

# National Flowing Waters Assessment Survey Design: 2008-2009

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## Description of Sample Design

### Objectives:

The objectives, or design requirements, for the National Flowing Waters Assessment are to produce:

1. Estimates of the 2008-2009 status of flowing waters nationally and regionally (9 aggregated Omernik ecoregions),
2. Estimates of the 2008-2009 status of wadeable streams and non-wadeable rivers nationally and regionally (9 aggregated Omernik ecoregions),
3. Estimates of the 2008-2009 status of urban flowing waters nationally,
4. Estimates of the change in status in wadeable streams between 2008-2009 and 2004, nationally and regionally (9 aggregated Omernik ecoregions).

A secondary objective is to have each state sample approximately an equal number of sites (37-38).

**Target population:** The target population consists of all streams and rivers within the 48 contiguous states that have flowing water during the study index period excluding portions of tidal rivers up to head of salt. The study index period extends from April/May to September and is generally characterized by low flow conditions. The target population includes the Great Rivers. Run-of-the-river ponds and pools are included while reservoirs are excluded.

**Sample Frame:** The sample frame was derived from the National Hydrography Dataset (NHD), in particular NHD-Plus. Attributes from NHD-Plus and additional attributes added to the sample frame that are used in the survey design include: (1) state, (2) EPA Region, (3) NAWQA Mega Region, (4) Omernik Ecoregion Level 3 (NACEC version), (4) WSA aggregated ecoregions (nine and three regions), (5) Strahler order, (6) Strahler order categories (1<sup>st</sup>, 2<sup>nd</sup>, ..., 7<sup>th</sup>, and 8<sup>th</sup>+), (6) FCode, (7) Urban, and (8) Frame07.

The version of NHD-Plus used includes two separate Strahler order calculations, one that is included on the publicly available NHD-Plus version. The other Strahler order calculation (SO attribute name) more accurately reflects the true Strahler order and is used for the survey design. The StrahCat attribute collapses 8<sup>th</sup>, 9<sup>th</sup>, and 10<sup>th</sup> order rivers in to a single category.

The Urban attribute was created by intersecting a modified version of the Census Bureau national urban boundary GIS coverage with NHD-Plus. The Census Bureau's boundaries were buffered 100 meters to include a majority of stream features intersecting and coincident with urban areas. Where this buffer did not completely gather all the river features within the urban areas (rivers intersecting cities are excluded from the Census Bureau's urban areas), the NHD-Plus river area (polygon) features were clipped at a three kilometer buffer around the urban areas and combined with the buffered urban area to create the modified urban database. If a stream or river segment was within this boundary, it is designated as "Urban"; otherwise as "NonUrban".

FCODE is directly from NHD-Plus and is used to identify which segments in NHD were included in the sample frame. The attribute Frame07 identifies each segment as either "Include" or "Exclude". Frame07 was created so that segments included in the sample frame could be easily identified. FCODE values included in the GIS shapefile:

Included in FW08 sample frame (Frame07='Include'):

- 33400 Connector
- 33600 Canal/Ditch
- 42801 Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = At or Near
- 46000 Stream/River
- 46003 Stream/River (Intermittent)
- 46006 Stream/River (Perennial)
- 58000 Artificial Path (removed from dataset if coded through Lake/Pond and Reservoirs)

Excluded in FW08 sample frame (Frame07='Exclude')

- 42800 Pipeline
- 42802 Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = Elevated
- 42803 Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = Underground
- 42804 Pipeline: Pipeline Type = Aqueduct; Relationship to Surface = Underwater
- 42806 Pipeline: Pipeline Type = General Case; Relationship to Surface = Elevated
- 4280 Pipeline: Pipeline Type = General Case; Relationship to Surface = Underground
- 42809 Pipeline: Pipeline Type = Penstock; Relationship to Surface = At or Near
- 42811 Pipeline: Pipeline Type = Penstock; Relationship to Surface = Underground
- 42813 Pipeline: Pipeline Type = Siphon
- 56600 Coastline

Rivers that had Strahler order greater than or equal to 5<sup>th</sup> order and had FCODE equal to 46003 (intermittent) were included in the FW08 sample frame for all states west of 96 degrees longitude (North Dakota to Texas and states west). This was done to ensure that all large rivers in the more arid west were included regardless of NHD-Plus intermittent code.

**Survey Design:** The survey design consists of two major components in order to address the dual objectives of (1) estimating current status for all flowing waters and (2) estimating change in status for wadeable streams from the 2004 Wadeable Stream Assessment. These two components are termed: (1) NFW design and (2) WSA\_Revisit design. A Generalized Random Tessellation Stratified (GRTS) survey design for a linear resource is used for the

NFW design and a GRTS survey design for a finite resource is used for the WSA\_Revisit design. The design includes reverse hierarchical ordering of the selected sites.

**Stratification:** The survey design is explicitly stratified by state for the NFW design. The original WSA design had several strata (EMAP West, New England, Virginia, Iowa, and remaining eastern states combined). The WSA\_Revisit design ignores these strata in the selection of the subset of sites from the WSA to be revisited as part of the current Flowing Water design.

**Multi-density categories:** A complex unequal probability selection process was used in each of the two components of the survey design. They are described separately.

**NFW design:** Unequal probability categories are defined separately for wadeable streams (1<sup>st</sup> to 4<sup>th</sup> order) and non-wadeable rivers (5<sup>th</sup> to 10<sup>th</sup> order). Note wadeable and non-wadeable are used to designate Strahler order classes and do not imply that the streams will actually be wadeable or non-wadeable. The expected sample size is 450 for wadeable streams and 900 for non-wadeable rivers.

For wadeable stream category, within each state unequal selection probabilities were defined for 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> order streams so that an equal number of sites would occur for each order. Then these unequal selection probabilities were adjusted by WSA nine aggregated ecoregion categories so that an equal number of sites would occur in each WSA nine aggregated ecoregion category.

For non-wadeable river category, unequal selection probabilities were defined for 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, and 8<sup>th</sup>+ order rivers so that the expected number of sites would be 350, 275, 175, and 100 sites, respectively. Then these unequal selection probabilities were adjusted by WSA nine aggregated ecoregion categories so that an equal number of sites would occur in each WSA nine aggregated ecoregion category.

Given these initial selection probabilities, the expected number of urban and non-urban sites was calculated to determine if at least 150 urban sites would be selected. Over 150 urban sites were expected so no additional adjustment was required to satisfy the urban design requirement.

The final adjustment of the selection probabilities was to adjust them to minimize the range in the number of sites across the 48 states while still meeting the other design requirements. Given a total of 1350 sites for the NFW design, each state would sample 28 sites. This could not be achieved, although the range was able to be decreased.

**WSA\_Revisit Design:** The Wadeable Stream Assessment sampled 1390 sites between 2000 and 2004. To estimate change, 450 of these sites will be revisited as part of the 2008-9 Flowing Waters assessment. The revisit design selects the 450 sites using unequal selection probabilities. Initially, all sites were assigned an equal selection probability of 1.

First, four intensification study regions were sampled as part of the WSA. These regions are the Wenatchee Watershed in Washington, Lower John Day and Deschutes watersheds in Oregon, Northern California coastal watersheds, and southern California coastal watersheds. The selection probabilities for sites within these regions were adjusted (lowered) to give the expected number of sites within a study region if a state-wide survey design was done without intensification.

Second, the density of sites sampled for the EMAP-West portion of the WSA was greater than for the 36 eastern states. The selection probabilities were reduced for EMAP-West states to adjust for this. The Southern Appalachian aggregated ecoregion sites in WSA had high weights and when the initial selection probabilities were increased for these sites as well to ensure that the final weights for these sites were not extreme.

Third, the selection probabilities developed above were then adjusted to achieve approximately an equal number of sites across all nine WSA aggregated ecoregions.

Fourth, the overall weight, inverse of selection probability, was calculated by multiplying the original WSA weight by the inverse of the above selection probability. This accounts for the fact that the WSA\_Revisit design is a two-stage sample of wadeable streams.

WSA\_Revisit design weights and NFW design weights associated with wadeable streams will have to be adjusted to account for fact that they are two independent survey designs of wadeable streams for the 48 states. This will be done after the sites are evaluated and sampled.

**State Designs:** For states that have a current, compatible state-wide probability design that cover all flowing waters, an option is provided to use their sites instead of the flowing water design sites. Whether the option is exercised for a state, requires that (1) their state design be a probability survey design, (2) their target population of streams and rivers includes the target population for the national Flowing Waters Assessment, (3) their sample frame includes the national Flowing Waters Assessment sample frame, and (4) their design is implemented state-wide in 2008-2009. The state must also agree to measure all the indicators included in the national Flowing Waters Assessment using the national field and laboratory protocols.

**Panels:** Design uses a single panel (Base).

**Expected sample size:** Expected sample size is 1800 flowing water sites, 450 sites revisited from the WSA, 450 new sites from 1<sup>st</sup> to 4<sup>th</sup> order, and 900 new sites from 5<sup>th</sup> to 10<sup>th</sup> order.

**Over sample:** No over sample sites were selected for the WSA\_Revisit design. The expectation is that all, or almost all, of the 450 sites selected will be sampled given they were sampled previously. For the NFW design, the over sample is nine times the expected sample size within each state. The large over sample size was done to accommodate those states who may want to increase the number of sites sampled within their state for a state-level design.

**Site Use:** Each stream/river selected to be sampled is given unique site identification (siteID) that consists of two parts: (1) NFW08 that identifies the sites as part of the 2008-9 National Flowing Waters Assessment and (2) the two-letter state FIPS code followed by a number between 001 and 999 within each state. It critical this siteID be used in its entirety to make sure that the stream and rivers sites are correctly identified.

Sites are organized to be used within each state. If a stream or river site is evaluated and determined that it can not be sampled, then it is to be replaced by another site within the state. Sites that are coded as 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> are to be replaced by over sample sites that are coded 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> or 4<sup>th</sup>, ignoring order within this range. For example, a 2<sup>nd</sup> order would be replaced by either a 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> or 4<sup>th</sup> order stream. Sites that are coded as 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, 8<sup>th</sup>, 9<sup>th</sup>, or 10<sup>th</sup> order are to be replaced by over sample sites that are coded 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, 8<sup>th</sup>, 9<sup>th</sup>, or 10<sup>th</sup> order, ignoring order within this range. For example, a 5<sup>th</sup> order river would be replaced by a 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, 8<sup>th</sup>, 9<sup>th</sup>, or 10<sup>th</sup> order river. In each case the next lowest siteID that is within the Strahler order set is used for the replacement.

**Site Revisits:** The monitoring design includes 200 site revisits to obtain estimates of local measurement variability and to satisfy quality assurance needs. Each state will complete four (4) site revisits: two Wadeable streams and two nonwadeable rivers. These sites will be the first two (in siteID order) Wadeable and nonwadeable river sites selected that are sampleable.

## Change Estimation

The design objectives include estimating the change in status in Wadeable streams between 2008-2009 and 2004, nationally and regionally (9 aggregated Omernik ecoregions). The survey design for accomplishing this is a split-panel design. The split-panel design for change estimation includes 1390 Wadeable sites visited as part of the Wadeable Stream Assessment in 2000-2004 and an expected 900 Wadeable sites visited in 2008-2009 of which 450 are repeat visits of a subset of the 1390 sites. This design enables two different types of change estimates to be made: net change and gross change. The difference in these can be illustrated by two tables. The Without Revisits table illustrates that it is possible to estimate net change between NFWA and WSA, in this case 33% impaired in WSA versus 22.2% in NFWA. The Using Revisits table illustrates that it is not only possible to estimate net change between the two time periods but also possible to estimate gross change, e.g.,  $60/150 = 40\%$  of WSA Impaired are no longer impaired or that  $10/300 = 3.3\%$  of WSA Not Impaired is now Impaired in NFWA. A split-panel design enables gross change estimates to be made while also providing opportunity to visit new stream locations.

Without Revisits	NFWA Impaired	NFWA Not Impaired	Total
WSA Impaired			150
WSA Not Impaired			300
Total	100	350	450

Using Revisits	NFWA Impaired	NFWA Not Impaired	Total
WSA Impaired	90	60	150
WSA Not Impaired	10	290	300
Total	100	350	450

## Sample Frame Summary

The sample frame is available as a shapefile. This shapefile was also summarized by all the unique combinations of attribute variables that could be used in determining the selection probabilities. A few summaries are given below in km.

FCODE	Exclude	Exclude-E	Include	Sum
33400	0	2	7007	7009
33600	0	425	276461	276886
33601	526	0	0	526
42800	66	0	0	66
42801	2334	2	6	2342
42802	26	0	0	26
42803	7239	2	0	7241
42804	1	0	0	1
42806	2	0	0	2
42807	39	0	0	39
42809	73	0	0	73
42811	15	0	0	15
42813	149	0	0	149
46000	0	0	126	126
46003	2298650	130	909432	3208212
46006	0	1625	1864018	1865643
55800	0	15372	122120	137492
56600	20384	23483	0	43867
Sum	2329504	41041	3179170	5549715

Frame07=Include only

Order	NonUrban	Urban	Sum
0	292695	27499	320194
1	1465222	66972	1532194
2	517101	26378	543479
3	317161	16441	333602
4	193440	10739	204179
5	123682	9891	133573
6	57788	8071	65859
7	25140	4511	29651
8	8527	2396	10923
9	2711	848	3559
10	1470	486	1956
Sum	3004937	174232	3179169

	Strahler Order										Sum	
	0	1	2	3	4	5	6	7	8	9		10
CPL	134111	355821	115083	61419	35768	19757	10636	7979	1485	223	1655	743937
NAP	5188	138080	41830	21806	11786	5735	2469	475	0	0	0	227369
NPL	8664	5880	7456	10429	11584	10847	7181	1801	807	404	0	65053
SAP	6987	406914	116267	67142	39233	18214	9458	2249	1445	256	0	668165

Revised 8/14/07

SPL	15512	10695	15403	17932	16928	15553	8034	4966	868	0	0	105891
TPL	24836	271573	91433	56266	32920	19909	7908	3595	1714	1747	302	512203
UMW	14483	116764	41908	24116	12817	6528	2202	122	697	0	0	219637
WMT	24706	200340	89421	52706	26633	13800	6510	1692	608	277	0	416693
XER	85707	26127	24676	21787	16512	23232	11464	6772	3299	653	0	220229
Sum	320194	1532194	543477	333603	204181	133575	65862	29651	10923	3560	1957	3179177

## Site Selection Summary

Number of sites for the National Flowing Waters Design:

By Aggregated Ecoregion and Wadeable (1<sup>st</sup> to 4<sup>th</sup>) and Non-wadeable (5<sup>th</sup> to 10<sup>th</sup>)

Base sites

	Wade	NonWade	Sum
CPL	136	125	261
NAP	100	104	204
NPL	68	101	169
SAP	147	131	278
SPL	74	95	169
TPL	104	85	189
UMW	83	75	158
WMT	101	63	164
XER	91	117	208
Sum	904	896	1800

Over Sample Sites

	Wade	NonWade	Sum
CPL	831	1098	1929
NAP	457	929	1386
NPL	310	741	1051
SAP	636	1226	1862
SPL	353	794	1147
TPL	475	862	1337
UMW	335	656	991
WMT	375	693	1068
XER	387	992	1379
Sum	4159	7991	12150

By Urban and Non Urban

	Base	OverSamp	Sum
NonUrban	1591	10475	12066
Urban	209	1675	1884
Sum	1800	12150	13950

By EPA Region

	Base	OverSamp	Sum
1	115	828	943
2	61	386	447
3	155	1121	1276
4	261	1884	2145
5	266	1772	2038
6	214	1422	1636
7	169	1194	1363
8	331	2032	2363

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Created by Tony Olsen

9	120	755	875
10	108	756	864
Sum	1800	12150	13950

	Base	OverSamp	Sum
AL	36	225	261
AR	37	252	289
AZ	36	252	288
CA	44	252	296
CO	48	252	300
CT	22	180	202
DE	21	180	201
FL	29	252	281
GA	27	216	243
IA	46	252	298
ID	35	252	287
IL	35	252	287
IN	33	252	285
KS	44	342	386
KY	40	252	292
LA	38	252	290
MA	19	162	181
MD	28	207	235
ME	21	90	111
MI	52	333	385
MN	48	333	381
MO	36	252	288
MS	33	252	285
MT	62	387	449
NC	41	252	293
ND	61	387	448
NE	44	342	386
NH	16	117	133
NJ	15	117	132
NM	31	252	283
NV	40	252	292
NY	46	270	316
OH	36	252	288
OK	52	342	394
OR	37	252	289
PA	39	243	282
RI	14	117	131
SC	24	207	231
SD	65	387	452
TN	33	252	285
TX	56	324	380
UT	41	252	293
VA	38	252	290
VT	23	162	185
WA	36	252	288
WI	55	315	370
WV	32	252	284
WY	55	369	424
Sum	1800	12150	13950

By Aggregated Ecoregion and Strahler Order

0	1	2	3	4	5	6	7	8	9	10	Sum
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CPL	16	57	31	17	15	38	33	36	9	1	8	261
NAP	0	37	34	14	15	60	35	9	0	0	0	204
NPL	4	0	13	21	30	47	40	8	4	2	0	169
SAP	1	57	40	33	16	51	59	14	6	1	0	278
SPL	5	6	18	23	22	38	28	26	3	0	0	169
TPL	1	35	28	20	20	37	22	11	6	9	0	189
UMW	3	28	32	12	8	45	16	2	12	0	0	158
WMT	2	31	33	27	8	32	23	5	3	0	0	164
XER	18	7	21	28	17	42	35	26	12	2	0	208
Sum	50	258	250	195	151	390	291	137	55	15	8	1800

## Description of Sample Design Output:

The dbf file for the shapefile (“*NFWA Sites Final*”) has the following variable definitions:

Variable Name	Description
siteID	Unique identification label for each stream/river in the sample
xalb83	x-coordinate of stream/river site (see Albers projection information below)
Yalb83	y-coordinate of stream/river site (see Albers projection information below)
Lon_dd83	Longitude in decimal degrees of stream/river site
Lat_dd83	Latitude in decimal degrees of stream/river site
mdcaty	inclusion probability used for the unequal probability selection of the sample stream/river
wgt	Weight (in km) to be used in the statistical analyses. It is the inverse of the inclusion probability
stratum	Strata used in design
panel	Base identifies the 1800 stream and river sites in the base design. Oversamp identifies sites to be used as replacements as necessary.
EvalStatus	Placeholder to record the results of the stream/river recon evaluation (see below)
EvalReason	Placeholder to record reason for the evaluation result.
COMID	NHD-PLUS unique segment identifier
GNIS_NAME	GNIS feature name
FCODE	NHD feature type name
SO	NHD-Plus new Strahler order
StrahCat	Strahler order categories used in survey design
STATE	FIPS state two letter code
EPA_REG	EPA region
FW_ECO9	Nine Omernik aggregated ecoregions
FW_ECO3	Three Omernik aggregated ecoregions
NACEC_ECO	Omernik ecoregion names based on North American Ecoregions
NAWQA_REG	NAWQA Mega Regions
Urban	Urban if site is within urban boundary. NonUrban otherwise

NFWACat	For NFW design, unique categories used to determine inclusion probabilities
WSA_SITEID	SiteID from the 2004 WSA design
WSA_STRATU	Strata used in the 2004 WSA design
WGT_WSA	WSA weight (weight for the first stage of two-stage WSA revisit design)
WSA_ECO9	WSA aggregated ecoregion (included since ecoregion boundaries changed)
WGT_RESAMP	Combined two-stage weight for WSA Revisit design
WSA_ORD	Strahler order based on RF3 as used in WSA design

### Projection Information

```

PROJCS["USA_Contiguous_Albers_Equal_Area_Conic_USGS_version",
GEOGCS["GCS_North_American_1983",
DATUM["D_North_American_1983",
SPHEROID["GRS_1980",6378137.0,298.257222101]],
PRIMEM["Greenwich",0.0],
UNIT["Degree",0.0174532925199433]],
PROJECTION["Albers"],
PARAMETER["False_Easting",0.0],
PARAMETER["False_Northing",0.0],
PARAMETER["Central_Meridian",-96.0],
PARAMETER["Standard_Parallel_1",29.5],
PARAMETER["Standard_Parallel_2",45.5],
PARAMETER["Latitude_Of_Origin",23.0],
UNIT["Meter",1.0]],
VERTCS["NAD_1983",
DATUM["D_North_American_1983",
SPHEROID["GRS_1980",6378137.0,298.257222101]],
PARAMETER["Vertical_Shift",0.0],
PARAMETER["Direction",1.0],UNIT["Meter",1.0]]
    
```

### Evaluation Process

The survey design weights that are given in the design file assume that the survey design is implemented as designed. Typically, users prefer to replace sites that can not be sampled with other sites to achieve the sample size planned. The site replacement process is described above. When sites are replaced, the survey design weights are no longer correct and must be adjusted. The weight adjustment requires knowing what happened to each site in the base design and the over sample sites. EvalStatus is initially set to "NotEval" to indicate that the site has yet to be evaluated for sampling. When a site is evaluated for sampling, then the EvalStatus for the site must be changed. Recommended codes are:

EvalStatus Code	Name	Meaning
TS	Target Sampled	site is a member of the target population and was

		sampled
LD	Landowner Denial	landowner denied access to the site
PB	Physical Barrier	physical barrier prevented access to the site
NT	Non-Target	site is not a member of the target population
NN	Not Needed	site is a member of the over sample and was not evaluated for sampling
Other codes		Many times useful to have other codes. For example, rather than use NT, may use specific codes indicating why the site was non-target.

### **Statistical Analysis**

Any statistical analysis of data must incorporate information about the monitoring survey design. In particular, when estimates of characteristics for the entire target population are computed, the statistical analysis must account for any stratification or unequal probability selection in the design. Procedures for doing this are available from the Aquatic Resource Monitoring web page given in the bibliography. A statistical analysis library of functions is available from the web page to do common population estimates in the statistical software environment R.

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### Web Pages:

US EPA Aquatic Monitoring Research: <http://www.epa.gov/nheerl/arm>

NHD Plus: <http://www.horizon-systems.com/nhdplus>