


Chromatic Consideration on the Colour of Nautical Charts

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As from April 2000, the Japanese Hydrographic Department (JHD) has changed the geodetic datum from Tokyo Datum to WGS-84. It is vital that chart users exactly know which geodetic datum they are using, as the discrepancy between two datum is some 500 meters around Japanese waters. In order to make the difference clearer to the chart users, JHD has changed the colour for land area from buff to grey. This paper provides the way JHD took to determine the new chart colours.

Characteristics of Nautical Chart Printing

JHD charts are produced according to the 'Chart Specifications of the IHO and the Regulations of the IHO for International (INT) Charts: thereinafter Chart Spec' in order that the charts provides the uniform interface to chart users internationally. Based on the Chart Spec necessary characteristics of colours of nautical charts are listed as follows:

1. Four colours; black, blue, magenta and buff (or grey) are used
2. Shallow water is shown in blue, and the land area in buff, heavy face
3. Inter-tidal areas are shown in overlapping colours of blue and buff (or grey)
4. Deep sea areas are left as the original paper colour without inks
5. Visibility under subdued bridge lighting is ensured
6. Information printed in black or magenta should override blue and buff (or grey)

Colour of Inks is composed by blending four base colour pigments of cyan, magenta, yellow and black.

Inks used for heavy face printing, i.e. land and shallow water are blended with medium (transparent extension material) is blended to make more than 90 per cent of total ink amount is medium. In this way, colour particles (pigments) are dispersed on the paper surface, to make black and magenta override the land and shallow water colours. Grey colour can be expressed with dispersed black ink, as well as grey ink.

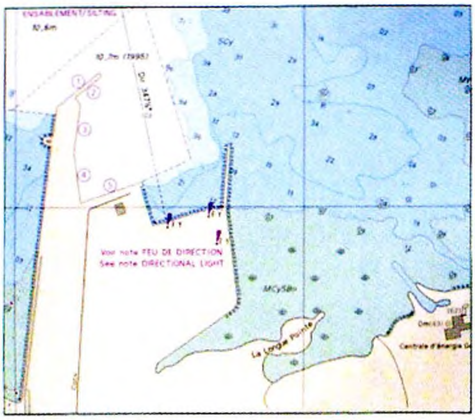

Figure 1: Canada

Figure 2: USA

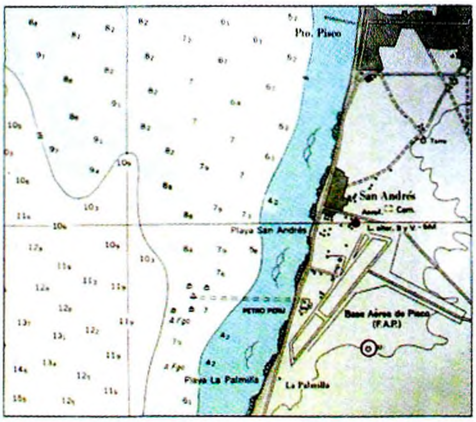

Figure 3: Peru

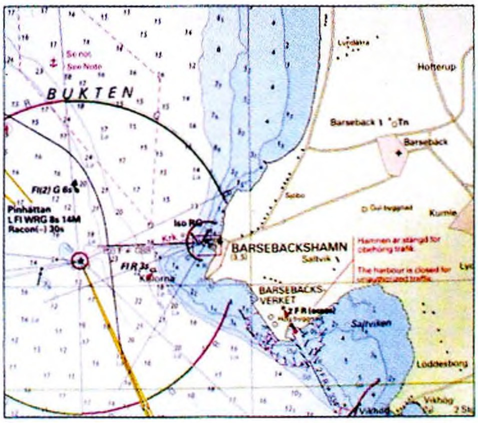

Figure 4: Sweden

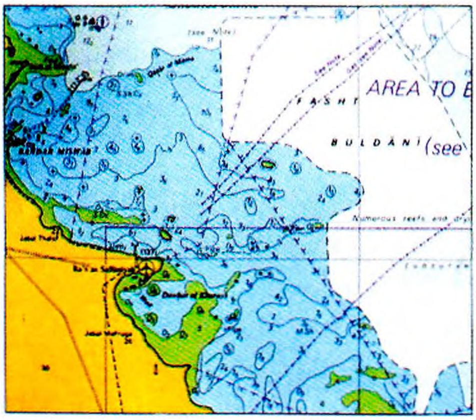

Figure 5: UK

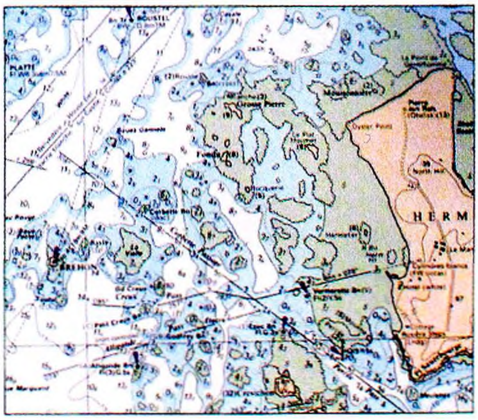

Figure 6: France

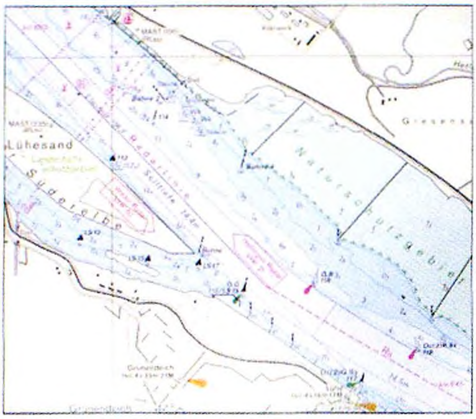

Figure 7: Germany

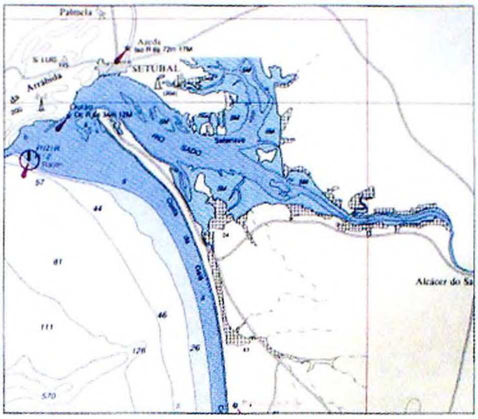

Figure 8: Portugal

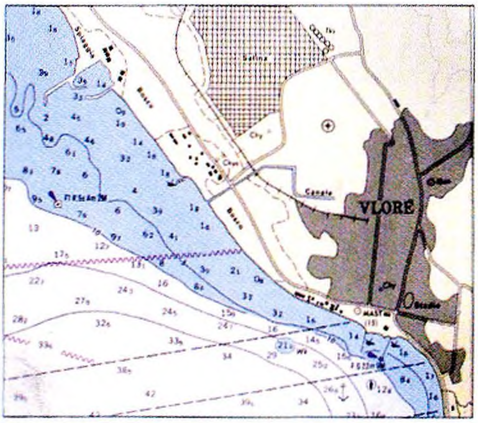

Figure 9: Italy

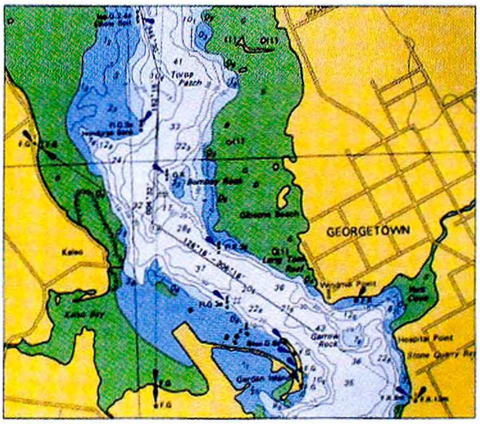

Figure 10: Australia

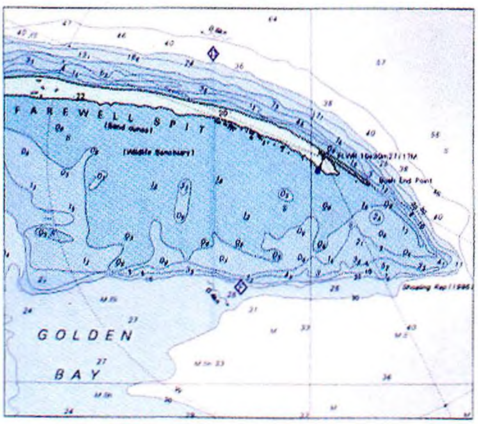

Figure 11: New Zealand

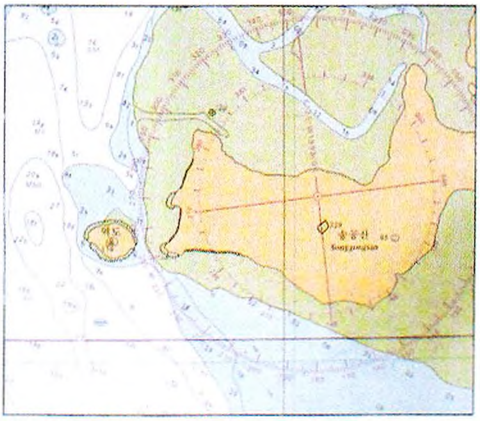

Figure 12: Korea

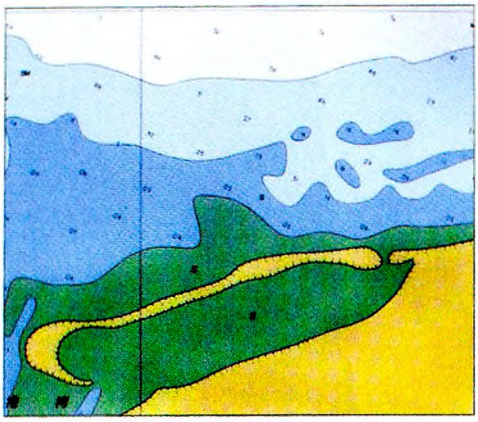

Figure 13: China

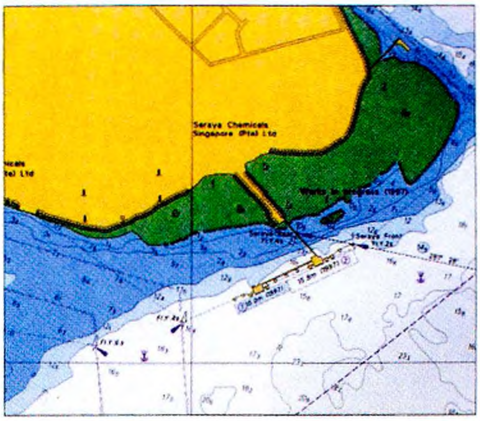

Figure 14: Singapore

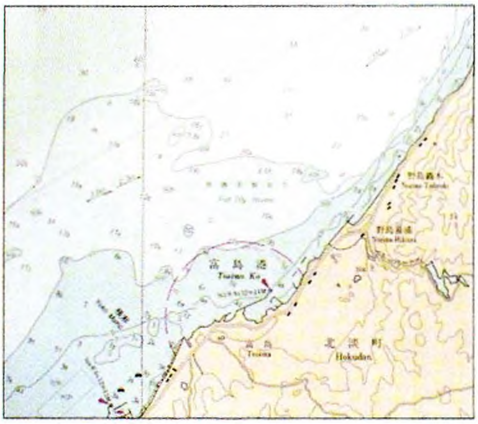

Figure 15: Japan (131)

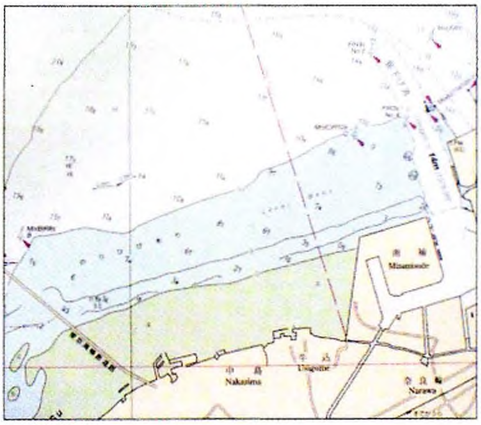

Figure 16: Japan (1061)

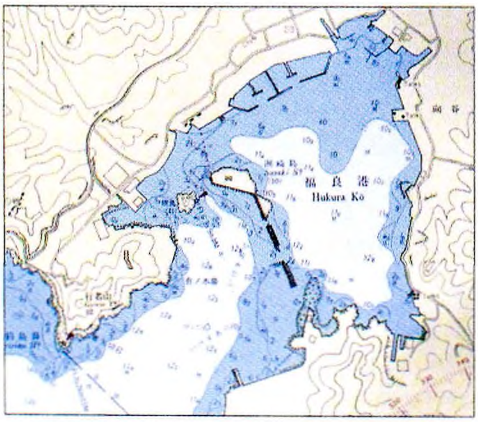

Figure 17: Japan (112)

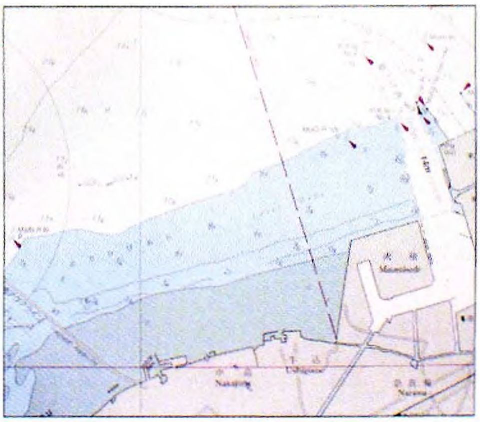

Figure 18: Japan (W1061)

Current Status of Colour in Different Countries

In order to determine the land and shallow water colours, authors investigated the practice of charts of other countries. Charts used are shown in table 1 and figures 1 to 18 (Figures are reduced in size into 1:2 approximately). Charts from figure 15 to 17 are Tokyo Datum Charts, whereas figure 18 represents the WGS-84 chart. Note that the newly introduced blue colour is adopted even for Tokyo Datum charts (see figure 17), in order to improve the visibility.

Shallow Water (in Blue)

Practice of shallow-water colour differs by country. Beyond the area tinted solid blue, Chart Spec recommends three different ways, i.e., deeper contours emphasised by being backed by a ribbon of blue tint normally about 1 mm wide on the shallower side, or by screened tints, or solid single hatches.

On the right hand column in table 1, shallow water representation is abbreviated by heavy (face), belt, screen and hatch in the sequence from shallower to deeper. Note that there are several countries which use screen colour for the shallowest solid portion instead of heavy face. There are countries which adopt multi-depth zones as shallow water. The way of expression is;

1. Belt; 1 mm belt inside the contour line; France (Figure 6), Germany (Figure 7)
2. Screen; Canada (Figure 1), Peru (Figure 3), Sweden (Figure 4), UK (Figure 5), Spain, Australia (Figure 10), New Zealand (Figure 11), Singapore (Figure 14); In these countries some use different screens to distinguish multiple depth zones. In this case, shallower area has denser screen
3. Hatch; Portugal (Figure 7), China (Figure 12, so finely hatched that naked eye would not distinguish the hatch. China also uses screen after 1998.)
4. USA (NIMA Figure 2), Brazil, Norway, the Netherlands, Italy (Figure 9), Russia, Korea (Figure 12), Japan do not use multi-depth zones

Land Area (in Buff or Grey)

The land area is expressed in buff or grey. Buff is defined in JIS (Japanese Industrial Standard) Z 8102 as hue; 7YR, lightness; 6.5, saturation; 6, dim or opaque reddish yellow. Another standard colour guide

Figure No.	Country	Chart No.	Scale(1/N)	Date of Print	Shallow Water Representation (in the order of shallower area to deeper area)
1	Canada	1313	15,000	Jan 1998	Screen, screen
2	USA (NIMA)	52043	15,000	Jul 1998	Screen
3	Peru	2171	50,000	Jun 1983	Heavy, screen
4	Sweden	921	60,000	Feb 1991	Screen, screen, screen
5	England	2882	350,000	Jun 1999	Heavy, screen
6	France	6903	25,000	Aug 1998	Heavy, belt
7	Germany	47	30,000	Apr 2000	Heavy, belt
8	Portugal	23	300,000	Jul 1987	Heavy, hatch
9	Italy	6016	50,000	Sept 1997	Screen
10	Australia	167	25,000	Mar 1997	Heavy, screen
11	New Zealand	NZ61	200,000	Apr 1999	Heavy, screen
12	Korea	342	50,000	Dec 1998	Heavy
13	China	9423	35,000	Aug 1997	Heavy, heatch
14	Singapore	101	10,000	Sept 1998	Heavy, screen
15	Japan	131	45,000	Jul 1997	Heavy
16	Japan	1061	50,000	Jan 1997	Heavy
17	Japan	112	18,000	Jun 2000	Heavy
18	Japan	W1061	50,000	Apr 2000	Solid

Table 1: List of nautical charts shown in this paper

Country	Chart No.	Date of Print	Darkness Level				Figure No.
			Deep Sea (Paper colour)	Shallow	Inter-tidal Areas	Land Areas	
Canada	1313	Jan 1998	14	47	61	31	1
Canada	1315	Nov 1998	12	50	60	31	
USA (NIMA)	52043	Jul 1998	17	48	87	58	2
USA (NIMA)	94082	Feb 2000	19	46	68	46	
Brasil	112	Apr 1999	10	70	88	31	
Brasil	51	Jul 1999	16	72	81	43	
England	2882	Jun 1999	8	35	61	42	
England	2884	Jun 1999	23	38	59	38	5
France	6381	Aug 1998	15	57	57	31	
France	6903	Aug 1998	13	32	52	32	6
Germany	47	Apr 2000	5	29	34	20	7
Germany	7	Jul 1997	16	40	39	22	
Italy	6016	Sept 1997	15	42	25	9	
Italy	6114	Sept 1997	18	33	18		
Australia	167	Mar 1997	12	41	62	37	10
Australia	722	Jun 1997	13	52	73	37	
New Zealand	NZ2533	Dec 1999	15	37	42	38	
New Zealand	NZ61	Apr 1999	16	44	63	45	11
Korea	342	Dec 1998	15	37	42	38	
China	9423	Aug 1997	17	65	81	30	13
Singapore	100	Sept 1998	16	44	63	45	
Singapore	101	Sept 1998	14	37	89	47	14
Japan	1061	Jan 1997	17	29	33	30	16
Japan	112	Jun 2000	12	35	55	34	17
Japan	W1061	Apr 2000	16	35	58	39	18

Table 2: Darkness of colours used as land tint, inter-tidal area tint, and shallow water tint, and of chart paper

by Buyodo, a printing industry in Japan defines buff as hue; 7.6 YR, lightness; 8.3, saturation; 2.6, and process colour indexes; C-0, M-8, Y-20. Countries using grey are USA(NIMA) and Peru. Here grey is expressed by screened black, whereas all the countries using buff print the land area by heavy face.

Lightness Measurement

It is known in the field of chromatics that the most important factor to determine the visibility is the difference of lightness. Also it is known that in the dark area rods supersede cones, and rods only sense brightness but no colour. In order to identify the visibility, the authors examined the lightness of colours of chart papers and colours used in various charts. For this measurement, a colour scanner which uses RGB filters was used. It only detects RGB components rather than spectrum obtained by spectrometers, but scanners are advantageous as they are inexpensive, easy to connect PCs, and widely available. The scanner and the driver the authors used was; EPSON GT-7000S (A4 size, flatbed type, 600dpi, CCD) and EPSON TWAIN3. Scannings were conducted with 300dpi, full colour, and saved as BMP format. Scanned areas of each chart were carefully selected to represent the colours of paper itself, shallow water, inter-tidal areas, and land areas.

Lightness was obtained using Adobe Photoshop 5.0J. Scanned images were converted to grey scale and channel black value was obtained at an area as large as possible, at least larger than 1 square centimetre. Channel black value shall be 0 for pure black, and 255 for pure white. However as the value obtained spread between 150 to 250, authors defined 'darkness index' which was derived from the value subtracted from 255, as shown in table 2. As older charts tend to become yellowish, charts printed after 1997 were selected for scanning. To confirm the repeatability of measurement and long term drifting of the scanner, standard colour samples were scanned every time. It was found that long term drift is within the repeatability, if any, as the absolute repeatability showed a standard deviation of 10, and relative repeatability showed a standard deviation of 5.

As the darkness index is proportional to the amount of pigments, it is natural that overlapped areas, i.e. inter-tidal areas had larger value in general. Darkness index between land and shallow water areas had no general tendency. Most countries printed shallow water darker than land area. Darkness index for these areas were almost same for charts of Japan and New Zealand. Charts from US-NIMA, UK and Singapore had darker land area than shallow water.

Table 2 showing representative trends of tested charts.

Consideration

The major purpose to change the colours of new WGS-84 charts is to provide totally different visual perception than the Tokyo Datum charts to users at every environment. Other than this, providing better visibility and more pleasing appearance was also intended. In addition, changing inks to more environment friendly ones were taken into account, taking this opportunity.

Visual Perception on Differences

Human eyes are very sensitive especially when two colours are compared. However what is required is an absolute awareness without comparison, by providing a feeling that something is wrong. As the Chart Spec allows two totally different hue as the land area colour, i.e. buff and grey, authors selected to move from buff to grey. Changing the hue within so-called buff was also examined but it was not possible to obtain intuitive difference to a satisfactory level.

Visibility in Twilight

Many experiments were conducted to identify the distinguishability under the various subdued lighting. It was found that difference in lightness between land and shallow water is important. The authors carefully selected the colour to make inter-tidal area melt into land area under the subdued lighting condition. Along with this, darkness index was so chosen that land area was darkest and dark index became smaller for deeper area. Deepest area where no ink was applied had smallest darkness index.

Decision of the Colours

Inks to print nautical charts are blended by ink industry. Other than grey ink, inks are chosen from the market. Grey ink was carefully arranged to have the best visibility at any lighting environment. Colour balance with shallow water, and visibility of black and magenta were considered, and after numerous tests, slightly greenish grey was selected by a colour designer, who also considered the artistic beauty and recent trend in colour. Greenish grey is complementary colour to magenta, and provides better visibility to information in magenta.

Shallow water colour was also investigated, and brighter cyan was chosen to fulfil the requirement, and to match the grey colour. It was decided that new shallow water colour was used for supplementary printing of Tokyo Datum charts, as it provided better visibility even with the land colour in buff (Figure 17).

New colour for the land area is defined as hue; 9.9Y, lightness; 7.9, saturation; 0.7, and JIS Z8102 expresses this colour as light greenish grey. For shallow water, hue; 3.8B, lightness; 7.7, saturation; 3.9, and JIS Z8102 expresses this colour as thin greenish blue.

Environment Friendly Inks

Soy bean oil inks with reduced petrologic volatile organic compounds were selected, to reduce the environmental impact when charts were disposed or incinerated.

Conclusion

Matching of geodetic datum between GPS setting and nautical charts in use is vital in Japan where geodetic discrepancy between Tokyo Datum and WGS-84 is some 500 meters. In order to provide self-identification to newly issued WGS-84 charts, adoption of new chart colours was considered. After quantitative analysis of various foreign charts and experiments under various lighting conditions, change of land area colour from existing buff to grey was determined, in order to provide absolute distinguishability for newly published WGS-84 based nautical charts. Shallow water colour was also selected to best match the grey land colour. Determination of exact hue, lightness and saturation required additional fine tuning, and comparison was made under various lighting conditions between subtle change of tint. With the help of colour designer new highly visible chart colours were determined.

Acknowledgement

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Biographies

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