Analysis of Effect of Grand Lake Power-Pool Elevations on Neosho River Levels During a Major Flood

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I. Introduction and Background

This report describes an analysis of the effects of proposed changes in Grand Lake (Oklahoma) power-pool elevations on maximum water-surface elevations in the Neosho River during passage of a major flood. The purpose is to demonstrate that raising the power-pool elevation from 741 ft PD (Pensacola Dam datum) to levels as high as 745 ft PD will have negligible to minimal effects on maximum flood elevations in the vicinity of Miami, Oklahoma.

The analysis is based on use of the same reservoir and river computational model that the author used to provide technical support for the litigation Dalrymple, et al vs. Grand River Dam Authority, Case CJ 94-444, District Court of Ottawa County, Miami, OK. That analysis is described in detail in Holly (2001).

II. Model Basis

The model description herein is taken largely from Holly (2001). The model includes the Neosho River from the Commerce Gage (RM 153.4) down to approximately Pensacola Dam (RM 86.07), and includes short sections of the Elk and Spring Rivers.

The river basin model is based on the fully dynamic unsteady flow equations in the river channel, and on non-inertial unsteady flow on the flood plains in areas of strong channel sinuosity, in particular upstream of the City of Miami. The C1/C2 software, written by the referee in the late 70's and in continuous industrial use by him and others since then, solves the de St. Venant equations for unsteady flow on a grid of cross sections in the river. The C1/C2 software was developed in close collaboration with Dr. Alexandre Preissmann, and uses the same Preissmann four-point numerical method that is used in other standard simulators such as UNET, DWOPR, DAMBRK, etc.

The C1/C2 software also solves the non-inertial flow and storage equations on a network of flood-plain cells connected to each other and to the river channel through weir-type and fluvial-type representations of overland and overbank flow exchanges. The portions of the HEC-2 cross sections corresponding to the river channel, as used in the litigation, were retained for the unsteady flow modeling. The overbank portions of these sections were also retained for the river downstream of Miami. Upstream of Miami, the overbank portions of these cross sections were used, along with digital terrain maps provided by the Plaintiffs and Defense, to define the flood-plain cell topographies and their associated weir-type and fluvial-type flow exchanges.

The overall purpose of this expanded modeling approach is to capture, as faithfully as possible in a one-dimensional modeling context, the dynamic storage effects of flood plain areas where the highly sinuous channel meanders within the flood plain, in particular upstream of Miami. The general purpose of using an unsteady flow approach is to capture dynamic effects in the relation between water level and discharge; and to obviate the need to make any assumptions regarding lag effects of tributary discharges to the Neosho River.

The temporal records of inflow discharge at the Commerce (Neosho River), Tiff City (Elk River) and Quawpaw (Spring River) gages were used, with uniform slight adjustments to reflect the apparent ungaged flow contributions as estimated by the Defense experts in the litigation.

The channel and floodplain roughnesses, floodplain cell configurations, and associated weir-type and fluvial-type exchanges among flood cells and between flood cells and the river, were slightly adjusted in Holly (2001) based on comparison with reported high-water marks through multiple repetitive model runs under with-dam conditions. It should be noted that since the C1/C2 model includes independent descriptions of channel, overbank, and flood-plain exchange roughnesses, it is not appropriate to force roughnesses to depend on discharge as part of the calibration.

III. Selection of Flood for Analysis

During the litigation, it was clear that the flood of June 1995 was the most severe of the 14 floods that were the subject of the proceedings, with respect to the effect of Pensacola Dam in increasing water-surface elevations in the Miami area during a flood. This flood, designated Flood 13, occurred from about 2 – 22 June 1995, and had peak discharges at the Commerce, Tiff City, and Quawpaw gages of approximately 70,000 cfs, 67,000 cfs, and 74,000 cfs, respectively. Since this flood represents conditions that actually occurred and caused extensive flooding in the Miami area, rather than representing a theoretical situation, it provides a useful reference for the power-pool analyses herein. It should be noted, however, that the actual Grand Lake levels during Flood 13 were considerably higher than the power-pool elevations analyzed in this study.

For the present analysis, the Flood 13 input hydrographs were run for five constant Pensacola Dam pool levels: 741 ft, 742 ft, 743 ft, 744 ft, and 745 ft PD. The model itself is based on the NGVD datum, where NGVD = PD + 1.07 ft.

For each run, the model was first allowed to stabilize at a steady-flow condition using the inflow discharges values on 2 June 1995, the designated beginning of Flood 13. Then, with the Pensacola Dam level held constant at the indicated value, the full 20-day flood hydrographs were allowed to run through the model, filling and emptying the channel and flood plains as the flood passed through, with a 15-minute time step. The simulation program, C1/C2, wrote discharges and water levels at computational points in the Neosho River channel to an output file. This output file was then processed using a Fortran program designed to detect the maximum NGVD elevations observed during the passage of the flood at each of the computational points. This program then wrote the results to a file that could be imported into a spreadsheet for the analyses shown further on.

IV. Results of Computations

Figure 1 shows the envelope of maximum water surface-elevations detected during the passage of Flood 13 at the computational points in the Neosho River channel, for each of the five power-pool levels (note that although the power-pool levels are referenced in the PD datum, all results are shown in the NGVD datum). The profiles extend from Pensacola Dam on the left to Commerce Gage on the right. One can note that the I44 bridges are at about RM 142; Tar Creek is at about RM 142.5; and the Miami Main Street (Hwy 125) bridge is at RM 143.7. For practical purposes, one can consider RM 142.0 to be the downstream limit of developed areas in the vicinity of Miami along the Neosho.

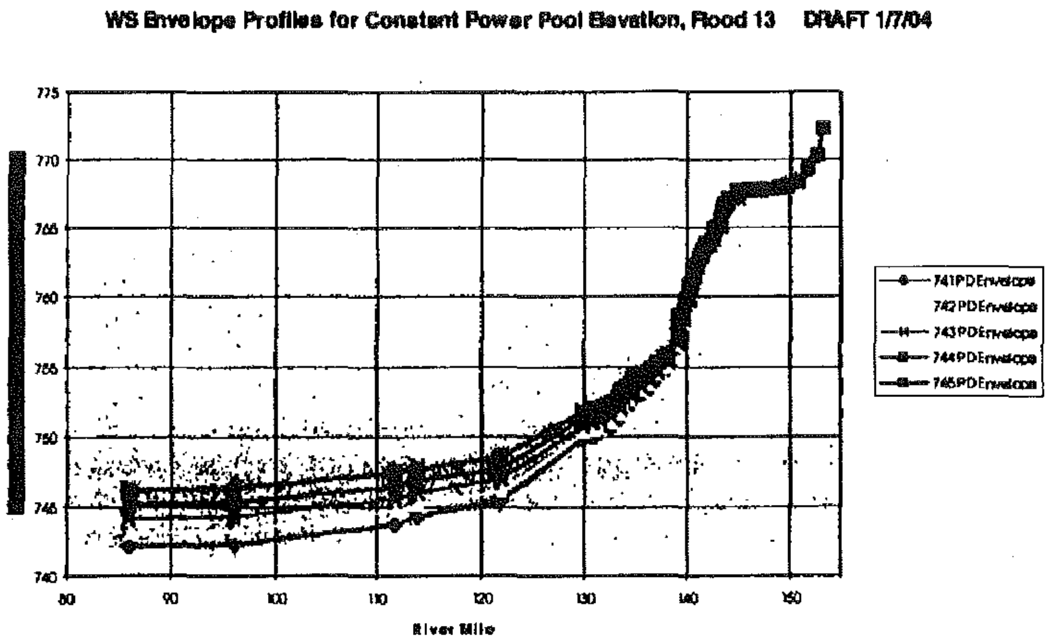

Figure 1. Water-Surface Envelope Profiles for Constant Power Pool Elevation, Flood 13

Figure 2 shows the increase in maximum water-surface elevations during Flood 13 for power-pool levels of 743, 744, and 745 ft PD compared to a reference of 742 ft PD, from Pensacola Dam to the Commerce Gage. At RM 142, the increase in maximum water-surface elevation caused by raising the power pool from 142 ft PD to 145 ft PD is approximately 0.2 feet, decreasing to less than 0.1 ft at RM 144 and further upstream. The effect is progressively less for pool-level increases to 144 and 143 ft PD, respectively.

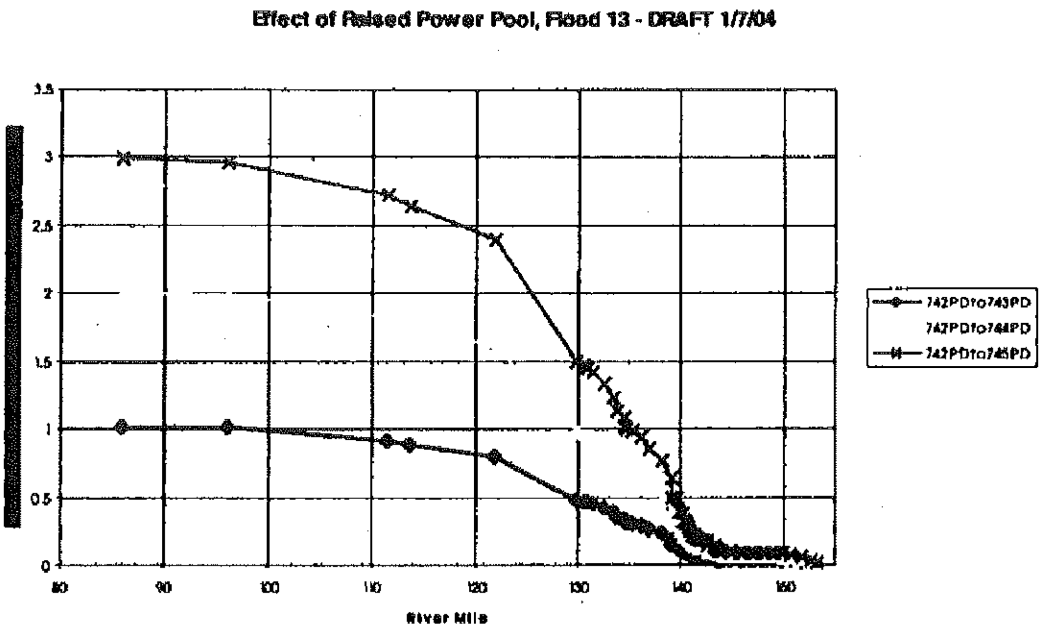

Figure 2. Effect of Raised Power Pool, Flood 13

Appendix I includes the tabular data from which Figures 1 and 2 were extracted; the data columns should be self-explanatory.

V. Discussion

It is apparent from the analysis and the resulting Figures that Miami is located just upstream of the zone of significant flood-level effects that would result from raising the Pensacola Dam power pool to 745 ft PD. Indeed, the river steepens significantly upstream of about RM 139, effectively eliminating significant backwater effects upstream of that point. The effect of raising the power pool by three feet (to 745 ft PD) is less than about 0.2 feet of maximum flood level just downstream of Miami, and progressively less at upstream locations and for lesser changes in power pool level.

References

Holly, F.M. Jr., (2001), "Flood Level and Duration Determination – Neosho River Below Commerce Gage", Limited Distribution Report No. 292, IIHR Hydroscience & Engineering, The University of Iowa, Iowa City, IA, April.

Appendix I. Tabulation of Computation Results

Analysis of Effect of Constant Power Pool Elevation on Envelope of Maximum w.s. Levels During Flood 13

F. Holly 6 Jan 2004

All elevations are NGVD. Mxdiff = difference in maximum w.s. envelopes, ft; mxflood = exceedance 760' surcharge, ft;

trefmx, refmx = hours after 2 June 1996 at which maximum w.s. elevation refmx occurs; taltmx, altmx = hours after 2 June 1995 at which maximum w.s elevation altmx occurs

		742 to 745 PD			(742)		(745)	**742 to 743 PD**			(742)		(743)	**742 to 744**			(742)		(744)
Pt	RM	mxdiff	mxflood	trefmx	refmx	taltmx	altmx	mxdiff	mxflood	trefmx	refmx	taltmx	altmx	mxdiff	mxflood	trefmx	refmx	taltmx	altmx
N001	153.40	0.01	0.01	264.00	772.31	264.00	772.32	0.00	0.00	264.00	772.31	264.00	772.31	0.01	0.01	264.00	772.31	264.00	772.32
N02A	152.76	0.03	0.03	270.75	770.24	271.25	770.27	0.01	0.01	270.75	770.24	270.75	770.25	0.02	0.02	270.75	770.24	271.25	770.26
N03A	151.85	0.06	0.06	276.00	769.29	276.75	769.35	0.02	0.02	276.00	769.29	276.25	769.31	0.03	0.03	276.00	769.29	276.00	769.33
N04A	150.90	0.07	0.07	279.00	768.33	279.25	768.40	0.02	0.02	279.00	768.33	279.25	768.35	0.05	0.05	279.00	768.33	279.25	768.37
N05A	150.11	0.08	0.08	279.75	768.08	280.00	768.16	0.02	0.02	279.75	768.08	280.00	768.11	0.05	0 05	279.75	768.08	279.75	768.13
N06A	149.92	0.08	0.08	280.25	768.03	280.00	768.11	0.02	0.02	280.25	768.03	280.00	768.05	0.05	0.05	280.25	768.03	280.00	768.08
NA06	149.38	0.09	0.09	280.25	767.94	280.00	768.03	0.03	0.03	280.25	767.94	280.25	767.97	0.05	0.05	280.25	767.94	280.25	767.99
NB06	149.38	0.09	0.09	280.25	767.94	280.00	768.03	0.03	0.03	280.25	767.94	280.25	767.97	0.05	0.05	280.25	767.94	280.25	767.99
N07A	149.16	0.09	0.09	280.25	767.92	280.25	768.00	0.03	0.03	280.25	767.92	280.25	767.94	0.05	0.05	280.25	767.92	280.00	767.97
N08A	148.46	0.09	0.09	280.50	767.81	280.25	767.90	0.03	0.03	280.50	767.81	280.50	767.84	0.06	0.06	280.50	767.81	280.50	767.87
NA08	148.01	0.09	0.09	280.25	767.79	280.00	767.88	0.03	0.03	280.25	767.79	280.00	767.82	0.06	0.06	280.25	767.79	280.50	767.85
NB08	148.01	0.09	0.09	280.25	767.79	280.00	767.88	0.03	0.03	280.25	767.79	280.00	767.82	0.06	0.06	280.25	767.79	280.50	767.85
N09A	147.42	0.09	0.09	280.50	767.75	280.50	767.84	0.03	0.03	280.50	767.75	280.25	767.78	0.06	0.06	280 50	767.75	280.75	767.81
N10A	147.28	0.09	0.09	280.50	767.75	280.25	767.84	0.03	0.03	280.50	767.75	280.25	767.77	0.06	0.06	280.50	767.75	280.25	767.80
NA11	147.03	0.09	0.09	280.50	767.73	280.25	767.82	0.03	0.03	280.50	767.73	280.25	767.76	0.06	0.06	280.50	767.73	280.25	767.79
NB11	146.30	0.09	0.09	280.50	767.73	280.25	767.82	0.03	0.03	280.50	767.73	280.25	767.76	0.06	0.06	280.50	767.73	280.25	767.79
N12A	146.30	0.09	0.09	280.50	767.72	280.75	767.81	0.03	0.03	280.50	767.72	280.25	767.75	0.06	0.06	280.50	767.72	280.25	767.78
NA12	146.04	0.09	0.09	280.25	767.72	280.50	767.81	0.03	0.03	280.25	767.72	280.50	767.75	0.06	0.06	280.25	767.72	280.50	767.78
NB12	145.91	0.09	0.09	280.25	767.72	280.50	767.81	0.03	0.03	280.25	767.72	280.50	767.75	0.06	0.06	280.25	767.72	280.50	767.78
N13A	145.91	0.09	0.09	280.50	767.72	280.25	767.81	0.03	0.03	280.50	767.72	280.25	767.74	0.06	0.06	280.50	767.72	280.25	767.77
N14A	145.07	0.09	0.09	280.25	767.71	280.50	767.80	0.03	0.03	280.25	767.71	280.50	767.74	0.06	0.06	280.25	767.71	280.75	767.77
N15A	145.06	0.10	0.10	280.50	767.15	280.50	767.25	0.03	0.03	280.50	767.15	280.50	767.18	0.06	0.06	280.50	767.15	280.50	767.21
N016	144.23	0.10	0.10	280.50	767.12	280.50	767.22	0.03	0.03	280.50	767.12	280.50	767.15	0.06	0.06	280.50	767.12	280.75	767.19
N017	144.22	0.10	0.10	280.75	767.12	280.50	767.21	0.03	0.03	280.75	767.12	280.75	767.14	0.06	0.06	280.75	767.12	280.75	767.18
N018	144.19	0.10	0.10	280.50	766.93	280.50	767.03	0.03	0.03	280.50	766.93	280.50	766.96	0.06	0.06	280.50	766.93	280.50	766.99
N019	144.02	0.11	0.11	280.75	766.66	280.75	766.77	0.03	0.03	280.75	766.66	281.00	766.69	0.07	0.07	280.75	766.66	280.75	766.72
N020	143.84	0.11	0 11	280.50	766.65	280.50	766.76	0.03	0.03	280.50	766.65	280.75	766.68	0.07	0.07	280.50	766.65	280.50	766.72
N021	143.81	0.11	0.11	281.00	766.64	280.75	766.75	0.03	0.03	281.00	766.64	280.50	766.67	0.07	0.07	281.00	766.64	280.75	766.71
N022	143.80	0.11	0.11	280.75	766.50	280.75	766.61	0.03	0.03	280.75	766.50	281.00	766.53	0.07	0.07	280.75	766.50	280.75	766.57
N023	143.70	0.11	0.11	280.75	766.49	280.50	766.60	0.03	0.03	280.75	766.49	281.00	766.53	0.07	0.07	280.75	766.49	280.50	766.56
N024	143.67	0.11	0.11	280.75	766.49	280.75	766.60	0.03	0.03	280.75	766.49	280.50	766.52	0.07	0.07	280.75	766.49	280.75	766.56

N025	143.66	0.12	0.12	280.75	766.30	280.75	766.42	0.03	0.03	280.75	766.30	280.75	766.34	0.07	0.07	280.75	766.30	281.00	766.38
N027	143.54	0.13	0.13	281.00	765.67	280.75	765.79	0.04	0.04	281.00	765.67	281.25	765.70	0.08	0.08	281.00	765.67	281.00	765.75
N028	143.52	0.15	0.15	280.75	765.07	281.25	765.22	0.04	0.04	280.75	765.07	281.00	765.11	0.09	0.09	280.75	765.07	281.00	765.16
N029	142.88	0.15	0.15	281.50	764.84	281.25	764.99	0.04	0.04	281.50	764.84	281.00	764.89	0.09	0.09	281.50	764.84	281.25	764.93
N030	142.85	0.15	0.15	281.00	764.67	280.75	764.83	0.05	0.05	281.00	764.67	281.00	764.72	0.10	0.10	281.00	764.67	280.75	764.77
N31A	142.62	0.16	0.16	281.00	764.46	281.00	764.62	0.05	0.05	281.00	764.46	281.00	764.51	0.10	0.10	281.00	764.46	281.00	764.56
N32A	142.72	0.17	0.17	281.50	764.09	281.25	764.26	0.05	0.05	281.50	764.09	281.00	764.14	0.11	0.11	281.50	764.09	281.00	764.20
N033	142.35	0.18	0.18	281.25	763.76	281.00	763.94	0.05	0.05	281.25	763.76	281.25	763.82	0.11	0.11	281.25	763.76	280.75	763.87
N034	142.06	0.18	0.18	281.00	763.71	280.75	763.89	0.05	0.05	281.00	763.71	281.25	763.76	0.11	0.11	281.00	763.71	281.00	763.82
N035	142.03	0.18	0.18	281.25	763.68	281.00	763.86	0.05	0.05	281.25	763.68	280.75	763.73	0.11	0.11	281.25	763.68	280.75	763.79
N036	142.00	0.18	0.18	281.00	763.65	281.00	763.83	0.05	0.05	281.00	763.65	281.00	763.70	0.11	0.11	281.00	763.65	281.00	763.76
N037	141.96	0.19	0.19	281.00	763.53	280.75	763.71	0.06	0.06	281.00	763.53	281.00	763.59	0.12	0.12	281.00	763.53	281.25	763.64
N038	141.84	0.19	0.19	281.00	763.37	280.75	763.56	0.06	0.06	281.00	763.37	281.00	763.43	0.12	0.12	281.00	763.37	280.75	763.49
N039	141.75	0.21	0.21	280.75	763.02	280.75	763.23	0.06	0.06	280.75	763.02	280.75	763.08	0.13	0.13	280.75	763.02	281.00	763.15
N040	141.49	0.21	0.21	281.00	762.83	281.00	763.04	0.06	0.06	281.00	762.83	280.75	762.89	0.13	0.13	281.00	762.83	280.75	762.96
N041	141.35	0.22	0.22	281.00	762.59	280.75	762.81	0.07	0.07	281.00	762.59	281.00	762.65	0.14	0.14	281.00	762.59	280.50	762.73
N042	141.20	0.24	0.24	281.00	762.12	280.50	762.36	0.07	0.07	281.00	762.12	280.75	762.19	0.15	0.15	281.00	762.12	280.75	762.27
N043	141.00	0.28	0.28	280.50	761.37	280.25	761.65	0.08	0.08	280.50	761.37	280.75	761.45	0.17	0.17	280.50	761.37	280.00	761.54
N044	140.71	0.30	0.30	280.25	760.94	280.00	761.24	0.09	0.09	280.25	760.94	280.00	761.03	0.19	0.19	280.25	760.94	280.25	761.13
N045	140.60	0.32	0.32	280.25	760.63	280.00	760.95	0.10	0.10	280.25	760.63	280.25	760.73	0.20	0.20	280.25	760.63	280.00	760.83
N046	140.51	0.32	0.32	280.50	760.61	280.00	760.93	0.10	0.10	280.50	760.61	280.00	760.70	0.20	0.20	280.50	760.61	280.25	760.81
N047	140.50	0.32	0.32	280.00	760.59	279.75	760.91	0.10	0.10	280.00	760.59	280.00	760.68	0.20	0.20	280.00	760.59	280.00	760.79
N048	140.49	0.32	0.32	280.25	760.56	279.75	760.89	0.10	0.10	280.25	760.56	280.00	760.66	0.20	0.20	280.25	760.56	280.25	760.77
N049	140.48	0.37	0.07	279.75	759.70	279.50	760.07	0.11	0.00	279.75	759.70	280.00	759.81	0.23	0.00	279.75	759.70	279.50	759.93
N050	140.07	0.40	0.00	279.50	759.36	279.25	759.75	0.12	0.00	279.50	759.36	279.50	759.47	0.25	0.00	279.50	759.36	279.50	759.61
N051	139.90	0.49	0.00	279.00	758.17	278.25	758.66	0.15	0.00	279.00	758.17	279.00	758.32	0.31	0.00	279.00	758.17	278.75	758.48
N052	139.36	0.49	0.00	279.25	758.16	278.50	758.65	0.15	0.00	279.25	758.16	279.25	758.31	0.31	0.00	279.25	758.16	278.75	758.47
N053	139.35	0.49	0.00	279.00	758.14	278.75	758.64	0.15	0.00	279.00	758.14	278.75	758.29	0.31	0.00	279.00	758.14	278.50	758.45
N054	139.34	0.50	0.00	279.00	758.13	278.50	758.62	0.15	0.00	279.00	758.13	279.00	758.28	0.31	0.00	279.00	758.13	278.50	758.44
N055	139.33	0.50	0.00	278.75	758.11	278.75	758.61	0.15	0.00	278.75	758.11	278.75	758.25	0.31	0.00	278.75	758.11	278.50	758.43
N056	139.32	0.64	0.00	277.75	756.52	277.25	757.15	0.19	0.00	277.75	756.52	278.00	756.71	0.40	0.00	277.75	756.52	277.25	756.92
N057	138.38	0.78	0.00	276.50	754.97	275.50	755.74	0.24	0.00	276.50	754.97	276.00	755.20	0.50	0.00	276.50	754.97	276.00	755.46
N058	137.21	0.85	0.00	275.50	754.30	275.25	755.15	0.26	0.00	275.50	754.30	275.25	754.56	0.55	0.00	275.50	754.30	275.25	754.85
N059	136.51	0.94	0.00	274.50	753.67	274.00	754.61	0.29	0.00	274.50	753.67	274.50	753.96	0.60	0.00	274.50	753.67	274.25	754.27
N060	135.60	0.99	0.00	274.00	753.24	273.25	754.23	0.31	0.00	274.00	753.24	273.50	753.55	0.64	0.00	274.00	753.24	273.50	753.87
N061	134.95	1.00	0.00	273.75	753.21	273.50	754.20	0.31	0.00	273.75	753.21	273.75	753.52	0.64	0.00	273.75	753.21	273.75	753.85
N062	134.91	1.00	0.00	274.00	753.19	273.25	754.19	0.31	0.00	274.00	753.19	273.75	753.50	0.64	0.00	274.00	753.19	273.50	753.83
N063	134.87	1.01	0.00	273.75	753.08	273.25	754.10	0.32	0.00	273.75	753.08	273.50	753.40	0.65	0.00	273.75	753.08	273.25	753.73
N064	134.72	1.09	0.00	272.50	752.51	272.00	753.60	0.34	0.00	272.50	752.51	272.25	752.85	0.70	0.00	272.50	752.51	272.25	753.21
N065	134.08	1.13	0.00	272.00	752.24	271.50	753.37	0.36	0.00	272.00	752.24	272.00	752.69	0.73	0.00	272.00	752.24	271.75	752.97

N066	133.63	1.23	0.00	270.50	751.58	270.00	752.81	0.39	0.00	270.50	751.58	270.25	751.97	0.79	0.00	270.50	751.58	270.00	752.37
N067	132.72	1.34	0.00	268.25	750.91	268.25	752.25	0.43	0.00	268.25	750.91	268.50	751.34	0.87	0.00	268.25	750.91	268.50	751.78
N068	131.71	1.43	0.00	255.25	750.60	254.00	752.02	0.46	0.00	255.25	750.60	254.75	751.05	0.93	0.00	255.25	750.60	254.25	751.52
N069	131.16	1.46	0.00	254.50	750.44	253.50	751.90	0.47	0.00	254.50	750.44	254.25	750.91	0.95	0.00	254.50	750.44	253.75	751.39
N070	130.82	1.46	0.00	254.50	750.43	253.50	751.89	0.47	0.00	254.50	750.43	254.00	750.90	0.95	0.00	254.50	750.43	253.75	751.38
N071	130.03	1.50	0.00	254.00	750.23	253.00	751.73	0.48	0.00	254.00	750.23	253.25	750.71	0.97	0.00	254.00	750.23	253.00	751.21
N120	122.00	2.40	0.00	250.00	746.15	249.50	748.55	0.80	0.00	250.00	746.15	249.75	746.95	1.59	0.00	250.00	746.15	249.75	747.74
N121	113.90	2.65	0.00	248.00	745.05	247.50	747.70	0.89	0.00	248.00	745.05	247.75	745.94	1.77	0.00	248.00	745.05	247.75	746.82
N221	111.66	2.73	0.00	248.00	744.63	247.50	747.36	0.92	0.00	248.00	744.63	247.75	745.55	1.82	0.00	248.00	744.63	247.75	746.45
N222	96.17	2.97	0.00	247.75	743.24	246.50	746.21	1.01	0.00	247.75	743.24	246.75	744.25	1.99	0.00	247.75	743.24	247.25	745.23
N223	86.07	2.99	0.00	226.25	743.08	225.75	746.06	1.02	0.00	226.25	743.08	226.00	744.09	2.00	0.00	226.25	743.08	225.75	745.08