bart and Hope (2014) antecedent cumulative discharge was considered for each recession event. However, rainfall is expected to be sparsely distributed in all the 324 basins and also as the basins were not confined to any particular topography so for accounting this average discharge from $N^{'}$ days before the peak of the recession event to $\frac{(N^{'}+N^{"})}{2}$ days i.e past discharge corresponding to 6, 20, 45, 80, 120 days were considered for each recession event. Interestingly in Bart and Hope (2014) analysis, the strength of the relationship of k and Q_{PWY} (cumulative streamflow from peak to the beginning of the corresponding water year) was much improved compared to traditional investigation of k with past streamflow Q_N (N = 8, 28, 118 days were adapted in Bart and Hope (2014) study). In our analysis also the similar kind of approach was undertaken. The main difference between their analysis and our analysis was, in Bart and Hope (2014) approach irrespective of position of recession event the section for selecting the past streamflow was fixed as the beginning of the water water whereas our study introduces a term Q_{avg} which was taken as the average of all the past average streamflows of Q_N upto which they showed an increasing pattern i.e. if $Q_6 \geq Q_N$ (where $N = 20, 45, 80, 120$, again average of the discharges till the above sequence followed was considered as Q_{avg}). If the sequence fails at the initial stage, 6 days average discharge before the recession was considered as Q_{avg}.

5.3 Calibration of k from the proposed novel approach

For calibrating the recession parameters individual recession events from half of the available data were selected. α and k parameters for each recession curve were computed by using nonlinear regression analysis. It was observed that for all the basins α of each recession event doesn't vary much, whereas k was shown an erratic behavior, which indicates that any change that takes place in the storage characteristics that will directly reflects in k. For example, Big Sur basin (USGS id: 11143000), has α distribution with a median value of 2.42 (with a standard error of ± 0.14). Similarly for the basins with USGS ids: $01488500, 11482500, 14185000, 14187000$ α values were reported as 2.69, 2.25, 2.42, 2.19 respectively. So k values were calculated for all the recession events using non linear regression analysis after fixing α of the basin as the median of α distribution of individual recession events. Represented α values of all the basins were provided in 8^{th} column of the supplementary material provided.

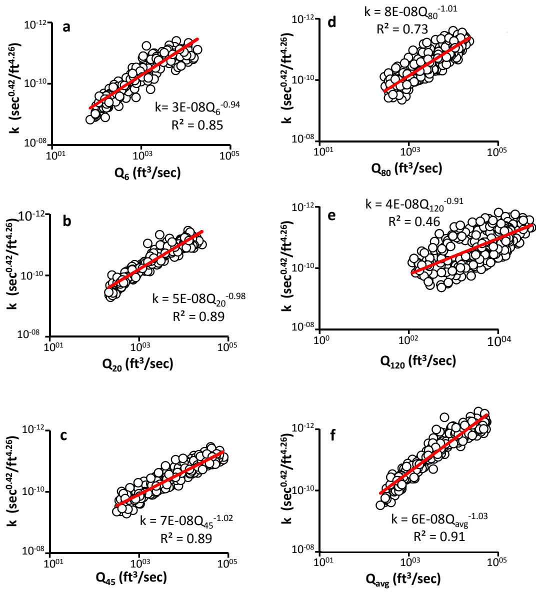

Figure 5.2: a to e illustrates the scatter plot of Q_N V_s k for $N = 6, 20, 45, 80, 120$ days for Siuslaw river near Mapleton (USGS id :14307620). f represents the scatter plot of Q_{avg} V_s k. Even though $R^2_{avg} \approx R^2_{20}$, a substantial improvement (higher R^2_{avg}) over R^2_N (Where $N = 6, 20, 45, 80, 120$ days from the peak) was observed in 74% of the basins.

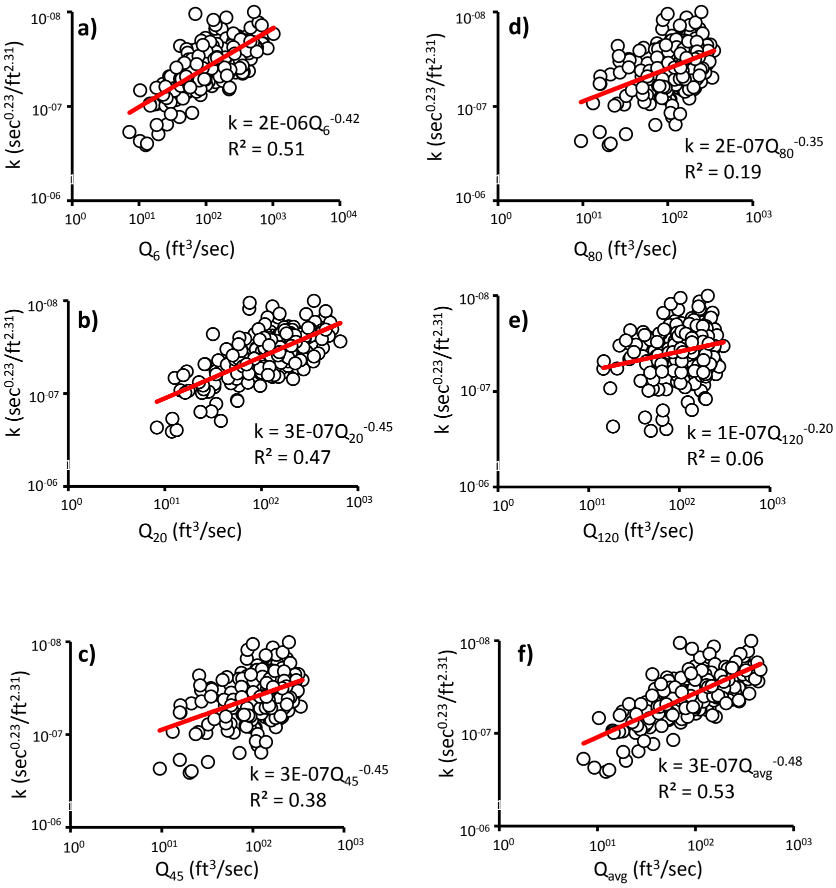

Figure 5.3: a to e illustrates the scatter plot of Q_N V_s k for $N = 6, 20, 45, 80, 120$ days for Siuslaw river near Mapleton (USGS id :03028000). f represents the scatter plot of Q_{avg} V_s k.

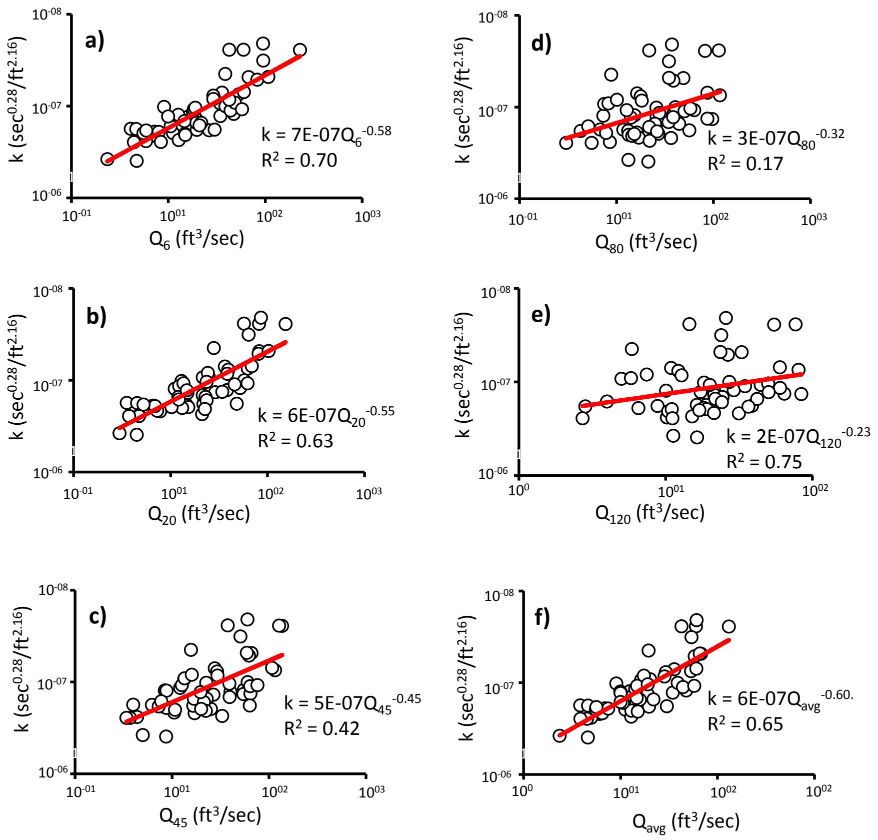

Figure 5.4: a to e illustrates the scatter plot of Q_N V_s k for $N = 6, 20, 45, 80, 120$ days for Siuslaw river near Mapleton (USGS id :08227500). f represents the scatter plot of Q_{avg} V_s k.

For each basin, recession rate k was investigated with past streamflow ($k = k^{'} Q_N{}^{-\lambda}$). The constants $k^{'}$, λ were find out by non linear regression analysis of k and Q_N. The scatter plot of k and Q_N for the basins with USGS id 14307620, 03028000, 08227500 were shown in the figure 5.2, 5.3, 5.4. For the basin 14307620, from the coefficient of determination values $R_6^2 = 0.85$, $R_{20}^2 = 0.89$, $R_{45}^2 = 0.89$, $R_{80}^2 = 0.73$, $R_{120}^2 = 0.46$, it was clear that the influence of antecedent streamflow over the recession with the time decreases i.e. as N increases R_N^2 decreases. R_N^2 where ($N = 6, 20, 45, 80, 120$) for all the basins were provided in columns $2 - 6$ of supplementary material provided.

Interestingly the strength of relationship ($R_{avg}^2 = 0.91$) was higher when k was investigated with

Q_{avg}. This was mainly due to the fact that for each recession event, our algorithm considers only past streamflow that contributes to basin storage for that recession period. For e.g. if $Q_6 < Q_{20}$, it indirectly indicates involvement of surface flow before 6 days from the recession peak (it can be best visualized if the reader observes 6, 20 days past streamflow of any recession event in which the above condition satisfies), so in such case our algorithm considers only 6 days past average discharge (Q_6) which indirectly equivalent to storage of basin which contributes to that recession. So the above mentioned condition avoids the surface flow, and considers only the subsurface flow (indirectly basin storage). This type of improved relationship was observed in 74% of the total basins and the improved coefficient of determination values for all the basins were reported in 7^{th} column of the supplementary material provided. Only in 20% of basins maximum value of R_N^2 exceeds R_{avg}^2 by 0.01. So for consistency, recession parameters $k^{'}$, λ were obtained from non linear regression analysis of k and Q_{avg}.

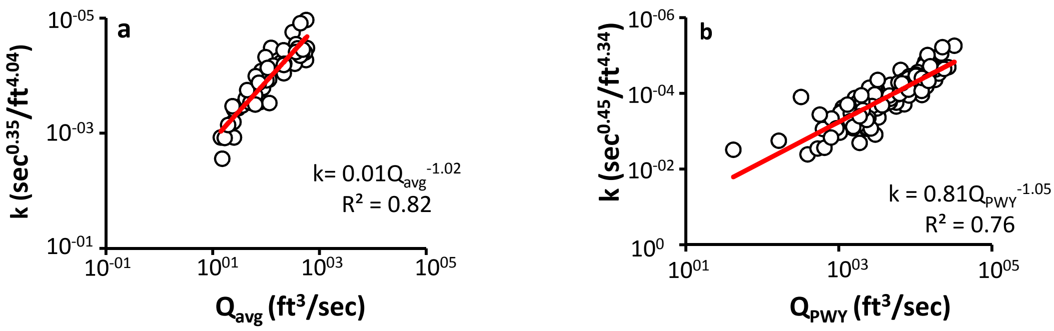

Figure 5.5: Two approaches of (a) Q_{avg} V_s k; (b) Q_{PWY} V_s k for Big sur basin (USGS id:11143000), where Q_{PWY} was the past cumulative streamflow of the recession event to the beginning of water year (October 1).

5.4 Comparison of Bart's approach and our approach

The comparison of k V_s Q_{avg} , k V_s Q_{PWY} (Q_{PWY} refers to the cumulative antecedent streamflow from recession event to beginning of water season) for the Big Sur basin (USGS id: 11143000) in California region was illustrated in figure 5.5. Interestingly R_{avg}^2 is observed to be greater than the R^2_{PWY}. The above values were corresponds to the recession events that occurred during the water season only. Obtained R^2_{PWY} values in our study and reported R^2_{PWY} values in Bart and Hope (2014) differs considerably. Proper selection of time step in the recession analysis might be one of the reason which can be assumed to distinguish R^2_{PWY} and R^2_{avg} values. Because in Bart and Hope (2014) analysis, the time step was corresponding to a period in which the decrease in the discharge exceeds by a fixed critical value (all those critical values were approximated by visual inspection and these was mainly to account the accuracy of the gauging station). Also the time step is highly affected by precession and noise involved in the data [14]. Rupp and Selker (2006) also suggested smaller time step during the early stage of recession and larger time step during the final stage of recession curve to detect the considerable decrease in the discharge. The Institute of Hydrology (1980) suggested a time step of 2 days to account the precession of the data and the exclusion of more recession events of shorter duration in the case of longer time steps. However in our study the time step was fixed as one day. This was mainly to avoid the possibility of discarding the basin properties in terms of recession events of smaller time step [5]. Besides this number of recession events in both cases also different as 120 days antecedent streamflow was a prerequisite in our approach. More interestingly R^2_{120} (0.86) was greater than both R^2_{avg} , R^2_{PWY}. However this type of anomaly was limited to two California basins only (USGS id: $11143000, 11148900$).

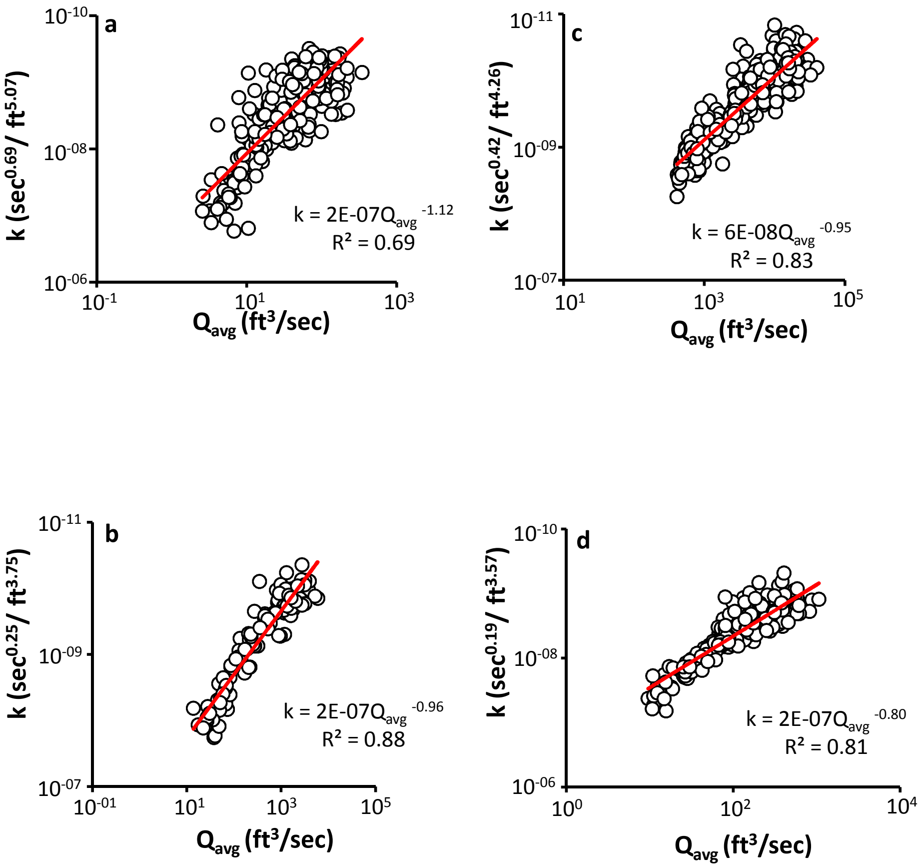

Figure 5.6: Except for Redwood C A Orick CA (USGS id:11482500) (b), R^2_{avg} was observed to exceed R^2_N for (a) Marshyhope creek (USGS id:01488500), (c) South Santiam river below Cascadia (USGS id:14185000), (d) Wiley creek near Foster (USGS id:14187000) basins.

The scatter plot of k and Q_{avg} for four randomly selected basins were shown in figure 5.6. As our approach yielding substantial good results so, k was investigated with Q_{avg} for all the basins to obtain k' and λ. Calibrated values of λ , $k^{'}$ for each basin during the model testing (the same data was used for both calibration and validation) with first half of the data were reported in 9^{th} and 10^{th} column of the supplementary material provided.

5.5 Prediction of dry weather flow

After calibrating the recession parameters, streamflows corresponding to the recession events were predicted by using equation 5.3 which is independent of initial discharge. The value of Q_N in predicting k was computed as in the case of calibration i.e. average of antecedent average streamflows prior to the peak of the recession event, provided up to which they show an increasing trend. In this way streamflow for all the recession events were predicted and grouped under Q_{mod}. Note that column 11^{th} of the supplementary of material provides the number of recession events during the model testing with first half of the data. After obtaining the parameters $k_N^{'}$ and λ_N equations 5.2, 5.3 were used to predict the dry weather flows of each recession event from 2^{nd} day and 4^{th} day of the recession event.

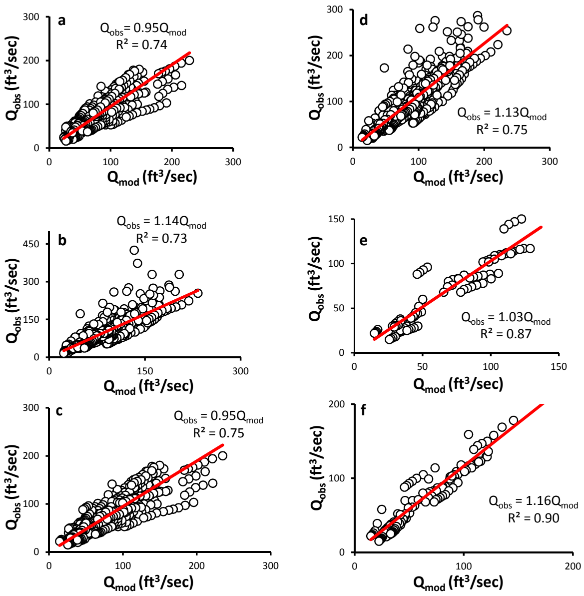

Figure 5.7: Scatter plots of predicted recession flows without using initial discharge and observed recession flows for the Panther Creek Near Toccoa, GA (USGS id:02182000) (a). Model testing using first half of the data, (c). Model testing using whole data, (b). For calibration using first half of data, validation using second half of data; for the same 3 cases (d), (f), (e) represents scatter plots of predicted recession flows with using initial discharge and observed recession flows.

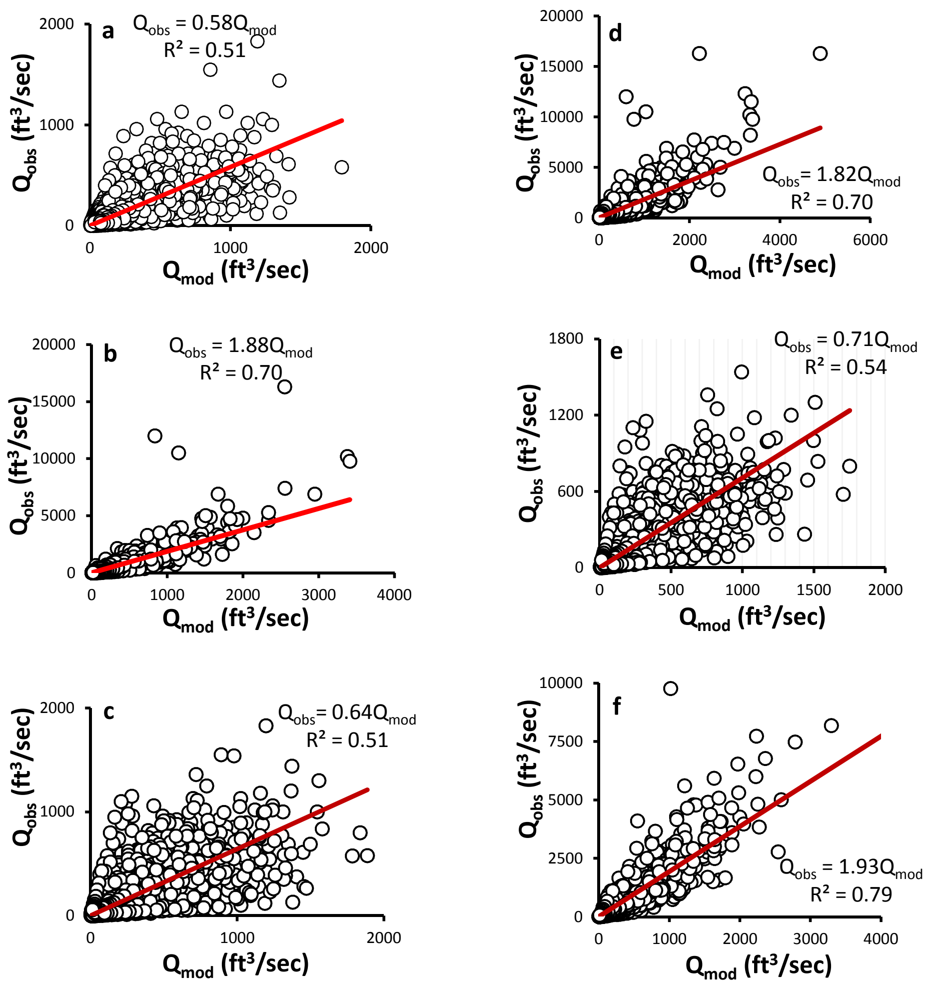

Figure 5.8: Scatter plots of predicted recession flows without using initial discharge and observed recession flows for the Middle Island Creek at Little, WV (USGS id:03114500) (a). Model testing using first half of the data, (c). Model testing using whole data, (b). For calibration using first half of data, validation using second half of data; for the same 3 cases (d), (f), (e) represents scatter plots of predicted recession flows with using initial discharge and observed recession flows.

Model was tested using first half and the whole data. For two basins with USGS id: 02182000, 03114500 the scatter plot of predicted streamflows (Q_{mod}) and observed streamflows (Q_{obs}) for the 3 cases (1. Model testing with first half of the data; 2. Model testing with whole data; 3. Calibration using first half of the data and validation using second half of the data) were shown in the Figure 5.7, 5.8 respectively. For the basin with USGS id:02182000 except in 3^{rd} case, both the coefficient of determination values (one for the prediction without considering the initial discharge and other with considering initial discharge) were observed to be almost same which signifies that all the predicted streamflows were solely function of k only whereas for the other basin with USGS id: 03114500 a substantial difference between both coefficient of determination values was observed. For the same cases of prediction the scatter plot of predicted and observed recession flows for the basins 08227500, 14034470 was shown in the following figures 5.9, 5.10 respectively.

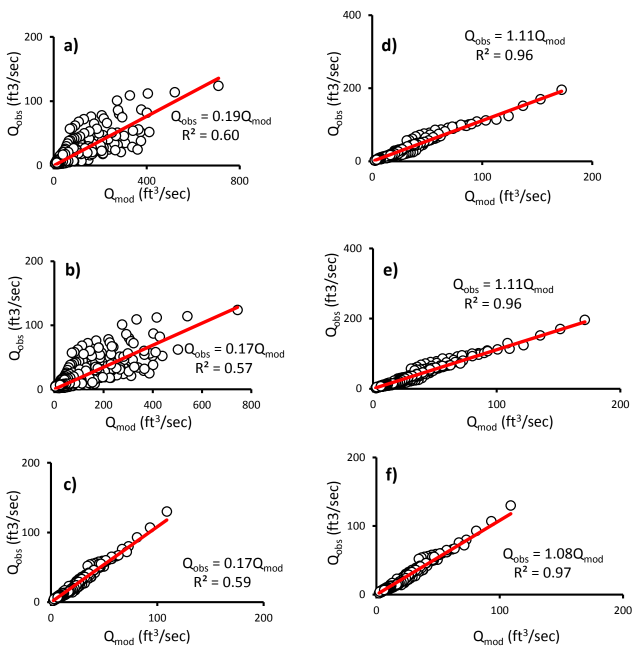

Figure 5.9: Scatter plots of predicted recession flows without using initial discharge and observed recession flows for the Middle Island Creek at Little, WV (USGS id:08227500) (a). Model testing using first half of the data, (c). Model testing using whole data, (b). For calibration using first half of data, validation using second half of data; for the same 3 cases (d), (f), (e) represents scatter plots of predicted recession flows with using initial discharge and observed recession flows.

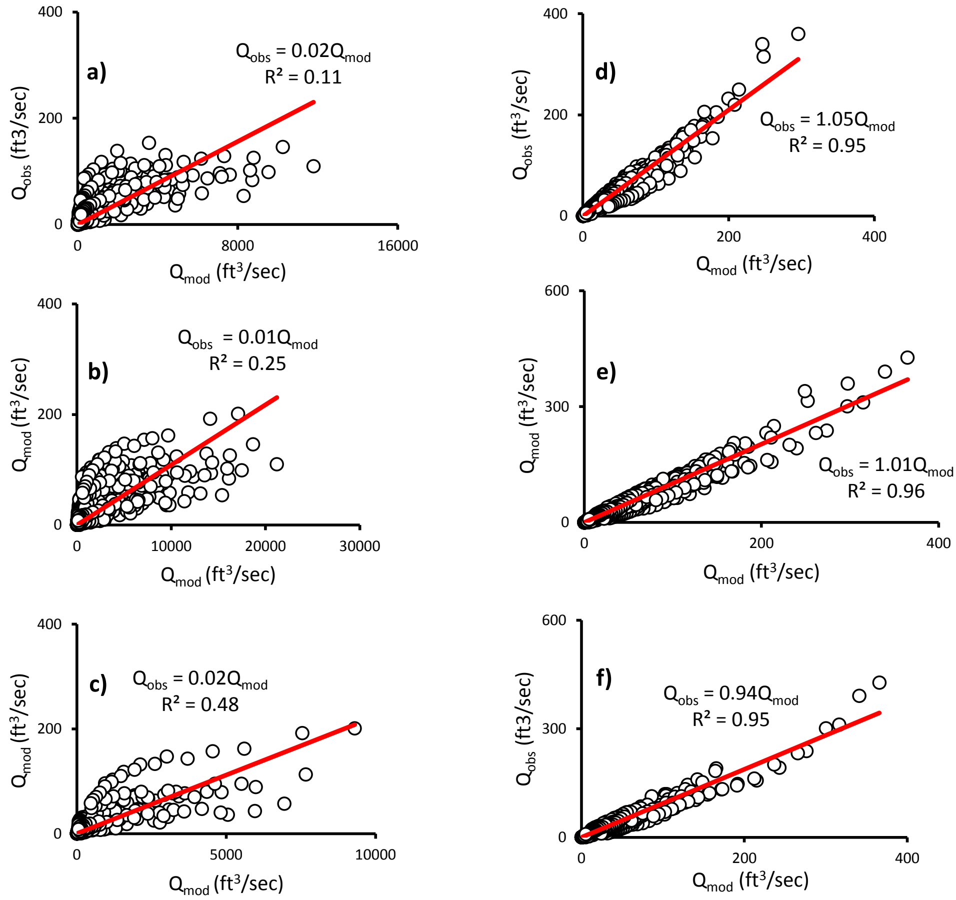

Figure 5.10: Scatter plots of predicted recession flows without using initial discharge and observed recession flows for the Middle Island Creek at Little, WV (USGS id:14034470) (a). Model testing using first half of the data, (c). Model testing using whole data, (b). For calibration using first half of data, validation using second half of data; for the same 3 cases (d), (f), (e) represents scatter plots of predicted recession flows with using initial discharge and observed recession flows.

5.6 Removing the bias error in the predicted dry weather flows

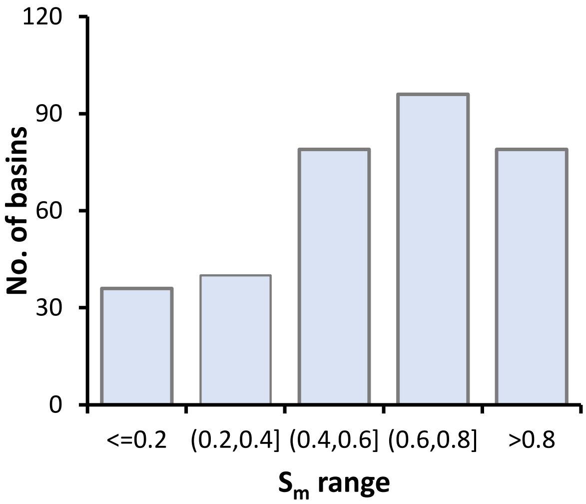

Figure 5.11: Histograms of number of basins, different ranges of slope for Q_{mod} Vs Q_{obs} (passing through origin) during the model testing with first half of the data. Only in 23% of the basins, slope was observed to be ≤ 0.4

Slope values for all the basins during model testing using first half of the data (for the prediction without using initial discharge i.e. using equation (5.3)) were shown in column 24^{th} of the supplementary material provided. Range of slope s_m and number of basins under that range are shown in figure 5.11. From the figure 5.11, it was clear that for 60% of the basins s_m value is greater than 0.6 and these slope values were multiplied with predicted streamflows to remove bias error involved in the predicted streamflows.

5.7 Evaluation of model

NSE (Nash Sutcliffe Efficiency) values of predicted and observed streamflows were reported to asses the efficiency of the model [18]. Columns $12-15$ indicates the unbiased and biased NSE values for the model testing using first half of the data. Unbiased and biased NSE values in columns $12-13$ of the supplementary material provided were based on the predicted streamflows (from 4^{th} day of the recession) without using initial discharge. Similarly columns $14 - 15$ indicates the unbiased, biased NSE values in which streamflows were predicted using the initial discharge. From the results it was clear that after eliminating the bias error NSE values were much more improved. Similarly model was tested using the whole data and the corresponding unbiased and biased NSE values were shown from columns $16 - 19$ of the supplementary material provided (for the prediction without using initial discharge and with using initial discharge). Similarly streamflows were predicted during second half of the data both from the second (using initial discharge) and fourth day (without using initial discharge) of the recession event after calibrating the parameters ($k^{'}$, λ) using first half of the data. Columns $20-21$ indicates the unbiased and biased NSE values of predicted streamflows during second half of the data. Note that while predicting the streamflows of each recession event during the validation period Q_{avg} was calculated using 120 days past discharge in the same way as in the calibration period. Columns $20 - 21$ of the supplementary material provided indicates the unbiased and biased NSE values for which the predicted streamflows was from 4^{th} day of the recession. In this case in 47% of the basins biased NSE values were fall under satisfactory range (NSE ≥ 0.5), the same percentage of NSE values were fall under the level of acceptance range (NSE ≥ 0) and in the remaining basins NSE values were fall under the region of rejection (i.e. mean observed value was to be a better predictor than the modelled value). In the former case by using the initial discharge, streamflows were predicted from 2^{nd} day of the recession and the corresponding unbiased and biased NSE were shown in columns 22, 23 respectively. In this case, in 89.36% of basins, biased NSE values were fall under satisfactory range (NSE ≥ 0.5) and only in 11% of the basins biased NSE values were fall under level of acceptance (NSE ≥ 0). Interestingly no NSE value fall under the region of rejection (NSE≤ 0, this was mainly due to authenticity of equation 5.2 which was derived from equation 2.1).

5.8 Cumulative frequency curves of model evaluation statistics

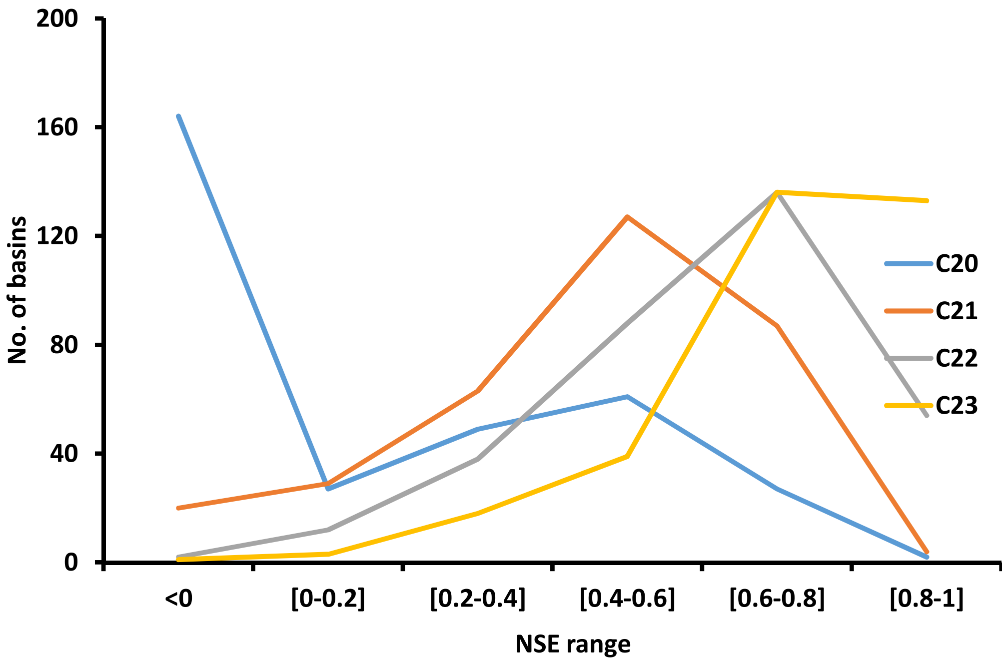

Figure 5.12: Cumulative frequency curves for all the basins and their NSE ranges for the four predicted cases ranging from column 20 to column 23 in the supplementary material provided. For better representation baisns with $\alpha < 1.5$ were excluded.

Cumulative frequency curve for the different ranges of NSE values listed from columns $20 - 23$ of the supplementary material provided and no.of basins was shown in figure 5.12. For better representation of these cumulative frequency curves the basins with $\alpha < 1.5$ were discarded. In model testing it was observed that for some of the basins NSE values were exceeded the limit of unacceptable range (for e.g. basins with USGS id 14034470, 13200500, 09268900) which signifies the poor prediction of streamflows. This was mainly attributed by the fact that α values of all those basins were not exceeding 1.5. But all the equations used to predict streamflow (equations 5.2, 5.3) were derived based on the assumptions that $\alpha \geq 1.5$ [5].

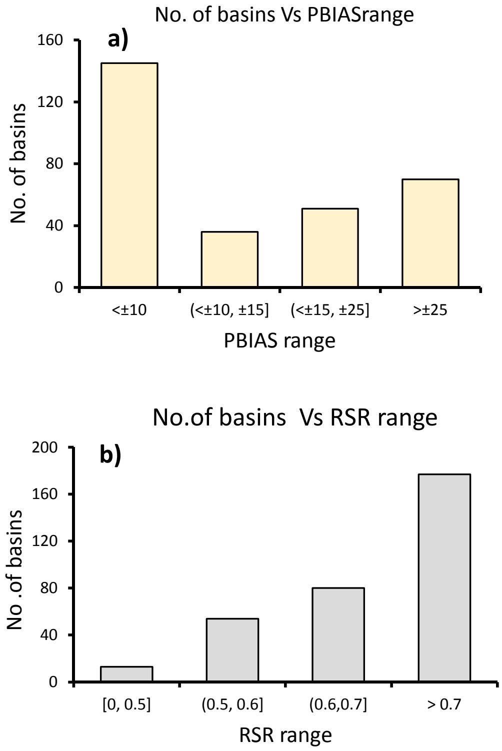

Figure 5.13: Histograms of no.of basins and ranges of model evaluation stastistics interms of a) PBIAS, b) RSR. The above values are corresponds to predicted recession flows without using initial discharge and observed recession flows during second half of data with calibrated k values from first half of the data. Hero also for better representation baisns with $\alpha < 1.5$ were not considered.

Model evaluation statistics like percent bias (PBIAS), RMSE-observation standard deviation ratio (RSR) were also calculated to check the performance of the model. Column $25 - 26$ of the supplementary material provided shows the biased PBIAS, RSR values of predicted recession flows without using initial discharge, observed streamflows during second half of the validation period. Figure 5.13 shows the no. of basins and ranges of PBIAS, RSR values. In 48% of the basins the predictions performance rating is very good (PBIAS $< \pm 10$), in 12% of basins the predictions performance rating is good ($\pm 10 \leq$PBIAS $< \pm 15$), in 16% of the basins the performance rating is satisfactory ($\pm 15 \leq$PBIAS $< \pm 25$) and in 23% of the basins the performance rating is unsatisfactory

(PBIAS $> \pm 25$). Similarly in terms of RSR in 4% basins performance rating is very good (RSR < 0.5), in 18% of basins rating is good ($0.5 <$ RSR ≤ 0.6), in 26% of basins performance rating is satisfactory ($0.6 <$ RSR ≤ 0.7) and in rest of basins (52%) of basins prediction is unsatisfactory (RSR > 0.7). The above mentioned general performance ratings are recommended for a monthly time step predictions. But our model predictions are in terms of daily time steps, so the above adapted recommended ratings from Moriasi et al (2007). shall be further decreased for daily step prediction which undoubtedly enhances the efficiency our model [18]. Since in literature only the reported NSE, PBIAS values are available, so to check the model performance of individual basin, performance ratings of monthly time steps were considered. All the above mentioned model evaluation statistics (PBIAS, RSR) are calculated only after removing the bias error in the predicted values. Also as our streamflow prediction models are not valid for the basins with $\alpha < 1.5$, so such basins were discarded in plotting figure 5.13.

Cumulative frequency curves of various model evaluation parameters and their ranges were shown from figures 5.14 to 5.19 for both the cases of prediction.

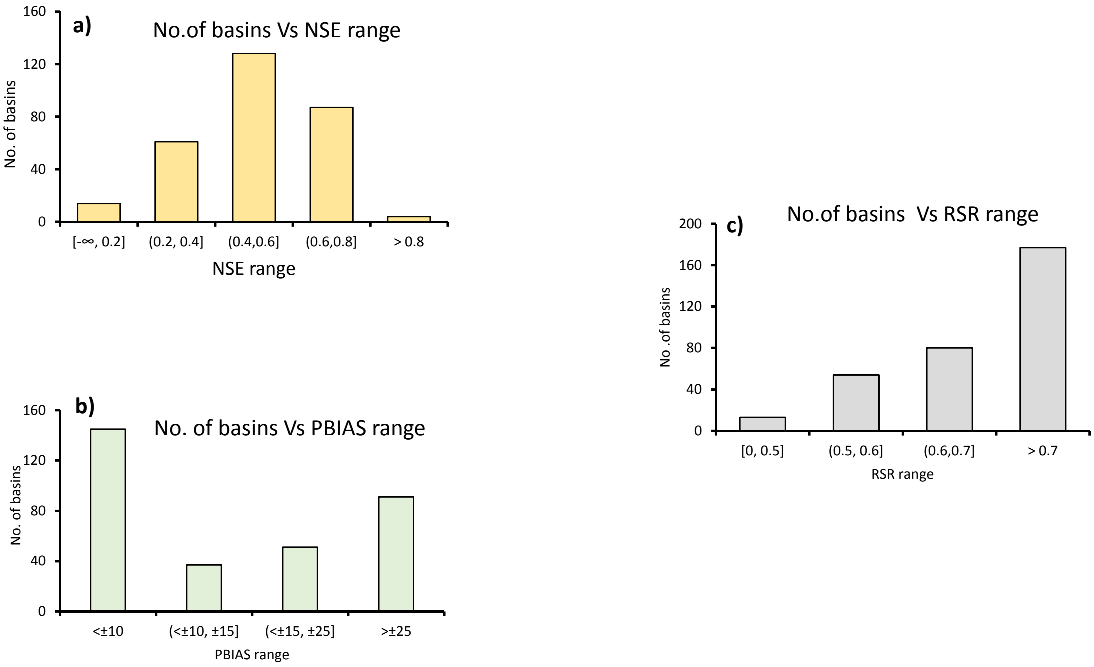

Figure 5.14: Histograms of no.of basins and ranges of model evaluation stastistics interms of a) NSE, b) PBIAS, c) RSR. The above values are corresponds to predicted recession flows without using initial discharge and observed recession flows during second half of data with calibrated k values from first half of the data. Here, baisns with $\alpha < 1.5$ were also considered.

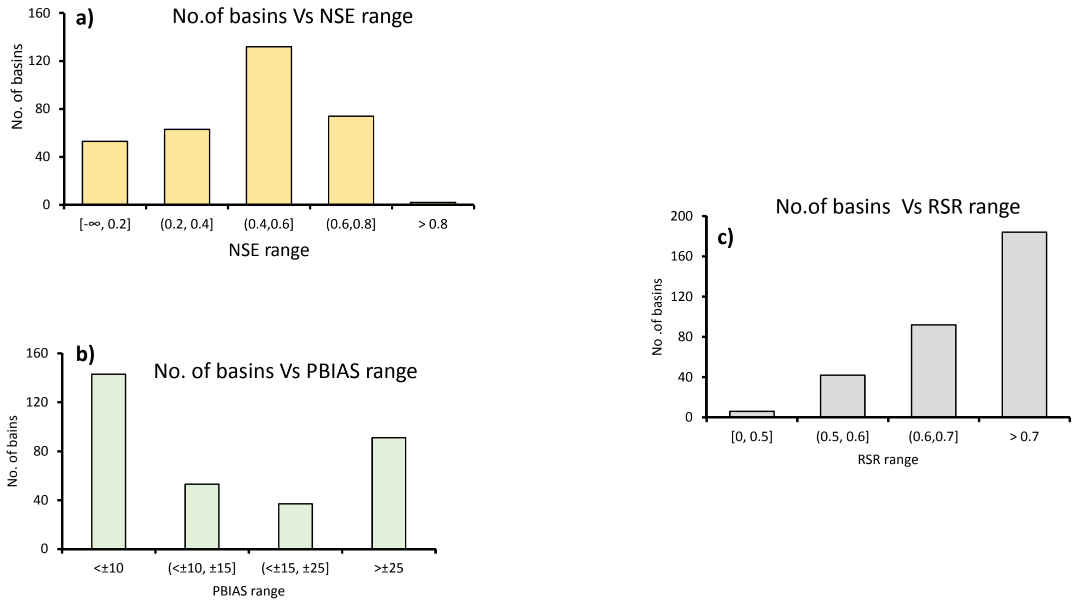

Figure 5.15: Histograms of no.of basins and ranges of model evaluation stastistics interms of a) NSE, b) PBIAS, c) RSR. The above values are corresponds to predicted recession flows without using initial discharge and observed recession flows during first half of data with calibrated k values from the same data. Here, baisns with $\alpha < 1.5$ were also considered.

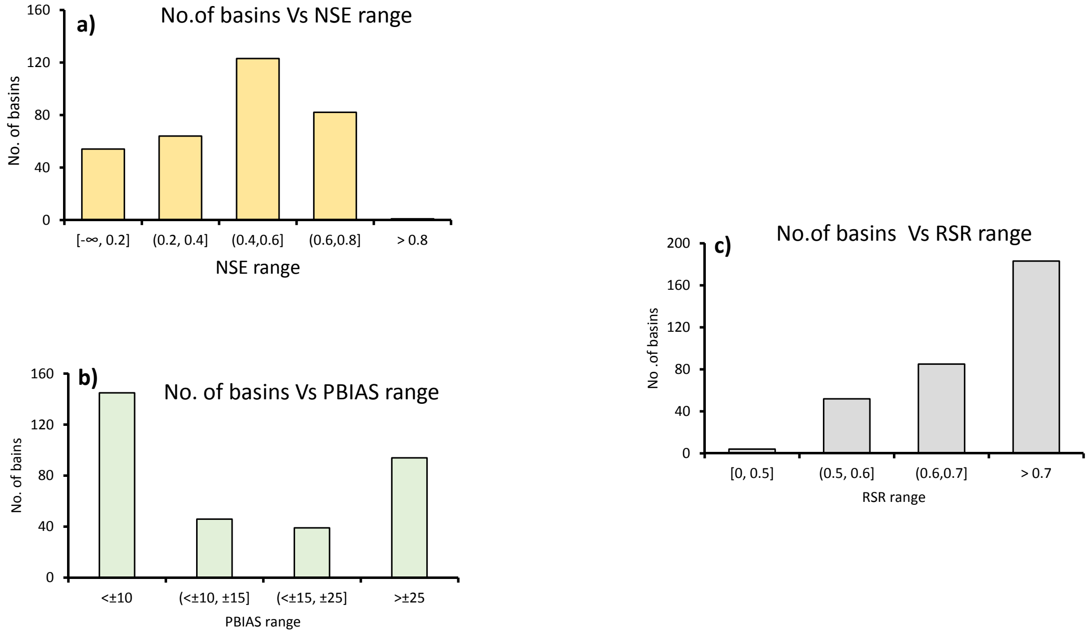

Figure 5.16: Histograms of no.of basins and ranges of model evaluation stastistics interms of a) NSE, b) PBIAS, c) RSR. The above values are corresponds to dry weather flow prediction without using the initial discharge by using whole data i.e. total data was used for both the calibration and validation. Here also, baisns with $\alpha < 1.5$ were also considered.

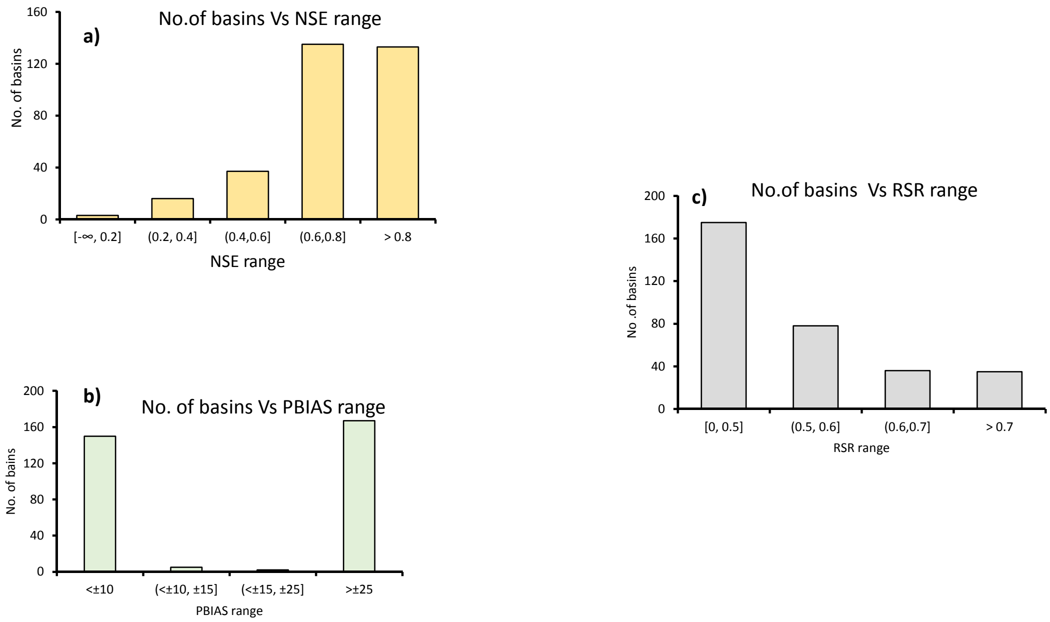

Figure 5.17: Histograms of no.of basins and ranges of model evaluation stastistics interms of a) NSE, b) PBIAS, c) RSR. The above values are corresponds to predicted recession flows with using initial discharge and observed recession flows during second half of data with calibrated k values from first half of the data. Here, baisns with $\alpha < 1.5$ were also considered.

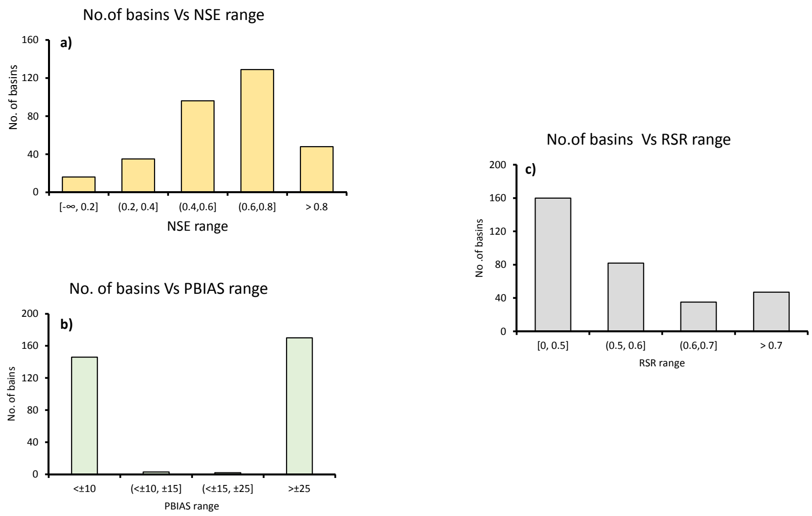

Figure 5.18: Histograms of no.of basins and ranges of model evaluation stastistics interms of a) NSE, b) PBIAS, c) RSR. The above values are corresponds to predicted recession flows with using initial discharge and observed recession flows during first half of data with calibrated k values from the same data. Here, baisns with $\alpha < 1.5$ were also considered.

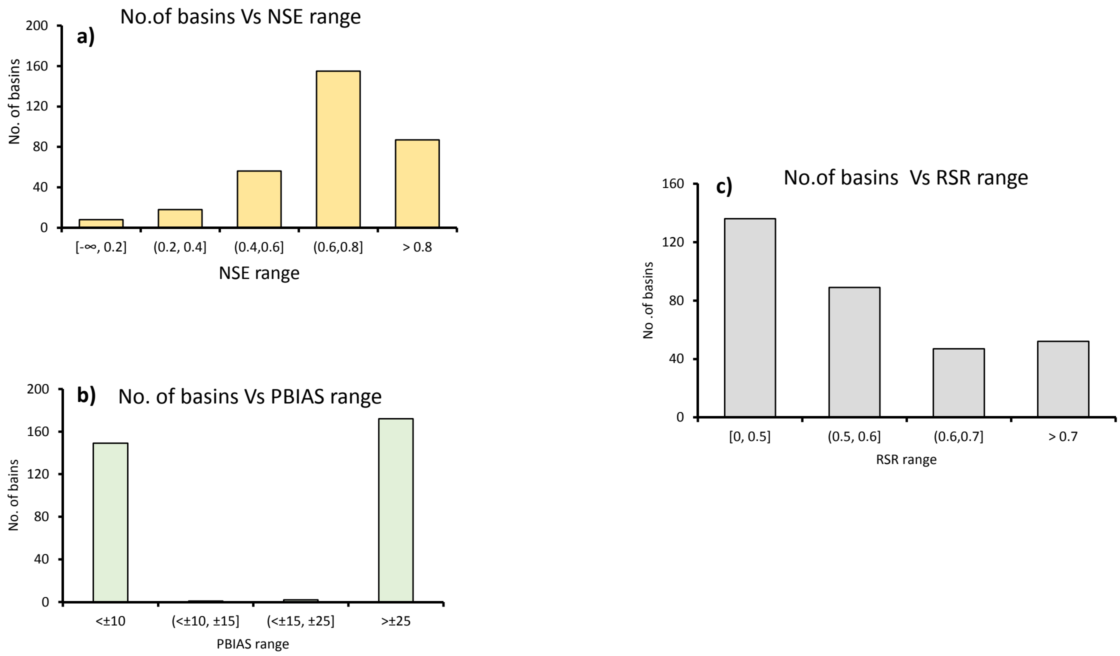

Figure 5.19: Histograms of no.of basins and ranges of model evaluation stastistics interms of a) NSE, b) PBIAS, c) RSR. The above values are corresponds to dry weather flow prediction with using the initial discharge by using whole data i.e. total data was used for both the calibration and validation. Here also, baisns with $\alpha < 1.5$ were also considered.

5.9 Interpretation of relative gravity results

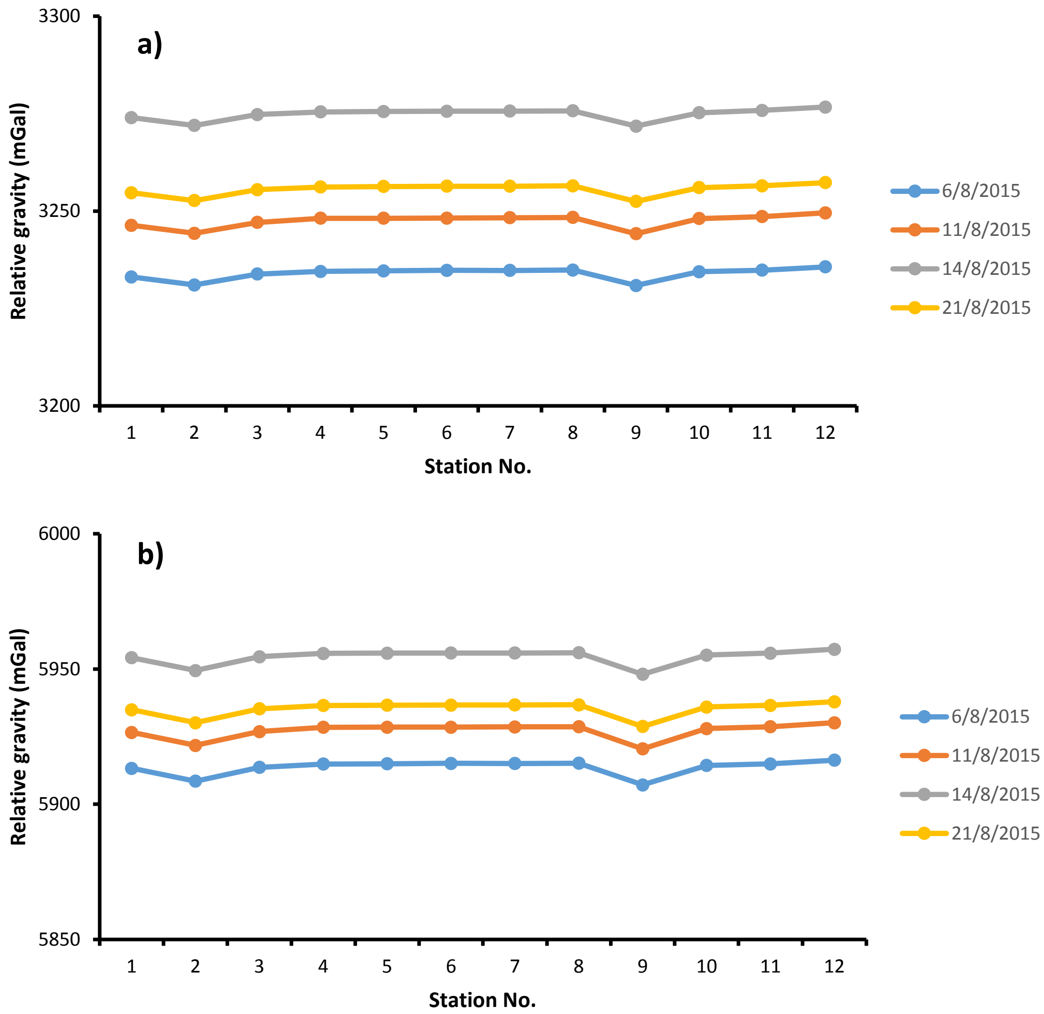

Figure 5.20: Spatial as well as temporal variation of gravity residual (see legend) is represented in (a). (b) represents the same spatial variation after applying the corrections for lattitude and elevation.

5.9.2 Nature of gravity corrections in this study

As all our gravity observing stations are above MSL, so due to the excess mass the observed gravity value will be more than actual gravity. So elevation correction will be negative in nature. Similarly correction for latitude will be positive this is because all of observations are moving towards the equator.

5.9.3 Temporal variation of raw and corrected gravity

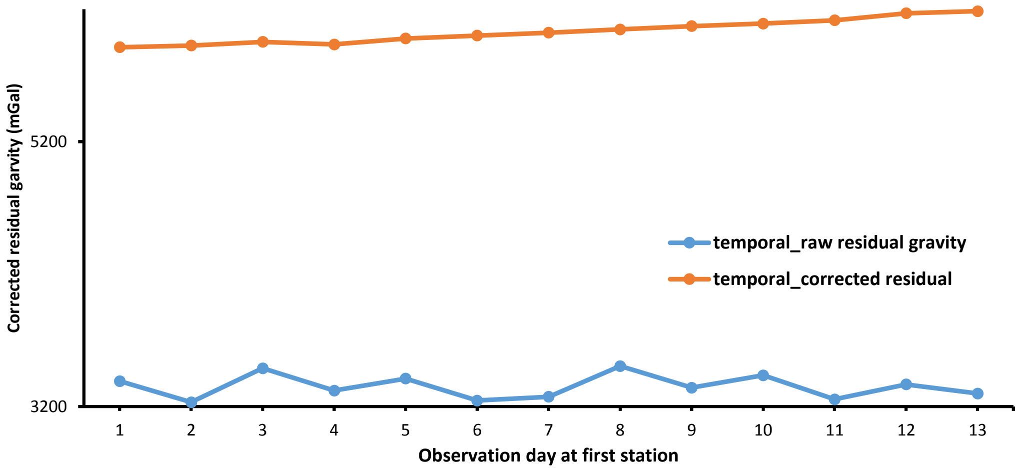

Figure 5.21: Temporal variation of raw residual and corrected gravity values at first observing station

5.9.4 Major factors in causing the variability of residual gravity

The study was intended to investigate the whether the variability of gravity can be used as tool or not in hydrological modelling. For investigating this the gravity values were observed at 12 stations during a period of 3 months (from 6/8/2015 to 14/11/2015) using Scientrix - CG5 gravimeter (relative gravimeter).

From the gravity corrections (see table 4.5), it is clear that the gravity observing stations were highly sensitive to latitude correction rather than the elevation correction. At some observing stations the sum of both the corrections is almost equal to the raw residual gravity. After applying the corrections due to latitude (additive), elevation (subtractive) there is a considerable hike from the raw gravity residual to the corrected gravity residual at each station.

The gravity values were observed on some rainy days except on $21-08-2015$ (see figure 7.2 in supplementary material) shows an increase in corrected gravity residual values from the previous gravity values. Since variation of gravity values were observed mainly on the rainy days so change of moisture (surface or subsurface) at the station is expected to effect the gravity values. Even though the mentioned gravity values at each and every station were not subjected to Bouger mass correction, (for the presence of mass between MSL and station) the trend in variation is not going to affect much due to constant correction of Bouger mass.

By observing the variation of gravity values from the previous observation, it is clear that the variation was high on $19-10-2015$ (with an average magnitude of 53.35 $mGal$), $21-08-2015$ (with an average magnitude of 44.69 $mGal$), $11-08-2015$ (with an average magnitude of 27.41 $mGal$). The same kind of pattern was observed on the remaining days except on $21-08-2015$. So the due to it's considerable affect, variation of moisture is emerges as a strongest factor in causing the variability of gravity values at micro scale. But variation of moisture can be on surface or subsurface. So at micro scale also it is inferred that the gravity values can be correlated with the variation of moisture and may be used to predict the fluctuations in the storage.

Chapter 6

Conclusions

6.1 Summary of Work

It is becoming more and more important to analyze and model dry weather flows in rivers due to Increase in demand of freshwater owing to population increase and lifestyle changes, particularly in developing countries like India. One of the challenges in this regard is quantification basin storage, which produces river flows in the absence of precipitation. In fact, none of the existing technologies can measure absolute storage in a basin. This has led scientists to explore alternative approaches for storage quantification like relating gravity field variation with basin storage. Particularly, GRACE (Gravity Recovery and Climate Experiment) satellite mission launched in 2002 gives storage anomalies (differences from the mean value), although at a coarse resolution (250 km spatial resolution and 30 days temporal resolution). To analyze the storage characteristics at micro level, variation of gravity fields can be measured by absolute gravity meters. However, the absolute gravity meters are expensive and are tedious for handling. So without much compromise in accuracy, relative gravity meters can be used for field measurements. Relative gravity meters give the difference in the gravity values at a reference point and a targeted location. The relative gravimeters are portable and can be used in remote areas. In our study, SCIENTRIX CG-5 (relative gravity meter) was used. Weekly gravity readings of 3 months (July-October) at 12 locations along a roughly straight path were taken near IIT Hyderabad (ODF campus).

Another way of storage characterization is to analyze dry weather flows or recession flows. A challenge in regard to recession flow analysis is identification of a reference time (it is not possible to say when recession flow begins). However, this problem can be overcome by adapting the method proposed by Brutsaert and Nieber (1977), which suggests to express time rate of change in discharge ($\frac{dQ}{dt}$) as a function of discharge (Q) itself: $-\frac{dQ}{dt} = kQ^{\alpha}$, k and α are constants, which can be estimated by means of least square linear regression. In the original Brutsaert and Nieber analysis it was assumed that k and α are constants for a basin. However, recently [8] found that while α remains fairly constant, k significantly varies across recession events. The eventual variation of k implies nothing but a dynamic relationship between storage and discharge of a basin. In fact k is a function of initial basin storage or storage in the basin during the beginning of the recession event. Since it takes significantly long time for a basin to drain its stored water, we can also expect k to be influenced by past storage. Considering past average discharge as a proxy for past storage state of a basin, recent studies have found out a power law relationship of the form: $k = k^{'} {Q_N}^{-\lambda}$ is past N days average streamflow and λ is the power law exponent. This strength is measured in terms of coefficient of determination. It was observed that the strength of $k - Q_N$ relationship decreases with N, which signifies that the role of antecedent storage has influence on streamflow for a limited time period. However, some basins show a peculiar trend of increase of $k - Q_N$ relationship strength with N. The main objective of our study was therefore to understand how $k - Q_N$ relationship emerges and find out an optimal way to predict k solely from Q_N. For analysis we considered the following values of N (in days): 6, 20, 45, 80, and 105. Whenever we found Q_N decreasing with N we considered the average of all the Q_N values. For example if it is found that $Q_6 > Q_{20} > Q_{45}$, we consider the average value of Q_6, Q_{20} and Q_{45} for the power law regression analysis. The whole analysis was performed for 324 basins listed in USGS database. Our proposed method showed a considerable improvement in prediction of k. In particular, our method gave superior results in 70% of the cases.

We then used the predicted value of k to directly predict recession discharge by integrating the power law equation $-\frac{dQ}{dt} = kQ^{\alpha}$, which gives $Q_t = Q_0(1 + (\alpha - 1))ktQ_0^{1-\alpha})^{\frac{1}{-\alpha+1}}$. For a large time t this equation suggests that discharge is a function of k : $Q_t = (kt(\alpha - 1))^{\frac{1}{-\alpha+1}}$. We observed that this approach predicts recession discharge satisfactorily whenever the underlying assumption is satisfied. In conclusion, our proposed method opens a new avenue for prediction of river flows during dry weathers by just considering the past discharge.

To check the usage of employing gravity variability at a micro scale as a tool in hydrological modelling, spatial (at 12 stations) and temporal (3 months during the monsoon period) gravity values were observed by using Scientrix CG-5 relative gravimeter. From the interpretation of gravity results, spatial variability is observed to be less sensitive to variation in moisture content rather than the temporal variability. So the fluctuations of moisture content reflects in the gravity values corrected for other factors. Our study at micro scale reveals that gravity studies at micro scale also helpful in hydrological modelling.

6.2 Conclusions

This study investigated the effects antecedent streamflow on the recession behavior of the basin. During recession periods, streamflows are noticed to be decreased by power law, with the magnitude of index as proximate to two. It was also proved that recession modelling is highly sensitive to k. So to predict k a novel algorithm was introduced for selecting the past streamflow (with lower limit as 120 days as an obligatory) prior to each recession event. The relationship between k and past average streamflow was much improved when the increase in the average past streamflow was considered instead of selecting direct past average streamflow. It was observed that past streamflow can be served as a proxy in predicting the future recession flows. Streamflows during the dry weather period were predicted for 324 USGS basins with a better accuracy.

Most of the low flow prediction models suffers limitations in terms of low flow definition and their duration [19]. Our model can predict the dry weather flows for any future recession period provided the non involvement of major surface flow. However, our algorithm needs discharge data so it's application is limited to gauged basins and it can be extended for ungauged basins also by correlating recession parameter k values of gauged basin with climate parameters of similar ungauged basin like rainfall, ET for the prediction of dry weather flows. Generally for streamflow prediction of ungauged basins regionalization techniques can be employed which deals with model uncertainty, uncertainty in optimizing the model parameter set, uncertainty in the selection of catchment attributes [20], whereas our algorithm can overcome most of these limitations, as our method requires only k values during dry weather period. For gauged basins, efforts were also made to identify the dominant catchment characteristics that affects the prediction of dry weather flows. So our future study will be on optimizing the relationship of gauged basin's model evaluation parameters and similar ungauged basin's catchment characteristics.

We found out that the investigation of recession parameter k with separated antecedent streamflow that contributes to storage during that recession period plays a crucial role in the better prediction of k, as a consequence the proposed algorithm can be used as a surrogate for recession flows prediction of river basins that are less or not influenced by human abstractions.

From the variation of gravity results during the 3 months of period, it was concluded that the variation of moisture is the strongest factor in causing the gravity variability. So our future work will be on distinguishing the effect of surface as well as subsurface moisture on the variation of gravity values at micro scale.

6.3 Limitations of work

1. Since our algorithm requires discharge data, our algorithm cannot be applicable to ungauged basins

2. As Storage-Discharge relationship doesn't holds good for the basins with $\alpha < 1.5$ hence our approach is not expected to give good results for such basins.

3. For the prediction of dry weather flows, 120 days past stream flow data is an obligatory.

4. Relative gravity should have corrected for Bouger mass correction

Chapter 7

Supplementary Material and M-code

7.1 Supplementary Material

Supplementary Material 1: Daily streamflow data of 324 USGS basins was used. Column 1 gives basin's ID. Column 2 to 6 indicates R^2 values between k and past discharge. Column 7 indicates optimized R^2 between k and combination of past discharges as per proposed algorithm. Columns from 8 to 11 indicates α, constants of k and Q_{avg} relation, no. of recession events of the basin (all were corresponding to first half of the available data). Columns 12 to 23, 25 to 26 shows various model evaluation parameters like NSE, Pbias and RSR for various prediction cases whose notations are given below. Column 23 gives slope value of origin passing linear regression analysis of modelled and observed values during the first half of available period.

a = Calibration using first half of data, prediction without using initial discharge; b = Validation using first half of data; all model efficiency parameters are inclusive of bias error
c = Validation using first half of data, all model efficiency parameters are exclusive of bias error; d = Calibration using first half of data, prediction with using initial discharge
e = Calibration using total data, prediction without using initial discharge; f = Validation using first total data; all model efficiency parameters are inclusive of bias error
g = Validation using first total data; all model efficiency parameters are exclusive of bias error; h = Calibration using total data, prediction with using initial discharge
I = Validation using second half data; all model efficiency parameters are inclusive of bias error; j = Validation using second half data; all model efficiency parameters are exclusive of bias error

BASIN ID	R^2_6	R^2_{20}	R^2_{45}	R^2_{80}	R^2_{120}	R^2_{avg}	α	λ	k'	No. of recs. events	NSE^a_b	NSE^a_c	NSE^d_b	NSE^d_c	NSE^e_f	NSE^e_g	NSE^h_f	NSE^h_g	NSE^a_i	NSE^a_j	NSE^d_i	NSE^d_j	Slope (s_m)	$Pbias^a_j$	RSR^a_j
14400000	0.74	0.81	0.81	0.66	0.43	0.8	2.16	0.66	3.30E-08	275	0.47	0.66	0.74	0.82	0.5	0.67	0.75	0.84	0.54	0.68	0.76	0.85	0.73	-2.82	0.56
14377100	0.8	0.81	0.71	0.51	0.29	0.84	2.3	0.9	7.17E-08	275	0.45	0.65	0.68	0.75	0.47	0.67	0.7	0.78	0.33	0.71	0.77	0.83	0.74	0.29	0.54
14325000	0.71	0.79	0.82	0.73	0.51	0.79	1.99	0.57	1.08E-07	425	0.12	0.65	0.66	0.75	0.22	0.68	0.7	0.79	0.17	0.7	0.76	0.85	0.64	0.29	0.54
14318000	0.75	0.81	0.81	0.71	0.52	0.82	2.09	0.72	1.61E-07	296	0.21	0.61	0.68	0.77	0.3	0.65	0.7	0.78	0.03	0.73	0.81	0.87	0.66	2.31	0.52
14308500	0.75	0.78	0.72	0.52	0.35	0.81	1.83	0.67	8.41E-07	252	-1.5	0.55	0.68	0.75	-2.72	0.33	0.66	0.72	-4.05	0.06	0.6	0.67	0.45	40.29	0.97
14308000	0.79	0.84	0.8	0.66	0.43	0.86	2.34	0.96	1.00E-07	417	0.51	0.63	0.62	0.7	0.54	0.68	0.67	0.74	0.55	0.74	0.76	0.82	0.77	0.84	0.51
14307620	0.85	0.89	0.89	0.73	0.46	0.91	2.42	1.03	5.60E-08	312	0.63	0.76	0.76	0.82	0.63	0.77	0.77	0.83	0.47	0.78	0.82	0.85	0.78	3.2	0.47
14306500	0.85	0.89	0.88	0.74	0.49	0.9	2.44	1.01	5.08E-08	495	0.53	0.7	0.76	0.81	0.58	0.71	0.75	0.81	0.62	0.73	0.75	0.82	0.76	-0.18	0.52
14305500	0.68	0.74	0.74	0.65	0.44	0.73	2.06	0.54	3.14E-08	425	0	0.67	0.81	0.88	0.42	0.69	0.76	0.84	0.09	0.67	0.79	0.87	0.64	-3.07	0.57
14301000	0.82	0.87	0.86	0.72	0.48	0.86	2	0.68	9.65E-08	517	-0.19	0.75	0.86	0.9	0.09	0.72	0.84	0.89	-0.04	0.7	0.83	0.89	0.57	1.22	0.55
14187000	0.75	0.77	0.73	0.6	0.38	0.81	2.19	0.8	1.80E-07	247	0.2	0.65	0.76	0.83	0.31	0.64	0.73	0.8	0	0.64	0.76	0.81	0.69	2.38	0.6
14185900	0.72	0.78	0.78	0.64	0.44	0.79	2.32	0.78	6.02E-08	253	0.62	0.72	0.68	0.8	0.61	0.7	0.68	0.79	0.64	0.69	0.66	0.77	0.81	-1.96	0.56
14185000	0.79	0.79	0.75	0.6	0.35	0.83	2.42	0.95	6.14E-08	440	0.56	0.7	0.71	0.78	0.57	0.72	0.74	0.81	0.59	0.74	0.76	0.83	0.79	-0.99	0.51
14166500	0.78	0.84	0.82	0.65	0.39	0.85	2.47	1.16	1.86E-07	349	0.31	0.65	0.76	0.81	0.2	0.65	0.75	0.79	0.35	0.65	0.72	0.77	0.72	5.75	0.59
14161500	0.64	0.66	0.6	0.54	0.4	0.71	2.27	0.8	1.17E-07	203	0.06	0.58	0.7	0.78	0	0.59	0.74	0.82	-0.09	0.59	0.76	0.82	0.69	2.91	0.64
14158790	0.57	0.58	0.51	0.42	0.26	0.63	1.92	0.56	2.60E-07	249	-1.98	0.57	0.84	0.9	-0.89	0.57	0.82	0.88	-1.92	0.54	0.83	0.88	0.49	4.39	0.68
14034470	0.65	0.59	0.36	0.15	0.05	0.66	1.44	0.53	1.39E-06	85	-3871.81	0.11	0.95	0.95	-10306.44	0.25	0.95	0.95	-2225.02	0.48	0.94	0.95	0.02	32.43	0.72
14020300	0.57	0.49	0.29	0.12	0.05	0.56	1.84	0.54	2.06E-07	147	-3.64	0.53	0.87	0.91	-1.62	0.57	0.81	0.87	-4.03	0.59	0.81	0.85	0.39	6.6	0.64
14013000	0.4	0.48	0.49	0.45	0.41	0.52	2.68	1.01	3.87E-08	172	0.2	0.52	0.76	0.83	0.21	0.51	0.65	0.74	0.21	0.51	0.61	0.68	0.79	0.49	0.7
13313000	0.8	0.69	0.42	0.1	0	0.72	2.4	0.83	2.81E-08	201	0.52	0.7	0.84	0.89	0.62	0.7	0.82	0.87	0.55	0.67	0.82	0.89	0.76	-11	0.57
13308500	0.85	0.69	0.35	0.05	0	0.72	2.76	1.08	1.23E-08	88	0.34	0.68	0.87	0.9	0.35	0.71	0.88	0.91	0.52	0.73	0.87	0.9	0.73	-7.19	0.52
13288200	0.76	0.65	0.45	0.21	0.1	0.7	2.69	1.12	2.65E-08	160	0.32	0.68	0.87	0.9	0.34	0.66	0.87	0.9	0.4	0.64	0.85	0.9	0.71	-4.99	0.6
13200500	0.72	0.74	0.56	0.32	0.27	0.74	1.46	0.38	8.18E-07	30	-1638.53	0.53	0.96	0.97	-387.81	0.3	0.92	0.94	-717.14	0.13	0.93	0.97	0.03	38.77	0.93
13196500	0.77	0.61	0.36	0.3	0.31	0.61	1.83	0.5	4.23E-07	16	-52.77	0.12	0.93	0.96	-985	0.28	0.97	0.98	-27.24	0.62	0.97	0.97	0.22	5.82	0.61
13077700	0.17	0.03	0.03	0.09	0.11	0.05	1.16	-0.1	4.04E-07	36	-2.80E+16	-1.78	0.97	0.98	-7.90E+13	-0.45	0.95	0.96	-6.48E+15	-0.4	0.95	0.95	0	80.38	1.19
12414500	0.84	0.82	0.7	0.46	0.23	0.85	2.67	1.23	2.57E-08	345	0.58	0.77	0.87	0.91	0.63	0.75	0.84	0.87	0.64	0.74	0.82	0.87	0.76	-4.43	0.51
12037400	0.65	0.67	0.63	0.52	0.34	0.7	2.27	0.98	1.64E-07	352	-0.12	0.58	0.77	0.81	0.22	0.61	0.75	0.8	0.08	0.57	0.75	0.81	0.62	7.84	0.66
12025700	0.63	0.75	0.76	0.63	0.4	0.74	2.44	0.79	4.37E-08	228	0.46	0.61	0.68	0.77	0.46	0.61	0.65	0.75	0.56	0.61	0.61	0.74	0.81	-1.04	0.63
12020000	0.74	0.81	0.82	0.69	0.45	0.82	2.18	0.72	8.38E-08	424	0.37	0.63	0.73	0.82	0.33	0.61	0.62	0.7	0.36	0.6	0.54	0.62	0.73	2.53	0.63
12013500	0.81	0.84	0.79	0.6	0.36	0.84	2.25	0.86	1.15E-07	334	0.39	0.69	0.8	0.86	0.12	0.65	0.81	0.87	0.37	0.63	0.76	0.84	0.72	4.09	0.61
12010000	0.63	0.7	0.69	0.57	0.37	0.69	2.05	0.48	4.76E-08	388	-0.44	0.59	0.8	0.89	0.09	0.63	0.78	0.87	-0.05	0.64	0.8	0.89	0.62	0.01	0.6
11532500	0.79	0.83	0.84	0.75	0.54	0.85	2.59	0.89	4.78E-09	504	0.72	0.75	0.56	0.66	0.72	0.75	0.6	0.7	0.71	0.75	0.68	0.77	0.88	-6.03	0.5
11521500	0.8	0.85	0.8	0.64	0.41	0.87	2.8	1.33	5.15E-08	287	0.53	0.67	0.48	0.52	0.66	0.73	0.56	0.61	0.66	0.8	0.77	0.81	0.78	-4.26	0.45
11516900	0.75	0.8	0.72	0.63	0.6	0.83	1.96	1.15	1.58E-06	31	-10.43	0.38	0.83	0.87	-6.26	0.41	0.83	0.87	-12.78	0.29	0.85	0.89	0.29	20.58	0.84
11489500	0.61	0.55	0.36	0.29	0.38	0.58	2.1	0.92	3.06E-07	48	-7.75	0.35	0.79	0.83	-2.04	0.36	0.73	0.79	-10.59	0.23	0.83	0.84	0.38	13.99	0.88
11482500	0.84	0.87	0.88	0.75	0.54	0.88	2.25	0.96	1.66E-07	119	0.04	0.4	0.78	0.85	-0.52	0.31	0.68	0.75	0.35	0.64	0.67	0.72	0.65	2.9	0.6
11481500	0.7	0.74	0.77	0.62	0.41	0.77	2.13	0.84	2.30E-07	143	-1.14	0.61	0.8	0.81	-0.14	0.7	0.82	0.84	-0.39	0.8	0.91	0.92	0.51	2.83	0.44
11481200	0.66	0.75	0.79	0.72	0.58	0.75	2.13	0.69	2.13E-07	253	0.41	0.59	0.65	0.77	0.49	0.6	0.65	0.77	0.44	0.62	0.72	0.82	0.76	0.89	0.62

11480390	0.72	0.75	0.71	0.53	0.26	0.77	1.7	0.61	9.59E-07	164	-6.14	0.62	0.84	0.87	-20.79	0.49	0.87	0.88	-5.66	0.39	0.88	0.92	0.29	35.17	0.78
11478500	0.75	0.83	0.85	0.72	0.51	0.82	1.94	0.59	1.53E-07	340	-0.35	0.63	0.72	0.79	0.02	0.69	0.74	0.81	0.08	0.76	0.8	0.87	0.54	-0.38	0.49
11477000	0.8	0.85	0.83	0.68	0.44	0.87	1.95	0.67	1.13E-07	459	-0.09	0.67	0.74	0.81	0.29	0.65	0.7	0.78	-0.14	0.63	0.75	0.8	0.56	6.3	0.61
11476600	0.66	0.74	0.76	0.68	0.55	0.74	1.71	0.48	3.99E-07	224	-6.16	0.55	0.86	0.89	-3.92	0.58	0.85	0.88	-6.24	0.61	0.88	0.91	0.31	13.02	0.62
11476500	0.68	0.76	0.81	0.73	0.53	0.76	1.98	0.56	6.03E-08	383	0.11	0.5	0.57	0.69	0.37	0.6	0.61	0.72	0.4	0.71	0.74	0.85	0.63	-4.75	0.54
11475800	0.8	0.86	0.87	0.74	0.53	0.86	2.23	0.83	9.76E-08	254	0.47	0.58	0.62	0.73	0.49	0.62	0.66	0.76	0.57	0.7	0.75	0.85	0.77	2.45	0.55
11475560	0.45	0.64	0.76	0.74	0.63	0.58	1.71	0.41	4.10E-07	179	-10.09	0.49	0.88	0.9	-5.14	0.61	0.87	0.9	-11.21	0.69	0.89	0.9	0.28	7.45	0.55
11475500	0.62	0.72	0.76	0.69	0.57	0.7	1.84	0.49	2.45E-07	97	-0.76	0.61	0.76	0.84	-0.6	0.43	0.6	0.71	-0.67	0.31	0.52	0.69	0.53	12.83	0.83
11475000	0.83	0.85	0.82	0.66	0.44	0.87	1.93	0.71	2.25E-07	329	-0.11	0.4	0.52	0.6	0.11	0.51	0.58	0.66	0.12	0.71	0.77	0.85	0.53	2.23	0.54
11474500	0.77	0.84	0.86	0.74	0.52	0.84	1.77	0.54	4.13E-07	218	-0.57	0.44	0.54	0.67	-0.61	0.48	0.56	0.66	-1.24	0.79	0.9	0.94	0.47	12.42	0.46
11472900	0.75	0.79	0.74	0.6	0.39	0.81	1.99	0.78	3.78E-07	148	-0.58	0.35	0.47	0.53	-0.52	0.41	0.51	0.56	-0.6	0.75	0.78	0.82	0.47	5.59	0.5
11469000	0.63	0.71	0.77	0.73	0.61	0.7	1.88	0.48	8.50E-08	132	-0.51	0.61	0.76	0.83	0.31	0.64	0.73	0.81	-0.39	0.64	0.81	0.88	0.54	2.88	0.6
11468500	0.63	0.76	0.85	0.81	0.68	0.74	1.94	0.62	2.63E-07	279	-0.44	0.47	0.68	0.75	-0.08	0.58	0.72	0.8	-0.06	0.71	0.78	0.85	0.54	2.02	0.54
11468000	0.63	0.75	0.82	0.74	0.6	0.74	1.91	0.54	1.57E-07	278	0.04	0.57	0.66	0.76	0	0.6	0.68	0.77	0.14	0.67	0.71	0.82	0.61	0.94	0.57
11467600	0.51	0.67	0.78	0.78	0.67	0.67	2.05	0.56	8.56E-08	89	-0.02	0.64	0.63	0.73	0.36	0.57	0.57	0.7	0.11	0.55	0.66	0.78	0.63	3.12	0.67
11463170	0.14	0.22	0.3	0.4	0.42	0.19	1.57	0.15	4.64E-07	69	-2.03	0.46	0.69	0.89	0.16	0.57	0.64	0.85	-4.08	0.45	0.78	0.91	0.4	-4.56	0.74
11451100	0.82	0.84	0.77	0.57	0.33	0.86	1.92	0.86	9.89E-07	168	-2.08	0.52	0.8	0.84	-2.08	0.63	0.81	0.82	-3.98	0.73	0.85	0.85	0.39	21.18	0.52
11451000	0.06	0.05	0.02	0.01	0	0.05	0.92	0.11	1.74E-06	108	-0.57	-0.56	0.86	0.86	-0.49	-0.49	0.88	0.88	-0.45	-0.5	0.9	0.9	2.62E+13	100	1.2
11449500	0.68	0.76	0.82	0.75	0.59	0.78	2.24	0.81	2.39E-07	229	0.24	0.63	0.59	0.67	0.34	0.66	0.65	0.72	0.52	0.69	0.68	0.77	0.7	4.24	0.56
11374000	0.62	0.66	0.62	0.54	0.38	0.71	2.65	1.16	6.20E-08	281	0.46	0.66	0.61	0.65	0.59	0.71	0.62	0.67	0.54	0.76	0.69	0.72	0.76	3.21	0.49
11200800	0.83	0.83	0.77	0.63	0.48	0.88	2.66	1.74	8.41E-07	105	-0.22	0.71	0.9	0.91	-0.3	0.74	0.85	0.86	-0.4	0.76	0.79	0.79	0.57	13.34	0.49
11182500	0.72	0.78	0.73	0.57	0.37	0.79	2.4	1.15	9.63E-07	89	0.35	0.46	0.49	0.56	0.37	0.57	0.51	0.58	0.61	0.74	0.49	0.56	0.77	4.26	0.51
11180960	0.79	0.76	0.73	0.51	0.37	0.83	2.07	0.77	1.03E-06	44	-0.02	0.39	0.34	0.5	0.42	0.65	0.39	0.48	0.41	0.87	0.77	0.82	0.65	0.6	0.36
11176400	0.77	0.79	0.7	0.47	0.24	0.81	1.83	0.75	1.40E-06	148	-4.96	0.1	0.61	0.61	-2.19	0.02	0.57	0.61	-2.19	0.27	0.47	0.52	0.25	39.16	0.85
11173200	0.76	0.85	0.88	0.76	0.51	0.84	1.98	0.63	4.08E-07	89	0.15	0.66	0.66	0.78	0.42	0.66	0.63	0.75	0.47	0.67	0.64	0.76	0.61	-0.4	0.57
11169500	0.39	0.46	0.51	0.39	0.36	0.49	1.66	0.51	1.08E-06	141	-2.96	0.52	0.7	0.8	-1.55	0.51	0.7	0.82	-7.22	0.52	0.8	0.86	0.38	12.48	0.69
11160000	0.67	0.77	0.8	0.76	0.67	0.78	2.3	0.94	3.60E-07	168	0.52	0.66	0.45	0.5	0.64	0.67	0.46	0.54	0.65	0.7	0.48	0.59	0.78	-0.26	0.54
11141280	0.59	0.69	0.76	0.73	0.66	0.72	2.5	1.05	3.26E-07	65	0.61	0.63	0.59	0.71	0.67	0.68	0.69	0.79	0.69	0.7	0.68	0.86	0.89	-7.7	0.54
11138500	0.64	0.72	0.75	0.66	0.51	0.73	1.76	0.64	5.91E-07	113	-1.29	0.54	0.75	0.91	-0.55	0.57	0.73	0.84	-3.45	0.55	0.87	0.91	0.39	17.08	0.67
11137900	0.62	0.66	0.61	0.49	0.41	0.66	1.59	0.46	8.92E-07	84	-16.46	0.65	0.83	0.85	-22.42	0.62	0.82	0.82	-74.5	0.55	0.68	0.69	0.19	29.27	0.67
11124500	0.64	0.69	0.67	0.54	0.38	0.72	1.83	0.79	1.11E-06	123	-8.77	-0.07	0.59	0.72	-12.51	-0.33	0.29	0.37	-0.89	0.45	0.78	0.87	0.14	33.67	0.74
11120500	0.45	0.54	0.63	0.65	0.61	0.53	1.7	0.41	1.97E-06	54	-0.91	0.39	0.46	0.68	0.18	0.31	0.22	0.58	0.27	0.46	0.33	0.76	0.51	-73.3	0.73
11113500	0.71	0.81	0.84	0.79	0.75	0.78	2.14	0.81	2.75E-07	113	-0.16	0.12	0.53	0.72	-0.23	0.16	0.53	0.73	0.39	0.43	0.34	0.51	0.61	6.44	0.76
11113000	0.61	0.6	0.55	0.42	0.3	0.63	1.95	0.81	5.96E-07	223	-4.08	-0.25	0.34	0.37	-1.72	-0.2	0.25	0.41	0.13	0.58	0.49	0.64	0.14	9.79	0.65
11111500	0.74	0.72	0.76	0.7	0.58	0.81	2.1	0.87	4.93E-07	87	0.2	0.51	0.29	0.38	-0.26	0.38	0.39	0.51	0.17	0.36	0.35	0.49	0.66	19.18	0.8
11109600	0.76	0.77	0.72	0.56	0.38	0.8	2.11	1.12	8.62E-07	104	-1.54	0.3	0.71	0.73	-5.32	0.09	0.61	0.61	-2.98	0.23	0.57	0.62	0.37	30.85	0.88
11098000	0.66	0.7	0.68	0.63	0.51	0.72	1.91	0.7	6.16E-07	154	-0.14	0.51	0.61	0.79	0.44	0.55	0.44	0.59	0.23	0.55	0.53	0.7	0.55	5.56	0.67
11063680	0.4	0.45	0.45	0.36	0.32	0.48	1.24	0.28	1.63E-06	62	-29166879	-0.14	0.34	0.58	-21.3	-0.22	0.29	0.29	-8089311	-0.1	0.9	0.9	0	69.41	1.03
11058500	0.62	0.65	0.69	0.63	0.52	0.71	2.39	1.07	4.99E-07	105	0.5	0.54	0.39	0.52	0.46	0.52	0.38	0.48	0.48	0.52	0.37	0.48	0.85	4.38	0.7
11055800	0.42	0.39	0.33	0.26	0.2	0.43	1.55	0.41	1.10E-06	146	-13.1	-0.32	0.53	0.68	-1.02	-0.22	0.09	0.17	-3.28	0.32	0.6	0.85	0.12	19.51	0.82
11055500	0.27	0.26	0.24	0.18	0.14	0.28	1.54	0.32	1.18E-06	108	-4.17	0.17	0.68	0.9	-1.79	-0.21	0.39	0.59	-0.9	0.45	0.69	0.92	0.28	8.09	0.74
11046300	0.52	0.44	0.36	0.25	0.21	0.48	2	0.54	5.23E-07	34	0.66	0.74	0.23	0.34	0.58	0.81	0.76	0.8	0.49	0.7	0.51	0.89	1.35	-26.3	0.54
11046100	0.73	0.89	0.9	0.8	0.69	0.84	1.19	0.3	2.87E-06	10	-2.57E+09	0.45	0.7	0.79	-1.97	0.71	0.79	0.94	-1.93E+09	0.27	0.85	0.86	0	65.5	0.86
11027000	0.65	0.74	0.75	0.65	0.59	0.74	2.16	0.88	1.57E-06	82	0.6	0.64	0.4	0.7	0.58	0.65	0.42	0.69	0.74	0.74	0.57	0.75	0.81	-1.49	0.51
11015000	0.55	0.71	0.63	0.57	0.37	0.7	1.32	0.49	2.37E-06	31	-501960.2	-0.03	0.64	0.8	-23.09	0.17	0.81	0.81	-522214.6	-0.1	0.73	0.75	0	86.52	1.06
11014000	0.08	0.1	0.07	0.05	0.04	0.08	1.36	0.14	1.77E-06	70	-54.48	0.06	0.58	0.79	-1.11	-0.14	0.08	0.2	-8.68	0.27	0.5	0.82	0.08	10.99	0.86
09484000	0.31	0.27	0.28	0.27	0.24	0.35	1.41	0.27	1.60E-06	277	-58.43	-0.16	0.58	0.73	-213.21	-0.11	0.58	0.74	-19.78	0.16	0.72	0.87	0.05	31.31	0.91
09268900	0.22	0.12	0.02	0.06	0.22	0.12	1.05	-0.1	3.73E-07	29	-1.41E+71	-2.33	0.95	0.95	-9407.75	0.03	0.97	0.97	-1.71E+74	-1	0.96	0.96	0	99.96	1.42
09268500	0.24	0.25	0.06	0	0.01	0.19	1.33	0.19	4.60E-07	32	-1036331	-0.28	0.97	0.97	-7923.93	0.22	0.98	0.98	-1083126	0.03	0.98	0.99	0	37.25	0.99
09245000	0.78	0.75	0.56	0.14	0.01	0.78	1.31	0.44	2.02E-06	83	-782784.2	0.08	0.96	0.97	-15697.06	0.35	0.95	0.96	-1216466	0.32	0.96	0.96	0	58.63	0.82
09060500	0.83	0.76	0.42	0.08	0.01	0.8	2.34	1.42	2.47E-06	25	0.62	0.69	0.8	0.89	-1.48	0.37	0.71	0.8	-0.2	0.1	0.39	0.45	0.83	17.42	0.95
09058800	0.15	0.09	0.01	0.01	0.03	0.1	1.21	0.1	7.79E-07	40	-2.22E+10	-0.49	0.92	0.96	-1749128	-0.12	0.93	0.97	-1.63E+10	-0.3	0.94	0.98	0	63.28	1.14
09058700	0.12	0.07	0.02	0	0	0.1	0.99	0.08	1.21E-06	38	-1.05	-1.05	0.89	0.9	-5.43E+13	-0.35	0.93	0.93	-0.88	-0.9	0.92	0.93	6.80E+128	99.92	1.37
09058500	0.81	0.72	0.42	0.04	0.04	0.75	1.59	0.59	1.47E-06	65	-53.92	0.53	0.89	0.93	-2	0.69	0.89	0.94	-46.16	0.71	0.94	0.97	0.13	12.75	0.54
08477110	0.55	0.53	0.5	0.49	0.44	0.58	1.84	0.74	7.59E-07	64	-1.41	0.24	0.54	0.71	-6.96	0.26	0.66	0.77	-8.03	0.39	0.71	0.73	0.4	29.59	0.78

08431700	0.55	0.62	0.24	0.16	0.09	0.55	1.34	0.35	3.29E-06	18	-377.15	-0.42	0.52	0.9	-27167.79	-0.39	0.72	0.86	-53.86	-0.2	0.44	0.65	0.02	75.56	1.1
08382730	0	0	0.01	0	0.03	0	1.19	-0	3.04E-06	18	-781718.2	-0.05	0.67	0.76	-6433.36	-0.13	0.62	0.78	-970873.6	-0.3	0.66	0.8	0	46.69	1.12
08324000	0.8	0.76	0.54	0.3	0.19	0.78	1.92	0.92	1.30E-06	76	-2.89	0.69	0.9	0.92	-1.53	0.59	0.85	0.88	-1.4	0.54	0.81	0.87	0.38	8.98	0.68
08321500	0.76	0.69	0.4	0.24	0.13	0.76	2.32	1.18	6.47E-07	64	0.5	0.66	0.8	0.87	0.5	0.66	0.8	0.87	0.5	0.66	0.8	0.87	0.75	-5.19	0.59
08289000	0.25	0.2	0.07	0	0	0.23	1.21	0.18	1.40E-06	121	-6.89E+08	0.27	0.94	0.97	-18756.09	0.41	0.92	0.96	-7.12E+08	0.14	0.93	0.97	0	57.69	0.93
08275600	0.86	0.82	0.79	0.64	0.27	0.84	1.44	0.38	7.19E-07	18	-9046.84	0.14	0.97	0.98	-0.65	0.74	0.91	0.93	-3261.21	0.34	0.96	0.96	0.01	34	0.81
08263000	0.44	0.49	0.46	0.27	0.15	0.45	1.56	0.44	4.61E-07	17	-730.05	0.2	0.95	0.97	-1.38	0.62	0.89	0.94	-2109.03	-0.3	0.96	0.96	0.05	20.54	1.13
08240500	0.37	0.39	0.33	0.27	0.23	0.36	1.73	0.34	1.25E-07	37	-253.27	-0.1	0.94	0.95	-3.29E+37	-2.48	0.93	0.93	-236.23	-0	0.95	0.97	0.11	15.97	1.02
08236000	0.78	0.74	0.59	0.28	0.05	0.78	2.01	0.92	6.22E-07	60	-4.61	0.83	0.95	0.96	-2.92	0.76	0.93	0.96	-4.69	0.72	0.94	0.95	0.37	3.05	0.53
08227500	0.7	0.63	0.42	0.17	0.07	0.65	1.72	0.6	6.24E-07	58	-28.56	0.6	0.94	0.96	-41.65	0.57	0.94	0.96	-55.21	0.59	0.96	0.97	0.19	9.4	0.64
08201500	0.67	0.66	0.63	0.58	0.57	0.69	2.06	0.87	3.55E-07	116	-3.41	0.3	0.66	0.7	-8.24	0.2	0.7	0.72	-1.53	0.26	0.64	0.7	0.36	30.77	0.86
08200000	0.67	0.66	0.61	0.62	0.62	0.7	2.07	0.92	3.42E-07	140	-3.1	0.16	0.82	0.87	-20.24	-0.51	0.31	0.34	-6.45	0.1	0.58	0.65	0.39	56.55	0.95
08198500	0.42	0.36	0.3	0.27	0.24	0.45	1.68	0.42	3.93E-07	125	-1.51	0.33	0.69	0.81	-4.82	0.24	0.72	0.79	-0.44	0.43	0.65	0.77	0.38	17.03	0.75
08198000	0.63	0.59	0.6	0.53	0.48	0.7	2.55	1.57	5.26E-07	107	-3.5	-0.62	0.19	0.26	-2.21	-0.42	0.24	0.28	-0.71	0.53	0.71	0.71	0.26	21.28	0.69
08196000	0.59	0.55	0.47	0.45	0.48	0.62	2.49	0.93	6.85E-08	158	0.15	0.31	0.39	0.48	-0.37	0.33	0.48	0.52	0.39	0.44	0.49	0.59	0.76	5.71	0.75
08195000	0.62	0.64	0.63	0.6	0.56	0.69	2.89	1.46	5.19E-08	117	-0.25	0.1	0.12	0.15	0.22	0.37	0.28	0.31	0.22	0.44	0.57	0.62	0.67	8.11	0.75
08190000	0.52	0.47	0.43	0.42	0.43	0.58	2.83	1.25	1.66E-08	217	-0.84	0.26	0.37	0.38	-0.34	0.21	0.28	0.29	0.23	0.31	0.27	0.33	0.58	5.67	0.83
08166000	0.47	0.58	0.64	0.65	0.62	0.62	2.71	1.36	2.61E-07	48	-1.93	-0.5	0.29	0.37	-0.21	-0.01	0.36	0.43	0.02	0.02	0.18	0.33	0.48	23.48	0.99
08165500	0.29	0.53	0.38	0.21	0.07	0.42	3.53	1.76	1.44E-08	13	0.02	0.09	0.59	0.72	0.01	0.04	0.6	0.77	-1.15	-1	0.12	0.3	0.91	11.97	1.42
08165300	0.17	0.19	0.32	0.37	0.37	0.27	3.19	0.75	1.62E-09	53	-0.38	-0.27	0.02	0.05	-0.43	-0.31	0.02	0.04	0.16	0.16	0.35	0.52	0.88	2.41	0.92
08164300	0.62	0.6	0.54	0.49	0.38	0.69	2.62	1.13	3.27E-07	226	-0.32	0.24	0.06	0.14	-1.05	0.07	0.04	0.07	-1.28	-0	0.01	0.02	0.61	43.5	1.01
08158810	0.34	0.34	0.29	0.22	0.22	0.38	1.4	0.27	7.21E-07	74	-6873.98	0.25	0.91	0.92	-1036.85	0.21	0.86	0.86	-3949.87	0.18	0.89	0.89	0.01	40.74	0.91
08158700	0.73	0.66	0.49	0.33	0.22	0.72	2.02	1.04	8.96E-07	111	-4.74	0.26	0.56	0.57	-4.9	0.35	0.67	0.68	-1.76	0.51	0.73	0.74	0.31	18.66	0.7
08153500	0.59	0.5	0.46	0.47	0.47	0.65	2.24	1.04	6.91E-07	333	-4.26	-0.29	0.15	0.22	-3.26	-0.3	0.14	0.19	0.17	0.33	0.3	0.46	0.19	26.34	0.82
08152000	0.45	0.4	0.2	0.13	0.11	0.49	1.74	0.57	1.22E-06	182	-0.67	0.09	0.36	0.51	-2.23	-0.04	0.4	0.57	-0.4	0.37	0.58	0.76	0.42	23.46	0.79
08150800	0.54	0.5	0.39	0.3	0.26	0.58	1.84	0.6	1.33E-06	173	-1.01	-0.11	0.23	0.37	-1.02	-0.04	0.36	0.49	0.48	0.49	0.4	0.65	0.33	16.64	0.72
08150700	0.48	0.48	0.43	0.44	0.44	0.58	3.79	1.9	3.74E-09	199	0	0.19	0.07	0.08	0.1	0.25	0.08	0.09	0.21	0.35	0.14	0.14	0.77	14.96	0.8
08150000	0.41	0.43	0.45	0.49	0.49	0.47	2.92	0.84	3.48E-09	165	0.06	0.17	0.04	0.09	-0.13	0.1	0.06	0.09	0.32	0.36	0.16	0.28	0.77	3.25	0.8
08066200	0.61	0.66	0.59	0.45	0.32	0.67	2.1	0.76	1.07E-06	273	-0.05	0.28	0.13	0.25	-0.25	0.19	0.15	0.27	-1.15	0.05	0.19	0.3	0.63	40.51	0.97
08066170	0.42	0.42	0.41	0.31	0.2	0.47	1.89	0.42	1.34E-06	255	0.29	0.3	0.15	0.36	0.1	0.1	0.03	0.09	0.03	0.03	0.02	0.06	0.94	24.58	0.99
08025500	0.71	0.75	0.66	0.51	0.34	0.75	2.29	0.86	4.07E-07	328	0.28	0.36	0.17	0.3	0.26	0.39	0.19	0.32	0.29	0.45	0.24	0.37	0.78	19.54	0.74
08023400	0.53	0.49	0.48	0.23	0.12	0.53	1.54	0.4	2.50E-06	41	-3.42	0.54	0.58	0.79	-1.28	0.54	0.32	0.55	-4.27	0.49	0.26	0.42	0.36	24.2	0.71
08023080	0.53	0.55	0.42	0.22	0.05	0.55	1.66	0.43	2.18E-06	146	-1.02	0.18	0.34	0.63	-0.98	0.06	0.28	0.61	-1.09	0.07	0.26	0.57	0.39	40.85	0.96
08013000	0.57	0.49	0.38	0.24	0.1	0.58	1.84	0.46	2.04E-07	376	0.43	0.43	0.45	0.75	0.39	0.4	0.41	0.7	0.37	0.39	0.38	0.68	0.99	-13.6	0.78
07362500	0.54	0.48	0.33	0.14	0.02	0.54	1.3	0.27	2.58E-06	327	-1477.92	0.12	0.67	0.77	-1445.74	0	0.61	0.74	-1011.92	0.07	0.67	0.85	0.02	55.72	0.96
07361500	0.58	0.52	0.38	0.2	0.05	0.6	1.58	0.42	9.86E-07	405	-10.46	0.32	0.65	0.74	-6.62	0.25	0.66	0.77	-9.24	0.23	0.74	0.84	0.24	34.79	0.88
07343000	0.3	0.33	0.23	0.16	0.08	0.33	1.58	0.27	1.83E-06	266	-1.13	-0.17	0.09	0.28	-0.99	-0.2	0.06	0.2	0.17	0.19	0.09	0.3	0.36	24.18	0.9
07340300	0.27	0.34	0.35	0.26	0.16	0.33	2.07	0.38	7.81E-08	285	0.3	0.38	0.49	0.71	0.32	0.41	0.5	0.71	0.29	0.49	0.57	0.76	0.85	0.74	0.71
07337900	0.5	0.47	0.35	0.14	0.03	0.53	1.64	0.39	5.85E-07	357	-2.5	0.35	0.64	0.79	-2.1	0.31	0.6	0.75	-2.54	0.44	0.61	0.76	0.39	21.29	0.75
07335700	0.45	0.42	0.2	0.05	0	0.47	1.48	0.36	1.34E-06	340	-57.49	-0.22	0.64	0.74	-114.99	-0.42	0.59	0.67	-47.21	0.25	0.73	0.8	0.1	34.67	0.87
07301410	0.61	0.58	0.52	0.3	0.16	0.63	2.02	0.89	1.31E-06	112	-1.98	0.24	0.52	0.57	-2.93	0.29	0.7	0.73	0.43	0.6	0.73	0.85	0.4	11.72	0.63
07283000	0.53	0.55	0.46	0.33	0.15	0.57	2.07	0.52	2.88E-07	322	0.33	0.33	0.09	0.28	0.31	0.31	0.09	0.25	0.29	0.29	0.13	0.32	0.99	7.8	0.84
07274000	0.46	0.47	0.42	0.31	0.16	0.52	2.05	0.53	1.43E-07	315	0.39	0.4	0.35	0.63	0.4	0.42	0.39	0.63	0.45	0.47	0.37	0.68	0.94	-5.1	0.73
07268000	0.58	0.62	0.57	0.43	0.23	0.65	2.55	0.87	6.48E-08	338	0.51	0.51	0.2	0.39	0.38	0.39	0.15	0.3	0.32	0.36	0.1	0.27	0.98	4.5	0.8
07261500	0.59	0.53	0.36	0.15	0.03	0.6	1.77	0.56	6.09E-07	509	-2.43	0.15	0.52	0.64	-3.92	0.11	0.56	0.66	-1.99	0.31	0.57	0.66	0.38	29.96	0.83
07261000	0.62	0.59	0.43	0.2	0.04	0.64	1.69	0.59	1.14E-06	397	-4.98	0.25	0.74	0.81	-5.98	0.11	0.68	0.76	-4.45	0.28	0.75	0.81	0.31	35.97	0.85
07260000	0.54	0.48	0.31	0.12	0.03	0.56	1.7	0.5	9.58E-07	381	-5.23	-0.09	0.53	0.67	-7.94	-0.25	0.54	0.69	-2.95	0.02	0.55	0.68	0.29	42.58	0.99
07257500	0.57	0.54	0.39	0.17	0.04	0.59	1.63	0.44	6.50E-07	314	-5.35	0.46	0.79	0.88	-5.92	0.44	0.7	0.79	-6.93	0.42	0.62	0.68	0.31	28.56	0.76
07252000	0.56	0.48	0.31	0.12	0.02	0.57	1.56	0.43	7.44E-07	488	-24.95	0.37	0.85	0.89	-11.94	0.38	0.82	0.87	-24.15	0.34	0.83	0.88	0.18	34.67	0.81
07197000	0.58	0.55	0.41	0.25	0.13	0.62	2.03	0.64	1.23E-07	416	-0.08	0.46	0.57	0.67	0.05	0.49	0.61	0.7	-0.15	0.5	0.7	0.79	0.63	9.26	0.71
07196900	0.63	0.58	0.45	0.29	0.15	0.66	2	0.75	8.76E-07	315	-0.18	0.31	0.41	0.49	-0.36	0.29	0.36	0.43	0.1	0.35	0.34	0.44	0.62	18.47	0.81
07185700	0.68	0.65	0.59	0.46	0.33	0.72	2.89	1.39	3.57E-08	280	0.35	0.58	0.71	0.76	0.34	0.55	0.66	0.72	0.28	0.46	0.57	0.65	0.77	10.44	0.74
07160500	0.4	0.44	0.39	0.35	0.33	0.46	2.1	0.55	5.00E-07	197	-0.11	-0.02	0.05	0.22	0.11	0.14	0.11	0.3	0.07	0.38	0.06	0.29	0.72	3.36	0.79
07148400	0.49	0.31	0.23	0.1	0.07	0.5	1.74	0.49	8.12E-07	96	-1.32	-0.05	0.37	0.7	-2.6	-0.2	0.46	0.62	0.28	0.29	0.38	0.65	0.39	20.48	0.84
07075300	0.55	0.48	0.32	0.15	0.03	0.57	1.7	0.6	1.04E-06	338	-7.61	0.2	0.76	0.8	-4.95	0.08	0.67	0.73	-10.76	0.02	0.68	0.74	0.28	42.43	0.99

07075000	0.57	0.52	0.37	0.16	0.03	0.58	1.69	0.48	6.39E-07	521	-2.29	0.34	0.7	0.83	-2.12	0.25	0.67	0.8	-4.46	0.28	0.78	0.85	0.4	35.85	0.85
07071500	0.71	0.7	0.69	0.61	0.54	0.76	3.65	1.88	2.01E-09	329	0.49	0.58	0.56	0.63	0.55	0.64	0.56	0.59	0.47	0.67	0.64	0.66	0.85	0.81	0.57
07066000	0.53	0.57	0.58	0.48	0.39	0.62	2.61	0.85	9.24E-09	313	0.48	0.51	0.52	0.67	0.53	0.56	0.52	0.63	0.54	0.58	0.59	0.71	0.9	-0.97	0.65
07064500	0.36	0.36	0.36	0.3	0.19	0.39	1.76	0.26	1.08E-06	86	0.03	0.4	0.51	0.76	0.02	0.36	0.45	0.67	0.2	0.36	0.43	0.69	0.7	6.89	0.8
07060710	0.46	0.55	0.58	0.54	0.42	0.56	2.15	0.58	2.33E-07	214	0.41	0.42	0.34	0.54	0.37	0.4	0.25	0.4	0.36	0.4	0.19	0.31	0.92	0.9	0.52
07058000	0.6	0.57	0.55	0.44	0.34	0.65	3.11	1.23	2.69E-09	405	0.52	0.52	0.5	0.62	0.53	0.54	0.41	0.5	0.53	0.56	0.38	0.45	0.95	-1.41	0.66
07057500	0.63	0.64	0.64	0.53	0.43	0.71	3.87	1.77	2.99E-10	408	0.54	0.58	0.6	0.67	0.58	0.6	0.54	0.6	0.56	0.62	0.54	0.59	0.92	-0.63	0.62
07056000	0.59	0.58	0.5	0.31	0.13	0.63	1.97	0.54	8.38E-08	482	0.22	0.53	0.66	0.81	0.26	0.57	0.63	0.76	0.27	0.61	0.62	0.75	0.68	4.86	0.62
07052500	0.46	0.52	0.46	0.28	0.13	0.51	7.99	3.72	2.04E-09	63	0.4	0.42	0.67	0.73	0.41	0.45	0.73	0.78	0.4	0.41	0.58	0.68	0.97	-0.03	0.77
07050700	0.58	0.55	0.44	0.27	0.12	0.63	1.89	0.59	2.94E-07	384	-0.45	0.46	0.68	0.78	-1.2	0.41	0.59	0.68	-1.48	0.35	0.5	0.58	0.57	18.35	0.8
07021000	0.5	0.46	0.37	0.2	0.04	0.53	2.16	0.52	2.79E-08	423	0.34	0.42	0.48	0.67	0.33	0.46	0.48	0.64	0.36	0.5	0.48	0.63	0.81	1.36	0.7
06928000	0.62	0.58	0.45	0.27	0.13	0.65	2.08	0.6	5.45E-08	530	0.37	0.56	0.53	0.68	0.4	0.57	0.47	0.61	0.43	0.59	0.37	0.49	0.74	2.46	0.64
06927000	0.47	0.45	0.32	0.12	0.01	0.5	1.83	0.41	3.98E-07	260	0.26	0.45	0.46	0.67	0.26	0.44	0.42	0.62	0.39	0.45	0.37	0.59	0.73	12.83	0.74
06918460	0.61	0.59	0.49	0.35	0.17	0.65	2.12	0.77	1.21E-07	333	-0.63	0.49	0.78	0.83	-0.5	0.5	0.79	0.83	-0.4	0.52	0.81	0.86	0.57	8.84	0.69
06918440	0.65	0.64	0.53	0.36	0.21	0.71	2.18	0.94	2.20E-07	304	-0.56	0.49	0.75	0.79	-0.58	0.5	0.76	0.79	-0.57	0.51	0.75	0.78	0.57	14.8	0.7
06431500	0.68	0.69	0.54	0.43	0.38	0.69	2.23	1.41	1.15E-06	37	-8.29	0.37	0.9	0.91	-1.39	0.22	0.7	0.72	-65.96	-1.1	0.61	0.67	0.43	28.79	1.45
06430500	0.39	0.47	0.56	0.5	0.49	0.51	2.85	1.2	5.56E-08	18	-0.38	-0.1	0.47	0.62	-1.97	0.21	0.68	0.71	0.1	0.65	0.74	0.77	0.81	1.1	0.59
06324970	0.36	0.33	0.29	0.2	0.11	0.38	1.38	0.32	2.08E-06	117	-164.19	0.25	0.8	0.91	-14.36	0.26	0.7	0.84	-65.63	0.25	0.73	0.88	0.05	85.59	1.41
06191000	0.85	0.75	0.47	0.16	0.05	0.77	4	1.87	8.14E-10	50	0.65	0.72	0.84	0.88	0.65	0.7	0.81	0.84	0.49	0.72	0.84	0.84	0.88	-2.86	0.53
05414820	0.29	0.52	0.5	0.61	0.75	0.43	2.52	0.82	1.23E-07	21	0.35	0.35	0.41	0.57	0.32	0.32	0.38	0.49	0.25	0.3	0.44	0.72	0.96	1.85	0.83
03604400	0.62	0.62	0.59	0.44	0.23	0.65	2.73	0.84	2.22E-09	538	0.54	0.6	0.49	0.59	0.57	0.63	0.46	0.55	0.63	0.66	0.45	0.57	0.87	-0.79	0.58
03550500	0.71	0.73	0.71	0.56	0.31	0.8	3.6	2.09	5.39E-08	376	0.61	0.63	0.58	0.65	0.62	0.64	0.59	0.66	0.58	0.69	0.67	0.72	0.93	1.81	0.55
03538225	0.52	0.59	0.53	0.38	0.21	0.6	2.28	0.74	1.55E-07	152	0.56	0.6	0.49	0.66	0.42	0.54	0.54	0.68	0.55	0.55	0.5	0.7	0.89	2.66	0.67
03518500	0.73	0.79	0.72	0.55	0.35	0.81	3.07	1.57	7.52E-08	424	0.57	0.61	0.68	0.76	0.59	0.63	0.65	0.73	0.66	0.68	0.6	0.69	0.9	0.13	0.57
03512000	0.69	0.75	0.74	0.59	0.39	0.79	3.27	1.67	2.11E-08	318	0.66	0.71	0.72	0.79	0.61	0.65	0.64	0.72	0.57	0.61	0.59	0.67	0.91	0.06	0.63
03504000	0.77	0.74	0.64	0.46	0.27	0.81	3.68	2.16	4.06E-08	378	0.56	0.61	0.71	0.78	0.56	0.61	0.68	0.75	0.55	0.6	0.65	0.71	0.9	0.59	0.63
03500240	0.74	0.77	0.79	0.67	0.47	0.83	4.03	2.38	2.77E-08	239	0.68	0.71	0.65	0.72	0.65	0.67	0.61	0.68	0.59	0.64	0.6	0.66	0.93	1.18	0.6
03500000	0.76	0.75	0.69	0.54	0.35	0.83	4.46	2.92	2.34E-08	381	0.67	0.68	0.61	0.67	0.69	0.7	0.64	0.7	0.67	0.72	0.7	0.73	0.96	1.51	0.53
03491300	0.68	0.71	0.7	0.61	0.41	0.74	2.52	1.04	4.08E-07	104	0.59	0.62	0.37	0.47	0.51	0.55	0.38	0.5	0.47	0.47	0.34	0.49	0.9	5.3	0.72
03491000	0.74	0.77	0.74	0.59	0.37	0.8	2.41	0.95	3.01E-07	299	0.57	0.64	0.51	0.61	0.55	0.62	0.56	0.67	0.62	0.62	0.59	0.74	0.85	3.37	0.61
03488000	0.59	0.67	0.63	0.47	0.24	0.68	2.17	0.68	1.02E-07	358	0.24	0.6	0.7	0.81	0.46	0.58	0.62	0.74	0.36	0.58	0.66	0.79	0.74	2.22	0.65
03479000	0.6	0.65	0.64	0.5	0.32	0.7	2.86	1.27	5.84E-08	384	0.43	0.5	0.54	0.65	0.41	0.49	0.51	0.62	0.48	0.5	0.47	0.61	0.88	2.59	0.71
03473000	0.64	0.68	0.64	0.5	0.28	0.72	2.62	0.93	1.73E-08	401	0.44	0.59	0.68	0.78	0.46	0.57	0.62	0.73	0.5	0.55	0.59	0.72	0.83	-0.32	0.67
03471500	0.5	0.6	0.63	0.53	0.33	0.63	2.36	0.7	4.50E-08	281	-0.38	0.27	0.68	0.77	0.06	0.35	0.64	0.74	0.11	0.49	0.67	0.77	0.73	1.8	0.71
03466228	0.66	0.69	0.66	0.54	0.39	0.73	3.66	2.05	1.37E-07	41	0.57	0.57	0.37	0.46	0.54	0.57	0.44	0.5	0.57	0.58	0.44	0.51	0.97	3.02	0.64
03463300	0.57	0.59	0.62	0.48	0.26	0.65	2.97	1.3	3.85E-08	298	0.42	0.47	0.49	0.59	0.45	0.5	0.5	0.6	0.45	0.53	0.55	0.63	0.9	0.94	0.68
03461200	0.57	0.55	0.44	0.3	0.18	0.63	2.17	0.91	5.54E-07	110	-0.5	0.53	0.76	0.83	-0.13	0.57	0.79	0.87	-0.38	0.57	0.83	0.9	0.65	6.69	0.66
03460000	0.69	0.69	0.68	0.58	0.38	0.76	2.87	1.25	4.11E-08	239	0.11	0.43	0.64	0.71	0.24	0.51	0.68	0.75	0.34	0.57	0.71	0.79	0.78	0.65	0.66
03455500	0.61	0.62	0.58	0.44	0.24	0.71	3.09	1.34	3.31E-08	251	0.46	0.51	0.62	0.72	0.49	0.52	0.56	0.66	0.43	0.5	0.57	0.65	0.9	1.04	0.71
03454000	0.64	0.68	0.67	0.52	0.33	0.73	2.83	1.28	7.37E-08	167	0.45	0.48	0.56	0.67	0.47	0.52	0.6	0.7	0.41	0.56	0.68	0.75	0.89	3.22	0.67
03441000	0.64	0.7	0.63	0.51	0.32	0.74	3.64	2.05	4.32E-08	399	0.52	0.54	0.48	0.56	0.55	0.57	0.54	0.61	0.58	0.6	0.59	0.68	0.94	1.84	0.63
03439000	0.64	0.65	0.62	0.5	0.34	0.71	4.12	2.3	6.96E-09	233	0.47	0.48	0.56	0.66	0.61	0.62	0.6	0.66	0.66	0.67	0.62	0.68	0.96	-0.32	0.58
03431800	0.39	0.48	0.47	0.29	0.15	0.5	2.43	0.76	7.97E-08	249	0.3	0.31	0.26	0.42	0.33	0.35	0.28	0.42	0.44	0.5	0.45	0.56	0.92	3.97	0.71
03427500	0.41	0.54	0.56	0.42	0.24	0.5	1.96	0.49	1.93E-07	277	0.33	0.44	0.33	0.53	0.39	0.48	0.34	0.53	0.49	0.54	0.38	0.61	0.8	1.75	0.68
03416000	0.67	0.71	0.64	0.43	0.22	0.73	2.17	0.76	2.38E-07	424	0.37	0.6	0.55	0.67	0.33	0.59	0.59	0.71	0.37	0.56	0.6	0.73	0.76	6.66	0.66
03415000	0.71	0.76	0.72	0.55	0.29	0.77	2.05	0.75	4.90E-07	347	0.4	0.63	0.59	0.72	0.31	0.56	0.59	0.72	0.05	0.38	0.6	0.74	0.75	20.5	0.79
03413200	0.49	0.59	0.56	0.45	0.26	0.57	1.98	0.53	3.99E-07	174	0.23	0.51	0.48	0.64	0.18	0.38	0.49	0.67	0.16	0.49	0.59	0.76	0.75	5.33	0.71
03403910	0.62	0.63	0.54	0.4	0.22	0.67	2.18	0.91	3.99E-07	283	0.36	0.45	0.45	0.59	0.4	0.47	0.45	0.59	0.34	0.51	0.54	0.68	0.81	10.78	0.7
03385000	0.33	0.27	0.17	0.12	0.07	0.38	1.63	0.39	2.29E-06	105	-0.4	0.17	0.31	0.65	-0.67	0.05	0.24	0.5	-2.51	0.36	0.4	0.62	0.54	21.96	0.8
03384450	0.62	0.55	0.37	0.15	0.03	0.64	1.75	0.54	1.49E-06	260	-1.83	0.17	0.48	0.64	-0.08	0.21	0.38	0.6	-0.13	0.21	0.39	0.59	0.42	16.74	0.89
03380475	0.46	0.36	0.26	0.17	0.06	0.47	1.56	0.33	2.70E-06	142	-0.24	0.02	0.21	0.66	-1.03	-0.1	0.18	0.49	-0.14	0.07	0.24	0.68	0.47	38.72	0.96
03374455	0.56	0.59	0.5	0.27	0.07	0.61	1.84	0.51	1.18E-06	214	-0.01	0.43	0.51	0.67	-0.42	0.15	0.4	0.52	-0.14	0.16	0.4	0.57	0.65	23.16	0.92
03368000	0.44	0.4	0.32	0.21	0.09	0.47	1.83	-0.5	2.16E-06	105	-0.48	-0.04	0.19	0.39	-0.21	0	0.2	0.38	-0.34	0.15	0.44	0.65	0.61	23.29	0.92
03366200	0.41	0.47	0.46	0.26	0.11	0.45	1.85	0.53	2.50E-06	162	0.14	0.3	0.43	0.7	-0.3	0.08	0.37	0.62	-0.61	0.01	0.31	0.52	0.75	31.11	0.99
03364500	0.59	0.56	0.42	0.25	0.11	0.61	1.82	0.71	1.57E-06	339	-1.91	0.08	0.6	0.74	-1.25	0.11	0.5	0.62	-2.04	0.16	0.55	0.66	0.44	34.69	0.91

03346000	0.65	0.63	0.53	0.36	0.22	0.68	2.08	0.69	5.58E-07	404	0.22	0.28	0.27	0.49	0.2	0.3	0.23	0.45	0.16	0.33	0.23	0.45	0.78	19.99	0.82
03344500	0.05	0.15	0.17	0.16	0.1	0.07	1.51	0.08	3.47E-06	38	-1.52	0.26	0.43	0.81	-0.44	0.04	0.27	0.69	-0.08	0.1	0.23	0.66	0.53	3.78	0.95
03335700	0.61	0.54	0.4	0.25	0.16	0.64	2.21	0.8	1.49E-07	166	0.29	0.44	0.59	0.74	0.3	0.43	0.55	0.67	0.34	0.43	0.52	0.64	0.77	5.59	0.75
03327520	0.49	0.46	0.37	0.23	0.08	0.51	2.18	0.6	1.18E-07	191	0.34	0.36	0.44	0.64	0.35	0.37	0.41	0.62	0.36	0.39	0.39	0.61	0.9	3.02	0.78
03320500	0.62	0.57	0.47	0.27	0.12	0.65	1.63	0.51	1.91E-06	445	-0.83	0	0.4	0.63	-1.66	-0.11	0.33	0.52	-0.19	0.08	0.37	0.65	0.38	43.42	0.96
03318800	0.57	0.5	0.39	0.19	0.05	0.59	1.63	0.51	2.33E-06	343	-0.5	0.03	0.29	0.49	-1.35	-0.07	0.27	0.45	-0.81	0.01	0.4	0.62	0.42	52.92	0.99
03307500	0.52	0.51	0.45	0.29	0.13	0.55	1.62	0.52	3.10E-06	112	-2.73	0.19	0.44	0.62	-3.09	-0.08	0.42	0.58	-1.2	0.28	0.58	0.75	0.39	27.07	0.85
03304500	0.36	0.33	0.33	0.1	0.03	0.41	1.61	0.28	2.22E-06	53	-3.21	0.39	0.66	0.85	-3.81	0.34	0.65	0.79	-2.2	0.48	0.68	0.84	0.46	8.37	0.72
03303000	0.7	0.69	0.58	0.36	0.17	0.73	2.19	0.85	2.12E-07	498	0.49	0.61	0.59	0.73	0.33	0.51	0.55	0.66	0.36	0.44	0.5	0.64	0.79	12.09	0.75
03302800	0.56	0.56	0.46	0.27	0.11	0.6	2.06	0.68	2.49E-07	316	0.33	0.48	0.52	0.66	0.27	0.5	0.54	0.69	0.25	0.53	0.55	0.69	0.77	10.96	0.69
03302680	0.59	0.53	0.43	0.25	0.1	0.62	1.8	0.6	1.39E-06	253	-1.27	0.32	0.58	0.72	-0.67	0.39	0.63	0.78	-1.43	0.39	0.7	0.81	0.48	22.19	0.78
03301500	0.62	0.62	0.5	0.28	0.12	0.66	1.73	0.52	6.79E-07	420	0.25	0.51	0.63	0.85	0.21	0.45	0.61	0.79	0.11	0.4	0.6	0.78	0.65	15.2	0.77
03300000	0.33	0.34	0.28	0.16	0.06	0.38	1.6	0.38	1.50E-06	87	-0.48	0.36	0.53	0.78	-4.05	0.19	0.6	0.78	-1.5	0.11	0.53	0.73	0.54	29.11	0.94
03292460	0.36	0.34	0.23	0.12	0.04	0.41	1.67	0.39	1.86E-06	125	-0.18	0.35	0.42	0.67	-0.74	0.15	0.33	0.53	-0.45	0.06	0.25	0.46	0.62	31.98	0.97
03290000	0.01	0.05	0.14	0.25	0.15	0.03	1.82	0.08	1.86E-06	35	0.21	0.25	0.08	0.29	0.27	0.28	0.08	0.28	-0.09	0.24	0.4	0.68	0.89	-3.73	0.87
03285000	0.64	0.59	0.47	0.23	0.08	0.66	1.67	0.54	1.53E-06	446	-1.19	0.37	0.61	0.77	-0.58	0.38	0.57	0.73	-0.13	0.4	0.53	0.72	0.44	19.96	0.77
03282500	0.65	0.61	0.49	0.26	0.07	0.68	1.81	0.65	1.23E-06	341	-0.86	0.44	0.64	0.76	-1.44	0.26	0.62	0.73	-1.63	0.16	0.61	0.72	0.51	29.98	0.92
03281100	0.58	0.6	0.52	0.33	0.13	0.63	1.74	0.61	1.43E-06	294	-0.86	0.38	0.55	0.7	-0.85	0.38	0.57	0.7	-1.59	0.37	0.65	0.75	0.51	23.78	0.79
03281040	0.62	0.63	0.59	0.41	0.16	0.67	1.84	0.73	1.47E-06	165	-0.8	0.37	0.51	0.61	-0.88	0.38	0.54	0.63	-1.35	0.43	0.69	0.75	0.54	25.59	0.76
03280700	0.64	0.64	0.55	0.37	0.17	0.69	1.81	0.76	2.07E-06	322	-1.13	0.32	0.55	0.64	-0.73	0.36	0.58	0.67	-1.39	0.28	0.64	0.75	0.48	26.91	0.85
03237500	0.56	0.58	0.52	0.32	0.11	0.61	1.82	0.58	1.10E-06	410	0.19	0.45	0.33	0.56	0.09	0.39	0.36	0.54	0.26	0.36	0.37	0.57	0.68	20.65	0.8
03217000	0.63	0.64	0.53	0.33	0.16	0.67	1.83	0.57	6.74E-07	449	0.03	0.59	0.6	0.76	-0.19	0.52	0.62	0.74	0.25	0.52	0.59	0.76	0.62	14.1	0.69
03213700	0.71	0.75	0.74	0.57	0.33	0.76	2.45	1.07	9.92E-08	259	0.58	0.66	0.67	0.77	0.6	0.65	0.66	0.75	0.57	0.64	0.69	0.8	0.84	2.48	0.6
03213500	0.58	0.62	0.51	0.35	0.18	0.63	1.78	0.59	1.39E-06	299	-1.12	0.43	0.61	0.73	-0.23	0.46	0.6	0.74	-0.18	0.46	0.66	0.83	0.52	16.25	0.74
03213000	0.77	0.79	0.72	0.54	0.3	0.82	2.38	1.08	2.52E-07	256	0.51	0.65	0.66	0.75	0.5	0.65	0.59	0.67	0.61	0.65	0.51	0.62	0.8	7.5	0.59
03210000	0.64	0.65	0.57	0.39	0.19	0.68	1.73	0.57	1.42E-06	386	-1.2	0.46	0.53	0.66	-0.66	0.41	0.55	0.66	-0.58	0.31	0.64	0.84	0.49	18.66	0.83
03208950	0.59	0.65	0.59	0.44	0.24	0.66	2.11	0.84	5.98E-07	235	-0.08	0.42	0.32	0.4	0.2	0.44	0.38	0.47	0.25	0.42	0.62	0.8	0.68	9.34	0.76
03208500	0.65	0.67	0.56	0.36	0.18	0.7	1.87	0.69	9.29E-07	502	-0.16	0.47	0.66	0.81	0.04	0.46	0.54	0.65	0.26	0.44	0.47	0.64	0.6	15.4	0.75
03207800	0.64	0.66	0.61	0.44	0.23	0.69	2.17	0.87	3.12E-07	237	0.19	0.48	0.42	0.5	0.41	0.53	0.49	0.57	0.61	0.63	0.67	0.84	0.73	3.76	0.61
03203600	0.61	0.62	0.59	0.42	0.23	0.67	2.23	0.82	9.45E-08	258	0.43	0.52	0.54	0.67	0.25	0.45	0.61	0.72	0.4	0.4	0.55	0.75	0.81	-2	0.77
03202750	0.67	0.72	0.63	0.4	0.21	0.73	1.99	0.72	5.45E-07	236	-0.02	0.49	0.63	0.76	0.29	0.51	0.61	0.75	0.08	0.49	0.66	0.79	0.67	8.98	0.72
03202400	0.63	0.71	0.66	0.5	0.31	0.71	2.38	0.93	9.33E-08	211	0.33	0.51	0.65	0.76	0.45	0.57	0.63	0.75	0.46	0.63	0.66	0.77	0.8	0.78	0.61
03202000	0.67	0.64	0.51	0.29	0.11	0.67	1.83	0.6	5.04E-07	429	-0.03	0.46	0.66	0.82	0.16	0.5	0.66	0.81	0.24	0.54	0.67	0.83	0.61	5.17	0.68
03201800	0.41	0.32	0.38	0.37	0.26	0.46	1.58	0.39	2.29E-06	54	-4.62	0.37	0.73	0.89	-4.92	0.23	0.66	0.8	-2.5	0.32	0.6	0.81	0.39	18.35	0.82
03201000	0.38	0.4	0.35	0.21	0.09	0.41	1.57	0.32	1.09E-06	216	-0.87	0.49	0.5	0.77	-0.23	0.49	0.51	0.74	-0.29	0.48	0.57	0.83	0.5	14.95	0.72
03194700	0.46	0.45	0.32	0.19	0.05	0.5	1.88	0.53	2.72E-07	310	-0.15	0.55	0.69	0.83	-0.05	0.54	0.7	0.84	0.03	0.55	0.72	0.87	0.64	5.71	0.67
03191500	0.59	0.57	0.45	0.28	0.11	0.63	1.76	0.59	1.39E-06	287	-0.53	0.49	0.66	0.79	-0.12	0.39	0.61	0.75	-0.88	0.1	0.62	0.85	0.55	19.48	0.95
03189100	0.48	0.46	0.32	0.2	0.07	0.52	1.75	0.5	3.79E-07	261	-1.45	0.54	0.74	0.85	-0.45	0.54	0.73	0.86	-1.04	0.55	0.78	0.9	0.5	8.03	0.67
03187500	0.54	0.5	0.42	0.32	0.14	0.58	1.74	0.57	9.59E-07	247	-1.89	0.46	0.74	0.85	-1.53	0.46	0.73	0.85	-1.79	0.46	0.74	0.86	0.48	14.42	0.73
03187000	0.51	0.47	0.36	0.19	0.05	0.52	1.7	0.46	5.57E-07	179	-2.11	0.53	0.73	0.86	-1.04	0.54	0.74	0.86	-2.04	0.54	0.78	0.89	0.45	8.95	0.68
03186500	0.58	0.58	0.48	0.31	0.11	0.62	1.78	0.6	8.99E-07	477	-0.94	0.53	0.74	0.85	-0.94	0.5	0.71	0.83	-0.79	0.47	0.68	0.8	0.53	13.19	0.73
03182500	0.56	0.58	0.48	0.31	0.12	0.61	1.87	0.57	3.00E-07	476	-0.1	0.56	0.71	0.85	0.07	0.53	0.68	0.82	0.08	0.5	0.66	0.82	0.63	7.5	0.71
03180500	0.59	0.59	0.52	0.35	0.13	0.63	1.79	0.6	7.51E-07	381	-1.87	0.49	0.77	0.86	-1.27	0.4	0.65	0.73	-1.32	0.33	0.6	0.68	0.48	14.81	0.82
03179000	0.68	0.7	0.66	0.46	0.23	0.73	2.18	0.82	2.26E-07	369	0.47	0.59	0.61	0.75	0.51	0.59	0.58	0.73	0.56	0.61	0.58	0.75	0.8	2	0.63
03173000	0.67	0.68	0.67	0.49	0.27	0.72	2.45	0.89	5.42E-08	471	0.54	0.61	0.65	0.78	0.5	0.6	0.66	0.78	0.59	0.6	0.6	0.76	0.85	0.02	0.63
03170000	0.58	0.63	0.64	0.58	0.45	0.68	3.99	2.23	1.16E-08	311	0.58	0.59	0.29	0.35	0.62	0.63	0.38	0.44	0.67	0.67	0.52	0.61	0.96	1.02	0.57
03167500	0.65	0.69	0.61	0.54	0.46	0.72	5.23	3.11	9.87E-10	118	0.57	0.57	0.35	0.42	0.65	0.65	0.43	0.5	0.66	0.67	0.44	0.5	0.98	-0.46	0.58
03165000	0.43	0.52	0.52	0.47	0.36	0.56	4.1	2.09	1.13E-08	193	0.49	0.5	0.28	0.35	0.51	0.52	0.35	0.44	0.53	0.53	0.44	0.56	0.97	1.8	0.69
03161000	0.68	0.71	0.67	0.53	0.35	0.76	4.18	2.63	2.54E-08	309	0.54	0.55	0.43	0.51	0.6	0.61	0.34	0.4	0.62	0.63	0.33	0.39	0.96	1.79	0.61
03159540	0.66	0.68	0.57	0.37	0.12	0.71	2.08	0.86	1.06E-06	249	0.06	0.34	0.42	0.59	-0.08	0.36	0.35	0.46	-0.13	0.37	0.28	0.35	0.69	21.8	0.79
03157000	0.48	0.55	0.5	0.36	0.2	0.56	2.57	0.78	4.80E-08	243	0.37	0.39	0.34	0.5	0.4	0.43	0.39	0.53	0.45	0.47	0.48	0.65	0.92	2.26	0.73
03155500	0.59	0.54	0.41	0.25	0.07	0.61	1.72	0.43	7.19E-07	295	0.23	0.54	0.41	0.63	0.12	0.49	0.47	0.67	0.45	0.52	0.49	0.77	0.67	10.19	0.69
03154500	0.69	0.6	0.53	0.3	0.11	0.69	1.65	0.43	1.94E-06	135	0.47	0.64	0.54	0.83	0.18	0.54	0.51	0.77	0.26	0.46	0.44	0.72	0.73	15.19	0.74
03154000	0.49	0.5	0.46	0.32	0.15	0.52	1.71	0.4	8.36E-07	192	0.33	0.59	0.46	0.71	-0.57	0.53	0.58	0.77	0.49	0.58	0.57	0.84	0.7	8.76	0.65
03153000	0.56	0.5	0.43	0.28	0.13	0.57	1.67	0.47	1.36E-06	228	-0.23	0.52	0.57	0.78	-0.79	0.49	0.62	0.79	-0.54	0.49	0.66	0.83	0.57	20.66	0.71

03151400	0.61	0.58	0.48	0.27	0.07	0.63	1.74	0.6	1.22E-06	219	-1.78	0.39	0.71	0.81	-1.12	0.47	0.71	0.82	-1.98	0.49	0.74	0.84	0.46	15.05	0.7
03140000	0.69	0.68	0.58	0.36	0.13	0.74	1.93	0.78	1.39E-06	298	-0.37	0.45	0.62	0.73	-0.16	0.5	0.65	0.75	-0.13	0.5	0.68	0.8	0.59	16.09	0.71
03115400	0.65	0.63	0.52	0.32	0.1	0.69	1.81	0.65	1.22E-06	285	-0.62	0.42	0.64	0.76	-0.49	0.45	0.44	0.53	-1.25	0.47	0.34	0.4	0.54	20.31	0.73
03114500	0.55	0.51	0.4	0.25	0.09	0.57	1.68	0.39	6.79E-07	418	-0.16	0.51	0.5	0.7	0.09	0.51	0.51	0.7	0.28	0.53	0.54	0.79	0.58	10.75	0.68
03076600	0.52	0.57	0.49	0.35	0.14	0.57	1.91	0.55	3.19E-07	251	-1.21	0.34	0.68	0.79	-0.54	0.44	0.7	0.8	-0.78	0.52	0.77	0.87	0.54	5.91	0.69
03070500	0.66	0.66	0.55	0.39	0.17	0.69	1.69	0.51	8.65E-07	441	-2.68	0.56	0.73	0.83	-0.9	0.5	0.71	0.82	-1.83	0.45	0.74	0.87	0.43	15.2	0.74
03069500	0.58	0.54	0.42	0.27	0.11	0.61	1.84	0.54	2.93E-07	489	0.1	0.48	0.66	0.84	0.19	0.51	0.66	0.82	0.04	0.52	0.68	0.85	0.67	7.09	0.69
03066000	0.56	0.55	0.41	0.31	0.12	0.59	2.1	0.68	3.23E-07	349	0.44	0.51	0.52	0.72	0.33	0.43	0.52	0.69	0.37	0.4	0.47	0.69	0.85	4.34	0.78
03061500	0.49	0.53	0.44	0.27	0.11	0.53	1.63	0.4	1.17E-06	373	-1.66	0.44	0.55	0.72	0.08	0.46	0.54	0.71	-0.03	0.45	0.59	0.85	0.47	14.46	0.74
03052500	0.5	0.45	0.31	0.21	0.05	0.54	1.67	0.49	1.75E-06	335	-2.09	0.26	0.61	0.77	-0.99	0.31	0.61	0.77	-1.1	0.51	0.66	0.82	0.44	14.81	0.7
03050000	0.59	0.58	0.44	0.27	0.11	0.61	1.78	0.53	7.13E-07	536	-0.3	0.56	0.66	0.82	-0.63	0.52	0.67	0.8	-0.15	0.51	0.65	0.8	0.59	12.3	0.7
03034500	0.66	0.63	0.52	0.33	0.09	0.69	1.76	0.6	1.07E-06	381	-1.44	0.45	0.68	0.79	-0.85	0.4	0.68	0.8	-1.2	0.29	0.68	0.85	0.48	17.96	0.84
03028000	0.51	0.47	0.38	0.19	0.05	0.53	1.77	0.48	3.28E-07	281	-7.25	0.45	0.85	0.92	-5.68	0.44	0.85	0.92	-6.97	0.41	0.85	0.92	0.37	9.87	0.77
03026500	0.48	0.43	0.34	0.17	0.03	0.51	1.7	0.45	8.02E-07	286	-8.43	0.26	0.78	0.86	-4.87	0.29	0.78	0.86	-9.62	0.27	0.83	0.88	0.33	15.72	0.85
03010500	0.67	0.65	0.52	0.28	0.07	0.69	1.88	0.62	2.50E-07	401	-0.93	0.43	0.55	0.65	-1.31	0.45	0.64	0.73	-1.01	0.47	0.74	0.85	0.51	7.64	0.73
02482550	0.46	0.48	0.42	0.26	0.12	0.48	1.56	0.33	2.42E-07	328	-16.32	0.61	0.85	0.93	-7.94	0.61	0.84	0.92	-22.08	0.58	0.88	0.94	0.2	7.14	0.64
02481880	0.54	0.49	0.39	0.27	0.1	0.55	1.38	0.39	2.11E-06	198	-803.96	0.14	0.83	0.86	-1278.55	0.26	0.86	0.9	-573.13	0.29	0.84	0.89	0.03	46.59	0.84
02415000	0.7	0.77	0.71	0.51	0.24	0.77	3.62	2.14	8.44E-08	194	0.66	0.66	0.58	0.66	0.44	0.49	0.48	0.55	0.47	0.47	0.4	0.5	0.97	7.61	0.72
02379500	0.78	0.81	0.76	0.62	0.4	0.87	5.66	4.02	1.50E-08	325	0.76	0.76	0.64	0.69	0.75	0.75	0.65	0.7	0.72	0.72	0.7	0.75	0.98	0.42	0.53
02373000	0.61	0.59	0.43	0.29	0.13	0.63	2.01	0.64	2.02E-07	354	0.47	0.59	0.6	0.79	0.24	0.35	0.53	0.71	0.36	0.41	0.53	0.73	0.77	-0.15	0.77
02372250	0.75	0.71	0.55	0.37	0.19	0.76	2.75	1.33	1.19E-07	222	0.67	0.67	0.49	0.61	0.59	0.61	0.48	0.59	0.52	0.54	0.42	0.51	0.96	2.01	0.68
02371500	0.69	0.6	0.44	0.3	0.14	0.68	2.28	0.91	1.35E-07	437	0.55	0.61	0.68	0.8	0.55	0.63	0.67	0.78	0.55	0.64	0.64	0.74	0.83	-3.8	0.6
02363000	0.61	0.53	0.38	0.24	0.1	0.62	1.93	0.78	6.23E-07	375	-0.51	0.61	0.77	0.82	0.18	0.65	0.71	0.79	-1.04	0.69	0.74	0.8	0.54	6.61	0.56
02333500	0.72	0.77	0.74	0.59	0.38	0.83	4.66	2.96	1.09E-08	344	0.7	0.71	0.49	0.53	0.73	0.75	0.58	0.62	0.76	0.78	0.68	0.72	0.96	0.18	0.47
02330450	0.8	0.81	0.77	0.67	0.48	0.86	4.81	3.37	6.15E-08	158	0.7	0.71	0.66	0.7	0.7	0.72	0.64	0.69	0.68	0.71	0.61	0.65	0.95	2.09	0.54
02182000	0.65	0.78	0.77	0.7	0.52	0.82	4.66	3.03	3.85E-08	176	0.72	0.74	0.68	0.73	0.73	0.75	0.69	0.74	0.87	0.87	0.83	0.9	0.95	-1.19	0.36
02177000	0.76	0.77	0.72	0.59	0.41	0.83	4.59	3.04	1.58E-08	385	0.65	0.67	0.63	0.69	0.72	0.73	0.69	0.73	0.75	0.77	0.74	0.78	0.95	-0.16	0.48
02160105	0.7	0.68	0.67	0.58	0.43	0.78	3.77	2.02	5.57E-09	220	0.63	0.67	0.42	0.49	0.62	0.68	0.47	0.53	0.64	0.7	0.46	0.53	0.92	0.75	0.55
02152100	0.51	0.62	0.68	0.64	0.55	0.69	4.29	2.12	4.16E-09	206	0.65	0.65	0.33	0.41	0.56	0.59	0.39	0.46	0.59	0.61	0.41	0.5	0.97	1.3	0.63
02143040	0.44	0.63	0.67	0.64	0.54	0.62	3.65	1.67	2.15E-08	151	0.5	0.52	0.24	0.32	0.58	0.63	0.4	0.47	0.73	0.74	0.53	0.63	0.96	-1.41	0.51
02112120	0.63	0.65	0.7	0.62	0.48	0.74	4.84	2.71	1.79E-09	194	0.6	0.61	0.32	0.38	0.58	0.59	0.4	0.46	0.55	0.58	0.49	0.55	0.97	1.2	0.65
02111500	0.56	0.58	0.62	0.56	0.45	0.71	4.8	3.01	1.17E-08	295	0.62	0.62	0.42	0.48	0.66	0.67	0.44	0.51	0.69	0.7	0.53	0.59	0.97	1.2	0.55
02111180	0.55	0.59	0.65	0.62	0.52	0.67	3.21	1.48	2.91E-08	201	0.44	0.53	0.42	0.5	0.47	0.54	0.47	0.56	0.41	0.58	0.62	0.68	0.89	3.58	0.65
02111000	0.42	0.51	0.53	0.49	0.42	0.57	3.19	1.39	3.26E-08	253	0.32	0.38	0.43	0.53	0.4	0.46	0.48	0.58	0.52	0.56	0.57	0.68	0.92	0.89	0.66
02053800	0.62	0.7	0.69	0.54	0.36	0.73	2.63	1.24	1.63E-07	209	0.29	0.47	0.52	0.62	0.39	0.53	0.54	0.63	0.32	0.52	0.58	0.65	0.81	5.31	0.69
02028500	0.68	0.61	0.58	0.42	0.25	0.72	2.39	1.17	2.91E-07	413	-0.24	0.41	0.6	0.68	-0.53	0.41	0.65	0.72	-0.19	0.45	0.65	0.72	0.68	9.19	0.74
02020500	0.51	0.49	0.43	0.27	0.1	0.55	1.89	0.5	2.58E-07	445	-0.42	0.48	0.64	0.78	-0.51	0.47	0.65	0.78	-0.25	0.47	0.64	0.78	0.61	9.31	0.73
02014000	0.46	0.54	0.53	0.43	0.26	0.55	2.03	0.53	1.02E-07	307	-0.35	0.47	0.69	0.8	-0.2	0.52	0.63	0.73	-0.13	0.54	0.61	0.73	0.64	2.8	0.68
02013000	0.51	0.58	0.58	0.42	0.18	0.61	2.19	0.63	1.05E-07	423	0.38	0.56	0.58	0.72	0.34	0.52	0.54	0.69	0.43	0.5	0.49	0.67	0.8	3.44	0.71
02011460	0.6	0.63	0.55	0.37	0.16	0.64	1.94	0.64	4.46E-07	233	-0.6	0.44	0.73	0.84	-0.11	0.56	0.72	0.83	-0.63	0.6	0.74	0.82	0.6	7.85	0.64
01632000	0.42	0.38	0.3	0.12	0.03	0.45	1.73	0.4	3.43E-07	503	-1.52	0.37	0.57	0.7	-1.29	0.43	0.61	0.74	-1.36	0.48	0.66	0.8	0.47	11.76	0.72
01620500	0.52	0.49	0.41	0.22	0.06	0.55	1.75	0.43	5.76E-07	346	-1.93	0.34	0.64	0.77	-1.92	0.34	0.61	0.73	-1.14	0.35	0.58	0.69	0.47	13.25	0.81
01611500	0.55	0.51	0.45	0.32	0.13	0.58	2.17	0.63	5.33E-08	499	0.49	0.55	0.6	0.77	0.48	0.55	0.6	0.76	0.51	0.54	0.6	0.79	0.83	0.67	0.68
01606500	0.61	0.61	0.58	0.4	0.19	0.66	2.14	0.68	6.71E-08	463	0.25	0.6	0.74	0.85	0.35	0.6	0.62	0.72	0.41	0.6	0.57	0.68	0.72	0.06	0.63
01606000	0.64	0.61	0.51	0.34	0.13	0.69	1.93	0.68	4.19E-07	255	-0.35	0.53	0.7	0.8	-0.47	0.53	0.74	0.84	-0.04	0.53	0.75	0.87	0.6	10.32	0.68
01605500	0.56	0.56	0.53	0.4	0.21	0.63	2.3	0.69	5.46E-08	280	0.33	0.54	0.67	0.8	0.25	0.49	0.3	0.37	0.37	0.47	0.22	0.29	0.79	0.36	0.73
01603500	0.69	0.69	0.58	0.4	0.18	0.74	2.1	0.84	4.91E-07	175	-0.33	0.42	0.6	0.7	-0.15	0.43	0.63	0.74	-0.36	0.42	0.66	0.76	0.64	9.75	0.76
01596500	0.6	0.62	0.53	0.34	0.09	0.64	1.74	0.55	8.13E-07	324	-2.17	0.43	0.75	0.84	-0.91	0.45	0.74	0.83	-3.56	0.43	0.81	0.87	0.44	16.91	0.75
01594936	0.7	0.62	0.48	0.36	0.2	0.71	2.1	0.73	1.12E-06	56	-0.41	0.6	0.81	0.91	-1.58	0.46	0.79	0.88	-0.41	0.45	0.73	0.82	0.68	6.38	0.74
01591400	0.71	0.85	0.78	0.61	0.48	0.82	4.04	2.59	2.35E-07	50	0.82	0.83	0.65	0.71	0.67	0.73	0.37	0.4	0.68	0.7	0.23	0.26	0.94	5.89	0.55
01583000	0.7	0.78	0.78	0.65	0.53	0.82	3.44	2.24	6.88E-07	38	0.43	0.53	0.62	0.68	0.51	0.6	0.66	0.72	0.91	0.91	0.88	0.94	0.86	-11.4	0.3
01552500	0.56	0.53	0.45	0.24	0.06	0.62	1.95	0.64	4.91E-07	353	-0.93	0.41	0.69	0.79	-0.82	0.39	0.7	0.8	-1.22	0.34	0.72	0.81	0.58	12.37	0.81
01550000	0.6	0.57	0.44	0.22	0.05	0.62	1.93	0.6	2.38E-07	498	-0.43	0.51	0.77	0.87	-0.64	0.45	0.7	0.79	-0.22	0.44	0.64	0.78	0.57	8.44	0.75
01549700	0.58	0.54	0.44	0.24	0.07	0.59	1.89	0.62	1.77E-07	344	-0.82	0.38	0.75	0.84	-1.34	0.42	0.78	0.86	-1.5	0.47	0.8	0.88	0.52	9.49	0.73
01549500	0.71	0.65	0.55	0.35	0.11	0.73	1.83	0.66	7.86E-07	381	-2.26	0.4	0.61	0.71	-1.92	0.34	0.65	0.74	-2.3	0.25	0.71	0.81	0.45	21.44	0.87
01548500	0.64	0.61	0.48	0.24	0.05	0.65	1.84	0.58	2.41E-07	451	-1.42	0.45	0.77	0.87	-2.14	0.44	0.78	0.87	-1.24	0.42	0.74	0.86	0.48	11.93	0.76
01545600	0.6	0.59	0.5	0.32	0.09	0.63	1.76	0.59	5.42E-07	272	-9.39	0.28	0.83	0.88	-13.98	0.22	0.84	0.87	-10.11	0.21	0.82	0.86	0.32	18.39	0.89
01544500	0.59	0.57	0.48	0.3	0.1	0.61	1.77	0.52	3.48E-07	396	-3.56	0.46	0.82	0.88	-4.61	0.41	0.81	0.87	-4.25	0.34	0.78	0.85	0.41	13.47	0.81
01543500	0.65	0.63	0.53	0.3	0.07	0.67	1.79	0.61	4.92E-07	430	-2.38	0.48	0.79	0.87	-1.48	0.47	0.78	0.86	-1.97	0.44	0.79	0.88	0.43	14.45	0.75
01542810	0.4	0.47	0.45	0.33	0.13	0.46	1.79	0.43	1.12E-06	257	-0.6	0.28	0.56	0.71	-0.79	0.35	0.62	0.76	-0.51	0.45	0.66	0.83	0.59	9.35	0.74
01491000	0.51	0.45	0.37	0.24	0.11	0.53	2.4	0.81	8.31E-08	202	0.22	0.32	0.26	0.36	0.28	0.39	0.28	0.35	0.52	0.52	0.31	0.44	0.83	3.17	0.69
01488500	0.66	0.63	0.57	0.44	0.26	0.69	2.69	1.12	1.55E-07	272	0.33	0.39	0.28	0.37	0.28	0.37	0.28	0.34	0.24	0.25	0.22	0.33	0.87	8.43	0.87
01413500	0.63	0.62	0.46	0.24	0.05	0.65	1.9	0.61	2.32E-07	379	-2.81	0.51	0.82	0.88	-1.66	0.43	0.79	0.86	-2.34	0.36	0.8	0.88	0.45	10.65	0.8
03083000	0.49	0.49	0.38	0.22	0.06	0.55	1.78	0.53	1.77E-06	142	-0.93	0.42	0.69	0.84	-1.66	0.43	0.7	0.83	-0.7	0.42	0.64	0.8	0.57	11.66	0.76
03078000	0.7	0.69	0.57	0.36	0.14	0.73	2.04	0.92	1.02E-06	280	-0.17	0.49	0.66	0.74	0.15	0.51	0.68	0.77	-0.25	0.5	0.76	0.84	0.63	12.9	0.71
03111150	0.6	0.58	0.43	0.23	0.06	0.66	1.97	0.97	1.98E-06	70	-2.02	0.24	0.54	0.61	-1.1	0.27	0.53	0.59	-0.63	0.37	0.56	0.66	0.46	18.58	0.79

7.2 Corrected gravity residual values

	Date of observation												
Station No.	6/8/2015	11/8/2015	14/08/2015	21/08/2015	30/08/2015	7/9/2015	15/09/2015	24/09/2015	3/10/2015	10/10/2015	19/10/2015	7/11/2015	14/11/2015
1	5913.30	5926.56	5954.19	5934.94	5979.72	6001.38	6023.32	6048.00	6073.07	6092.33	6116.70	6170.07	6185.85
2	5908.51	5921.76	5949.43	5930.13	5974.92	5996.58	6018.52	6043.18	6068.29	6087.51	6111.89	6165.27	6181.06
3	5913.62	5926.87	5954.53	5935.27	5979.19	6001.68	6023.61	6048.26	6073.39	6092.59	6116.98	6170.34	6186.13
4	5914.84	5928.46	5955.76	5936.49	5981.26	6002.90	6024.83	6049.50	6074.62	6093.90	6118.21	6171.56	6187.35
5	5914.97	5928.49	5955.87	5936.62	5981.36	6003.01	6024.94	6049.58	6074.74	6093.90	6118.30	6171.65	6187.45
6	5915.10	5928.50	5955.91	5936.67	5981.42	6003.03	6024.95	6049.60	6074.78	6093.93	6118.35	6171.70	6187.49
7	5915.08	5928.60	5955.95	5936.70	5981.45	6003.06	6024.99	6049.68	6074.79	6093.94	6118.35	6171.68	6187.50
8	5915.18	5928.67	5956.02	5936.77	5981.53	6003.12	6024.94	6049.66	6074.86	6094.00	6118.44	6171.78	6187.57
9	5907.16	5920.45	5948.04	5928.74	5973.60	5995.16	6017.00	6041.61	6066.83	6085.96	6110.40	6163.74	6179.53
10	5914.36	5927.98	5955.14	5935.95	5980.70	6002.28	6024.20	6048.79	6074.02	6093.15	6117.59	6170.94	6186.74
11	5914.89	5928.63	5955.89	5936.55	5981.23	6002.81	6024.73	6049.31	6074.55	6093.67	6118.14	6171.45	6187.24
12	5916.31	5930.15	5957.30	5937.90	5982.65	6004.24	6026.14	6050.73	6075.96	6095.09	6119.62	6172.92	6188.66

Note: All gravity values are in mGal

7.3 M-code

```
clear all
clc
format long
fid(1)=fopen('#0003368000.xlsx');
xlswrite('fid.xlsx',fid);
KK=1;
for corr=1:length(fid)
Qq=xlsread(fopen(fid(corr)));
nnn=find(isnan(Qq));
```

```
Qq(nnn)=0;
q = Qq(1 : round(length(Qq) * 0.5));
t=0;
L=1;
z=[];
r=[];
corr
n=1;
G=130;
j=1;
o=1;
ZZ=[];
u=length(q)-1;
j=1;
n=1;
z=1;
r=[];
e=1;
PPP=[2,2,2,2,2];
QQQ=[6,20,45,80,120];
for i=G:u
if      ((q(i)> q(i+1)) && (q(i)~= q(i+1)))
          x(n,j)=q(i);
          n=n+1;
else
          x(n,j)=q(i);
          i;
          j=j+1;
          n=1;
```

```
end
end
e=x;
e(1,:)=[];
r=[];
l = length(e);
for     i=1:l
a=e(:,i);
if     (nnz(a)> 6)
        r=[[r],a];
end
end
xlswrite('1_mdisCHARGE.xlsx',r)
xlswrite('q.xlsx',Qq(1:round(length(Qq)*0.5)));
xlswrite('index.xlsx',corr);
clear all
d=xlsread('1_mdisCHARGE.xlsx');
G=130;
n=1;
j=1;
t=0;
PPP=[2,2,2,2,2];
QQQ=[6,20,45,80,120];
q=xlsread('q.xlsx');
u=length(q)-1;
for     i=G:u
if     ((q(i)> q(i+1)) && (q(i)~= q(i+1)))
        x(n,j)=q(i);
        n=n+1;
```

```
            y=j;
            s=nnz(x(:,y))-1;
else
            x(n,j)=q(i);
            j=j+1;
            n=1;
            y=j-1;
            s=nnz(x(:,y))-1;
if          (s > 6)
            t=t+1;
for         k=1:5
if          (s > 6)
            v=(i - s - PPP(k)) : -1 : (i - s - (QQQ(k) + 1));
            i;
            s;
            QQQ(k);
            v;
            q(v);
            a=mean(q(v));
            Qn(t,k)=a;
else
end
end
else
end
end
end
[m, n]=size(Qn);
f=Qn(:,1);
```

```
f=find(f==0);
Qn(f,:)=[];
xlswrite('Qn.xlsx',Qn)
Qn=xlsread('Qn.xlsx');
n_m=1;
j_m=1;
[m,n]=size(Qn);
for     l_m=1:m
        q_m = Qn(l_m,:);
        q_m = q_m';
for     i_m=1:4
if      ((q_m(i_m) > q_m(i_m + 1))&& (q_m(i_m) ~= q_m(i_m + 1)))
        x_m(n_m, j_m) = q_m(i_m);
        n_m = n_m + 1;
if        (i_m == 4)
        x_m(n_m, j_m) = q_m(i_m + 1);
        j_m = j_m + 1;
else
end
else
        x_m(n_m, j_m) = q_m(i_m);
        q_m(i_m + 1 : length(q_m)) = 0;
        j_m = j_m + 1;
        n_m = 1;
end
end
end
r_m = [];
[sx, sy] = size(x_m);
```

$e\_m = x\_m;$

for $\quad i\_m = 1 : sy$

$\quad a\_m = e\_m(:, i\_m);$

if $\quad (nnz(a_m)\;0)$

$\quad r\_m = [[r\_m], a\_m];$

end

end

$[sx, sy] = size(r\_m);$

for $\quad m\_r = 1 : sy$

$\quad P\_m = r\_m(:, m\_r);$

$\quad P\_m(P\_m == 0) = [];$

$\quad R\_nm(m\_r) = mean(P_m);$

end

xlswrite $('Qus.xlsx', R\_nm')$

clear all

clc

corr=xlsread('index.xlsx');

if (corr>1)

ns=xlsread('ns.xlsx');

NSE=xlsread('NSE.xlsx');

rmse=xlsread('rmse.xlsx');

rrmse=xlsread('rrmse.xlsx');

pbias=xlsread('pbias.xlsx');

ppbias=xlsread('ppbias.xlsx');

rsr=xlsread('rsr.xlsx');

rrsr=xlsread('rrsr.xlsx');

ns7=xlsread('ns7.xlsx');

NSE7=xlsread('NSE7.xlsx');

rmse7=xlsread('rmse7.xlsx');

```
rrmse7=xlsread('rrmse7.xlsx');
pbias7=xlsread('pbias7.xlsx');
ppbias7=xlsread('ppbias7.xlsx');
rsr7=xlsread('rsr7.xlsx');
rrsr7=xlsread('rrsr7.xlsx');
QQ=xlsread('QQ.xlsx');
ss=xlsread('s.xlsx');
cor=xlsread('cor.xlsx');
roc=xlsread('corr.xlsx');
id=xlsread('id.xlsx');
fid=xlsread('fid.xlsx');
alfa=xlsread('alpha.xlsx');
delete ('cor.xlsx');
delete('alpha.xlsx');
delete('QC.xlsx');
delete('QQ.xlsx');
delete ('s.xlsx');
delete ('corr.xlsx');
delete('ns.xlsx');
delete ('NSE.xlsx');
delete ('rmse.xlsx');
delete ('rrmse.xlsx');
delete ('pbias.xlsx');
delete ('ppbias.xlsx');
delete ('rsr.xlsx');
delete ('rrsr.xlsx');
delete('ns7.xlsx');
delete ('NSE7.xlsx');
delete ('rmse7.xlsx');
```

```
        delete ('rrmse7.xlsx');
        delete ('pbias7.xlsx');
        delete ('ppbias7.xlsx');
        delete ('rsr7.xlsx');
        delete ('rrsr7.xlsx');
else
end
corr=xlsread('index.xlsx');
fid=xlsread('fid.xlsx');
delete ('q.xlsx');
delete ('Qn.xlsx');
Qq=xlsread(fopen(fid(corr)));
nnn=find(isnan(Qq));
Qq(nnn)=0;
q = Qq(1 : round(length(Qq) * 0.5));
t=0;
L=1;
r=[];
n=1;
G=130;
j=1;
o=1;
ZZ=[];
u=length(q)-1;
j=1;n=1;
z=1;
r=[];
e=1;
PPP=[2,2,2,2,2];
```

```
QQQ=[6,20,45,80,120];
for     i=G:u
if     ((q(i) > q(i + 1)) && (q(i) ~= q(i + 1)))
        x(n,j)=q(i);
        n=n+1;
else
        x(n,j)=q(i);
        i;
        j=j+1;
        n=1;
end
end
e=x;
e(1,:)=[];
r=[];
l = length(e);
for     i=1:l
        a=e(:,i);
if     (nnz(a) > 6)
        r=[[r],a];
end
end
xlswrite('mdisCHARGE.xlsx',r)
d=xlsread('mdisCHARGE.xlsx');
size(d);
[m, n] = size(d);
y=[];
x=[];
j=1;l=1;
```

```
for        i=1:n
           p=d(:,i);
           p(p==0)=[];
           r=length(p);
for        k=1:r-1
           [Y] = log(-((p(j+1) - p(j))/86400));
           y=[y;Y];
           [X] = log((p(j) + p(j+1))/(2));
           x=[x;X];
           j=j+1;
end
           syms a b ;
           eqn(1) = sum(y) - a * sum(x) - (length(x)) * b;
           eqn(2) = sum(x. * y) - a * sum(x. * x) - b * sum(x);
           [a, b] = solve(eqn(1), eqn(2));
           Q(l,1)=double(a);
           Q(l,2)=exp(double(b));
           l=l+1;
           x=[];
           [X] = [];
           [Y] = [];
           y=[];
           j=1;
end
xlswrite('recessionconstants.xlsx',Q);
q=xlsread('recessionconstants.xlsx');
a=median(q(:,1));
alfa(corr)=a;
d=xlsread('mdisCHARGE.xlsx');
```

```
[m, n] = size(d);
y=[];
x=[];
j=1;l=1;
for     i=1:n
        p=d(:,i);
        p(p==0)=[];
        r=length(p);
for     k = 1 : r − 1
        [Y] = log(−((p(j + 1) − p(j))/86400));
        y=[y;Y];
        [X] = log((p(j) + p(j + 1))/(2));
        x=[x;X];
        j=j+1;
end
        syms c ;
        eqn(1) = sum(y) − a ∗ sum(x) − (length(x)) ∗ c;
        [c] = solve(eqn(1));
        c=double(c);
        Z(l,1)=exp(c);
        l=l+1;
        x=[];
        [X] = [];
        [Y] = [];
        y=[];
        j=1;
end
xlswrite('finalk.xlsx',Z)
z=[];
```

```
t=0;
z=[];
r=[];
n=1;
j=1;
o=1;
clear q
q = Qq(1 : round(length(Qq) * 0.5));
for      i=G:u
if      ((q(i) > q(i + 1))&&(q(i) ~= q(i + 1)))
         x(n,j)=q(i);
         n=n+1;
         y=j;
         s = nnz(x(:, y)) - 1;
else
         x(n,j)=q(i);
         j=j+1;
         n=1;
         y = j - 1;
         s = nnz(x(:, y)) - 1;
if      (s > 6)
         t=t+1;
for      k=1:5
if      (s > 6)
         v = (i - s - PPP(k)) : -1 : (i - s - (QQQ(k) + 1));
         i;
         s;
         QQQ(k);
         v;
```

```
q(v);
a=mean(q(v));
Qn(t,k)=a;
else
end
end
else
end
end
end
[m,n] = size(Qn);
f=Qn(:,1);
f=find(f==0);
Qn(f,:)=[];
W=xlsread('finalk.xlsx');
W(f)=[];
delete ('finalk.xlsx');
xlswrite('finalk.xlsx',W);
xlswrite('Qn.xlsx',Qn)
Qn=xlsread('Qn.xlsx');
n_m = 1;
j_m = 1;
[m,n] = size(Qn);
for l_m = 1 : m
q_m = Qn(l_m, :);
q_m = q_m';
for (i_m = 1 : 4)
if (((q_m(i_m) > q_m(i_m + 1))&&(q_m(i_m) ~= q_m(i_m + 1))))
x_m(n_m, j_m) = q_m(i_m);
```

$n\_m = n\_m + 1;$

if $i\_m == 4$

$x\_m(n\_m, j_m) = q\_m(i\_m + 1);$

$j\_m = j\_m + 1;$

else

end

else

$x\_m(n\_m, j\_m) = q_m(i\_m);$

$q\_m(i\_m + 1 : length(q\_m))$=0;

$j\_m = j\_m + 1;$

$n\_m = 1;$

end

end

end

$r\_m = [];$

$e\_m = x\_m;$

$[sx, sy] = size(x\_m);$

for $i\_m = 1 : sy$

$a\_m = e\_m(:, i\_m);$

if $(nnz(a_m) > 0)$

$r\_m = [[r\_m], a\_m];$

end

end

$[sx, sy] = size(r_m);$

for $m\_r = 1 : sy$

$P\_m = r\_m(:, m_r);$

$P\_m(P\_m == 0) = [];$

$R\_nm(m\_r) = mean(P\_m);$

end

$xlswrite('Q.xlsx', R\_nm')$

```
Q=xlsread('Q.xlsx');
Qn=xlsread('Qn.xlsx');
Qn=[Qn,Q];
[M,N] = size(Qn);
W=xlsread('finalk.xlsx');
W=W(1:M);
for     K=1:N
        X=Qn(:,K);
        Y=W;
        nnz(X);
        f=find(X==0);
        X(f)=[];
        Y(f)=[];
        nn=find(isnan(X));
        X(nn)=[];
        Y(nn)=[];
        X=log(X);
        size(Qn);
        size(X);
        size(Y);
        A=sum(X);
        B=sum(Y);
        C=sum(X.*X);
        D=sum(Y.*Y);
        E=sum(X.*Y);
        R = (length(X)*E - A*B)/sqrt((length(X)*C - A^2)*(length(X)*D - B^2));
        cor(corr,K) = R^2;
        syms a b
```

```
        (1)=sum(Y)-a*sum(X)-(length(X))*b;
        eqn(2)=sum(X.*Y)-a*sum(X.*X)-b*sum(X);
        [a,b] = solve(eqn(1),eqn(2));
        QQ(corr,1)=double(a);
        QQ(corr,2)=exp(double(b));
        xlswrite('QQ.xlsx',QQ);
end
[v,I] = max(cor(corr,:));
id(corr)=I;
xlswrite('alpha.xlsx',alfa);
xlswrite('cor.xlsx',cor);
xlswrite('id.xlsx',id);
m=1;
alfa=alfa';
alfa=alfa(corr);
m=1;
clear p
clear d
d = xlsread('1_mdisCHARGE.xlsx');
Qus=xlsread('Qus.xlsx');
for     k=1:length(Qus)
        p=d(:,k);
        for l=1:nnz(p)
        QC(m,k) = ((alfa-1)*QQ(corr,2)*l*86400*(Qus(k)^(QQ(corr,1))))^(1/(1-alfa));
        m=m+1;
end
        p(p==0)=[];
        y=p;
        m=1;
```

```
end
xlswrite('QC.xlsx',QC)
size(QC);
size(d);
r=[];
s=[];
k=1;
k=1;
r=[];
s=[];
for     j=4
        Qus=xlsread('Qus.xlsx');
        f=find(Qus==0);
        xx = xlsread('1_mdisCHARGE.xlsx');
        xx(:,f)=[];
        yy=xlsread('QC.xlsx');
        yy(:,f)=[];
if      (j - 1) > 0
        xx(1 : j - 1, :) = [];
        yy(1 : j - 1, :) = [];
for       i = 1 : length(Qus) - length(f)
        X=xx(:,i);
        X(X==0)=[];
        r=[(r);X];
end
        size(r);
        fori = 1 : length(Qus) - length(f)
        Y=yy(:,i);
        Y(Y==0)=[];
```

s=[(s);Y];

end

size(s);

x=r;

y=s;

$ss(corr, k) = sum(x. * y)/sum(y. * y)$;

Y=ss(corr,k).*y;

$a = sum((Y - x).^2)$;

$b = sum((x - mean(x)).^2)$;

$roc(corr, k) = 1 - a/b$;

$ns(corr, k) = 1 - (sum((r - s).^2)/sum((r - mean(r)).^2))$;

$rmse(corr, k) = sqrt(sum((r - s).^2)/length(r))$;

$pbias(corr, k) = (sum((r - s)) * 100)/sum((r))$;

$rsr(corr, k) = sqrt((sum((r - s).^2)/sum((r - mean(r)).^2)))$;

$s = s. * ss(corr, k)$;

$NSE(corr, k) = 1 - (sum((r - s).^2)/sum((r - mean(r)).^2))$;

$rrmse(corr, k) = sqrt(sum((r - s).^2)/length(r))$;

$ppbias(corr, k) = (sum((r - s)) * 100)/sum((r))$;

$rrsr(corr, k) = sqrt((sum((r - s).^2)/sum((r - mean(r)).^2)))$; rr=xlsread('QC.xlsx');

$s\_s = xlsread('1\_mdisCHARGE.xlsx')$;

$rr = rr(7, :)$;

$s\_s = s\_s(7, :)$;

rr=rr';

$s\_s = s\_s'$;

$sj = length(s\_s) - length(rr)$;

if $(sj > 0)$

$s\_s = s\_s(1 : length(s\_s) - sj)$;

else

end

$xlswrite('rr.xlsx', [rr, s\_s]);$

$ns7(corr, k) = 1 - (sum((s\_s - rr).^2)/sum((s\_s - mean(s\_s)).^2));$

$rmse7(corr, k) = sqrt(sum((rr - s\_s).^2)/length(rr));$

$pbias7(corr, k) = (sum((s\_s - rr)) * 100)/sum((s_s));$

$rsr7(corr, k) = sqrt((sum((s_s - rr).^2)/sum((s_s - mean(s\_s)).^2)));$

$s_ss(corr, k) = sum(rr. * s\_s)/sum(rr. * rr);$

$rr = rr. * s\_ss(corr, k);$

$NSE7(corr, k) = 1 - (sum((s\_s - rr).^2)/sum((s_s - mean(s\_s)).^2));$

$rrmse7(corr, k) = sqrt(sum(rr - s\_s).^2/length(rr));$

$ppbias7(corr, k) = (sum((s\_s - rr)) * 100)/sum((s\_s));$

$rrsr7(corr, k) = sqrt((sum((s\_s - rr).^2)/sum((s\_s - mean(s_s)).^2)));$

rr=[];

$s\_s = [];$

r=[];

s=[];

else

end

xlswrite('corr.xlsx',roc);

xlswrite('s.xlsx',ss);

xlswrite('ns.xlsx',ns);

xlswrite('NSE.xlsx',NSE);

xlswrite('rmse.xlsx',rmse);

xlswrite('rrmse.xlsx',rrmse);

xlswrite('pbias.xlsx',pbias);

xlswrite('ppbias.xlsx',ppbias);

xlswrite('rsr.xlsx',rsr);

xlswrite('rrsr.xlsx',rrsr);

xlswrite('ns7.xlsx',ns7);

xlswrite('NSE7.xlsx',NSE7);

```
xlswrite('rmse7.xlsx',rmse7);
xlswrite('rrmse7.xlsx',rrmse7);
xlswrite('pbias7.xlsx',pbias7);
xlswrite('ppbias7.xlsx',ppbias7);
xlswrite('rsr7.xlsx',rsr7);
xlswrite('rrsr7.xlsx',rrsr7);
clear all
ns=xlsread('ns.xlsx');
NSE=xlsread('NSE.xlsx');
rmse=xlsread('rmse.xlsx');
rrmse=xlsread('rrmse.xlsx');
pbias=xlsread('pbias.xlsx');
ppbias=xlsread('ppbias.xlsx');
rsr=xlsread('rsr.xlsx');
rrsr=xlsread('rrsr.xlsx');
ns7=xlsread('ns7.xlsx');
NSE7=xlsread('NSE7.xlsx');
rmse7=xlsread('rmse7.xlsx');
rrmse7=xlsread('rrmse7.xlsx');
pbias7=xlsread('pbias7.xlsx');
ppbias7=xlsread('ppbias7.xlsx');
rsr7=xlsread('rsr7.xlsx');
rrsr7=xlsread('rrsr7.xlsx');
ss=xlsread('s.xlsx');
roc=xlsread('corr.xlsx');
corr=xlsread('index.xlsx');
id=xlsread('id.xlsx');
fid=xlsread('fid.xlsx');
alfa=xlsread('alpha.xlsx');
```

```
        QQ=xlsread('QQ.xlsx');
        delete ('Qus.xlsx');
        delete ('finalk.xlsx');
        delete ('Qn.xlsx');
        delete ('recessionconstants.xlsx');
        delete ('Q.xlsx');
        delete ('mdisCHARGE.xlsx');
        delete ('1_mdisCHARGE.xlsx');
        delete ('QC.xlsx');
end
end
delete ('fid.xlsx');
delete('id.xlsx');
delete ('s.xlsx');
delete ('recessionevents.xlsx');
delete ('QQ.xlsx');
delete ('QC.xlsx');
delete ('index.xlsx');
delete('corr.xlsx');
delete ('cor.xlsx');
delete ('alpha.xlsx');
delete('ns.xlsx');
delete ('NSE.xlsx');
delete ('rmse.xlsx');
delete ('rrmse.xlsx');
delete ('pbias.xlsx');
delete ('ppbias.xlsx');
delete ('rsr.xlsx');
delete ('rrsr.xlsx');
```

delete('ns7.xlsx');

delete ('NSE7.xlsx');

delete ('rmse7.xlsx');

delete ('rrmse7.xlsx');

delete ('pbias7.xlsx');

delete ('ppbias7.xlsx');

delete ('rsr7.xlsx');

delete ('rrsr7.xlsx');

xlswrite($'Q\_4\_50m50\_lmVslp\_341.xlsx', [ns7, NSE7, rmse7, rrmse7, pbias7, ppbias7, rsr7, rrsr7]$);

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