CONDUIT GENERATOR – CONGEN (VERSION 1.10)

Note: necessary input file modifications in comparison to previous versions of CONGEN are marked with red font

CONGEN is a tool to generate the MODFLOW-2005 Conduit Flow Process (CFP) dataset that describes how nodes are connected to the MODFLOW model cells, and how node-pipe connections are formed; see line 8 of the CFP input file (documented in Shoemaker et al. 2008, p. 28). CONGEN uses a matrix with node elevations to calculate the node network (node number, neighboring nodes and tubes etc.). ***Please note:*** *CONGEN is tested with several test problems. Despite our best efforts, errors may still exist. Distribution of CONGEN does not constitute any warranty. No responsibility is assumed for use or misuse of CONGEN. Recent changes:*

- *Version 1.9 (June 14, 2013) considers nodes organized in different planes, which can be vertically connected. See example 5 for further details*
- *Version 1.10 (July 30, 2013) considers the layer elevation as matrix data (rather than an uniform value for the whole domain)*

Input file: CONGEN should be executed without parameters. The executable needs an *input.dat* file placed in the same folder. The *input.dat* file should be structured as described subsequently. Further formatting (e.g. position within the input line) is not necessary.

Table 1: Input for CONGEN

Line No#	Content	Example with uniform layer elevation	Example with cell-by-cell layer elevation
1	matrix dimensions (number of rows, number of columns, both integers)	25 25	25 25
2	number of layers (integer; a negative value marks that top and bottom elevation data for each layer in lines 3a/b is provided as matrix with a value for each cell), (optional) number of node planes	2 2	-2 2
3a +	Comment line; one line for each data set (3b/3c+)	# layer 1 top	# layer 1 top
3b	layer top of the upper layer (real)	50.0	50.0 50.0 50.0 50.0 50.0 … …
		# layer 1 bottom	# layer 1 bottom
3c+	bottom elevation (real)	10.0	10.0 10.0 10.0 10.0 10.0 … …
		# layer 2 bottom	# layer 2 bottom
		0.0	0.0 0.0 0.0 0.0 0.0 … …
4a +	Comment line; one line for each plane	# plane 1	# plane 1
4b +	cell value (-999 for matrix only cells – otherwise the node height; real numbers), nodes that are considered as vertical connections between two planes should be marked by a preceding "c" in each plane; *nrow lines; one data set for each plane*	-999 c40.2 -999 40.2 -999 … …	-999 c40.2 -999 40.2 -999 … …
		# plane 2	# plane 2
		-999 c20.2 -999 20.2 -999 … …	-999 c20.2 -999 20.2 -999 … …

Output: CONGEN generates an output control file. Within this file, the node network table as used by CFP is marked. From there it can be directly copied into the CFP input file.

Example 1: This example uses the simple matrix which comes with the CAVE model (case study 1, also used for the CFP report). The matrix consists of 4 rows and 5 columns. The conduit network is designed as shown in the following scheme:

```
      CONDUIT SYSTEM:                       MODFLOW CELLS:
       node numbers                   columns
                                         1    2    3    4    5
                                       ------------------------
         1                          1  |    |    |    |    |    |  r
         |                             |    |    |    |    |    |  o
     2---3---4---5                     ---------------------     w
                                    2  |    | 1  |    |    |    |  s
       tube numbers                    |    | |  |    |    |    |
                                       ---------------------
         *                          3  | 2- |-3- |-4- |-5  |    |
         |1                            |    |    |    |    |    |
     *---*---*---*                     ---------------------
       2   3   4                    4  |    |    |    |    |    |
                                       |    |    |    |    |    |
                                       ---------------------
```

Furthermore, the model domain is divided in two layers. Layer one reaches from 50 m to 19 m and layer two from 19 m to 0 m. The node elevations are: node 1 = 20.1 m, node 2 = 19.1 m, node 3 = 20 m; node 4 = 19 m, and node 5 = 18.9 m.

Input.dat

```
         4          5
         2
#layer 1 top
        50
#layer 1 bottom
        19
#layer 2 bottom
         0
#plane 1
 -999 -999 -999 -999 -999
 -999 20.1 -999 -999 -999
 19.1 20.0   19 18.9 -999
 -999 -999 -999 -999 -999
```

Node network table within the output control file (NO is node number; MC, MR, ML are column, row, and layer number with regard to the MODFLOW model; NB1 to NB6 are neighbor node numbers; TB1 to TB6 are neighbor tube numbers; for further explanation please refer to Shoemaker et al. 2008, p. 28)

NO	MC	MR	ML	NB1	NB2	NB3	NB4	NB5	NB6	TB1	TB2	TB3	TB4	TB5	TB6
1	2	2	1	3	0	0	0	0	0	1	0	0	0	0	0
2	1	3	2	3	0	0	0	0	0	2	0	0	0	0	0
3	2	3	1	1	4	2	0	0	0	1	3	2	0	0	0
4	3	3	2	5	3	0	0	0	0	4	3	0	0	0	0
5	4	3	2	4	0	0	0	0	0	4	0	0	0	0	0

Example 2: In this case a more complex conduit geometry will be handled. Therefore the application of a graphic pre-processing tool such as spreadsheet programs can be helpful (for example MICROSOFT EXCEL). Figure 1 shows the conduit network structure.

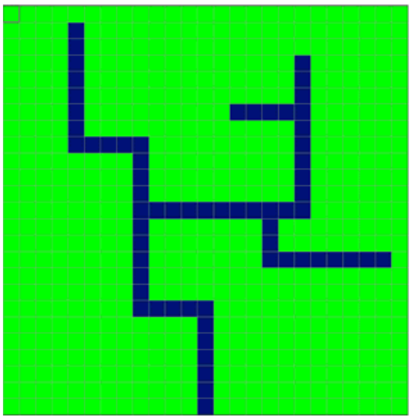

Figure 1: Illustration of the conduit network (blue cells are conduit nodes)

The model domain consists of one layer (0 m to 20 m) and the node height is always 10 m. The first suggested step is to create the model grid with a spreadsheet program (e.g. MICROSOFT EXCEL). The whole matrix should get the value -999, which means no node in this cell. Next, conduit nodes can be included by assigning cells with their specific conduit height. Finally, the matrix can be copied to the text input file. It can be necessary to re-format the saved matrix (e.g. substitution of formatting signs by simple spaces). Finally add lines 1 to 3 (see Table 1) and save the data as input.dat.

Input.dat

```
        25        25
         1
#layer 1 top
        20
#layer 1 bottom
         0
# plane 1
 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999   10   10   10   10   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999   10   10   10   10   10 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10   10   10   10   10   10   10   10   10   10   10 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999   10   10   10   10   10   10   10   10 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999   10   10   10   10   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999
 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999 -999   10
```

NBR data within the output control file

NO	MC	MR	ML	NB1	NB2	NB3	NB4	NB5	NB6	TB1	TB2	TB3	TB4	TB5	TB6
1	5	2	1	2	0	0	0	0	0	1	0	0	0	0	0
2	5	3	1	1	3	0	0	0	0	1	2	0	0	0	0
3	5	4	1	2	5	0	0	0	0	2	3	0	0	0	0
4	19	4	1	6	0	0	0	0	0	4	0	0	0	0	0
5	5	5	1	3	7	0	0	0	0	3	5	0	0	0	0
6	19	5	1	4	8	0	0	0	0	4	6	0	0	0	0
7	5	6	1	5	9	0	0	0	0	5	7	0	0	0	0
8	19	6	1	6	14	0	0	0	0	6	8	0	0	0	0
9	5	7	1	7	15	0	0	0	0	7	9	0	0	0	0
10	15	7	1	11	0	0	0	0	0	10	0	0	0	0	0
11	16	7	1	12	10	0	0	0	0	11	10	0	0	0	0
12	17	7	1	13	11	0	0	0	0	12	11	0	0	0	0
13	18	7	1	14	12	0	0	0	0	13	12	0	0	0	0
14	19	7	1	8	16	13	0	0	0	8	14	13	0	0	0
15	5	8	1	9	17	0	0	0	0	9	15	0	0	0	0
16	19	8	1	14	22	0	0	0	0	14	16	0	0	0	0
17	5	9	1	15	18	0	0	0	0	15	17	0	0	0	0
18	6	9	1	19	17	0	0	0	0	18	17	0	0	0	0
19	7	9	1	20	18	0	0	0	0	19	18	0	0	0	0
20	8	9	1	21	19	0	0	0	0	20	19	0	0	0	0
21	9	9	1	23	20	0	0	0	0	21	20	0	0	0	0
22	19	9	1	16	24	0	0	0	0	16	22	0	0	0	0
23	9	10	1	21	25	0	0	0	0	21	23	0	0	0	0
24	19	10	1	22	26	0	0	0	0	22	24	0	0	0	0
25	9	11	1	23	27	0	0	0	0	23	25	0	0	0	0
26	19	11	1	24	28	0	0	0	0	24	26	0	0	0	0
27	9	12	1	25	29	0	0	0	0	25	27	0	0	0	0
28	19	12	1	26	39	0	0	0	0	26	28	0	0	0	0
29	9	13	1	27	30	40	0	0	0	27	29	30	0	0	0
30	10	13	1	31	29	0	0	0	0	31	29	0	0	0	0
31	11	13	1	32	30	0	0	0	0	32	31	0	0	0	0
32	12	13	1	33	31	0	0	0	0	33	32	0	0	0	0
33	13	13	1	34	32	0	0	0	0	34	33	0	0	0	0
34	14	13	1	35	33	0	0	0	0	35	34	0	0	0	0
35	15	13	1	36	34	0	0	0	0	36	35	0	0	0	0
36	16	13	1	37	35	0	0	0	0	37	36	0	0	0	0
37	17	13	1	38	41	36	0	0	0	38	39	37	0	0	0
38	18	13	1	39	37	0	0	0	0	40	38	0	0	0	0
39	19	13	1	28	38	0	0	0	0	28	40	0	0	0	0
40	9	14	1	29	42	0	0	0	0	30	41	0	0	0	0
41	17	14	1	37	43	0	0	0	0	39	42	0	0	0	0
42	9	15	1	40	44	0	0	0	0	41	43	0	0	0	0
43	17	15	1	41	45	0	0	0	0	42	44	0	0	0	0
44	9	16	1	42	53	0	0	0	0	43	45	0	0	0	0
45	17	16	1	43	46	0	0	0	0	44	46	0	0	0	0
46	18	16	1	47	45	0	0	0	0	47	46	0	0	0	0
47	19	16	1	48	46	0	0	0	0	48	47	0	0	0	0
48	20	16	1	49	47	0	0	0	0	49	48	0	0	0	0
49	21	16	1	50	48	0	0	0	0	50	49	0	0	0	0
50	22	16	1	51	49	0	0	0	0	51	50	0	0	0	0
51	23	16	1	52	50	0	0	0	0	52	51	0	0	0	0
52	24	16	1	51	0	0	0	0	0	52	0	0	0	0	0
53	9	17	1	44	54	0	0	0	0	45	53	0	0	0	0
54	9	18	1	53	55	0	0	0	0	53	54	0	0	0	0
55	9	19	1	54	56	0	0	0	0	54	55	0	0	0	0
56	10	19	1	57	55	0	0	0	0	56	55	0	0	0	0
57	11	19	1	58	56	0	0	0	0	57	56	0	0	0	0
58	12	19	1	59	57	0	0	0	0	58	57	0	0	0	0
59	13	19	1	60	58	0	0	0	0	59	58	0	0	0	0
60	13	20	1	59	61	0	0	0	0	59	60	0	0	0	0
61	13	21	1	60	62	0	0	0	0	60	61	0	0	0	0
62	13	22	1	61	63	0	0	0	0	61	62	0	0	0	0
63	13	23	1	62	64	0	0	0	0	62	63	0	0	0	0
64	13	24	1	63	65	0	0	0	0	63	64	0	0	0	0
65	13	25	1	64	0	0	0	0	0	64	0	0	0	0	0
66	25	25	1	0	0	0	0	0	0	0	0	0	0	0	0

Example 3: This example is similar to example 1 but with nodes organized in two similar planes, which are connected by one vertical tube. The model domain is divided in three layers. Layer one reaches from 50 m to 19 m, layer two from 19 m to 10 m, and layer three from 10 m to 0 m. The node elevations are: node 1 = 20.1 m, node 2 = 19.1 m, node 3 = 20.0 m; node 4 = 19.0 m, node 5 = 18.9 m, and node 6 to 10 = 5.0 m. The conduit network and the position within the continuum model are shown in Figure 2.

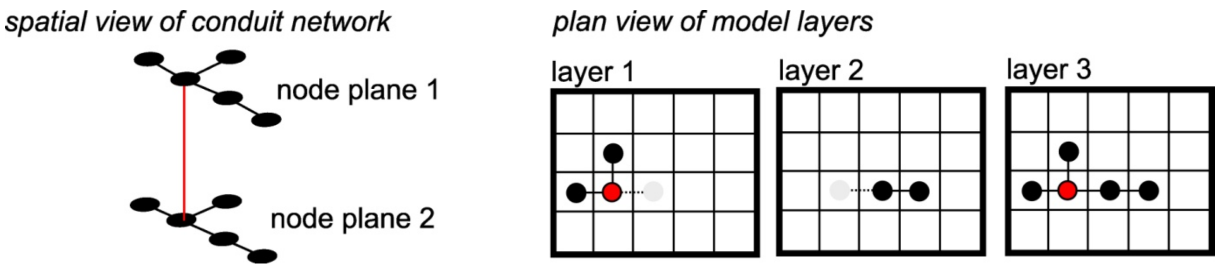

Figure 2: Spatial view of the conduit network and plan view of model layers with embedded conduit network, red elements denote the vertical connection between the two node planes

Input.dat

```
           4          5
           3  2
#layer 1 top
          50
#layer 1 bottom
          19
#layer 2 bottom
          10
#layer 3 bottom
           0
#plane 1
 -999 -999 -999 -999 -999
 -999 20.1 -999 -999 -999
 19.1 c20.0  19 18.9 -999
 -999 -999 -999 -999 -999
#plane 2
 -999 -999 -999 -999 -999
 -999    5 -999 -999 -999
    5   c5    5    5 -999
 -999 -999 -999 -999 -999
```

NBR data within the output control file:

NO	MC	MR	ML	NB1	NB2	NB3	NB4	NB5	NB6	TB1	TB2	TB3	TB4	TB5	TB6
1	2	2	1	3	0	0	0	0	0	1	0	0	0	0	0
2	1	3	1	3	0	0	0	0	0	2	0	0	0	0	0
3	2	3	1	1	4	2	8	0	0	1	3	2	9	0	0
4	3	3	2	5	3	0	0	0	0	4	3	0	0	0	0
5	4	3	2	4	0	0	0	0	0	4	0	0	0	0	0
6	2	2	3	8	0	0	0	0	0	5	0	0	0	0	0
7	1	3	3	8	0	0	0	0	0	6	0	0	0	0	0
8	2	3	3	6	9	7	3	0	0	5	7	6	9	0	0
9	3	3	3	10	8	0	0	0	0	8	7	0	0	0	0
10	4	3	3	9	0	0	0	0	0	8	0	0	0	0	0

Example 4: This example is similar to example 3 but with layer top and bottom elevation assigned as individual value for each cell. The top elevation of layer 2 in the middle row is decreases to 17 m (see the subsequently provided input.dat). The conduit network and the position within the continuum model are shown in Figure 3. Due to the changes in the top elevation of layer 2, one node in plane 1 is situated in layer 1 (instead of layer 2 as in example 3; compare figures 2 and 3).

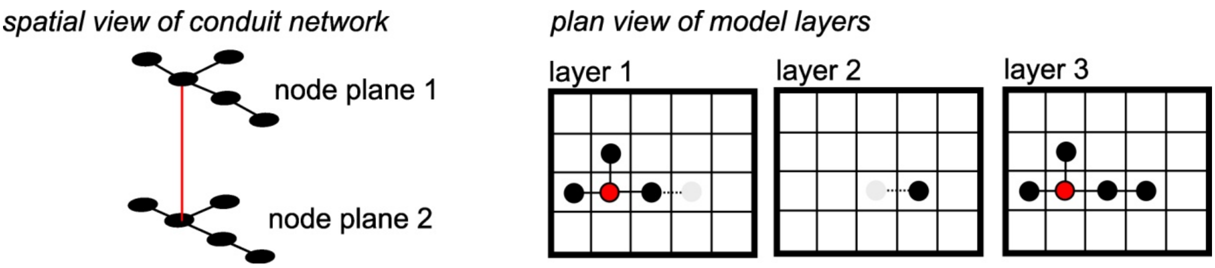

Figure 3: Spatial view of the conduit network and plan view of model layers with embedded conduit network, red elements denote the vertical connection between the two node planes

Input.dat

```
4 5
-3 2
#TOP LAYER 1
50.0 50.0 50.0 50.0 50.0
50.0 50.0 50.0 50.0 50.0
50.0 50.0 50.0 50.0 50.0
50.0 50.0 50.0 50.0 50.0
#BOT LAYER 1
19.0 19.0 17.0 19.0 19.0
19.0 19.0 17.0 19.0 19.0
19.0 19.0 17.0 19.0 19.0
19.0 19.0 17.0 19.0 19.0
#BOT LAYER 2
10.0 10.0 10.0 10.0 10.0
10.0 10.0 10.0 10.0 10.0
10.0 10.0 10.0 10.0 10.0
10.0 10.0 10.0 10.0 10.0
#BOT LAYER 3
0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0
# plane 1
-999 -999 -999 -999 -999
-999 20.1 -999 -999 -999
19.1  c20   19 18.9 -999
-999 -999 -999 -999 -999
# plane 2
-999 -999 -999 -999 -999
-999    5 -999 -999 -999
   5   c5    5    5 -999
-999 -999 -999 -999 -999
```

NBR data within the output control file:

# NO	MC	MR	ML	NB1	NB2	NB3	NB4	NB5	NB6	TB1	TB2	TB3	TB4	TB5	TB6
1	2	2	1	3	0	0	0	0	0	1	0	0	0	0	0
2	1	3	1	3	0	0	0	0	0	2	0	0	0	0	0
3	2	3	1	1	4	2	8	0	0	1	3	2	9	0	0
4	3	3	1	5	3	0	0	0	0	4	3	0	0	0	0
5	4	3	2	4	0	0	0	0	0	4	0	0	0	0	0
6	2	2	3	8	0	0	0	0	0	5	0	0	0	0	0
7	1	3	3	8	0	0	0	0	0	6	0	0	0	0	0
8	2	3	3	6	9	7	3	0	0	5	7	6	9	0	0
9	3	3	3	10	8	0	0	0	0	8	7	0	0	0	0
10	4	3	3	9	0	0	0	0	0	8	0	0	0	0	0

Reference: Shoemaker, W. B., E. L. Kuniansky, S. Birk, S. Bauer, and E. D. Swain, 2008, Documentation of a Conduit Flow Process (CFP) for MODFLOW-2005: U.S. Geological Survey Techniques and Methods, Book 6, Chapter A24, 50 p.