CE 3372 Water Systems Design
Exam 3
Spring 2018

Instructions:

1. Be sure to put your name on **each** sheet(including this one!).
2. Choose the closest answer for questions with multiple choice answers; show work if you desire partial credit (e.g. arithmetic mistakes cost less if you include your work).

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1. (6 pts) Write three equations (name and equation) that deal with head loss due to pipe friction. Which of the three equations is intended for use with only water?

2. (6 pts) Describe how to use the system head curve in a pressure pipe system. What does it help a designer select?

3. (6 pts) Define and explain in the context of specific energy; subcritical, critical, and supercritical flow in a channel. What does it help a designer select?

4. (6 pts) Explain why population forecasting is important for both water distribution and wastewater collection system designs.

5. (6 pts) Explain why combined sewer systems are no longer constructed in the USA (and elsewhere).

6. (6 pts) What is a lift station, why are they useful?

7. (6 pts) Define the inlet time for an urbanized drainage area.

8. (6 points) Define inflow and infiltration in the context of a sanitary sewer system.

9. (24 Points) Consider the pipe network portion shown in Figure 1.

   Node 6 has total head of 200 meters
   P1 friction factor is $f = 0.015$; P2 friction factor is $f = 0.017$
   P3 friction factor is $f = 0.017$; P4 friction factor is $f = 0.035$
   P5 friction factor is $f = 0.017$; P6 friction factor is $f = 0.017$
   P7 friction factor is $f = 0.035$; P8 friction factor is $f = 0.017$
   The elevation of the nodes are all 0 meters.

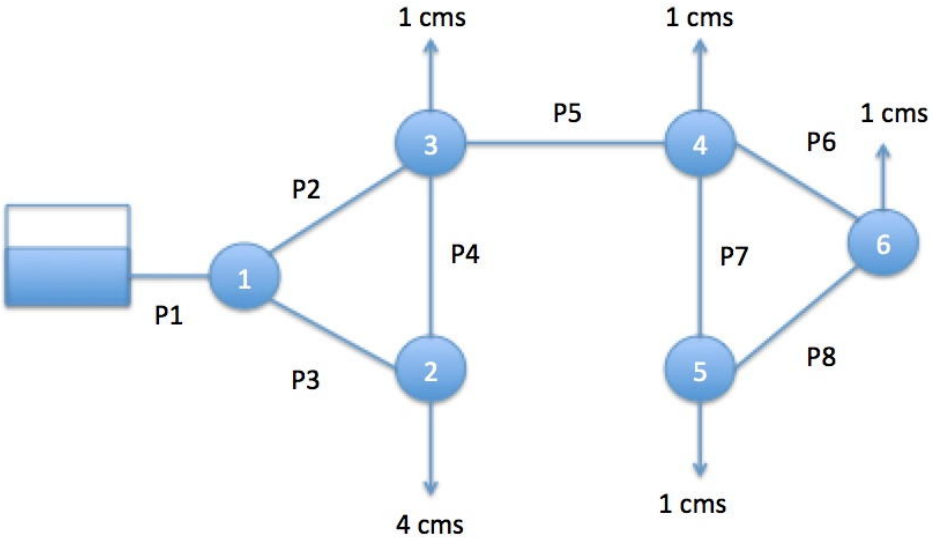

Figure 1. Pipe Network.

a) What is the discharge, in cubic meters per second in Pipe P1?

b) What is the discharge, in cubic meters per second in Pipe P5?

c) Assume the discharge leaving Node 1, divides evenly into pipe P2 and P3. What is the discharge, in cubic meters per second in Pipe P2?

d) What is the discharge, in cubic meters per second in Pipe P3?

e) Compute the head loss using the Darcy-Weisbach loss model. What is the head loss in pipe P2 in meters?

f) What is the head loss in pipe P3 in meters?

g) What is the discharge, in cubic meters per second in Pipe P4? (Explain)

h) What is the head loss in pipe P5 in meters?

i) Assume the discharge leaving Node 4, divides evenly into pipe P6 and P7. What is the discharge, in cubic meters per second in Pipe P6?

j) What is the discharge, in cubic meters per second in Pipe P7?

k) What is the head loss in pipe P6 in meters?

l) What is the head loss in pipe P7 in meters?

m) What is the discharge, in cubic meters per second in Pipe P8? (Explain)

n) What is the **head** in meters at each node (including the reservoir pool elevation)?

10. (10 points) Figure 2 shows ten (10) sources of non-permitted drainage into a sanitary sewer system. For each listed source classify the source type as infiltration or inflow and complete Table 1

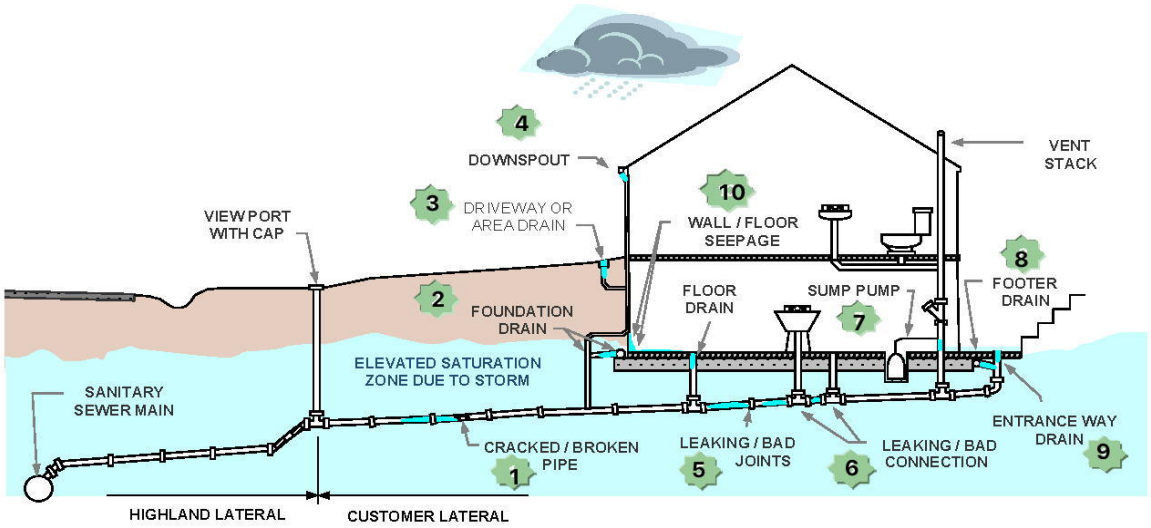

Figure 2. Schematic of Inflow and Infiltration Sources.

Table 1. Inflow and Infiltration Source Classification.

Source ID	Source Name	Source Type (Inflow or Infiltration?)
1	Cracked/Broken Pipe	
2	Foundation Drain	
3	Driveway or Area Drain	
4	Downspout	
5	Leaking/Bad Joints	
6	Leaking/Bad Connection	
7	Sump Pump	
8	Footer Drain	
9	Entrance Way Drain	
10	Wall/Floor Seepage	

11. (26 pts) Consider the three drainage areas that drain to the inlets connected to the pipes as shown in Figure 3. A stormwater drainage system is being designed to carry the flow from the three areas. Table 2 lists drainage area information.

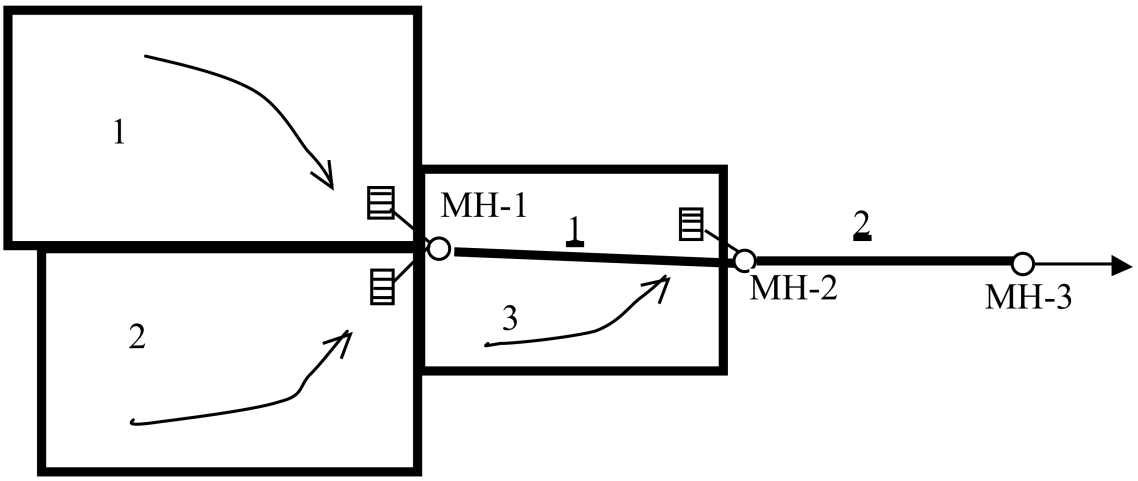

Figure 3. Drainage System Layout.

Table 2. Contributing Area Information.

Area ID	Area (acres)	C (runoff coefficient)	Inlet Time (minutes)
DA-1	6.0	0.66	18
DA-2	5.1	0.56	15
DA-3	3.5	0.75	13

Table 3 lists pipe information.

Table 3. Pipe Information.

Pipe_ID	Upstream Junction	Downstream Junction	Length (feet)	Slope	Manning's n
P1	MH-1	MH-2	600	0.003	0.015
P2	MH-2	MH-3	600	0.003	0.015

The allowable velocity at design flow is between 2 and 10 feet-per-second. The pipes are to be sized so they flow 1/2 full at the design discharge.

$$I = \frac{56.6}{(T_c + 8.6)^{0.823}} \tag{1}$$

Equation 1 is the 10-year ARI intensity equation for the area, where I is intensity in inches-per-hour, and T_c is the averaging time, in minutes. Depending on the location in the system it may be just the local inlet time, or a time of concentration that includes upstream contributions and pipe travel time.

Determine the design flow rates in cfs and diameters in inches for both pipes. Use Table 4 to summarize your results, and show your work. (The next page is blank and should be used to show your work)

Table 4. Drainage Preliminary Design.

Pipe_ID	Length (ft)	Area (ac.)	$\sum CA$	T_C (min)	I (in/hr)	Q (cfs)	$D_{calc.}$ (ft)	D_{used} (in)	V_{pipe} (ft/s)	T_{pipe} (min)
P-1	600									
P-2	600									

Problem 11 (Continued space if needed)

12. (32 points) Listing 1 is a SWMM input file listing, and Listing 2 is a SWMM summary file for a particular sewer system. Using these files answer the following questions:

    a) How many sub-catchments are modeled?

    b) How many outfalls are modeled?

    c) How many conduits are modeled?

    d) What is the intensity of the design storm applied in the SWMM model (in inches per hour)?

    e) How long (in hours) is the storm applied to the drainage system?

    f) What is the maximum discharge from the system in cubic feet per second?

    g) What is the diameter in inches of the most downstream conduit?

    h) What is the diameter in feet of the most upstream conduit?

    i) How many junctions are modeled?

    j) Are any of the conduits offset relative to a connecting junction?

    k) What was the run date of the model?

l) Which conduit had the largest peak flow?

m) Which drawing below is representative of the downstream (outfall) boundary condition in the SWMM model?

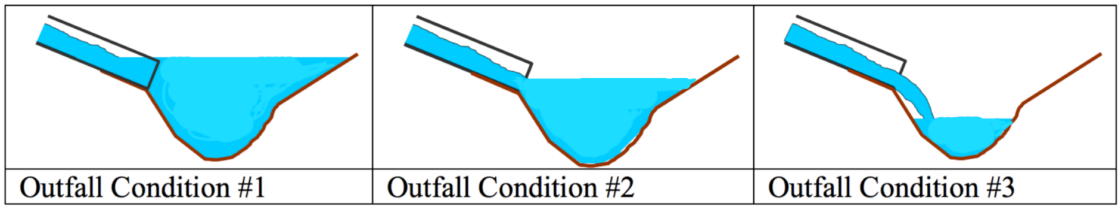

Figure 4. Conceptual downstream boundary conditions.

n) Which conduit had the smallest peak flow?

o) What was the depth of water in the conduit with the smallest flow (in feet)?

p) What was the depth of water in the conduit with the largest flow (in feet)?

q) What was the total runoff, in watershed inches, for the model?

r) What hydrologic method was used in the model?

s) What flow routing method was used in the model?

t) What version number and build number of SWMM was used in the model?

u) Sketch a plan view of the system. Label the nodes and links using the naming convention in the file(s); indicate flow directions on the sketch. Indicate on your sketch where flows enter the sewer system, where it exits the system, and the magnitude of peak flow(s) as indicated in the files. Indicate the conduit lengths and diameters. Indicate the node invert elevations.

Listing 1. SWMM Input File Listing.

```
[TITLE]
;;Project Title/Notes
[OPTIONS]
;;Option             Value
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         KINWAVE
LINK_OFFSETS         DEPTH
MIN_SLOPE            0
ALLOW_PONDING        NO
SKIP_STEADY_STATE    NO
START_DATE           04/26/2017
START_TIME           00:00:00
REPORT_START_DATE    04/26/2017
REPORT_START_TIME    00:00:00
END_DATE             04/26/2017
END_TIME             06:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:01:00
WET_STEP             00:01:00
DRY_STEP             01:00:00
ROUTING_STEP         0:00:30
INERTIAL_DAMPING     PARTIAL
NORMAL_FLOW_LIMITED  BOTH
FORCE_MAIN_EQUATION  H-W
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         12.557
MAX_TRIALS           8
HEAD_TOLERANCE       0.005
SYS_FLOW_TOL         5
LAT_FLOW_TOL         5
[EVAPORATION]
;;Evap Data      Parameters
;;-------------- ----------------
CONSTANT         0.0
DRY_ONLY         NO
[RAINGAGES]
;;Gage           Format    Interval SCF      Source
;;-------------- --------- ------ ------ ----------
1                INTENSITY 1:00     1.0      TIMESERIES DESIGN-STORM
[SUBCATCHMENTS]
;;Subcatchment   Rain Gage        Outlet           Area     %Imperv  Width    %Slope
;;-------------- ---------------- ---------------- -------- -------- -------- --------
1                1                4                6        65       2500     0.5
2                1                4                5.1      55       2000     0.5
3                1                5                3.5      70       2000     0.5
[SUBAREAS]
;;Subcatchment   N-Imperv   N-Perv     S-Imperv   S-Perv     PctZero    RouteTo
;;-------------- ---------- ---------- ---------- ---------- ---------- ----------
1                0.01       0.1        0.05       0.05       25         OUTLET
2                0.01       0.1        0.05       0.05       25         OUTLET
3                0.01       0.1        0.05       0.05       25         OUTLET
[INFILTRATION]
;;Subcatchment   MaxRate    MinRate    Decay      DryTime    MaxInfil
;;-------------- ---------- ---------- ---------- ---------- ----------
1                10         6          4          7          0
2                12         6          4          7          0
3                12         6          4          7          0
[JUNCTIONS]
;;Junction       Invert     MaxDepth   InitDepth  SurDepth   Aponded
;;-------------- ---------- ---------- ---------- ---------- ----------
4                6.34       10         0          0          0
5                3.92       10         0          0          0
6                2          10         0          0          0
[OUTFALLS]
;;Outfall        Invert     Type       Stage Data       Gated
;;-------------- ---------- ---------- ---------------- --------
7                0          FREE                        NO
[CONDUITS]
;;Conduit     From    To      Length  Roughness  InOffset OutOffset InitFlow MaxFlow
             Node    Node
;;--------- ---------- ---------- ------- -------- ------- -------    -------  -------
2            5            6       600    0.013      0       0       0          0
1            4            5       600    0.013      0       .5      0          0
3            6            7       600    0.013      0       0       0          0
[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
2                CIRCULAR     3.5              0          0          0          1
1                CIRCULAR     3                0          0          0          1
3                CIRCULAR     3.5              0          0          0          1
[TIMESERIES]
;;Time Series    Date       Time       Value
;;-------------- ---------- ---------- ----------
DESIGN-STORM                0          4.4
DESIGN-STORM                1          4.4
DESIGN-STORM                2          4.4
```

```
DESIGN-STORM                3          4.4
DESIGN-STORM                4          0
DESIGN-STORM                5          0
DESIGN-STORM                6          0
DESIGN-STORM                7          0
[REPORT]
;;Reporting Options
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
[TAGS]
[MAP]
DIMENSIONS 0.000 0.000 10000.000 10000.000
Units      None
[COORDINATES]
;;Node           X-Coord            Y-Coord
;;-------------- ------------------ ------------------
4                -371.901           8402.204
5                1584.022           8388.430
6                3415.978           8415.978
7                5234.160           8429.752
[VERTICES]
;;Link           X-Coord            Y-Coord
;;-------------- ------------------ ------------------
[Polygons]
;;Subcatchment   X-Coord            Y-Coord
;;-------------- ------------------ ------------------
1                -2162.534          9242.424
1                -633.609           9228.650
1                -647.383           8484.848
1                -2162.534          8512.397
1                -2148.760          9256.198
2                -2148.760          8319.559
2                -647.383           8333.333
2                -688.705           7617.080
2                -2176.309          7603.306
2                -2176.309          8388.430
3                -96.419            9228.650
3                1528.926           9228.650
3                1460.055           8457.300
3                -165.289           8484.848
3                -110.193           9201.102
[SYMBOLS]
;;Gage           X-Coord            Y-Coord
;;-------------- ------------------ ------------------
1                -2231.405          9641.873
```

Listing 2. SWMM Output Summary File Listing.

```
 EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.007)
  ------------------------------------------------------------
  ***********************************************************
  NOTE: The summary statistics displayed in this report are
  based on results found at every computational time step,
  not just on results from each reporting time step.
  ***********************************************************
  ****************
  Analysis Options
  ****************
  Flow Units ............... CFS
  Process Models:
    Rainfall/Runoff ........ YES
    RDII ................... NO
    Snowmelt ............... NO
    Groundwater ............ NO
    Flow Routing ........... YES
    Ponding Allowed ........ NO
    Water Quality .......... NO
  Infiltration Method ...... HORTON
  Flow Routing Method ...... KINWAVE
  Starting Date ............ APR-26-2017 00:00:00
  Ending Date .............. APR-26-2017 06:00:00
  Antecedent Dry Days ...... 0.0
  Report Time Step ......... 00:01:00
  Wet Time Step ............ 00:01:00
  Dry Time Step ............ 01:00:00
  Routing Time Step ........ 30.00 sec
  Variable Time Step ....... YES
  Maximum Trials ........... 8
  Head Tolerance ........... 0.005000 ft
  ************************         Volume         Depth
  Runoff Quantity Continuity     acre-feet        inches
  ************************     ---------       -------
  Total Precipitation ......        21.413        17.600
  Evaporation Loss .........         0.000         0.000
  Infiltration Loss ........         7.986         6.564
  Surface Runoff ...........        13.402        11.015
  Final Surface Storage ....         0.029         0.024
```

```
Continuity Error (%) .....        -0.018
**************************        Volume         Volume
Flow Routing Continuity        acre-feet      10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......        13.402          4.367
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........         0.000          0.000
External Outflow .........        13.396          4.365
Internal Outflow .........         0.000          0.000
Evaporation Loss .........         0.000          0.000
Exfiltration Loss ........         0.000          0.000
Initial Stored Volume ....         0.000          0.000
Final Stored Volume ......         0.001          0.000
Continuity Error (%) .....         0.043
****************************
Time-Step Critical Elements
****************************
None
********************************
Highest Flow Instability Indexes
********************************
All links are stable.
*************************
Routing Time Step Summary
*************************
Minimum Time Step           :    30.00 sec
Average Time Step           :    29.96 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     2.08
Percent Not Converging      :     0.14
****************************
Subcatchment Runoff Summary
****************************
-------------------------------------------------------------------------------------------------------

                          Total      Total      Total      Total      Total       Total
                         Precip  Peak Runon     Evap      Infil     Runoff      Runoff
                                 Runoff Coeff
Subcatchment                 in         in         in         in         in    10^6 gal
          CFS
-------------------------------------------------------------------------------------------------------

1                         17.60       0.00       0.00       6.16      11.42        1.86
        17.30   0.649
2                         17.60       0.00       0.00       7.92       9.66        1.34
        12.45   0.549
3                         17.60       0.00       0.00       5.28      12.30        1.17
        10.87   0.699
*******************
Node Depth Summary
*******************
-----------------------------------------------------------------------
                              Average  Maximum  Maximum  Time of Max
                                Depth    Depth      HGL   Occurrence
Node                 Type        Feet     Feet     Feet  days hr:min
-----------------------------------------------------------------------
4                    JUNCTION    1.37     2.01     8.35     0  00:44
5                    JUNCTION    1.49     2.19     6.11     0  00:09
6                    JUNCTION    1.47     2.16     4.16     0  00:10
7                    OUTFALL     1.35     1.99     1.99     0  00:11
********************
Node Inflow Summary
********************
-------------------------------------------------------------------------------------------------------

                                Maximum  Maximum                    Lateral       Total
                                Lateral    Flow
                                  Total  Time of Max      Inflow      Inflow
                                Balance
                                 Inflow   Inflow   Occurrence      Volume      Volume
                                  Error
Node                 Type           CFS      CFS  days hr:min    10^6 gal    10^6 gal
        Percent
-------------------------------------------------------------------------------------------------------

4                    JUNCTION     29.75    29.75     0  00:45         3.2         3.2
          0.026
5                    JUNCTION     10.87    40.62     0  00:46        1.17        4.37
          0.001
6                    JUNCTION      0.00    40.62     0  00:23           0        4.37
          0.027
7                    OUTFALL       0.00    40.81     0  00:11           0        4.36
          0.000
**********************
Node Surcharge Summary
**********************
No nodes were surcharged.
**********************
```

```
Node Flooding Summary
*********************
No nodes were flooded.
**********************
Outfall Loading Summary
***********************
-------------------------------------------------------------
                        Flow       Avg       Max       Total
                        Freq      Flow      Flow      Volume
Outfall Node            Pcnt       CFS       CFS    10^6 gal
-------------------------------------------------------------
7                      99.86     27.02     40.81       4.365
-------------------------------------------------------------
System                 99.86     27.02     40.81       4.365
********************
Link Flow Summary
********************
-------------------------------------------------------------------------------
                                Maximum  Time of Max   Maximum    Max/    Max/
                                 |Flow|   Occurrence   |Veloc|    Full    Full
Link                 Type           CFS  days hr:min    ft/sec    Flow   Depth
-------------------------------------------------------------------------------
2                    CONDUIT      40.62     0  00:23      7.03    0.71    0.62
1                    CONDUIT      29.75     0  00:45      6.37    0.79    0.63
3                    CONDUIT      40.81     0  00:11      6.89    0.70    0.59

**************************
Flow Classification Summary
**************************
-------------------------------------------------------------------------------------------
                    Adjusted    ---------- Fraction of Time in Flow Class ----------
                     /Actual         Up    Down  Sub   Sup   Up    Down  Norm  Inlet
Conduit               Length    Dry  Dry   Dry   Crit  Crit  Crit  Crit  Ltd   Ctrl
-------------------------------------------------------------------------------------------
2                       1.00   0.00  0.00  0.00  0.98  0.02  0.00  0.00  0.33  0.00
1                       1.00   0.00  0.00  0.00  0.00  0.00  0.00  1.00  0.00  0.00
3                       1.00   0.00  0.00  0.00  0.80  0.20  0.00  0.00  0.02  0.00
*************************
Conduit Surcharge Summary
*************************
No conduits were surcharged.
Analysis begun on:  Wed Apr 26 19:29:56 2017
Analysis ended on:  Wed Apr 26 19:29:56 2017
Total elapsed time: < 1 sec
```

List your team members names below. For each team member assess their performance. Consider their actual participation, their timeliness at completing assignment tasks, their reliability on completing assignment tasks. Also state (1) whether you would be willing to work with them again on team assignments, and (2) whether you would recommend them to a friend who is trying to assemble a team for a future class.

1) _____

2) _____

3) _____

4) _____

5) _____