Direct BREP Solid Integration: A Step towards Virtual Ship's High Resolution Stability

Marc Pommellet / Sistre (www.sistre.eu)

From 2D Stations to BREP Solids

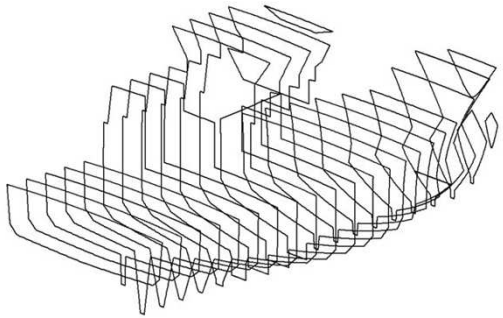
As long as ship's master model was a hand-drawn lines plan, the hydrostatic and stability calculations were based on 2D lines integration.

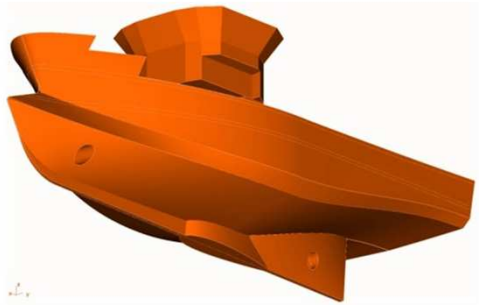
The computerization of this process has then simply consisted in transcribing this manual process by modeling the ship lines, allowing to speed-up the calculations and to process quickly heavier ship models.

But finally, following to computer's growing power and affordability, the traditional lines plans have been gradually replaced by 3D surface models, so that most of today's hulls are now designed and faired as 3D surface models.

Although the common sense shows that compartments and tanks are solids by nature, this deep mutation of the hull design process hasn't yet brought many changes in the field of hydrostatic and stability calculations, which still remains most often a line process, in which the surface -> lines conversion introduces significant time, interactivity and accuracy wastes.

The goal of this paper is therefore to discuss the benefits of direct BREP solid integration in the ship design process, thanks to our experience in developing MAAT Hydro, Sistre's new hydrostatic solver.



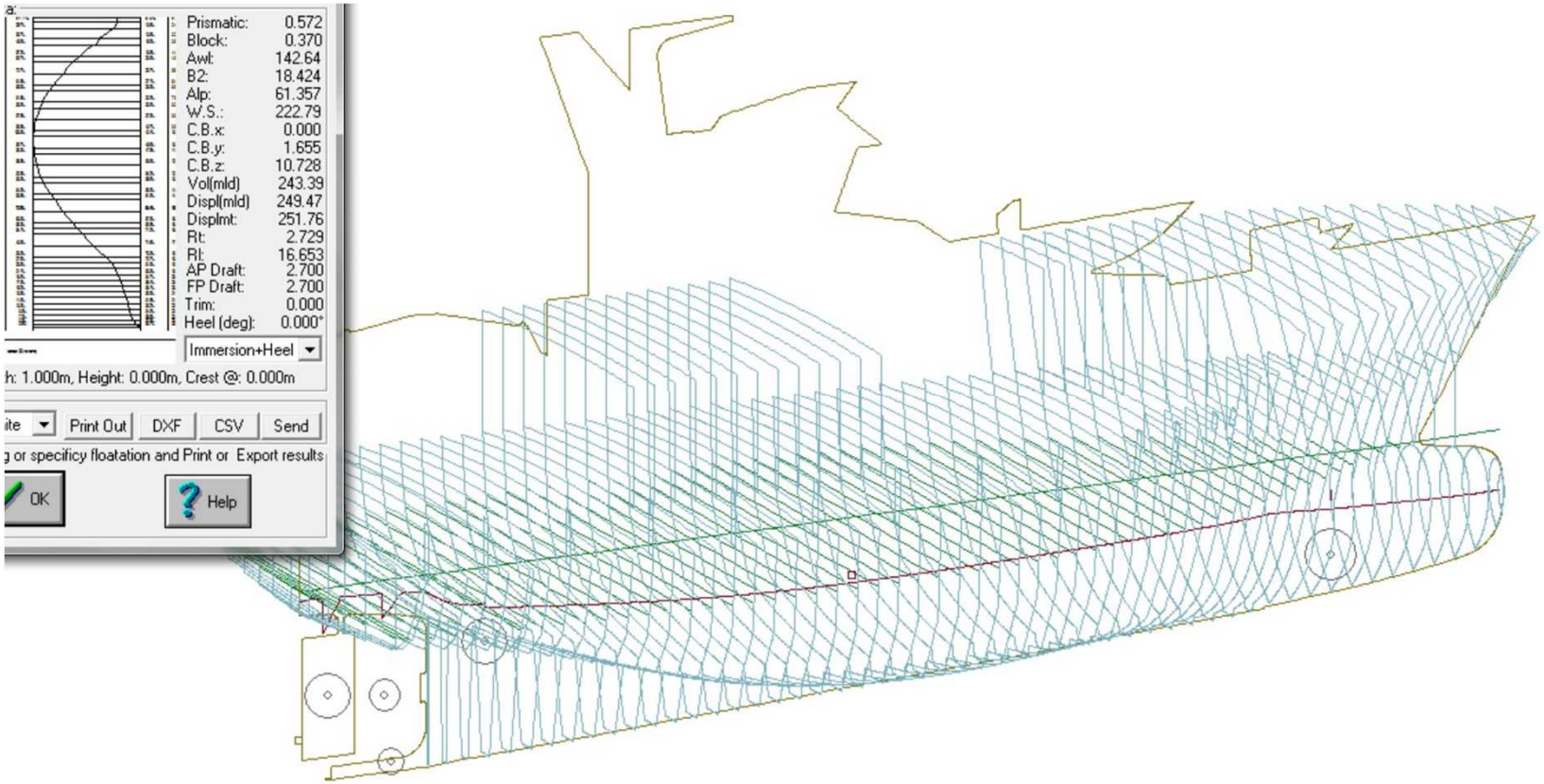






Classical (Stations based) Hydrostatic Calculation:

As an introduction, let us recall shortly the classical way to carry out the hydrostatic and stability calculations, in which float's geometry is represented by a set of stations, corresponding to ship's hand drawn lines:



Classical (Stations based) Calculation Pros and Cons:

Most often, these lines are simply closed / planar polygons, whose immersed area under any floatation plane can be easily calculated by the trapezoidal rule. These polygonal descriptors can be easily obtained by:

- Digitizing existing body plans (but a significant accuracy loss may result from poor quality plans as well as from a too rough acquisition).
- Importing a table of offsets (but numerous offsets may be necessary for getting accurate results).
- Evaluating NURBS descriptors (but Gauss method allows integrating NURBS directly and accurately).
- Etc…

As soon as station's beams of waterline, immersed areas and girths are integrated for a given floatation, Sectional Area Curve, floatation and hull's data can be easily obtained.

Multiple compartments and tanks can also be easily represented by this proceeding, but it must be recalled that such models can only be subdivided by a transverse plane when it corresponds to an existing station.

Let us also mention that this proceeding doesn't allow calculating the wetted surface area accurately, which may slightly influence the plate thickness displacement correction.

Direct BREP (Solid based) Hydrostatic Calculation

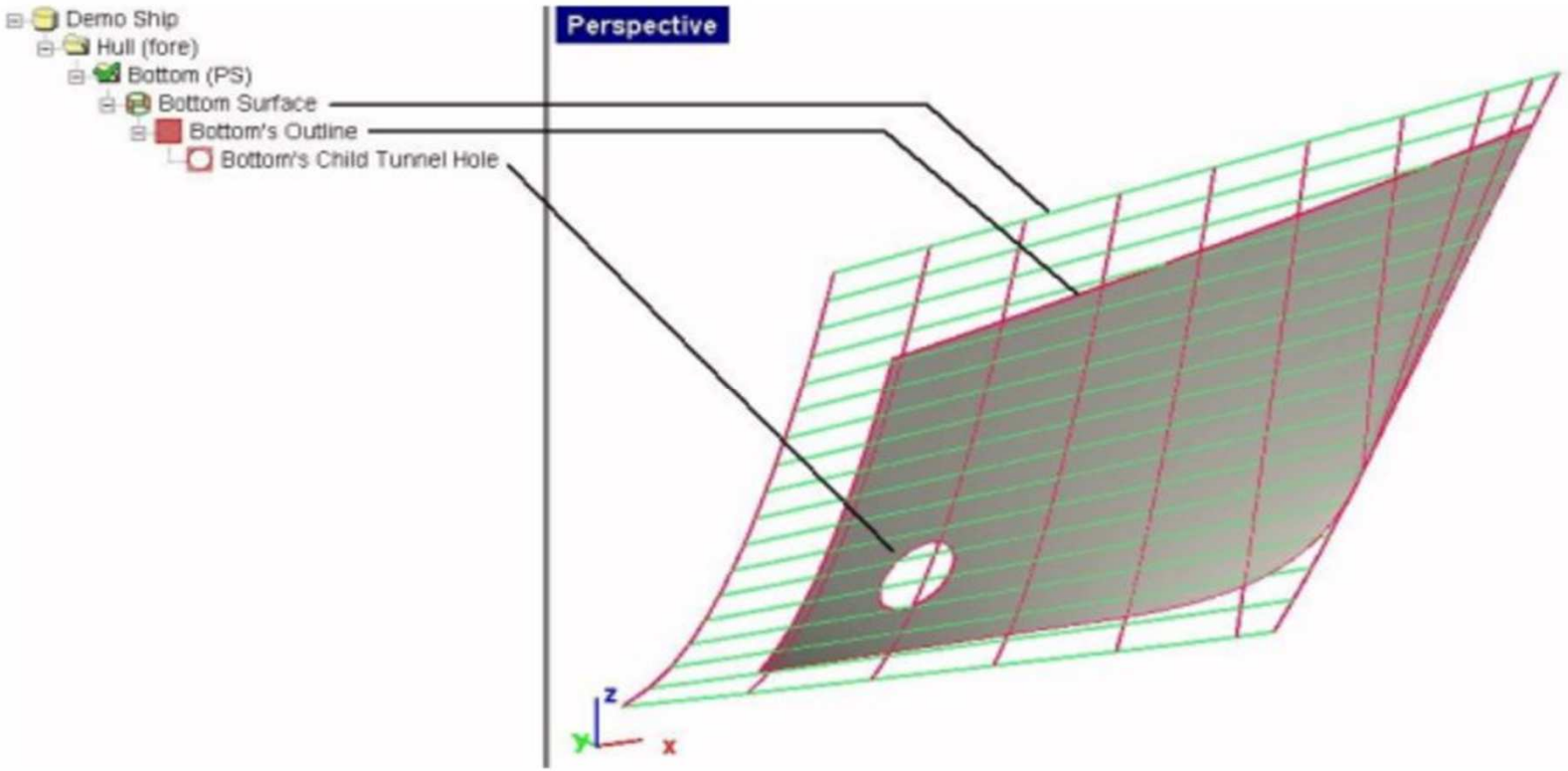
3D surface and solid modeling having now become a hull design standard, updating the hydrostatic analysis algorithms accordingly now seems to be an urgent need: Why continuing to waste time and accuracy for converting high level ship models into stations while their direct process is now possible ?

Obviously, any buoyant object is, first of all, a closed (i.e. watertight) set of faces and can, therefore, be represented by a BREP solid (i.e. Boundary REPresentation solid), which is, nowadays, a well-known 3D modeling standard, handled by almost any 3D modeler:

In such a BREP solid, each of its boundaries is defined as a trimmed NURBS, which consists in a plain (untrimmed) NURBS surface 'owning' a set of bound closed trimming curves defining face's 'real' boundaries:

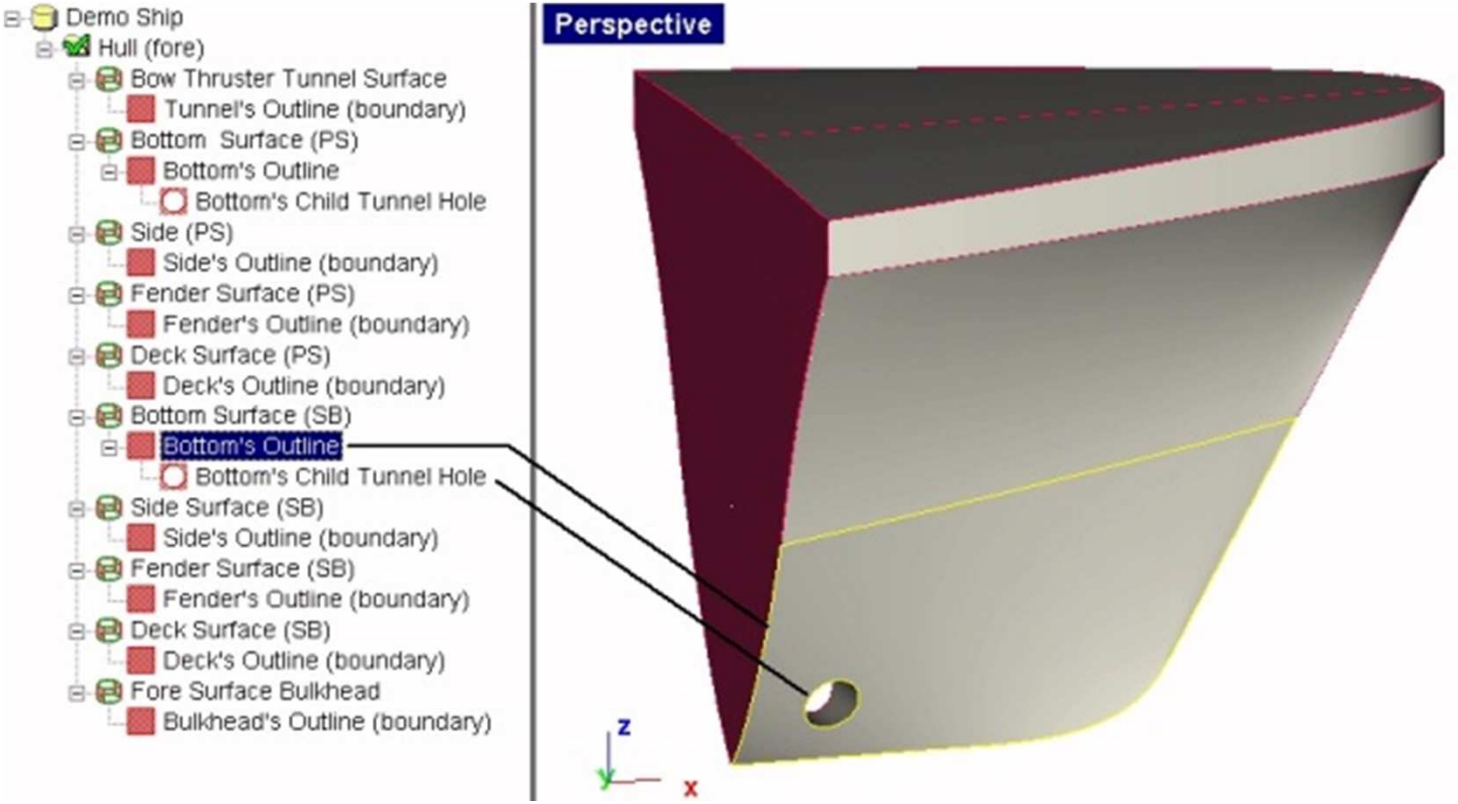
A BREP Solid Boundary is a trimmed NURBS

A trimmed NURBS, consists in a plain NURBS surface (represented by its red / green iso-parametric network) ‘owning’ a set of bound closed trimming curves defining face’s ‘real’ boundaries (represented by the solid red outlines).



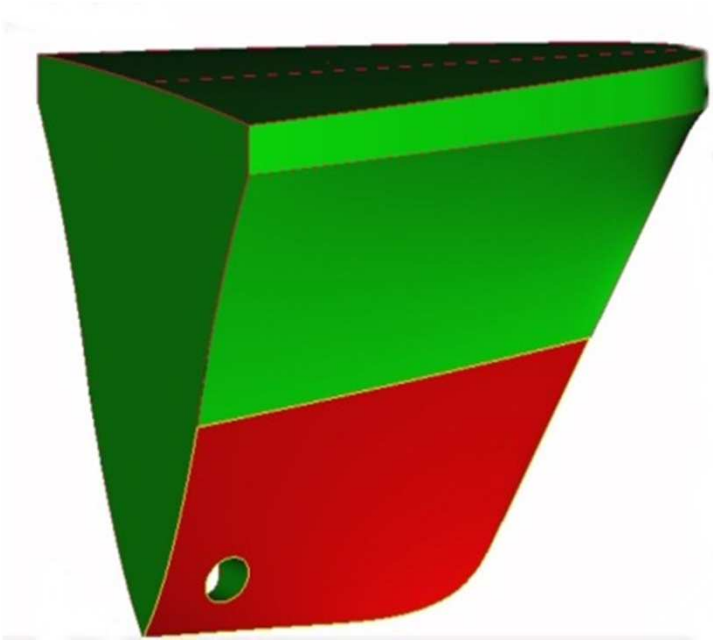
A BREP Solid is a closed set of trimmed NURBS

A BREP solid is, therefore, simply represented by a closed (i.e. watertight) set of trimmed NURBS:

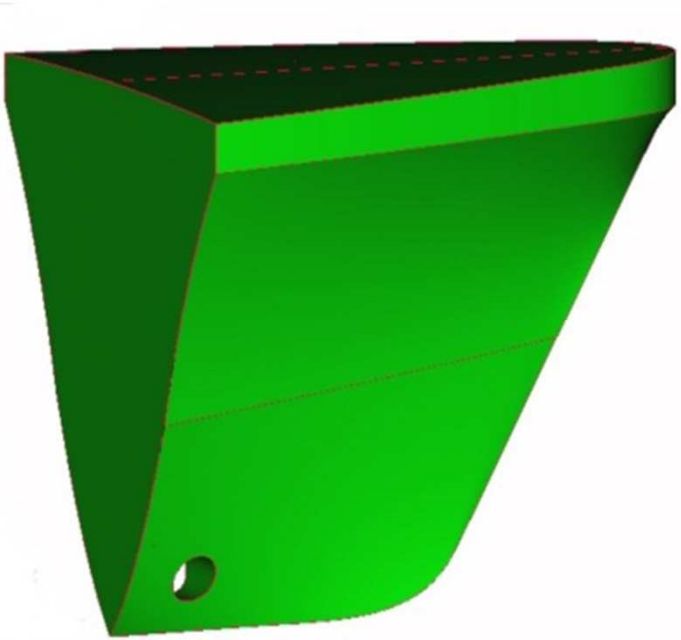


BREP Solid Boundaries must also be oriented

When all the float faces are gathered into a single BREP solid, a special attention still has to be paid to their orientation: As each face has two sides (let's say a wet–outer-green and a dry–inner-red side), these sides have to be correlated in order to avoid accounting reversed pressures in float's total buoyancy:



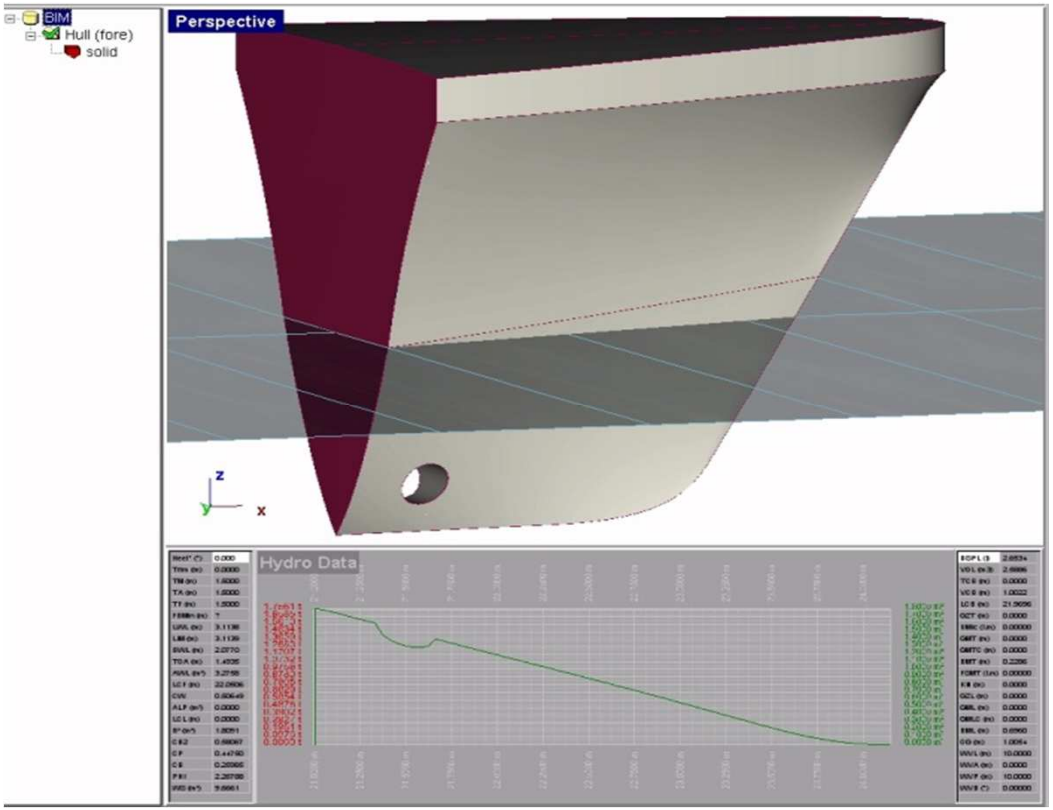
Reversed Pressure on Bottom Face



Normal Pressure on all Faces

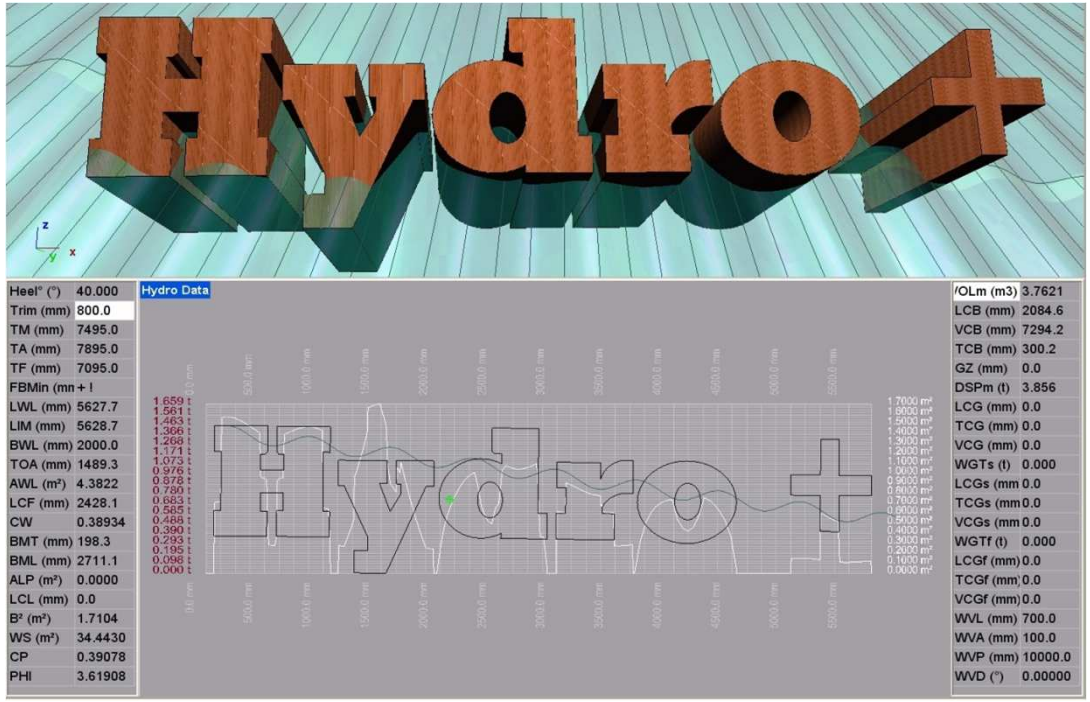
BREP Solid’s Hydrostatic can be integrated directly

When float’s boundaries are so defined and gathered in a watertight solid, a well-known Ship theory’s demonstration shows that float’s buoyancy simply corresponds to the sum of water’s elementary pressures on its immersed faces:

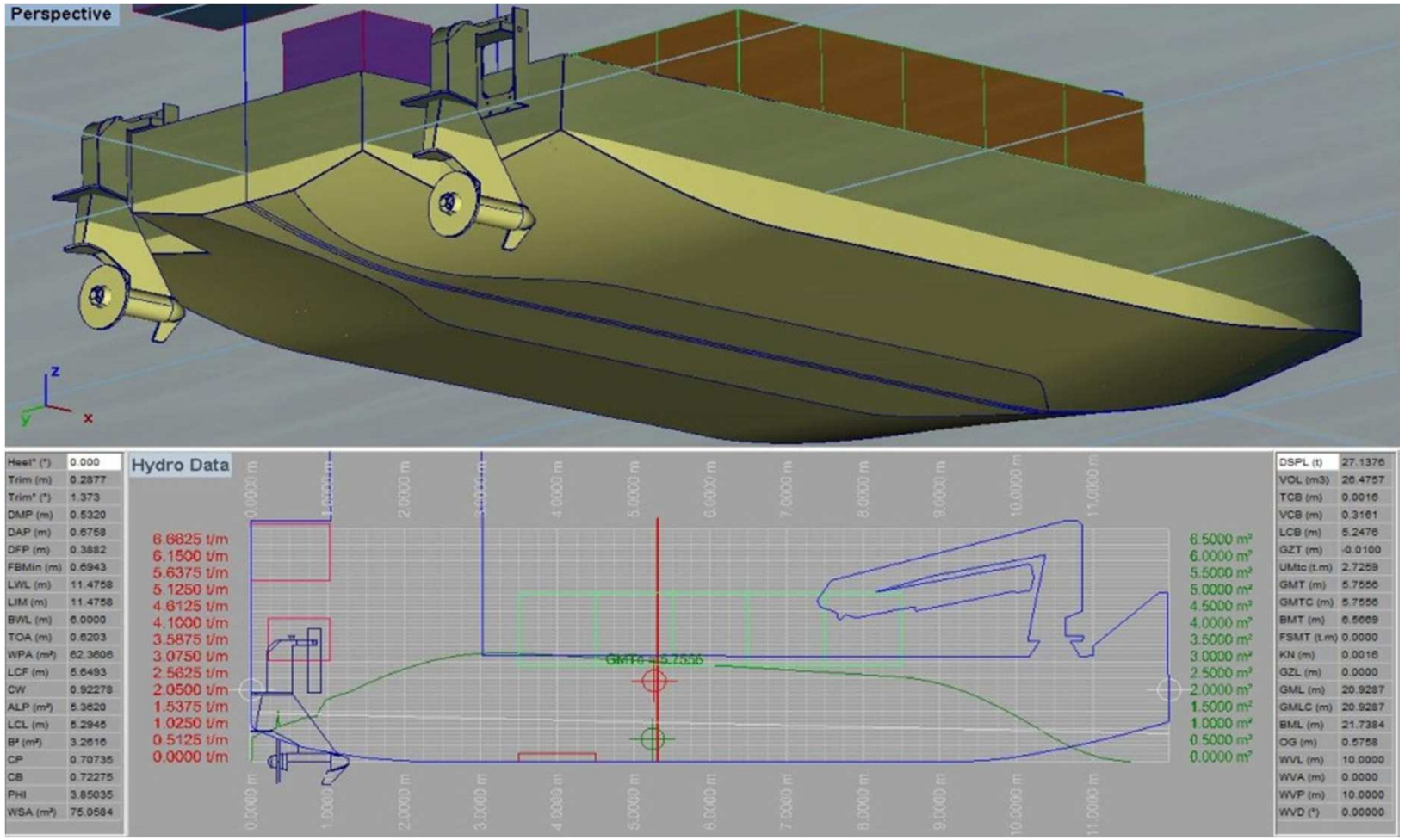


BREP Solid's direct Integration provides an accurate, intuitive and real-time process of ship's buoyancy

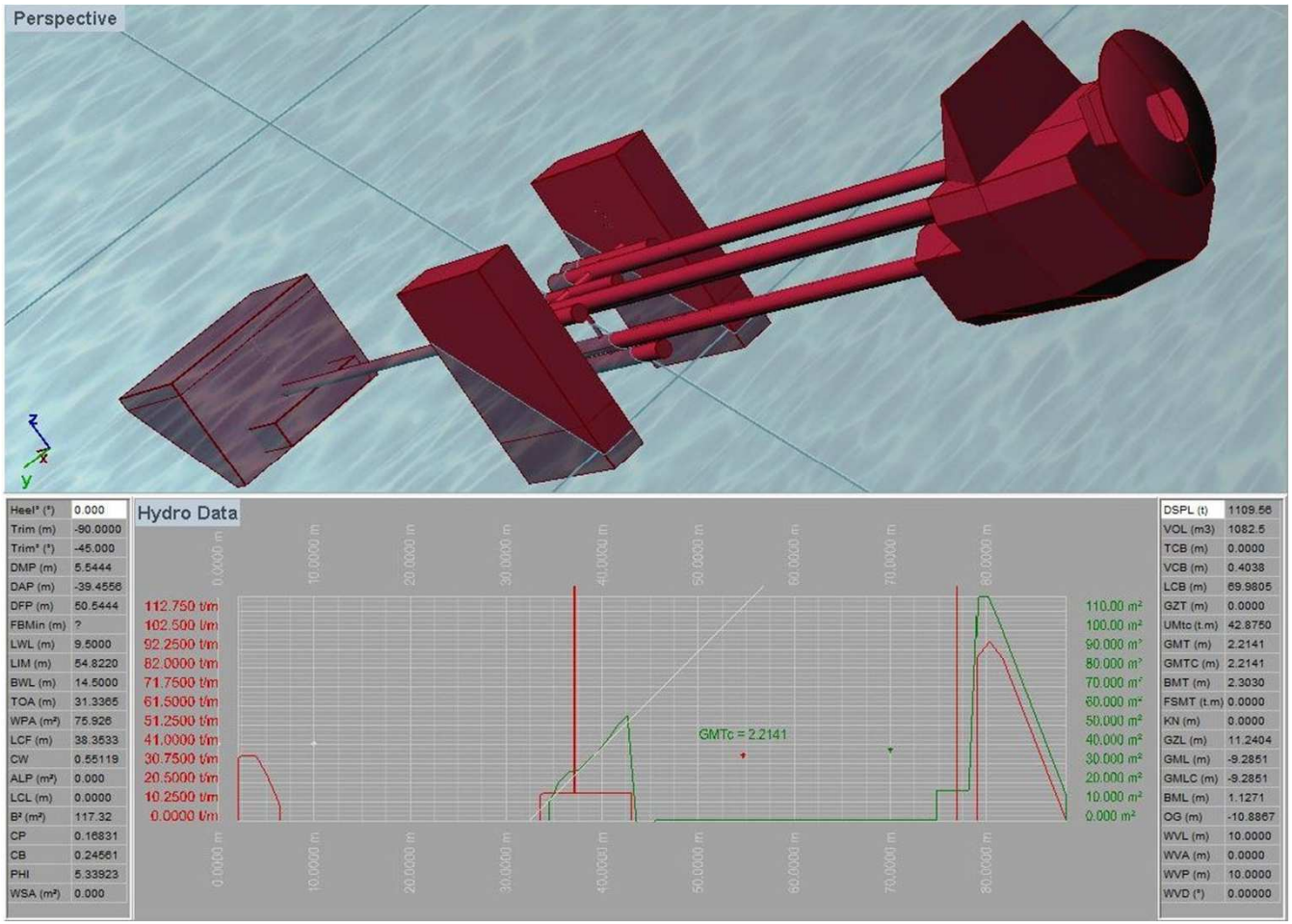
Finally, BREP solid's direct integration appears as the most natural and intuitive proceeding for integrating hydrostatic analysis into a 3D Design Process, allowing to process accurately the most complex objects as easily as the simple ones:



12m Salmon Barge (Credit: CMN)



‘Polar Pod’ 75m Inhabited SPAR Buoy
(Credit Ship Studio / J. L. Etienne)



Classical Stations based / BREP solid based Hydrostatic Comparison for a 1m Radius / half immersed Sphere

According to the important differences between the classical (stations based) and the direct (BREP solid based) buoyancy calculations, let us first compare the speed and accuracy of these proceedings for a 1m radius / half immersed sphere:

	Reference	Trapez. Rule / 20 sta.	Trapez. Rule / 200 sta.	Direct Integration
V (m^3):	2.09439	2.08916 (0.250%)	2.0943 (0.004 %)	2.095 (0.029%)
VCB (m)	-0.37500	-0.3758 (0.210%)	-0.375 (0.000%)	-0.375 (0.000 %)
WPA (m^2)	3.14159	3.0175 (3.950%)	3.1404 (0.038%)	3.1428 (0.038%)
BMT (m)	0.37500	0.3733 (0.450%)	0.3749 (0.027 %)	0.3754 (0.100%)
BML (m)	0.37500	0.3611 (3.710%)	0.3745 (0.130 %)	0.3754 (0.100%)
B^2 (m^2)	1.57079	1.5708 (0.000%)	1.5708 (0.000%)	1.5704 (0.025%)
WSA (m^2)	6.28318	4.8765 (22.40%)	4.9329 (21.49%)	6.2838 (0.010%)
Mean Error (without WSA)	0%	1.430%	0.029%	0.049%
Mean Error (with WSA)	0%	4.420%	3.090 %	0.043%
Calculation time (s)		0.0029	0.0195	0.0012

Let us remark that the trapezoid rule has been ideally applied here to the exact stations and not to their rough polygonal approximation.

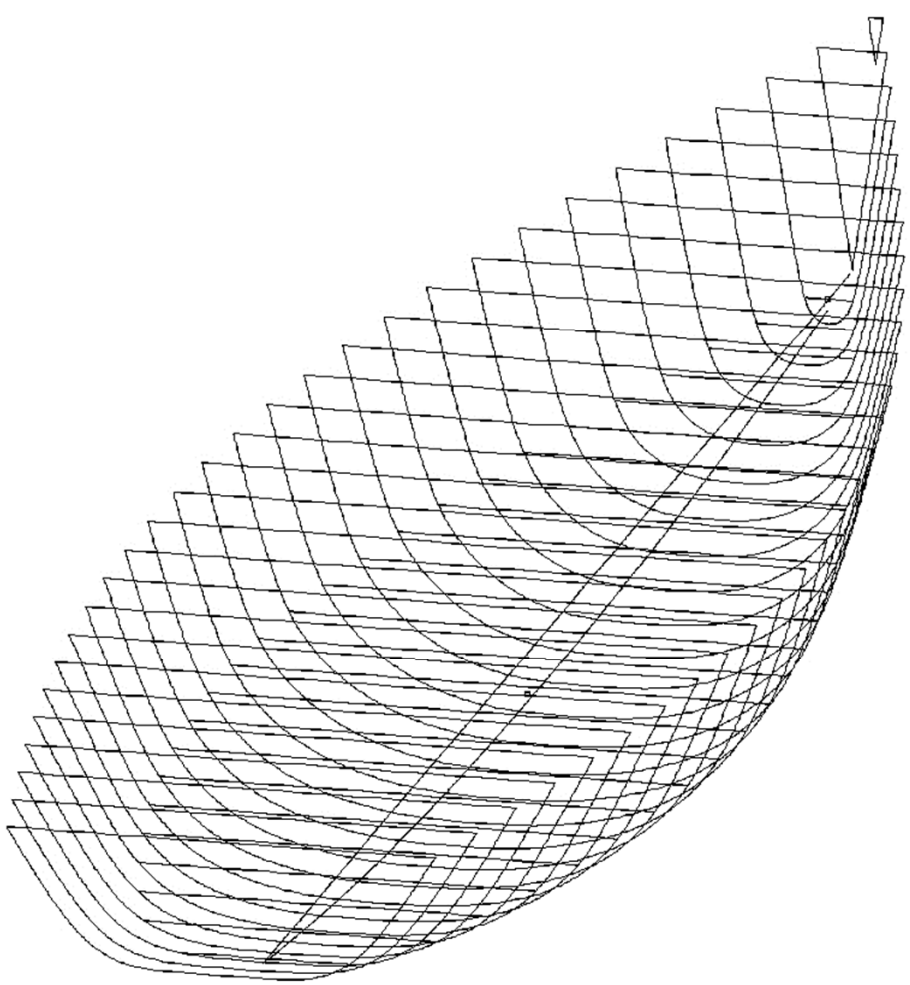
On the other hand the BREP sphere we have integrated is only a non-rational polynomial approximation, whose features may differ slightly from the theoretical sphere.

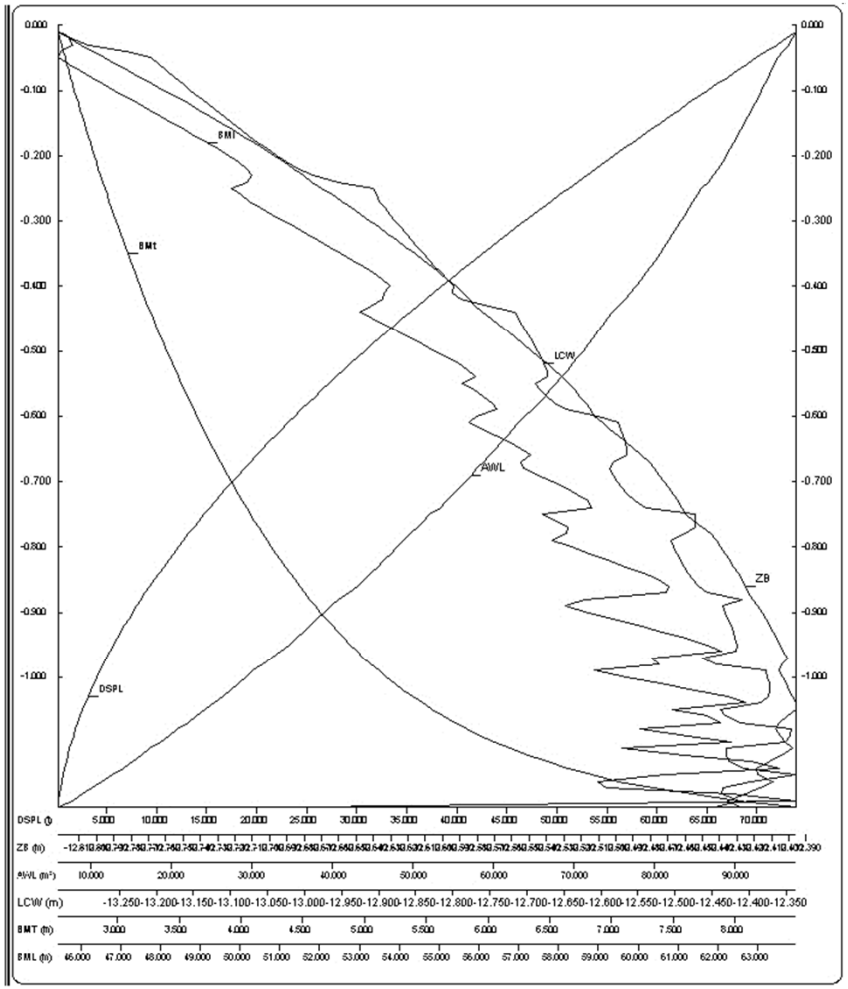
BREP Solid based Integration Pros

We hope to have now clearly shown that the direct BREP solid integration provides accurate results in a fraction of the trapezoid rule calculation time without bringing any of its constraints. Moreover, other advantages must also be mentioned here:

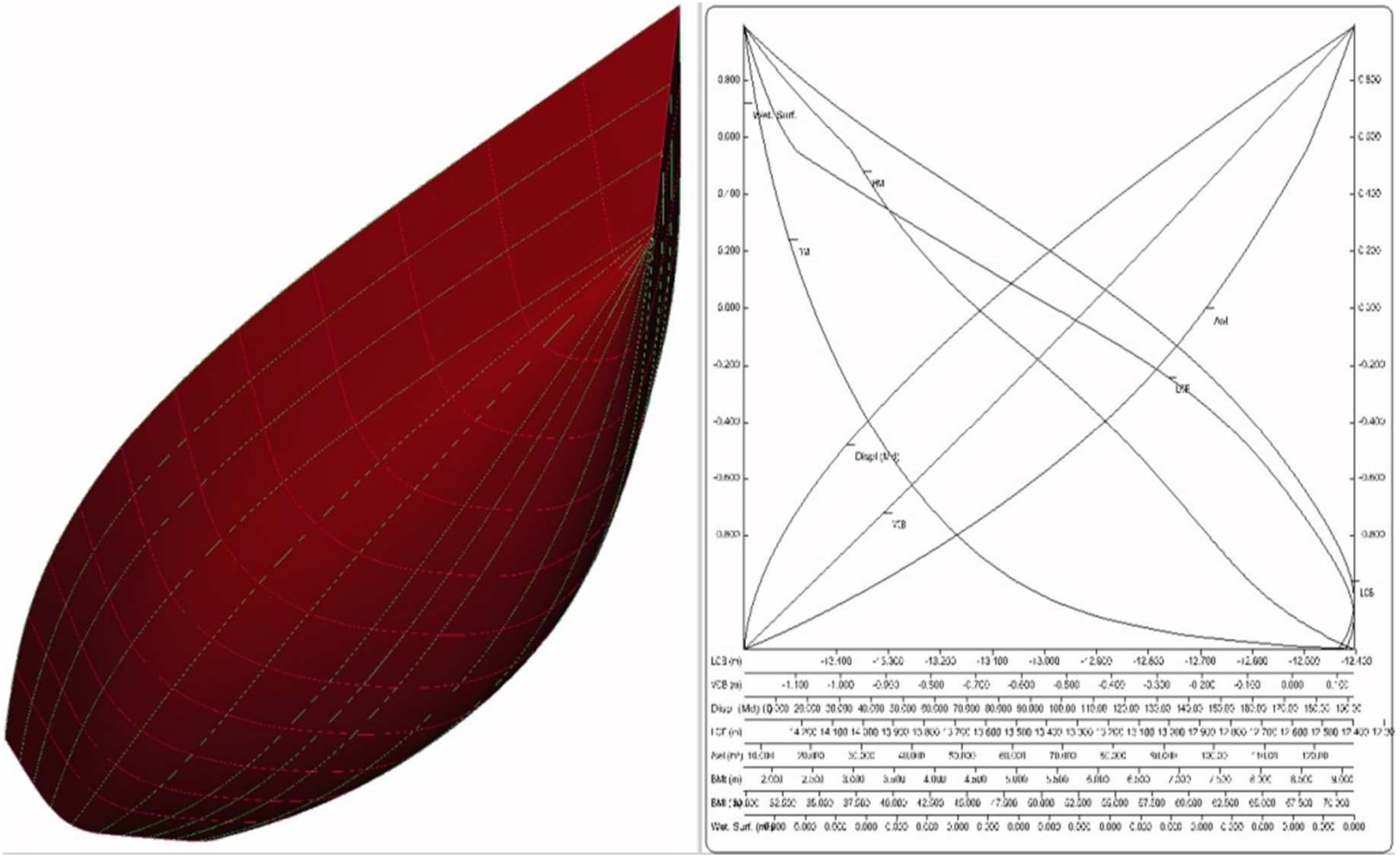
- Direct BREP integration allows a more intuitive and ‘lifelike’ process of complex models.
- Ship’s design model is almost directly usable for hydrostatic calculations.
- Ship’s hydrostatic analysis has almost no complexity or topological limit.
- Float’s hydrostatic features no longer depend on a sectioning grid or definition referential.
- Wetted surface can be calculated very accurately.
- WPA, BMT and BML can be calculated without aberration for flat bottom hull’s lowest floatations (see next plates).
- Etc…

BMT/BML/WPA Curves obtained for a Flat Bottom Hull (2D Stations provide rough results)





BMT/BML/WPA Curves obtained for a Flat Bottom Hull (BREP Solids provide smooth results)



BREP Solid based Integration Cons:

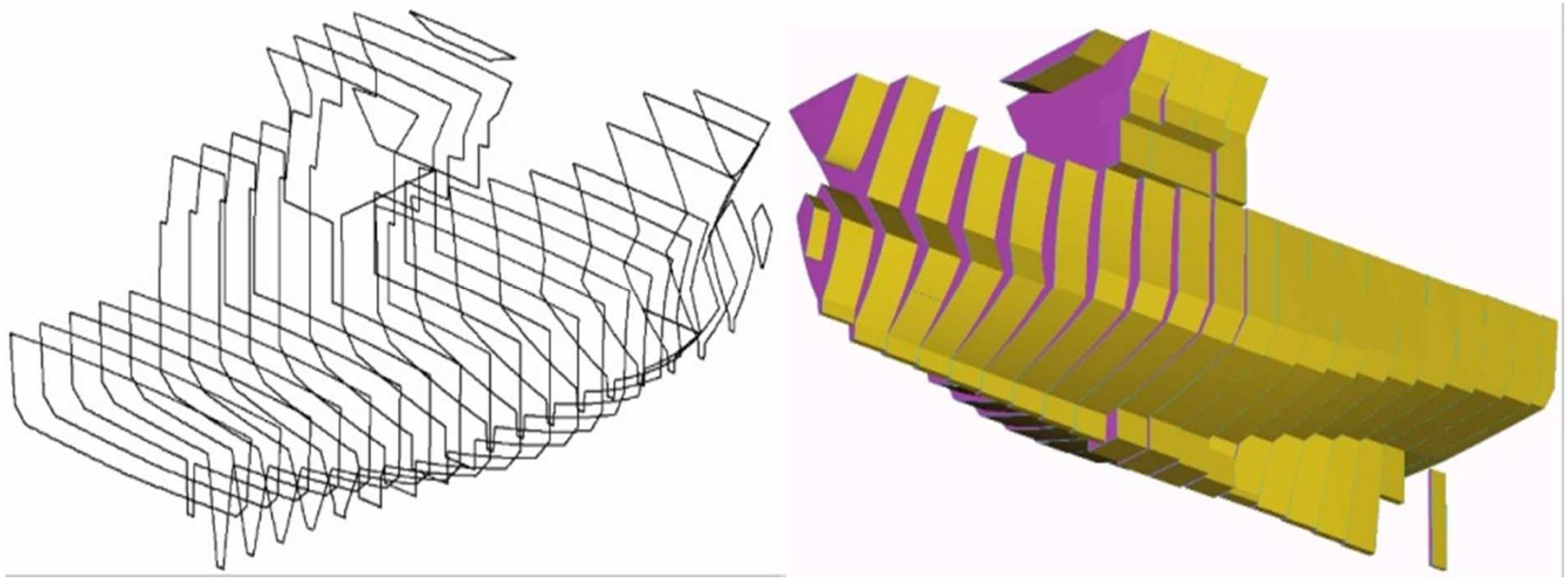
In order to complete this preliminary comparison, two disadvantages must also be mentioned:

- As float's integration directly operates on its 3D faces, no station is available for calculating the Sectional Area Curve, so that a heavier and more complex process must be carried out for getting this important data without stations. Fortunately, the SAC calculation is only necessary for ship's upright hydrostatic analysis and can be omitted in most of the other calculations.

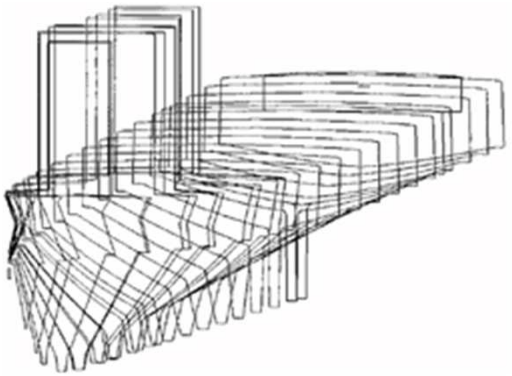
- Ship's BREP descriptor may sometimes be extremely heavy, especially when a lot of small construction details (fillets, chamfers, thicknesses, etc…) are included in the model, slowing down the calculations without improving their accuracy. As 3D modeling allows defining a lot of geometric details very easily, it must be kept in mind that these details may significantly slow down the calculations without any profit if they are too numerous.

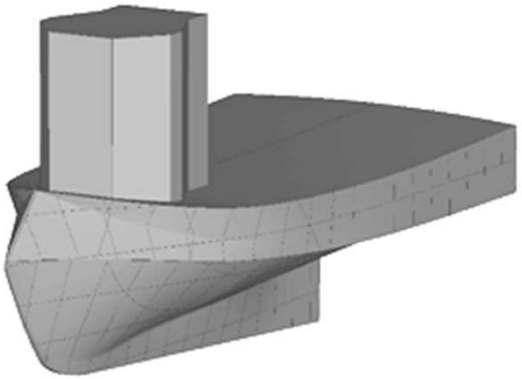
2D Stations / BREP Solid Conversion

In rare cases, ship's model may be unavailable as a BREP solid (i.e. old and/or traditionally designed ships) and its lines may therefore have to be converted into an equivalent BREP solid to make its hydrostatic analysis possible.



Compared Results for a small 10.080 m x 4.700 m x 2.180 trawler





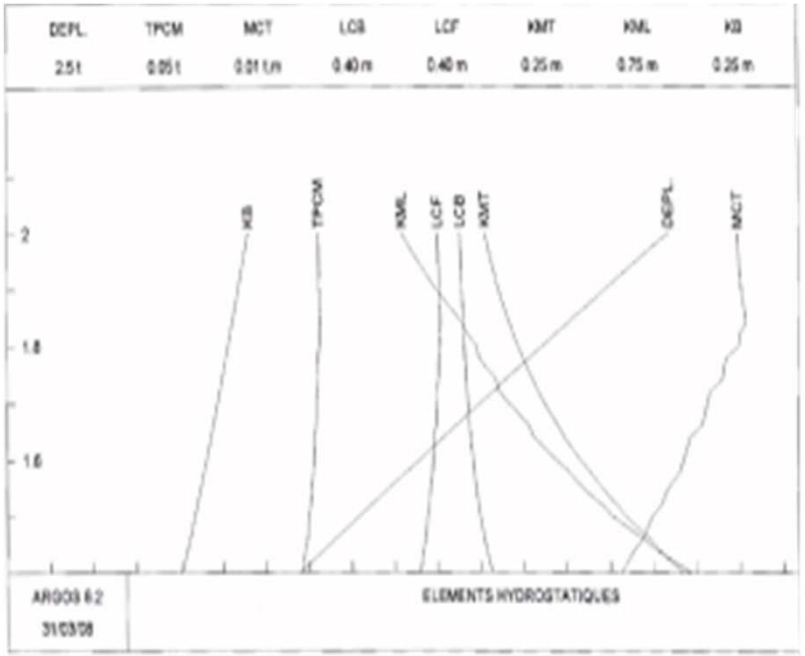
First of all, it is important to recall that BREP integration can operate almost immediately on the design model, while the accuracy of the trapezoid rule highly depends on station's locations:

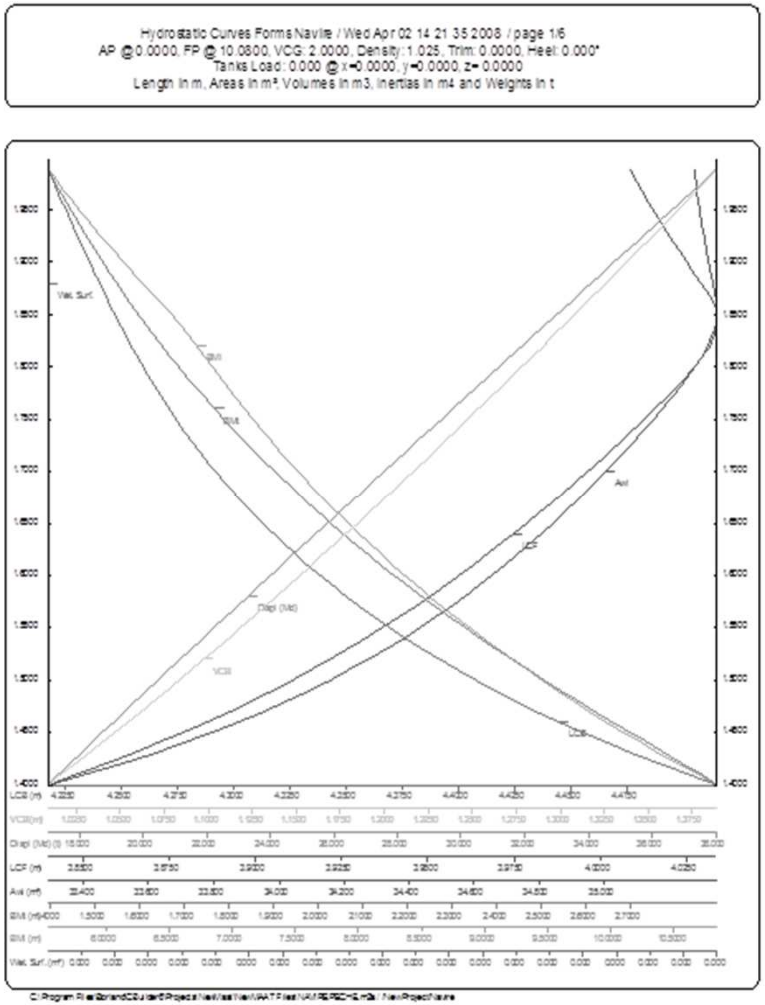
-Double stations must frame SAC's potential steps (i.e. on skeg's end and cabin's front / rear faces in this case) in order to get accurate results.

-Stations must be set on SAC's potential angles (i.e. on cabin's angles in this example)

Such constraints often avoid fully automating the access to hydrostatic analysis.

Compared Hydrostatic Curves
(2D Stations / BREP Solid)





Compared Hydrostatic Data
(2D Stations / BREP Solid)

TABLE DES ELEMENTS HYDROSTATIQUES

T/BASE (m)	DEPLAC. (t)	TPCM (t)	MCT/CM (t.m)	LCB (m)	LCF (m)	KMT (m)	KML (m)	KB (m)
1.400	16.98	0.34	0.178	4.507	3.835	3.914	11.89	1.009
1.410	17.32	0.34	0.179	4.492	3.843	3.881	11.74	1.017
1.420	17.66	0.34	0.180	4.478	3.850	3.847	11.59	1.025
1.430	18.00	0.34	0.181	4.466	3.857	3.812	11.44	1.033
1.440	18.35	0.35	0.182	4.455	3.864	3.778	11.30	1.040
1.450	18.69	0.35	0.183	4.444	3.876	3.754	11.19	1.048
1.460	19.04	0.35	0.184	4.434	3.886	3.729	11.07	1.055
1.470	19.39	0.35	0.185	4.424	3.890	3.692	10.94	1.062
1.480	19.74	0.35	0.186	4.414	3.894	3.655	10.80	1.070
1.490	20.09	0.35	0.186	4.405	3.898	3.620	10.66	1.077
1.500	20.44	0.35	0.187	4.397	3.902	3.586	10.54	1.084
1.510	20.79	0.35	0.188	4.389	3.912	3.562	10.45	1.091
1.520	21.14	0.35	0.190	4.381	3.922	3.539	10.36	1.098
1.530	21.49	0.35	0.190	4.373	3.925	3.508	10.24	1.105
1.540	21.84	0.35	0.191	4.366	3.928	3.477	10.12	1.112
1.550	22.19	0.35	0.192	4.359	3.933	3.451	10.02	1.119
1.560	22.55	0.35	0.193	4.352	3.940	3.425	9.93	1.126
1.570	22.90	0.35	0.194	4.346	3.947	3.402	9.85	1.133
1.580	23.26	0.35	0.195	4.340	3.954	3.378	9.77	1.139
1.590	23.63	0.36	0.196	4.336	3.956	3.351	9.66	1.146
1.600	23.99	0.36	0.196	4.331	3.958	3.324	9.55	1.152
1.610	24.34	0.36	0.197	4.325	3.960	3.300	9.45	1.159
1.620	24.69	0.36	0.197	4.318	3.962	3.277	9.36	1.166
1.630	25.04	0.36	0.198	4.313	3.964	3.255	9.26	1.172
1.640	25.40	0.36	0.198	4.308	3.966	3.232	9.17	1.179
1.650	25.76	0.36	0.200	4.304	3.976	3.215	9.13	1.185
1.660	26.11	0.36	0.202	4.299	3.986	3.197	9.09	1.192
1.670	26.47	0.36	0.202	4.295	3.987	3.177	9.00	1.198
1.680	26.83	0.36	0.202	4.291	3.988	3.157	8.91	1.204
1.690	27.19	0.36	0.203	4.287	3.989	3.138	8.82	1.211
1.700	27.54	0.36	0.203	4.283	3.990	3.119	8.74	1.217
1.710	27.90	0.36	0.203	4.279	3.991	3.101	8.66	1.223
1.720	28.26	0.36	0.204	4.276	3.992	3.084	8.58	1.229
1.730	28.62	0.36	0.206	4.272	4.001	3.069	8.55	1.236
1.740	28.98	0.36	0.207	4.269	4.010	3.054	8.52	1.242
1.750	29.34	0.36	0.208	4.266	4.010	3.039	8.44	1.248
1.760	29.70	0.36	0.208	4.263	4.010	3.023	8.36	1.254
1.770	30.06	0.36	0.208	4.260	4.010	3.009	8.29	1.260
1.780	30.42	0.36	0.209	4.257	4.012	2.995	8.22	1.266
1.790	30.78	0.36	0.211	4.255	4.020	2.981	8.20	1.272

Hydrostatic Curves Forms Navire / Wed Apr 02 16 03 46 2008 / page 2/6
AP @ 0.0000, FP @ 10.0800, VCG: 2.0000, Density: 1.025, Trim: 0.0000 m, Heel: 0.000°
Tanks Load: 0.000 @ x=0.0000, y=0.0000, z= 0.0000
Length in m, Areas in m², Volumes in m3, Inertias in m4 and Weights in t

	MP Imm.	AP Imm.	FP Imm.	Displ (Md)	Vol (Md)	LCB	TCB	VCB	LCB/F(%)	Wet. Surf.
1	1.4000	1.4000	1.4000	17.007	16.592	4.5156	0.0000	1.0085	54.27	49.243
2	1.4100	1.4100	1.4100	17.349	16.926	4.5024	0.0000	1.0163	54.41	49.567
3	1.4200	1.4200	1.4200	17.692	17.260	4.4898	0.0000	1.0240	54.53	49.883
4	1.4300	1.4300	1.4300	18.036	17.596	4.4778	0.0000	1.0317	54.66	50.195
5	1.4400	1.4400	1.4400	18.381	17.932	4.4663	0.0000	1.0393	54.77	50.498
6	1.4500	1.4500	1.4500	18.727	18.270	4.4554	0.0000	1.0468	54.88	50.800
7	1.4600	1.4600	1.4600	19.074	18.608	4.4450	0.0000	1.0542	54.99	51.098
8	1.4700	1.4700	1.4700	19.421	18.947	4.4350	0.0000	1.0615	55.09	51.390
9	1.4800	1.4800	1.4800	19.770	19.287	4.4255	0.0000	1.0688	55.19	51.681
10	1.4900	1.4900	1.4900	20.119	19.628	4.4165	0.0000	1.0761	55.28	51.967

	MP Imm.	B²	Awl	LCF	Tons / cm	MTCm	BMt	BMl	T Inertia	L Inertia
1	1.4000	2.633	33.288	3.8399	0.34120	0.1662	2.8948	10.8402	48.030	179.862
2	1.4100	2.678	33.405	3.8483	0.34240	0.1669	2.8568	10.6816	48.353	180.793
3	1.4200	2.722	33.513	3.8565	0.34351	0.1677	2.8178	10.5284	48.635	181.722
4	1.4300	2.767	33.613	3.8644	0.34453	0.1684	2.7782	10.3802	48.885	182.648
5	1.4400	2.811	33.706	3.8719	0.34549	0.1691	2.7385	10.2361	49.108	183.559
6	1.4500	2.856	33.793	3.8791	0.34638	0.1699	2.6989	10.0964	49.308	184.461
7	1.4600	2.900	33.875	3.8860	0.34722	0.1706	2.6595	9.9606	49.490	185.349
8	1.4700	2.945	33.952	3.8926	0.34801	0.1713	2.6205	9.8282	49.652	186.219
9	1.4800	2.989	34.024	3.8989	0.34875	0.1720	2.5820	9.6993	49.801	187.073
10	1.4900	3.034	34.093	3.9050	0.34945	0.1726	2.5441	9.5734	49.936	187.907

	MP Imm.	Block	Prismatic	LV^1/3	Wpl Ratio	B² Area Ratio	WS Ratio	Lwl	Bwl	Draft
1	1.4000	0.19744	0.64006	3.86016	0.73181	0.30848	1.97214	9.8455	4.6200	1.8475
2	1.4100	0.20033	0.64206	3.83464	0.73440	0.31200	1.95895	9.8455	4.6200	1.8575
3	1.4200	0.20319	0.64403	3.80970	0.73677	0.31550	1.94587	9.8455	4.6200	1.8675
4	1.4300	0.20604	0.64592	3.78532	0.73897	0.31898	1.93305	9.8455	4.6200	1.8775
5	1.4400	0.20887	0.64787	3.76149	0.74102	0.32239	1.92031	9.8455	4.6200	1.8875
6	1.4500	0.21168	0.64978	3.73818	0.74294	0.32577	1.90793	9.8455	4.6200	1.8975
7	1.4600	0.21447	0.65166	3.71539	0.74474	0.32911	1.89581	9.8455	4.6200	1.9075
8	1.4700	0.21724	0.65351	3.69308	0.74642	0.33242	1.88382	9.8455	4.6200	1.9175
9	1.4800	0.21999	0.65531	3.67126	0.74801	0.33570	1.87215	9.8455	4.6200	1.9275
10	1.4900	0.22272	0.65709	3.64990	0.74951	0.33895	1.86067	9.8455	4.6200	1.9375

Compared Hydrostatic Data Table
(2D Stations / BREP Solid)

	Displ. (t)	TPCM (t)	LCB (m)	LCF (m)	KMT (m)	KML (m)	KB (m)
DMP=1.400:	16.98-17.007 (0.159%)	0.34 – 0.3412 (0.35%)	4.507 – 4.5156 (0.19%)	3.835 – 3.8399 (0.127%)	3.914 – 3.9033 (0.27%)	11.89 – 11.8487 (0.35%)	1.009 – 1.0085 (0.049%)
DMP=1.500 :	20.44 – 20.468 (0.136%)	0.35 – 0.3501 (0.03%)	4.397 – 4.4078 (0.25%)	3.902 – 3.9108 (0.22%)	3.586 – 3.5901 (0.11%)	10.54 – 10.534 (0.06%)	1.084 – 1.0832 (0.074%)
DMP=1.600 :	23.99 – 23.997 (0.029%)	0.36 – 0.3552 (1.4%)	4.331 – 4.3384 (0.17%)	3.958 – 3.9591 (0.03%)	3.324 – 3.3229 (0.11%)	9.55 – 9.5211 (0.30%)	1.152 – 1.1519 (0.008%)

Compared Stability Data
(2D Stations / BREP Solid)

'AS DE CHARGEMENT : NAVIRE FILETS POISSONS CHARGE MAXIMALE 100% GAZOLE

COURBE GZ - Gite … tribord

GITE (deg)	TMIL (m)	ASSIETTE (m)	LCB (m)	YB (m)	KB (m)	KN (m)	GZ (m)	AIRE (m.rad)
0.0	1.580	0.047	4.298	0.000	1.142	0.000	0.000	0.000
5.0	1.577	0.056	4.298	0.193	1.151	0.293	0.114	0.005
10.0	1.568	0.061	4.297	0.365	1.173	0.563	0.207	0.019
15.0	1.548	0.032	4.300	0.505	1.204	0.799	0.267	0.040
20.0	1.519	-0.004	4.303	0.615	1.238	1.001	0.299	0.065
25.0	1.495	-0.045	4.307	0.687	1.268	1.159	0.291	0.091
30.0	1.471	-0.082	4.310	0.738	1.295	1.287	0.260	0.115
35.0	1.449	-0.127	4.314	0.775	1.318	1.391	0.213	0.136
40.0	1.427	-0.173	4.317	0.802	1.339	1.475	0.155	0.152
50.0	1.377	-0.279	4.322	0.841	1.377	1.596	0.022	0.167

Status:	Heel:	AP Draft:	FP Draft:	TCB:	VCB:	LCB:	KN:	MS:	GZ:	Area:
	0.000	1607.3	1547.9	0.0	1141.4	4297.7	0.0	0.0	0.0	-0.000
Equilbrium	0.000	1607.3	1547.9	0.0	1141.4	4297.7	0.0	0.0	0.0	-0.000
	5.000	1608.5	1543.7	192.6	1149.8	4297.2	292.1	113.7	113.7	0.005
	10.000	1601.1	1531.5	364.6	1172.1	4296.7	562.6	207.2	207.2	0.019
	15.000	1568.2	1522.9	504.3	1202.8	4298.9	798.4	268.6	268.6	0.040
	20.000	1520.9	1515.4	613.9	1237.0	4302.5	999.9	299.8	299.8	0.065
GZ Max	21.588	1507.1	1513.0	637.1	1246.5	4303.5	1050.1	297.6	297.6	0.073
	25.000	1477.5	1507.8	686.9	1266.9	4305.7	1158.0	292.9	292.9	0.090
	30.000	1436.0	1502.3	737.2	1292.9	4308.8	1284.9	261.4	261.4	0.115
	35.000	1394.2	1499.4	773.6	1316.0	4311.9	1388.5	214.4	214.4	0.135
	40.000	1350.3	1499.1	800.9	1336.8	4315.0	1472.9	157.1	157.1	0.152
	45.000	1302.2	1501.5	822.0	1356.1	4318.0	1540.2	92.8	92.8	0.162
	50.000	1247.6	1507.1	838.7	1374.3	4320.8	1591.9	23.8	23.8	0.168
	55.000	1183.1	1516.5	852.1	1391.8	4323.4	1628.9	-48.0	-48.0	0.166
	60.000	1103.2	1531.3	862.9	1408.9	4325.6	1651.6	-121.1	-121.1	0.159
	65.000	998.2	1554.3	871.7	1425.9	4327.5	1660.7	-194.5	-194.5	0.145
	70.000	850.2	1591.2	878.9	1443.2	4329.0	1656.8	-266.8	-266.8	0.125
	75.000	626.6	1654.4	884.7	1462.1	4329.5	1641.3	-336.0	-336.0	0.099
	80.000	253.6	1780.9	889.9	1485.6	4328.6	1617.6	-398.3	-398.3	0.067
	85.000	-619.4	2167.5	894.4	1520.2	4325.6	1592.4	-446.8	-446.8	0.030
	89.900	-83545.9	46026.7	896.3	1562.4	4323.1	1564.0	-483.0	-483.0	-0.010

Compared Stability Data Table
(2D Stations / BREP Solid)

	DMP (m)	Trim (m)	LCB (m)	YB (m)	KB (m)	KN (m)	GZ (m)
0° :	1.58 1.578 (0.126%)	0.047 0.059 (0.012)	4.298 4.2977 (0.007%)	0 0 (0%)	1.142 1.1414 (0.27%)	0 0 (0%)	0 0 (0)
20° :	1.519 1.5182 (0.056%)	-0.004 0.005 (0.001)	4.397 4.4078 (0.25%)	0.615 0.6139 (0.18%)	1.238 1.237 (0.08%)	10.54 10.534 (0.06%)	1.084 1.0832 (0.0008)
50° :	1.377 1.3773 (0%)	-0.279 0.2595 (0.019)	4.322 4.3208 (0.03%)	0.841 0.8387 (0.27%)	1.377 1.3743 (0.20%)	1.596 1.5919 (0.26%)	0.022 0.0238 (0.0018)

Compared Cross Curves Data
(2D Stations / BREP Solid)

TABLE DES BRAS DE LEVIERS DE REDRESSEMENT

DEPLACEMENTS (t)	ANGLES DE GITE (deg)								
	5.0	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0
16.98	0.314	0.574	0.800	1.000	1.181	1.329	1.539	1.668	1.740
17.48	0.314	0.575	0.801	1.003	1.182	1.329	1.536	1.664	1.733
17.98	0.314	0.576	0.802	1.004	1.184	1.328	1.533	1.659	1.726
18.48	0.313	0.575	0.803	1.006	1.185	1.327	1.530	1.653	1.719
18.98	0.312	0.575	0.803	1.007	1.184	1.324	1.526	1.648	1.712
19.48	0.311	0.574	0.804	1.008	1.184	1.322	1.521	1.642	1.706
19.98	0.310	0.574	0.804	1.008	1.182	1.319	1.516	1.637	1.700
20.48	0.308	0.573	0.803	1.009	1.180	1.315	1.511	1.631	1.695
20.98	0.306	0.571	0.803	1.009	1.177	1.310	1.505	1.625	1.689
21.48	0.304	0.570	0.802	1.008	1.174	1.306	1.500	1.619	1.684
21.98	0.302	0.568	0.801	1.006	1.171	1.301	1.493	1.613	1.679
22.48	0.299	0.567	0.800	1.004	1.167	1.295	1.487	1.607	1.674
22.98	0.296	0.565	0.799	1.002	1.162	1.290	1.481	1.601	1.669
23.48	0.293	0.563	0.798	0.999	1.157	1.285	1.474	1.594	1.664
23.98	0.290	0.561	0.796	0.996	1.152	1.279	1.467	1.588	1.659
24.48	0.287	0.558	0.795	0.992	1.146	1.273	1.460	1.581	1.655
24.98	0.285	0.556	0.793	0.988	1.141	1.267	1.452	1.575	1.650
25.48	0.282	0.553	0.791	0.984	1.135	1.260	1.445	1.569	1.644
25.98	0.280	0.551	0.789	0.979	1.129	1.253	1.437	1.562	1.640
26.48	0.277	0.548	0.786	0.974	1.123	1.245	1.429	1.556	1.635
26.98	0.275	0.546	0.783	0.969	1.117	1.237	1.421	1.549	1.630
27.48	0.273	0.543	0.780	0.962	1.110	1.229	1.414	1.543	1.626
27.98	0.271	0.540	0.776	0.956	1.103	1.221	1.406	1.536	1.621
28.48	0.269	0.538	0.772	0.950	1.095	1.213	1.398	1.529	1.616
28.98	0.267	0.534	0.767	0.944	1.087	1.205	1.390	1.523	1.612
29.48	0.265	0.531	0.763	0.938	1.079	1.196	1.382	1.516	1.607
29.98	0.263	0.528	0.757	0.931	1.071	1.188	1.374	1.510	1.602
30.48	0.261	0.524	0.752	0.924	1.062	1.179	1.365	1.503	1.598
30.98	0.260	0.521	0.746	0.916	1.053	1.170	1.357	1.496	1.594
31.48	0.258	0.518	0.739	0.908	1.045	1.161	1.349	1.490	1.590
31.98	0.257	0.515	0.733	0.900	1.036	1.151	1.341	1.483	1.586
32.48	0.255	0.511	0.726	0.892	1.026	1.142	1.333	1.477	1.581
32.98	0.254	0.508	0.720	0.883	1.017	1.133	1.324	1.471	1.577
33.48	0.253	0.504	0.713	0.874	1.007	1.123	1.316	1.464	1.573
33.98	0.251	0.500	0.706	0.865	0.998	1.114	1.308	1.458	1.569
34.48	0.250	0.496	0.698	0.856	0.988	1.104	1.299	1.451	1.564
34.98	0.249	0.491	0.690	0.846	0.978	1.094	1.291	1.444	1.560
35.48	0.248	0.486	0.681	0.836	0.968	1.085	1.283	1.438	1.556
35.98	0.247	0.481	0.672	0.826	0.958	1.075	1.274	1.432	1.553

Cross Curves Forms NAVIREPECHEOKT.m2a, Initial Trim: 0.0000 / Wed Apr 09 19 57 54 2008 / page 2/2
AP @ 0.0000, FP @ 10.0800, K point @ 0.0000, Density: 1.0250, Length in m, Weight in t
Total Load: 16.980 to 35.980, (Tanks 0.000 t included)

Displ.	DAP	DFP	DMP	KN 5°	KN 10°	KN 15°	KN 20°	KN 25°	KN 30°	KN 40°	KN 50°	KN 60°
16.980	1.3992	1.3992	1.3992	0.3129	0.5726	0.7981	0.9990	1.1792	1.3282	1.5393	1.6668	1.7378
17.480	1.4723	1.3185	1.3954	0.3157	0.5807	0.8104	1.0147	1.1958	1.3421	1.5495	1.6733	1.7369
17.980	1.4814	1.3424	1.4119	0.3148	0.5799	0.8099	1.0146	1.1946	1.3388	1.5437	1.6661	1.7284
18.480	1.4907	1.3658	1.4282	0.3137	0.5789	0.8092	1.0144	1.1929	1.3351	1.5377	1.6591	1.7205
18.980	1.5000	1.3888	1.4444	0.3124	0.5777	0.8083	1.0141	1.1908	1.3311	1.5316	1.6522	1.7130
19.480	1.5095	1.4113	1.4604	0.3109	0.5764	0.8074	1.0136	1.1884	1.3268	1.5253	1.6454	1.7060
19.980	1.5191	1.4335	1.4763	0.3093	0.5749	0.8064	1.0128	1.1855	1.3222	1.5189	1.6386	1.6994
20.482	1.5288	1.4553	1.4920	0.3074	0.5733	0.8052	1.0118	1.1823	1.3173	1.5124	1.6319	1.6933
20.982	1.5386	1.4768	1.5077	0.3053	0.5717	0.8040	1.0104	1.1787	1.3122	1.5058	1.6253	1.6874
21.481	1.5484	1.4980	1.5232	0.3030	0.5699	0.8027	1.0086	1.1748	1.3069	1.4991	1.6187	1.6818
21.981	1.5584	1.5189	1.5387	0.3005	0.5680	0.8013	1.0066	1.1706	1.3013	1.4923	1.6121	1.6765
22.480	1.5685	1.5395	1.5540	0.2978	0.5660	0.7998	1.0041	1.1661	1.2955	1.4854	1.6055	1.6713
22.980	1.5786	1.5599	1.5693	0.2951	0.5639	0.7983	1.0013	1.1614	1.2895	1.4784	1.5990	1.6664
23.480	1.5889	1.5801	1.5845	0.2923	0.5618	0.7967	0.9982	1.1563	1.2833	1.4714	1.5925	1.6615
23.980	1.5992	1.6001	1.5996	0.2896	0.5596	0.7950	0.9947	1.1510	1.2769	1.4642	1.5861	1.6567
24.480	1.6095	1.6199	1.6147	0.2870	0.5574	0.7933	0.9909	1.1455	1.2704	1.4571	1.5797	1.6521
24.980	1.6199	1.6395	1.6297	0.2844	0.5551	0.7914	0.9868	1.1397	1.2636	1.4498	1.5734	1.6476
25.480	1.6304	1.6589	1.6446	0.2820	0.5527	0.7893	0.9823	1.1336	1.2567	1.4425	1.5671	1.6432
25.980	1.6410	1.6781	1.6595	0.2795	0.5503	0.7869	0.9776	1.1274	1.2497	1.4352	1.5609	1.6389
26.481	1.6516	1.6971	1.6744	0.2772	0.5478	0.7843	0.9726	1.1209	1.2424	1.4279	1.5548	1.6347
26.981	1.6623	1.7161	1.6892	0.2750	0.5453	0.7813	0.9673	1.1143	1.2351	1.4205	1.5487	1.6305
27.481	1.6730	1.7348	1.7039	0.2728	0.5428	0.7781	0.9618	1.1074	1.2275	1.4131	1.5426	1.6265
27.982	1.6838	1.7534	1.7186	0.2708	0.5402	0.7745	0.9560	1.1004	1.2199	1.4057	1.5366	1.6226
28.482	1.6947	1.7719	1.7333	0.2688	0.5376	0.7707	0.9499	1.0931	1.2121	1.3982	1.5307	1.6187
28.982	1.7056	1.7902	1.7479	0.2669	0.5347	0.7665	0.9437	1.0857	1.2042	1.3908	1.5248	1.6149
29.483	1.7166	1.8083	1.7624	0.2650	0.5315	0.7620	0.9371	1.0781	1.1961	1.3834	1.5189	1.6112
29.983	1.7276	1.8264	1.7770	0.2632	0.5281	0.7572	0.9304	1.0704	1.1880	1.3760	1.5131	1.6076
30.480	1.7387	1.8443	1.7915	0.2615	0.5248	0.7521	0.9234	1.0624	1.1798	1.3686	1.5073	1.6040
30.980	1.7497	1.8622	1.8060	0.2599	0.5216	0.7467	0.9162	1.0543	1.1715	1.3612	1.5016	1.6005
31.482	1.7608	1.8801	1.8205	0.2583	0.5182	0.7410	0.9088	1.0461	1.1632	1.3538	1.4959	1.5971
31.981	1.7718	1.8981	1.8350	0.2568	0.5149	0.7351	0.9011	1.0377	1.1548	1.3464	1.4903	1.5938
32.480	1.7829	1.9161	1.8495	0.2554	0.5114	0.7289	0.8933	1.0292	1.1463	1.3390	1.4847	1.5905
32.980	1.7939	1.9343	1.8641	0.2541	0.5079	0.7224	0.8853	1.0206	1.1378	1.3316	1.4792	1.5873
33.480	1.8048	1.9524	1.8786	0.2528	0.5042	0.7156	0.8770	1.0119	1.1292	1.3242	1.4736	1.5842
33.980	1.8158	1.9706	1.8932	0.2516	0.5004	0.7084	0.8686	1.0031	1.1206	1.3168	1.4682	1.5812
34.480	1.8267	1.9889	1.9078	0.2504	0.4964	0.7009	0.8600	0.9942	1.1120	1.3094	1.4627	1.5782
34.980	1.8376	2.0072	1.9224	0.2493	0.4922	0.6931	0.8512	0.9852	1.1033	1.3021	1.4574	1.5753
35.480	1.8485	2.0256	1.9370	0.2482	0.4879	0.6850	0.8423	0.9762	1.0946	1.2947	1.4520	1.5725
35.980	1.8594	2.0439	1.9517	0.2473	0.4834	0.6767	0.8333	0.9671	1.0858	1.2873	1.4467	1.5697

The ‘Virtual Ship’ Concept:

As most of today’s 3D modelers allow handling BREP solids as virtual objects, the ‘Virtual Ship’ concept naturally appears as the logical consequence of their direct hydrostatic process.

Basically, MAAT Hydro’s goal is therefore simply to **provide a Virtual Tank for simulating Virtual Ship**’s hydrostatic behavior directly.

First of all, it is important to stress that **a ‘Virtual Ship’ must remain a visual object**, whose behavior must accurately replicate Real Ship’s behavior, in order to remain easy to handle.

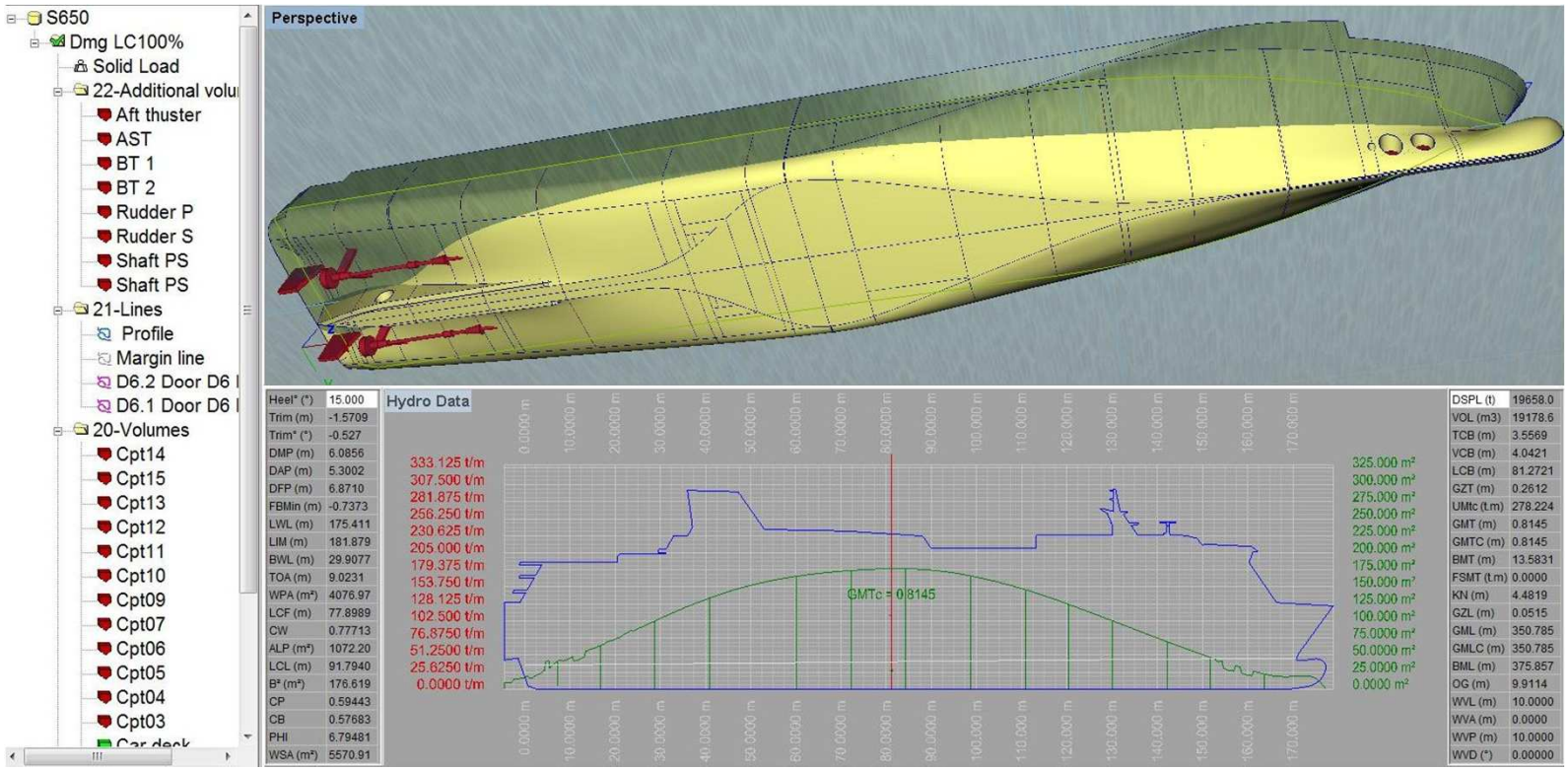
Basically, it therefore consists in a simple set of BREP solids, imported from any 3D modeler, describing the geometry of ship’s buoyant components (compartments, tanks, …).

Most often, several lines must also be added, in order to allow complementary calculations: Silhouette for windage calculations, openings controlling compartment’s downflooding / tank’s overflow, sheer lines for freeboard calculation, etc…

At last, one or more mass(es) must also be added, defining ship’s solid load, in addition to tank’s content.

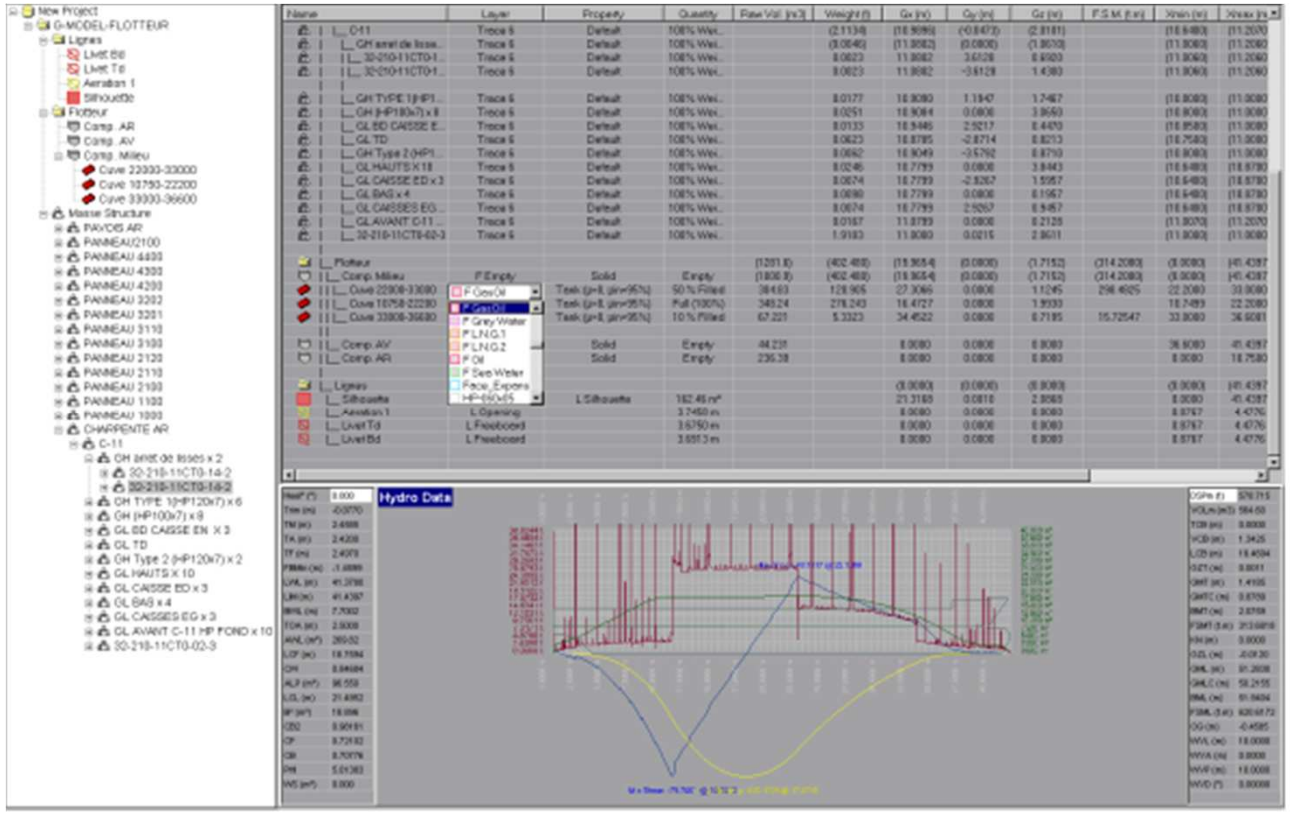
The ‘Virtual Ship’ can be easily handled with a dedicated data browser…

Combining realtime BREP solid rendering and today’s user interface standards with real-time hydrostatic feedback makes float’s modeling and stability calculations extremely visual and intuitive. A highly recursive and object oriented data architecture allows modelling complex behaviors like conditional flooding, hopper spilling, progressive flooding, etc…s in a few clicks.



… and a spreadsheet

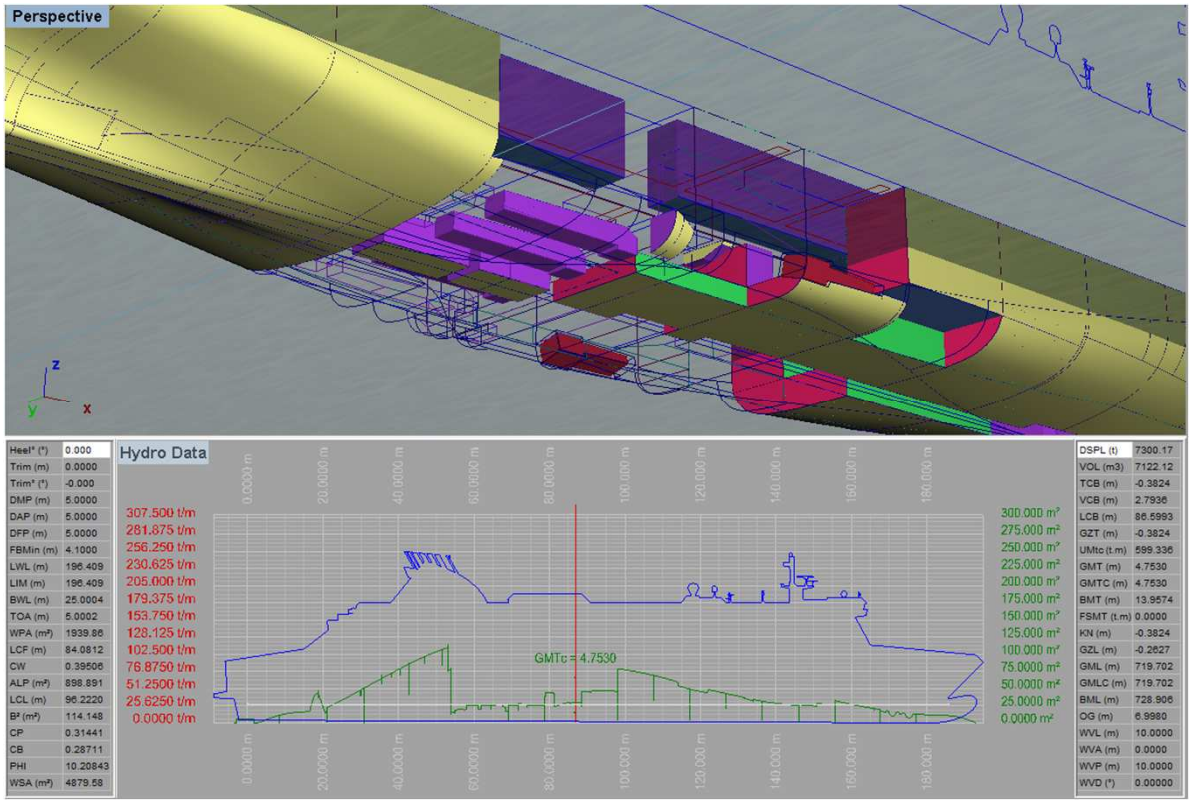
Whenever necessary, a dedicated / realtime spreadsheet can also instantly replace the 3D views for setting any ship data accurately (tank's content or filling, load's weight, position or extent, etc…), allowing to define complex configurations and damages easily and safely.



Moreover, MAAT Hydro's highly recursive data architecture allows encapsulating any weight estimate / curve in a parent mass containing child items, subitems, etc...

Damages can be easily and accurately Modelled with BREP Solids…

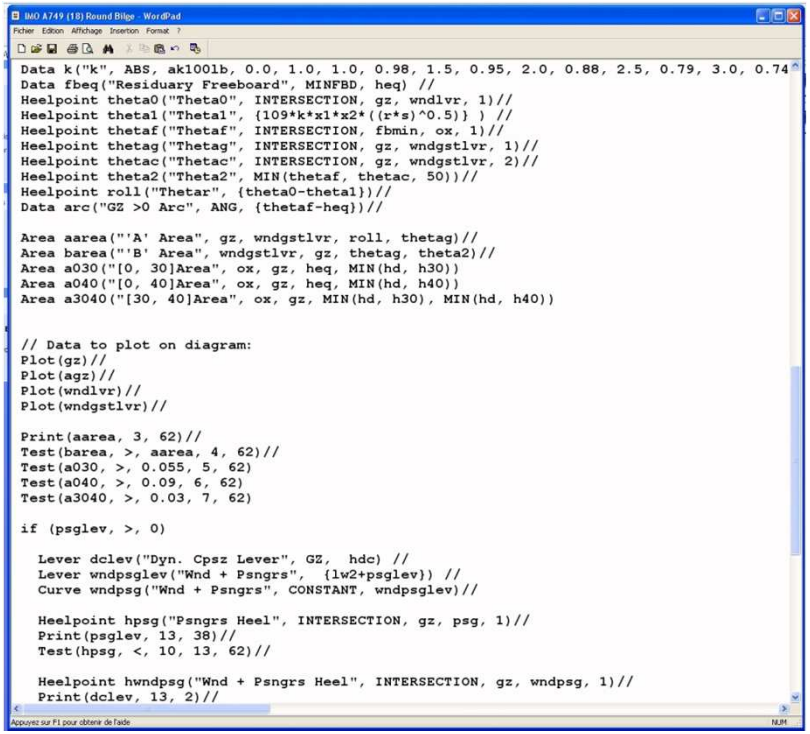
By nature, a BREP solid models provide an exact definion of ship's buoyancy, which can be used for defining the most complex damages,



(210 m / 110 Compartments Passenger Vessel / Verhaaren Naval Architects)

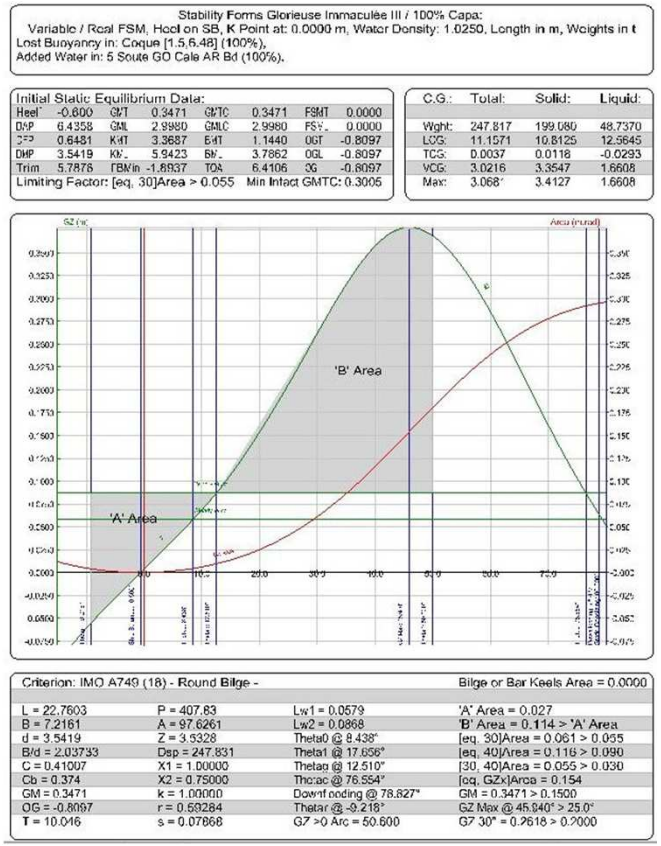
… and Stability Criteria / Layout are easy to define and customize thanks to STC Scripting

In addition to the advantages of processing BREP solids directly, MAAT Hydro also includes a script interpreter allowing to define or customize almost any deterministic or probabilistic criterion, in order to face easily their growing number and complexity.



Typical Intact / Damaged Stability Results:

In order to conclude this brief presentation of the interests of direct BREP solid integration in the field of intact and damaged stability calculations, let us illustrate this proceeding by a set of reports obtained with our MAAT Hydro Software:



Stability Forms Glorieuse Immaculée III / 100% Capa:
Variable / Real FSM, Heel on SB, K Point at: 0.0000 m, Water Density: 1.0250, Length in m, Weights in t
Lost Buoyancy in: Coque [1,5,6,48] (100%),
Added Water in: 5 Soute GO Cale AR Bd (100%).

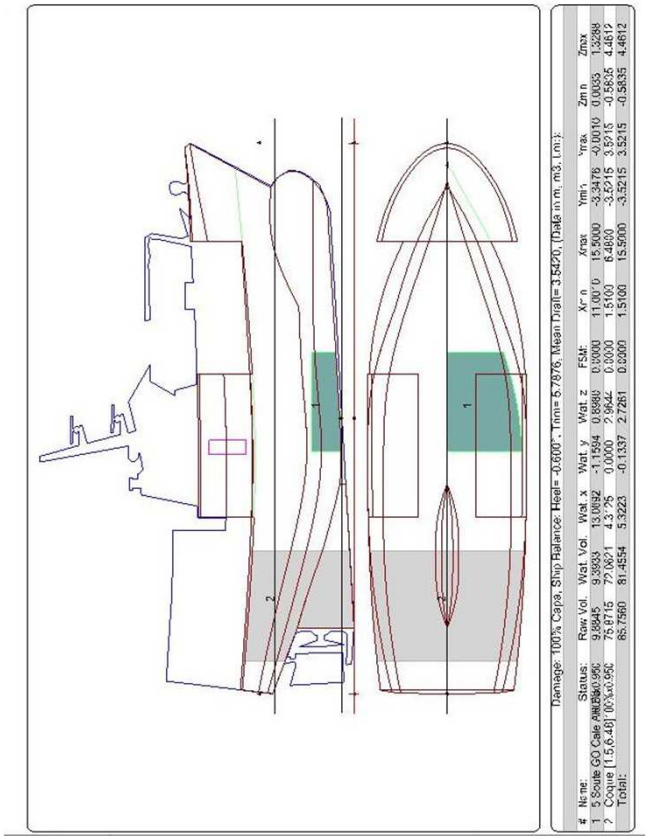
Initial Static Equilibrium Data:

Heel	-0.600	GMT	0.3471	GMTC	0.3471	FSMT	0.0000
DMP	6.4358	GML	2.9980	GMLC	2.9980	FSML	0.0000
TPP	0.6481	KMT	3.3687	BMT	1.1440	OGT	-0.8097
DMP	3.5419	KML	5.9423	BML	3.7862	OGL	-0.8097
Trim	5.7876	TRMin	-1.8937	TOA	6.4106	SG	-0.8097
Limiting Factor: [eq. 30]Area > 0.055				Min Intact GMTC: 0.3005			

C.G.:	Total:	Solid:	Liquid:
Wght:	247.817	199.080	48.7370
LCG:	11.1571	10.8125	12.5645
TCG:	0.0037	0.0118	-0.0293
VCG:	3.0216	3.3547	1.6608
Max:	3.068°	3.4127	1.6608

Criterion: IMO A749 (18) - Round Bilge - | Bilge or Bar Keels Area = 0.0000

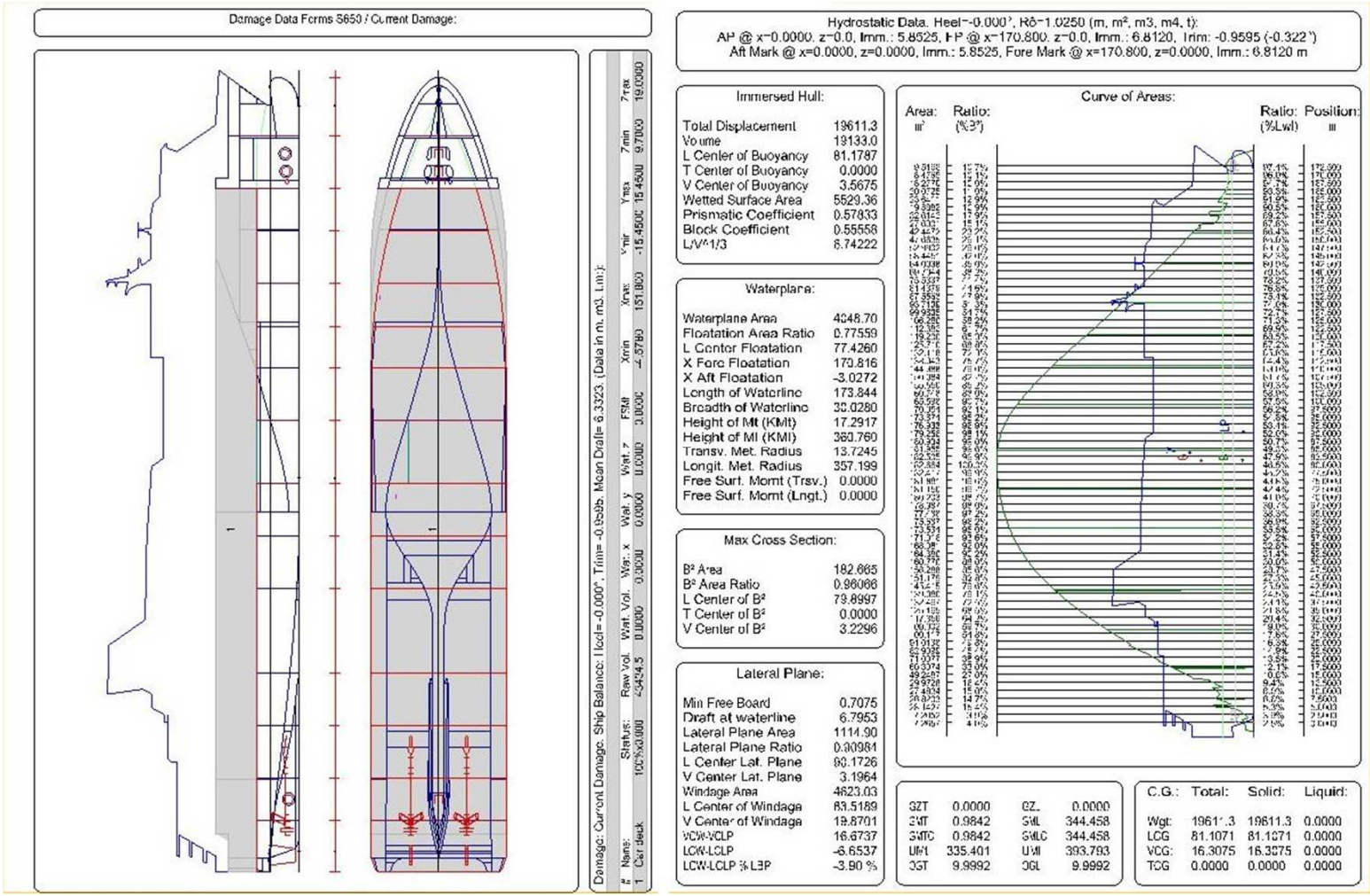
L = 22.7603	P = 407.83	Lw1 = 0.0579	'A' Area = 0.027
B = 7.2161	A = 97.6261	Lw2 = 0.0868	'B' Area = 0.114 > 'A' Area
d = 3.5419	Z = 3.5328	Theta0 @ 8.438°	[eq. 30]Area = 0.061 > 0.055
B/d = 2.03733	Dsp = 247.831	Theta1 @ 17.656°	[eq. 40]Area = 0.116 > 0.090
C = 0.41007	X1 = 1.00000	Thetap @ 12.510°	[30, 40]Area = 0.055 > 0.030
Cb = 0.374	X2 = 0.75000	Thetac @ 76.554°	[eq. GZx]Area = 0.154
GM = 0.3471	k = 1.00000	Downflooding @ 78.827°	GM = 0.3471 > 0.1500
OG = -0.8097	r = 0.69284	Thetar @ -9.218°	GZ Max @ 45.940° > 25.0°
T = 10.046	s = 0.07868	GZ >0 Arc = 50.600	GZ 30° = 0.2618 > 0.2000



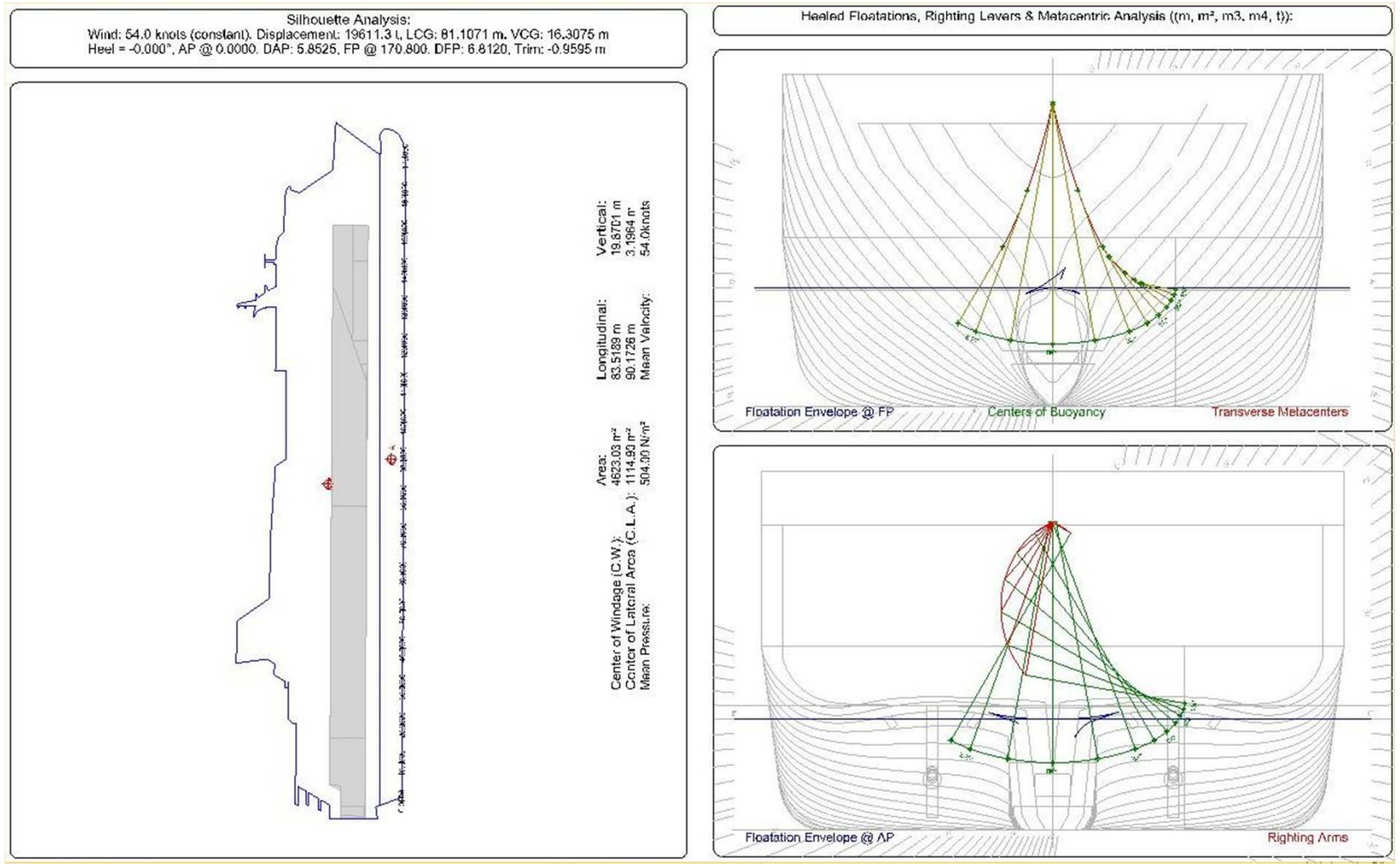
Damage: 100% Capa, Ship Balance: Heel = -0.600°, Tmin = 5.7876, Mean Draft = 3.5420, (Data in m, m3, t/m3):

#	Name:	Status:	Raw Vol.	Wat. Vol.	Wat. x	Wat. y	Wat. z	FSM:	Xr n	Xmax	Ymin	Ymax	Zmin	Zmax
1	5 Soute GO Cale AR Bd	100.0%	9.8845	9.3933	13.0692	-1.1594	0.8886	0.0000	11.0010	15.5000	-3.3476	-0.0010	0.0035	1.3288
2	Coque [1,5,6,48]	100.0%	75.8715	72.0621	4.3795	0.0000	7.9642	0.0000	1.5100	6.4600	-3.5215	3.5215	-0.5835	4.4619
	Total:		85.7560	81.4554	5.3223	-0.1337	2.7261	0.0000	1.5100	15.5000	-3.5215	3.5215	-0.5835	4.4612

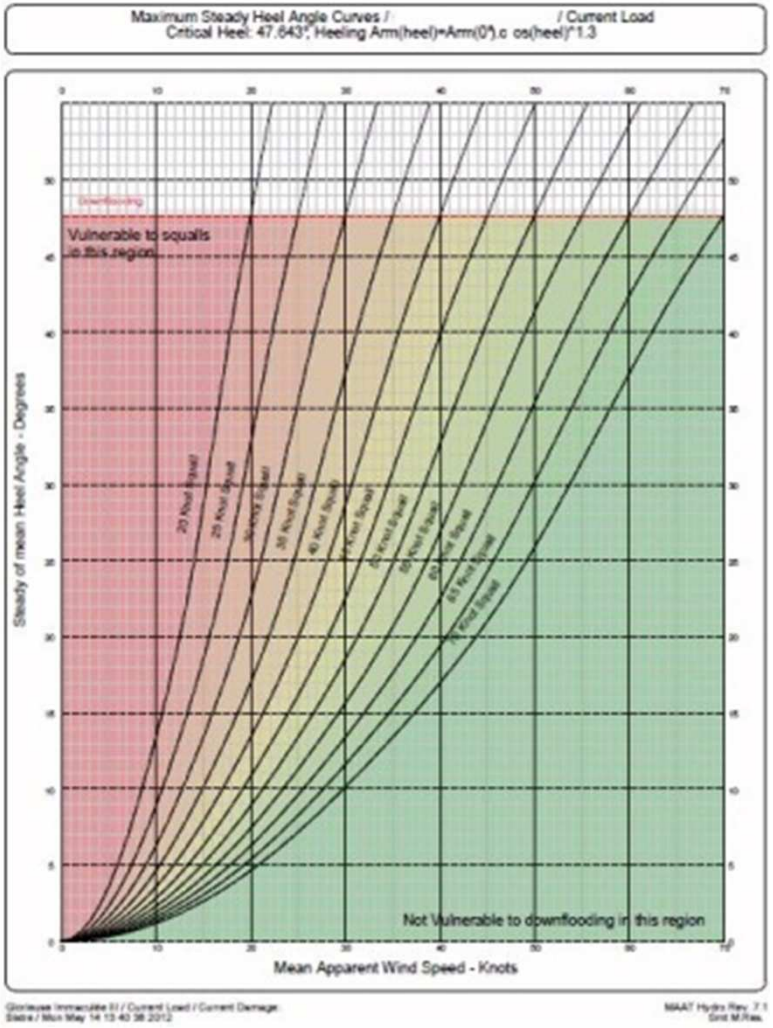
Typical Ship's Status and Upright Analysis:



Typical Windage and Metacentric Analysis:



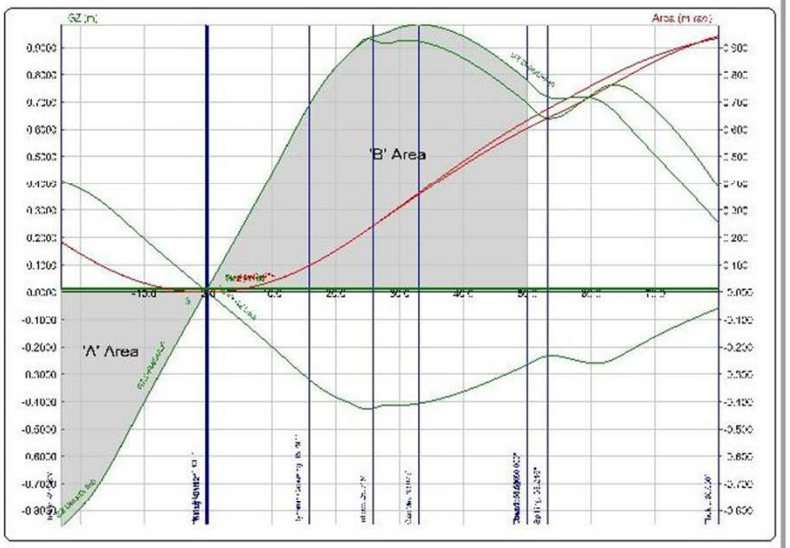
Typical Max Steady Heel Angles Results:



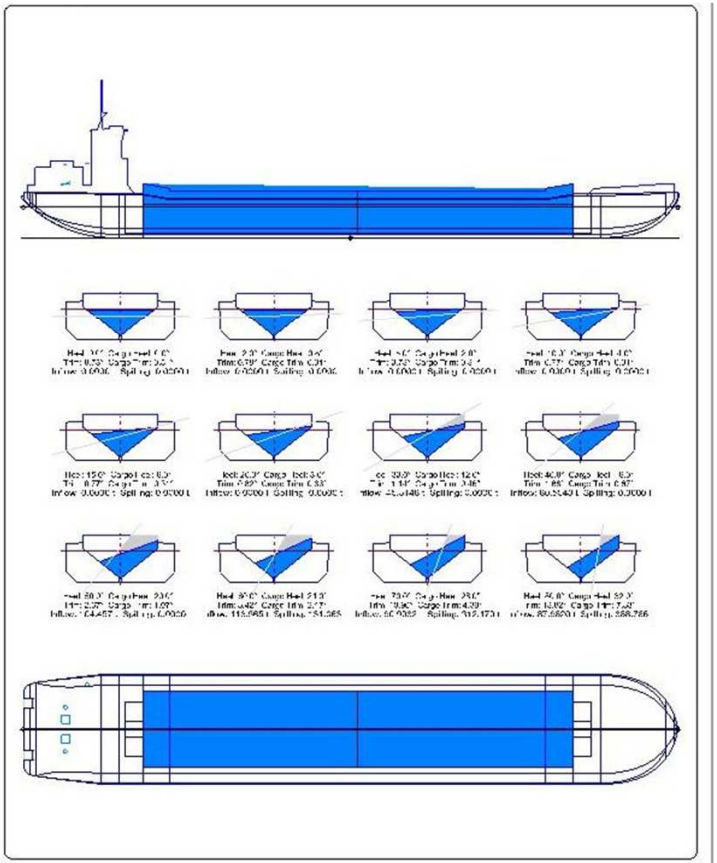
Typical Dredge Stability Results:

Ship Balance:							
Heel °	-0.432	SHT	2.8457	SHTC	2.3250	FSMT	456.5924
TA	2.4127	SML	115.828	SMLC	94.3418	FSML	18844.04
TF	1.6684	KMT	4.6924	BMT	3.6088	OGT	0.3095
Tm	2.0405	KML	117.664	BML	116.609	OGL	21.2785
Trim	0.7444	FBMin	0.9190	TCA	2.3381	OG	-0.2112

C.G.:	Total:	Solid:	Liquid:
Wght:	876.889	395.832	481.057
LCG:	26.1564	24.7320	27.3285
TCG:	-0.0214	-0.0342	-0.0109
VCG:	1.8465	1.9473	1.7636

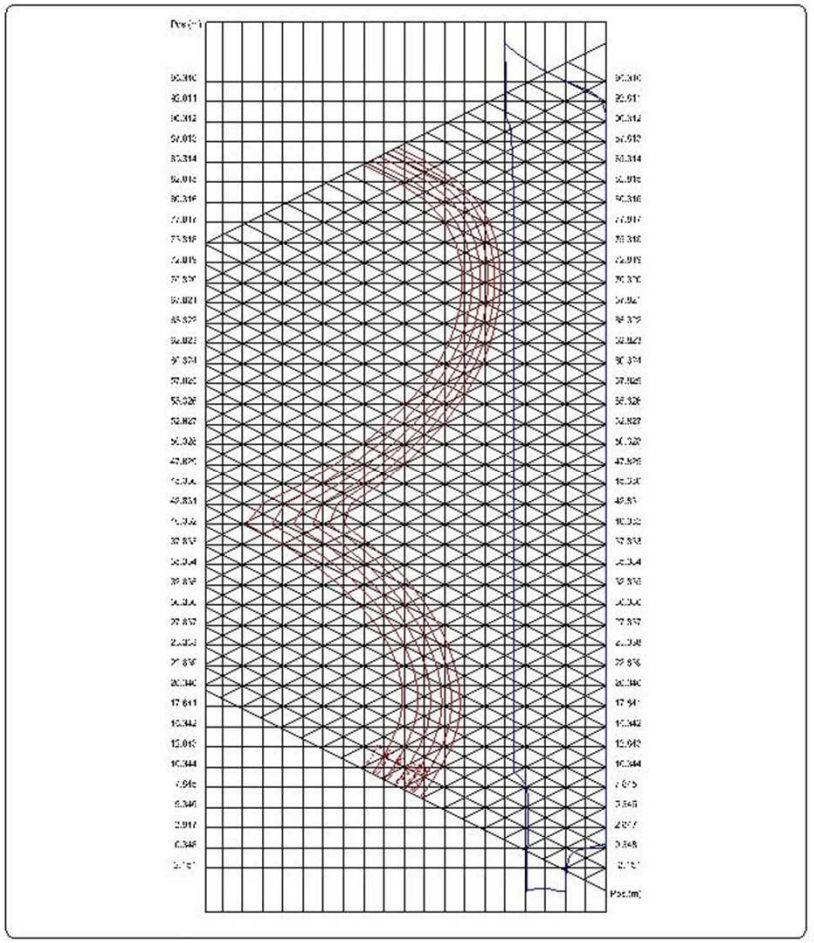


Criterion: D 231 - 2.02			Bilge or Bar Keels Area = 0.0000
Lambda = 2.2	Lambdaf = 0.88	Cargo Heel° @eq = -0.173	Cargo Trim° @eq = 0.311
Cargo W = 478.153	Cargo X: = 27.4745	Cargo Y = 0.0015	Cargo Z = 1.7651
L = 52.8990	P = 351.49	Lw1 = 0.0108	'A' Area = 0.191
B = 9.1683	A = 104.217	Lw2 = 0.0161	'B' Area = 0.619 > 0.191
d = 2.0405	Z = 2.5287	Thota0 @ -0.172°	[eq, 30]Area = 0.312 > 0.055
B/d = 4.49308	Dsp = 877.041	Theta1 @ 22.893°	[eq, 40]Area = 0.482 > 0.090
C = 0.45359	X1 = 0.80000	Thetag @ -0.042°	[30, 40]Area = 0.169 > 0.030
Cb = 0.825	X2 = 1.00000	Thetac @ 80.000°	[eq, GZx]Area = 0.365
GM = 2.3250	k = 1.00000	No Opening	GM = 2.3250 > 0.1500
OG = -0.1386	r = 0.68924	Thetar @ -23.065°	GZc Max @ 33.079° > 25.0°
T = 5.455	s = 0.10000	Min GZ >0 Arc = 50.432	GZc 30° = 0.9733 > 0.2000



Name: C.ME	Raw Vol.: 543.356	Gx: 27.9984	Xmin: 10.0000	Xmax: 46.0000
Permeability: 1.00000	Weight: 1195.38	Gy: 0.0000	Ymin: -3.1500	Ymax: 3.1500
	Max FSMt: 480.6858	Gz: 2.6440	Zmin: 0.3000	Zmax: 4.5355
Content: Déblai 2.2	Filling: 40.0%	Density: 2.20000	FSM Density: 0.88000	Permeability: 0.0%

Typical Floodable Length Results:



Sta. Pos.	Mu	Floodable L.	F. Volume	F. LCB	DAP	DFP	Freeboard	GMt
7.845	0.900	24.638	1577.6	10.587	3.431	-1.929	0.066	0.824
	0.950	23.271	1567.0	10.357	3.428	-1.940	0.069	0.815
	1.000	22.049	1561.8	10.151	3.432	-1.953	0.064	0.807
10.344	0.750	28.318	1689.9	13.440	3.424	-1.762	0.073	0.911
	0.800	26.322	1679.5	13.101	3.432	-1.786	0.065	0.906
	0.850	24.541	1664.0	12.801	3.427	-1.802	0.070	0.905
	0.900	23.000	1651.7	12.552	3.423	-1.815	0.074	0.905
	0.950	21.669	1647.5	12.339	3.432	-1.831	0.065	0.905
	1.000	20.447	1639.6	12.139	3.432	-1.843	0.065	0.907
12.843	0.750	26.873	1774.8	15.319	3.422	-1.640	0.075	0.986
	0.800	24.840	1759.7	14.990	3.423	-1.662	0.074	0.994
	0.850	23.096	1747.3	14.717	3.423	-1.680	0.073	1.001
	0.900	21.595	1738.7	14.499	3.426	-1.696	0.071	1.008
	0.950	20.301	1731.1	14.314	3.427	-1.708	0.070	1.015
	1.000	19.120	1722.0	14.158	3.424	-1.717	0.073	1.021
15.342	0.750	25.785	1874.0	17.217	3.427	-1.507	0.070	1.072
	0.800	23.785	1856.8	16.946	3.422	-1.525	0.075	1.084
	0.850	22.118	1847.0	16.732	3.424	-1.542	0.073	1.095
	0.900	20.695	1838.9	16.559	3.425	-1.555	0.072	1.103
	0.950	19.445	1832.6	16.422	3.427	-1.565	0.070	1.110
	1.000	18.342	1826.2	16.301	3.426	-1.573	0.071	1.116
17.841	0.750	25.199	1986.8	19.253	3.423	-1.345	0.074	1.148
	0.800	23.318	1975.8	19.042	3.425	-1.363	0.072	1.161
	0.850	21.727	1968.9	18.878	3.429	-1.378	0.068	1.170
	0.900	20.306	1957.0	18.743	3.423	-1.387	0.074	1.181
	0.950	19.093	1951.0	18.637	3.423	-1.395	0.074	1.187
	1.000	18.031	1946.0	18.546	3.424	-1.403	0.073	1.193
20.340	0.750	25.231	2124.2	21.411	3.422	-1.153	0.075	1.206
	0.800	23.397	2118.1	21.253	3.429	-1.169	0.069	1.219
	0.850	21.818	2109.8	21.123	3.429	-1.182	0.068	1.229
	0.900	20.421	2099.3	21.029	3.423	-1.189	0.074	1.237
	0.950	19.251	2098.0	20.943	3.429	-1.198	0.068	1.245
	1.000	18.193	2093.0	20.881	3.428	-1.204	0.069	1.249
22.839	0.750	25.816	2291.0	23.668	3.424	-0.923	0.074	1.247
	0.800	23.945	2282.9	23.515	3.426	-0.937	0.072	1.260
	0.850	22.365	2276.2	23.443	3.427	-0.948	0.070	1.271
	0.900	20.969	2269.5	23.371	3.426	-0.956	0.072	1.278
	0.950	19.758	2263.9	23.301	3.426	-0.963	0.072	1.286
	1.000	18.698	2262.4	23.255	3.428	-0.969	0.069	1.291
25.338	0.750	26.870	2488.4	25.984	3.423	-0.650	0.075	1.272
	0.800	24.961	2481.3	25.886	3.425	-0.662	0.072	1.286
	0.850	23.340	2476.0	25.807	3.427	-0.673	0.070	1.297
	0.900	21.907	2470.8	25.751	3.427	-0.680	0.070	1.306
	0.950	20.654	2466.0	25.695	3.428	-0.687	0.070	1.314
	1.000	19.557	2465.0	25.659	3.430	-0.691	0.067	1.321
27.837	0.750	28.436	2728.5	28.339	3.425	-0.323	0.073	1.282
	0.800	26.446	2722.0	28.258	3.427	-0.335	0.070	1.298
	0.850	24.702	2712.1	28.195	3.424	-0.345	0.074	1.312
	0.900	23.177	2705.3	28.146	3.423	-0.352	0.075	1.322
	0.950	21.904	2707.2	28.109	3.429	-0.357	0.069	1.331
	1.000	20.690	2697.9	28.075	3.423	-0.362	0.075	1.339

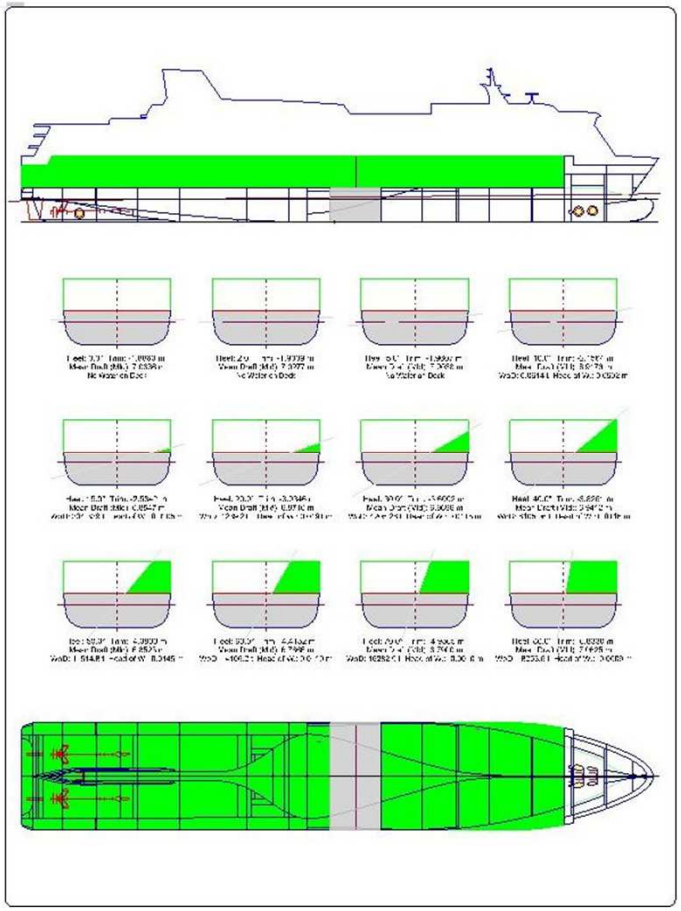
Typical Stability Results
with Water on Deck (Stockholm):

Hydrostatic Data @ Equilibrium:							
Heel°	-0.000	GMT	0.6992	GvTC	0.7001	FSMT	0.0000
DAP	6.0906	GML	374.208	GMLC	374.208	FSML	0.0000
DFP	7.9766	KMT	17.0067	BMT	13.0062	OGT	9.3198
DWP	7.0336	KML	390.492	BML	386.514	OGL	9.3199
Trim	-1.8860	FBMin	-0.4585	TOA	7.9435	OG	9.3207

Weight Data @ 0° (KMt0 = 17.2917):			
	Total:	Solid:	Liquid:
Wght:	19611.3	19611.3	0.0011
LCG:	81.1071	81.1071	14.1462
TCG:	0.0000	0.0000	-0.0001
VCG:	16.3075	16.3075	6.9985



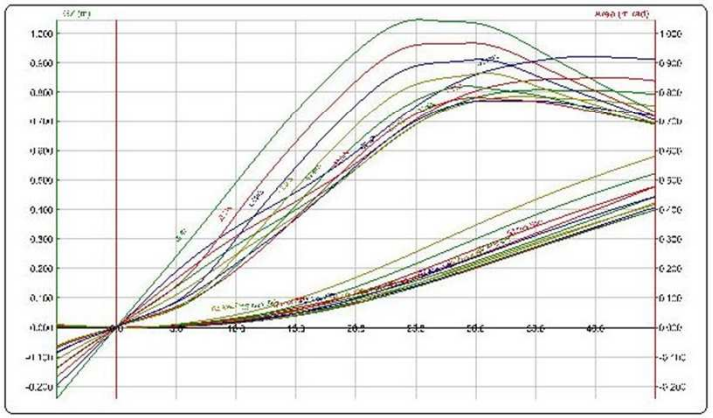
Criterion: SOLAS 2004 / Stockholm			Number of Damaged Compartment(s) = 1
Dmg from Xmin = 84.3000	Dmg to Xmax = 98.8000		Height of Swell (hs) = 1.5000
	RoRo Res. Fbd (fr) = 2.5182		Height of Added Water (hw) = 0.0000
Passengers Moment = 0.0000	Rafts Moment = 0.0000		Windage Moment = 920.276
Windage Area = 4502.69	Windage Ctr Hght = 20.2184		Half Draft = 3.5168
R8 / 2.3.1:Equilibrium @ -0.000°	Thetanu @ 15.183°	Thetaf @ 39.474°	[Eq-Cpsz] Rge = 15.183 > 15.000
R8 / 2.3.2:Nb of Dmg Compts = 1	Limit @ 22.000°	Thetaf @ 39.474°	[Eq-cpsz] Area = 0.019 > 0.015
R8 / 2.3.3:GZpsg = 0.0400	GZrft = 0.0400	GZwnd = 0.0869	GZmax = 0.1247 > Max(psg, rft, w



Typical Intermediate Floding Stages Results:

Intermediate Flooding Stages (individual inflows) Forms :
Variable / Real FSM, Heel on PS, K Point at: 0.000 m, Water Density: 1.0250, Length in m, Weights in t
No Lost Buoyancy
Added Weight in: R333 R131 R133, R511 R513 R521 R523, R604, R603, R602, R601, R611, R609,
No Water on Deck

Ship Data @ Equilibrium:			Solid Weight:		13276	LCGs:	87.978	TCGs:	0.007	VCGs:	12.000
Flooding:	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heel °	-0.044	-0.083	-0.145	-0.197	-0.201	-0.179	-0.145	-0.109	-0.085	-0.068	0.025
KP Imm.	5.006	5.061	5.115	5.168	5.220	5.272	5.323	5.374	5.424	5.473	5.521
Trim	-0.007	0.171	0.343	0.510	0.670	0.825	0.973	1.114	1.248	1.375	1.494
GMc	2.683	0.628	0.451	0.462	0.601	0.713	0.864	1.022	1.176	1.349	2.125
Min FBd	4.082	3.931	3.772	3.619	3.481	3.352	3.230	3.112	2.997	2.884	2.782
Total Wgt	13216	13429	13642	13854	14067	14280	14493	14706	14918	15131	15344
LCGt	87.978	87.515	87.063	86.621	86.192	85.775	85.370	84.977	84.594	84.221	83.862
TCGt	0.007	0.005	0.002	-0.002	-0.003	-0.002	0.000	0.002	0.003	0.004	0.010
VCGt	12.000	11.837	11.687	11.547	11.417	11.296	11.184	11.080	10.984	10.897	10.816
F.S.M. t.	0.00	29686	34698	37537	36508	39584	40090	40503	40763	40828	31884



Criterion: SOLAS 2004

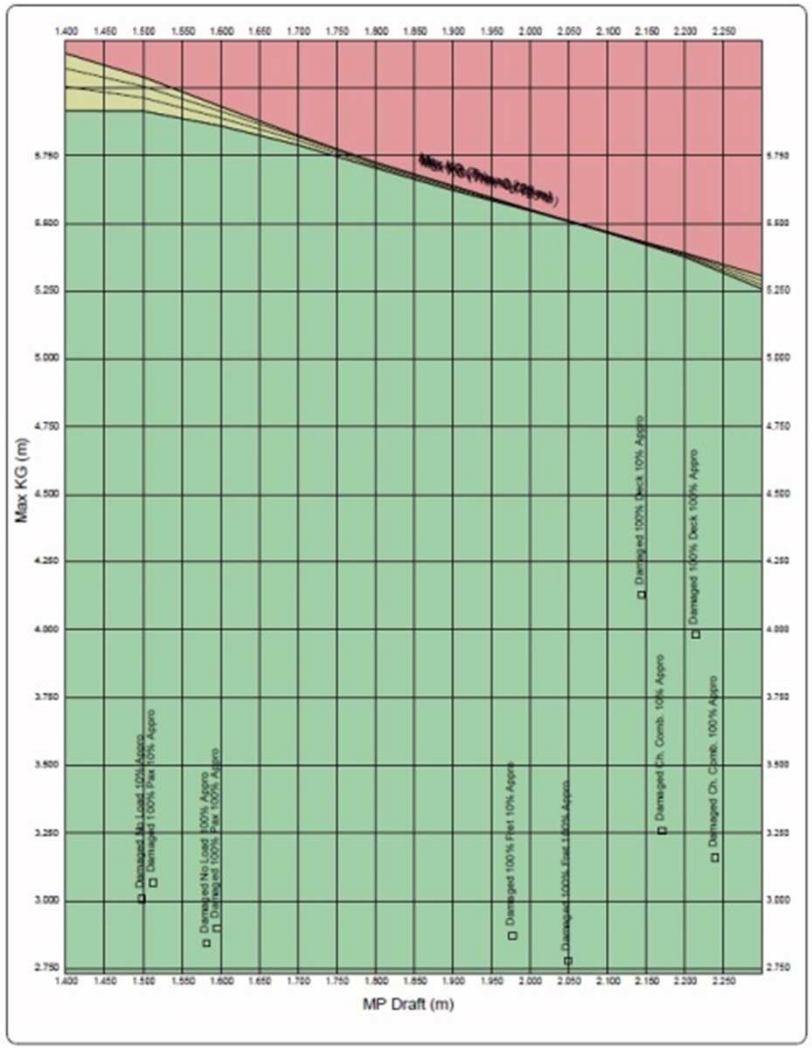
Flooding:	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
[Eq-Dfl] Range > 15.000	45.044	45.083	45.145	45.197	45.201	45.179	45.145	45.109	45.085	45.068	44.975
[Eq-27°] Area > 0.015	0.292	0.249	0.218	0.193	0.175	0.163	0.162	0.166	0.173	0.183	0.198
GZmax > Max(psg, rft, 0.040)	1.040	0.963	0.898	0.841	0.791	0.747	0.726	0.721	0.726	0.745	0.795
GMOc > 0.050	2.683	0.628	0.451	0.462	0.601	0.713	0.864	1.022	1.176	1.349	2.125
Ship balance < 12.000	0.044	0.083	0.145	0.197	0.201	0.179	0.145	0.109	0.085	0.068	0.025
Res. Fbd > 0.076	4.082	3.931	3.772	3.619	3.481	3.352	3.230	3.112	2.997	2.884	2.782

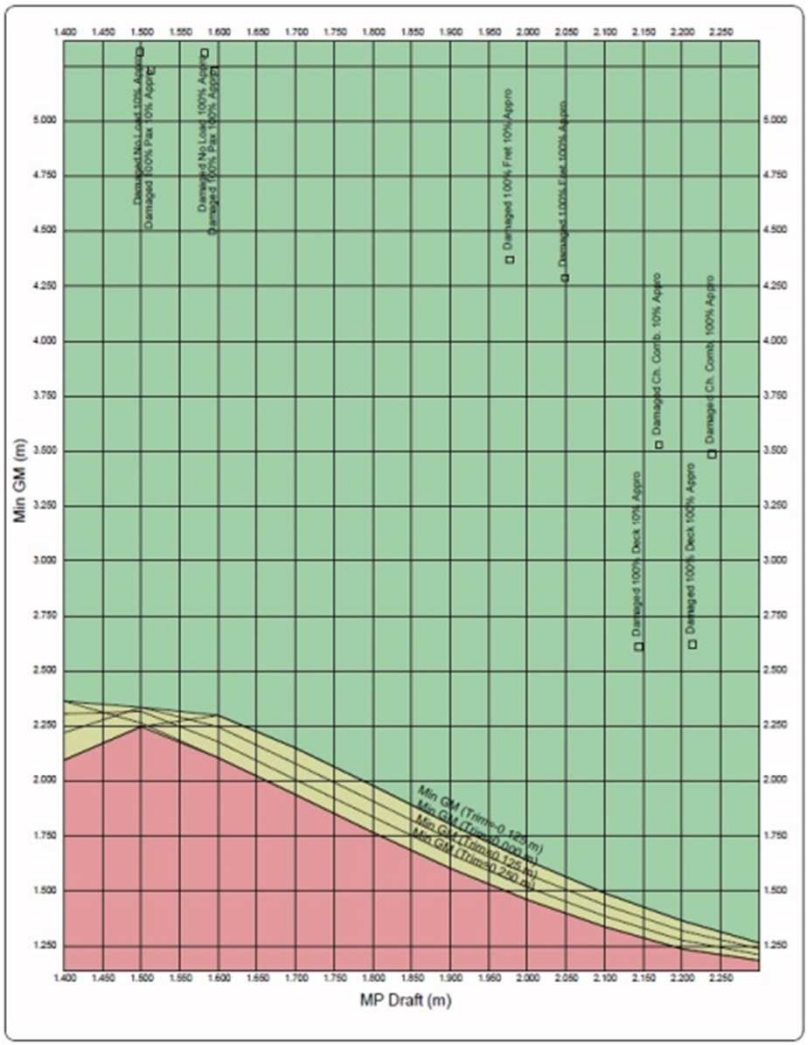
Flooding:	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Passengers Moment.	890.4	890.4	890.4	890.4	890.4	890.4	890.4	890.4	890.4	890.4	890.4
Windage Area	4867.8	4857.2	4847.0	4836.9	4826.9	4817.0	4807.3	4797.7	4788.3	4778.9	4769.7
Equilibrium	-0.044	-0.083	-0.145	-0.197	-0.201	-0.179	-0.145	-0.109	-0.085	-0.068	0.025
No of Dmg Compts	0	0	0	0	0	0	0	0	0	0	0
GZpsg	0.107	0.106	0.105	0.104	0.103	0.102	0.101	0.101	0.100	0.099	0.098
Rafts Moment	703.0	703.0	703.0	703.0	703.0	703.0	703.0	703.0	703.0	703.0	703.0
Windage Ctr Hght	18.471	18.499	18.528	18.555	18.583	18.609	18.636	18.662	18.688	18.713	18.738
Thetanu	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000
Limit	27.000	27.000	27.000	27.000	27.000	27.000	27.000	27.000	27.000	27.000	27.000
GZrft	0.093	0.092	0.092	0.091	0.090	0.089	0.088	0.088	0.087	0.086	0.086
Downfl.	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000
Downfl.	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000
GZwnd	0.112	0.111	0.109	0.108	0.107	0.106	0.105	0.104	0.103	0.102	0.101
Number of Damaged Compartment(s)	8	8	8	8	8	8	8	8	8	8	8
Windage Moment	951.2	949.2	947.3	945.3	943.4	941.6	939.7	937.9	936.1	934.3	932.6
Half Draft	2.503	2.530	2.558	2.584	2.611	2.636	2.662	2.687	2.712	2.737	2.761

Saved: Wed Oct 05 15:55:58 2011
5335 : T5_Trc_KG1.h

MAAT Hydro Rev. 7.0 i
SmVI Rev

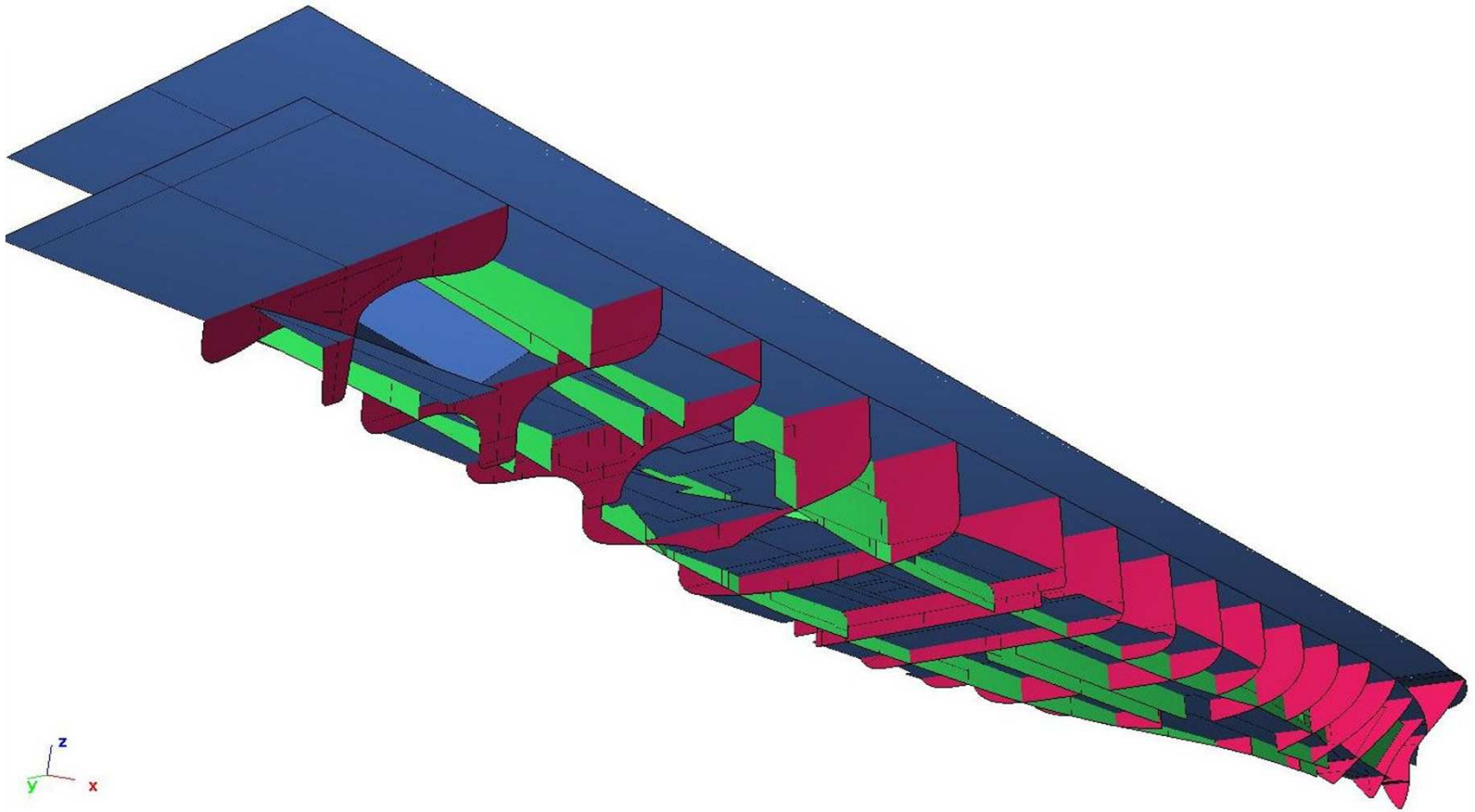
Typical Automated Deterministic Stability Results:





Automatic Ship Subdivision Scanning

BREP Solid modeling directly provides the watertight bulkheads geometry necessary for creating the probabilistic damage system automatically:



Typical Automated Probabilistic Stability Results:

Damaged Stability Forms - Criterion: MSC194(80) Reg. 7 / PS Heel / PS Damages
Salvable Passengers: 10, Extra Passengers: 0 - Length in m, Area in m², Volume in m3, Weight in t

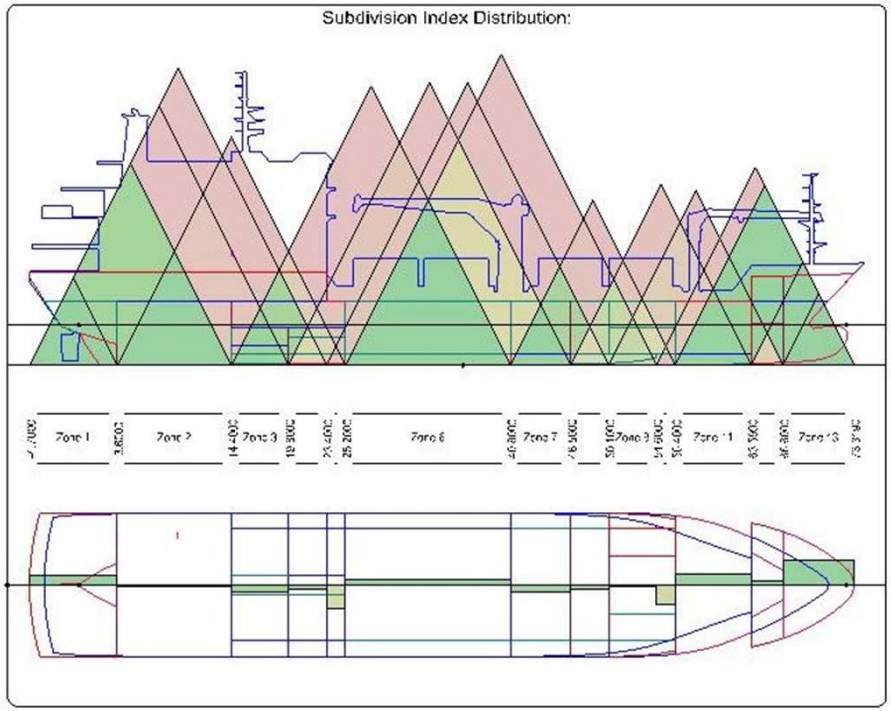
Deepest subdivision draught		Partial subdivision draught		Light subdivision draught	
Total Load:	2916.00	Total Load:	2444.00	Total Load:	1734.00
LCG:	33.2000	LCG:	33.4960	LCG:	33.3460
TCG:	0.0000	TCG:	0.0000	TCG:	0.0000
VCG:	5.0230	VCG:	5.3110	VCG:	5.6210
Solid Load:	2916.00	Solid Load:	2444.00	Solid Load:	1734.00
LCG:	33.2000	LCG:	33.4960	LCG:	33.3460
TCG:	0.0000	TCG:	0.0000	TCG:	0.0000
VCG:	5.0230	VCG:	5.3110	VCG:	5.6210
Liquid Load:	0.0000	Liquid Load:	0.0000	Liquid Load:	0.0000
LCG:	0.0000	LCG:	0.0000	LCG:	0.0000
TCG:	0.0000	TCG:	0.0000	TCG:	0.0000
VCG:	0.0000	VCG:	0.0000	VCG:	0.0000
FSMt:	0.0000	FSMt:	0.0000	FSMt:	0.0000
TA:	3.7515	TA:	3.2231	TA:	2.5143
TM:	3.7515	TM:	3.2110	TM:	2.3865
TF:	3.7515	TF:	3.1989	TF:	2.2187
Trim:	0.0000	Trim:	0.0241	Trim:	0.2956
Heel:	0.000	Heel:	0.000	Heel:	0.000
GMt:	1.2954	GMt:	1.4070	GMt:	2.3581
Freeboard:	2.2485	Freeboard:	2.7853	Freeboard:	3.5882
1 Zone Damages:	117	1 Zone Damages:	117	1 Zone Damages:	117
Sum(pi.vj)	0.48489	Sum(pi.vj)	0.48489	Sum(pi.vj)	0.48489
Mean Survivability:	0.99881	Mean Survivability:	0.98599	Mean Survivability:	0.97811
Attained Index A1:	0.48431	Attained Index A1:	0.47810	Attained Index A1:	0.47428
2 Zones Damages:	204	2 Zones Damages:	204	2 Zones Damages:	204
Sum(pi.vj)	0.31928	Sum(pi.vj)	0.31928	Sum(pi.vj)	0.31928
Mean Survivability:	0.54295	Mean Survivability:	0.69015	Mean Survivability:	0.83700
Attained Index A2:	0.17335	Attained Index A2:	0.22035	Attained Index A2:	0.26724
3 Zones Damages:	317	3 Zones Damages:	317	3 Zones Damages:	317
Sum(pi.vj)	0.13674	Sum(pi.vj)	0.13674	Sum(pi.vj)	0.13674
Mean Survivability:	0.39013	Mean Survivability:	0.45421	Mean Survivability:	0.67321
Attained Index A3:	0.05334	Attained Index A3:	0.06211	Attained Index A3:	0.09205
4 Zones Damages:	393	4 Zones Damages:	393	4 Zones Damages:	393
Sum(pi.vj)	0.04073	Sum(pi.vj)	0.04073	Sum(pi.vj)	0.04073
Mean Survivability:	0.08091	Mean Survivability:	0.10011	Mean Survivability:	0.39349
Attained Index A4:	0.00330	Attained Index A4:	0.00408	Attained Index A4:	0.01603
Total Calculated Damages:	1031	Total Calculated Damages:	1031	Total Calculated Damages:	1031
Total Sum(pi.vj):	0.98164	Total Sum(pi.vj):	0.98164	Total Sum(pi.vj):	0.98164
Mean Survivability:	0.72766	Mean Survivability:	0.77894	Mean Survivability:	0.86548
As = A1+A2+A3+A4:	0.71431	Ap = A1+A2+A3+A4:	0.76464	Al = A1+A2+A3+A4:	0.84960

Ship's Damaged Stability Complies with MSC194(80) Reg. 7 Criterion
Attained Subdivision Index A=0.4.As+0.4.Ap+0.2.Al:0.76150 Required Subdivision Index R: 0.67380
As (>0.9.R): 0.71431 Ap (>0.9.R): 0.76464 Al (>0.9.R): 0.84960

Ship Balance:							
Heel°	0.000	GMT	1.2951	GMTC	1.2951	FSMT	0.0000
TA	3.7481	GML	101.079	GMLC	101.079	FSML	0.0000
TF	3.7561	KMT	6.3181	BMT	4.3102	OGT	1.2712
TM	3.7521	KML	106.102	BML	104.094	OGL	1.2712
Trim	-0.0080	Fac	2.2472	TCA	3.7540	CG	1.2712

C.G.:	Total:	Solid:	Liquid:
Wght:	2916.00	2916.00	0.0000
LCG:	33.2000	33.2000	0.0000
TCG:	0.0000	0.0000	0.0000
VCG:	5.0230	5.0230	0.0000

Subdivision Index Distribution:



Criterion: SOLAS 2009

Lsmin:	-4.7000	Lsmax:	73.3190	Ls:	78.0190	B:	13.6019	Ds:	3.7515
Min Heel:	-10.000	Max Heel:	70.000	Heel Step:	2.500			R:	0.67380

1 Division:		2 Divisions:		3 Divisions:		4 Divisions:		Total:	
Damages:	117	Damages:	204	Damages:	317	Damages:	393	Damages:	1031
Sum(dA):	0.48431	Sum(dA):	0.17335	Sum(dA):	0.05334	Sum(dA):	0.00330	Sum(dA):	0.71431
Sum(pi.vj):	0.48489	Sum(pi.vj):	0.31928	Sum(pi.vj):	0.13674	Sum(pi.vj):	0.04073	Sum(pi.vj):	0.98164
Mean smin:	0.99881	Mean smin:	0.54295	Mean smin:	0.39013	Mean smin:	0.08091	Mean smin:	0.72766

Thank You for your Attention !