ABSTRACT

A new methodology for estimating the potential salinity hazard (PSH) of all grid cells in an area of interest was developed, applied and evaluated for a large and environmentally diverse region in Alberta, Canada. The test area consisted of an entire 1:250,000 NTS map sheet (116 by 142 km) which included 3 different Soil Zones and Eco-Regions. PSH was estimated for over 27 million grid cells with dimensions of 25 by 25 m (0.25 ha).

The hybrid method combined the computational approach used in multi-criteria evaluation (MCE) with an analysis of evidence similar to that used in evidential reasoning (Bayesian logic). The method integrated a variety of data sets including a digital soil survey database, widely available environmental maps, satellite imagery and terrain derivatives computed from a 25 m gridded DEM. Maps of visible salinity prepared previously for portions of the study area provided the evidence used to establish the probability of occurrence of 8 different types of salinity given a particular map class on each of 19 input maps. Probabilities were re-scaled to compute factor scores that reflected the relative likelihood of a particular type of salinity occurring in a particular class of any given source map. The relative extent of each type of salinity within each unique map class was compared to the proportional extent of each map class within the study area to provide a measure of the relative ability of each classed map to explain the observed variation in mapped salinity. This provided an indication of the information content, or discriminating value, of each input map in terms of its usefulness in predicting the spatial distribution of visible salinity. The absolute values for information content were used to compute factor weights for the MCE equation for each type of input map for each type of salinity. Application of the MCE equation involved multiplying the re-scaled factor score for each class of each input map by the appropriate weighting factor for the map and computing the sum of these products for 19 individual input maps for each grid cell.

A randomly selected 10% subset of the available information on visible salinity was excluded from the analysis used to develop and apply the PSH rules for each type of salinity within the region of interest. This random subset was subsequently used to evaluate the ability of the PSH procedure to predict the relative likelihood of occurrence of visible salinity for each of the 8 different kinds of salinity mapped in the region of interest. Most (70-90%) of the mapped visible salinity included in the 10% random subset was located within a limited proportion of the map sheet area (8 - 25%) with high predicted values for PSH.

Application of the procedures resulted in identification of sites (or cells) with environmental and topographical conditions similar to those at sites of known visible salinity. The PSH value (0-100) was interpreted as an indication of how similar these other sites were to sites at which visible salinity was known to occur. The procedures may be applied to presently unmapped areas to predict the most likely sites of visible salinity prior to field mapping. Alternately they may be re-applied to the areas used to develop the rules to identify sites which depart from the general conditions used to define the rules and which may, therefore, qualify as misclassified sites or outliers.

In addition to providing a highly effective portrayal of the most likely spatial distribution of potential salinity hazard (PSH), the technique generated a quantitative rule base of knowledge on the manner, direction and degree to which the examined environmental and topographical factors influenced the spatial occurrence of salinity. The digital soil survey database was consistently the most effective at explaining and predicting the spatial distribution of potential salinity hazard. The evidential reasoning analysis was found to strengthen understanding of how environmental and topographical factors affect or reflect the spatial pattern of occurrence of visible salinity.

INTRODUCTION

Why did Alberta Agriculture, Food and Rural Development want to evaluate the PSH methodology?

- The PSH method was developed in previous project for a small area
  - PSH was developed for a test watershed of 15 km by 15 km (MacMillan and Marciak (1996 a,b)
  - Results were encouraging for this small test watershed
- Alberta Agriculture, Food and Rural Development (AAFRD) were interested in seeing if the methodology could be scaled up to be applicable to a much larger area of interest.
  - Initially to an area of at least 1 1:250,000 NTS map sheet in size
  - Eventually to the entire agricultural portion of Alberta (referred to as the "White Area")
  - White Area is 280,000 km^2 and very ecologically diverse.
- AAFRD operate an Environmentally Sustainable Agriculture Program (AESA) that has a Soil Quality Program (SQP) component
- The SQP has a mandate to monitor and assess the quality of soils in Alberta.
  - Dryland salinity is one of the factors considered in assessing soil quality
- In the context of soil salinity the questions of concern to SQP were:
  - What is the present extent and location of visible saliinty?
  - What is the risk of change in location & extent of visible salinity?
- PSH was thought to offer potential for assessing the risk of change.

What kinds of similar work have been previously reported and how is it relevant to the current work?

- Very little published work in the area of analysing the risk of development or change in dryland salinity
- Corwin et al., (1988, 1989) published 2 germane studies
  - First (Corwin et al., 1988) overlaid maps to identify areas that exceeded threshold values relative to 4 salinisation factors.
    - Factors were: soil permeability, depth to groundwater, groundwater quality (E.C), and leaching fraction at drill points.
    - Models had poor predictive performance
  - Second (Corwin et al., (1989) used more rigorous, multiple regression models that weighed relative importance of each salinisation factor.
    - Required detailed and expensive point data to produce "blobs"
- In Canada, Eilers (1995) has developed a procedure for predicting the potential for change in salinity expressed as a salinity risk index (SRI).
  - Based on use of very general, but widely available maps & data
  - Uses expert judgement and opinion rather than statistical analysis.
  - Primary criteria is land use and potential for changes in land use.
- A number of different techniques for analysing spatial co-occurence are relevant but have not been used to analyse dryland salinity.
  - Mutual information analysis (Davis and Dozier, 1990)
  - Bayesian Logic (Skidmore et al., 1996, Aspinall and Veitch, 1993)
  - Multi-criteria evaluation (MCE) (Eastman et al., 1995).
- In all of these, evidence, in the form of maps, can be cross referenced against available maps to assess spatial co-occurrence & build rules.

ACKNOWLEDGEMENTS

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Conny Thomas, David Spiess and Gerald Stark of AAFRD assisted in obtaining and providing the hard copy and digital data sets used for PSH analysis. Karen Cannon (AAFRD) provided contract liaison with the Soil Quality Program steering committee. David Hildebrand (Hildebrand Consulting Ltd.) produced and installed ArcView 3 Spatial Analyst scripts required to compute distance to divide and channel. Jennie Lutz (SLRI Consultants Inc.) scanned, digitized and geo-referenced all data layers that were originally available only as hard copy maps.

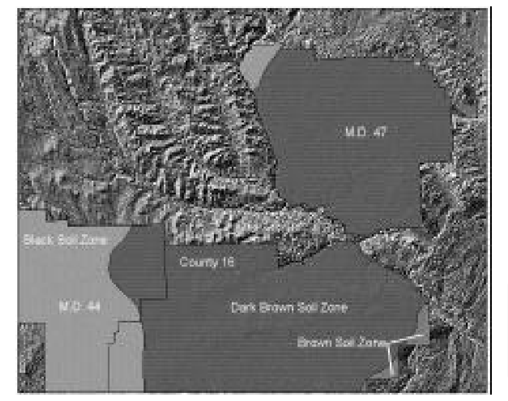
The authors would like to acknowledge Hank VanderPluym, now retired from AAFRD, for posing the original questions and challenging the authors to devise a unique and effective solution.

OBJECTIVE

To evaluate the capability of the previously developed PSH methodology to provide useful input to the SQP program by predicting the location and extent of areas of high potential salinity hazard (PSH) for a large and ecologically diverse region.

METHODS

STEP 1.
Description of the study area
(NTS 1:250,000 Map Sheet 82P)



Latitude 51-52 N
Long: 114 - 112 W
116 by 142 km
16.4 million ha.

4640 rows
5680 columns
25 m grid spacing
26.3 million points

Salinity maps for 3 rural municipalities
Cover just under 50% of the map sheet

Table 1. Extent of visible salinity by type in the MD's and County within NTS sheet 82P

Type of Salinity	Extent of Salinity in	MD 47	Extent of Salinity in	MD 44	Extent of Salinity in	CO 16	Extent of Salinity in	Total Area
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Artesian	0.00	0.00	2.31	0.00	69.81	0.02	72.13	0.01
Canal Seep	4.19	0.00	1702.75	0.99	1341.88	0.38	3048.81	0.39
Contact	177.13	0.07	2125.56	1.24	1570.13	0.44	3872.81	0.49
Coulee	160.13	0.06	60.94	0.04	2479.44	0.70	2700.50	0.34
Depression	1606.06	0.61	4848.75	2.82	2366.63	0.67	8821.44	1.12
Natural	0.00	0.00	240.50	0.14	793.63	0.22	1034.13	0.13
Outcrop	3.06	0.00	57.56	0.03	250.81	0.07	311.44	0.04
Slough Ring	361.19	0.14	26.56	0.02	279.31	0.08	667.06	0.08
Total Salinity	2311.75	0.88	9064.94	5.27	9151.63	2.57	20528.31	2.60
Non Saline	259304.63	99.12	162852.75	94.73	346406.38	97.43	768563.75	97.40
Total Area	261616.38	100.00	171917.69	100.00	355558.00	100.00	789092.06	100.00

Table 2. Extent of mapped visible salinity by type in the 3 Soil Zones within NTS sheet 82P

Type of Salinity	Black Soil Zone	Extent	Dark Brown Soil Zone	Extent	Brown Soil Zone	Extent	Total Area	Extent
	ha.	%	ha.	%	ha.	%	ha.	%
Artesian	0.00	0.00	70.88	0.01	1.25	0.01	72.13	0.01
Canal Seep	1204.38	0.71	1844.44	0.30	0.00	0.00	3048.81	0.39
Contact	1983.31	1.17	1889.00	0.31	0.50	0.01	3872.81	0.49
Coulee	166.88	0.10	2369.13	0.39	164.50	1.77	2700.50	0.34
Depression	4038.69	2.39	4782.75	0.78	0.00	0.00	8821.44	1.12
Natural	27.50	0.02	1006.63	0.16	0.00	0.00	1034.13	0.13
Outcrop	58.44	0.03	225.50	0.04	27.50	0.30	311.44	0.04
Slough Ring	29.75	0.02	637.31	0.10	0.00	0.00	667.06	0.08
Total Salinity	7508.94	4.44	12825.63	2.10	193.75	2.08	20528.31	2.60
Non-saline	161670.50	95.56	597781.94	97.90	9111.31	97.92	768563.75	97.40
Total Area	169179.44	100.00	610607.56	100.00	9305.06	100.00	789092.06	100.00

STEP 2.
Prepare and input all relevant and available spatial data layers

Table 3. Description of the 19 spatial data layers of environmental and topographical data used in the final PSH analysis

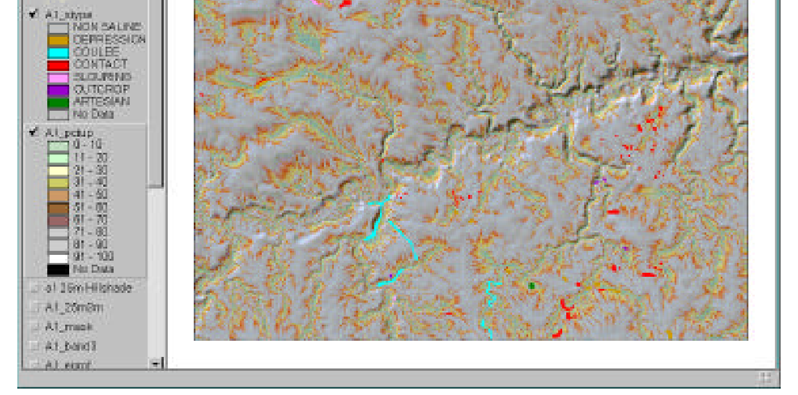
No.	Map Name	Description	Source Map	Reference
1	82P_BRT	Type of bedrock (classes)	Geological Map of Alberta	Green (1972)
2	82P_Z2BR	Depth to bedrock (classes)	Bedrock Contour Map	unattributed
3	82P_SG	Surficial Geology (classes)	Surficial Geology of Southern Alberta	Shetsen, 1987
4	82P_SALC	Soil Map Unit salinity classes	AGRASID Digital Soil Map	CAESA, 1998
5	82P_LU25	Land Use Classes	PFRA classification of TM data	PFRA, 1995
6	82P_B316	Band 3 data in 16 equal classes	Raw unclassified TM data	PFRA, 1995
7	82P_B416	Band 4 data in 16 equal classes	Raw unclassified TM data	PFRA, 1995
8	82P_B516	Band 5 data in 16 equal classes	Raw unclassified TM data	PFRA, 1995
9	82P_FLOW	Rate of groundwater flow in aquifer	Hydrogeology Map of Drumheller, AB	Borneuf, 1972
10	82P_TDS	Total Dissolved Solids in groundwater	Hydrogeology Map of Drumheller, AB	Borneuf, 1972
11	82P_DCRC	Discharge/Recharge areas on map	Hydrogeology Map of Drumheller, AB	Borneuf, 1972
12	82P_SLPC	Slope gradient classed as per CSSC	Computed from 25 m DEM	Eyton, 1991
13	82P_ASPC	Slope azimuth (aspect) (classes)	Computed from 25 m DEM	Eyton, 1991
14	82P_PROF	Plan curvature (classes)	Computed from 25 m DEM	Eyton, 1991
15	82P_PLAN	Profile curvature (classes)	Computed from 25 m DEM	Eyton, 1991
16	82P_PCTU	Percent length upslope from depression (10 equal classes from 0 - 100)	Computed from 25 m DEM	Custom method
17	82P_L2ST	Length from cell to pit or channel in m (classes)	Computed from 25 m DEM	ESRI, 1996
18	82P_FILZ	Maximum depth of ponding (m) if all depressions were to fill to capacity	Computed from 25 m DEM	ESRI, 1996
19	82P_Z2WT	Depth to water table (m) (classes)	DEM & TM Imagery	Custom method

Table 4. Identification of additional spatial data layers used in the PSH analysis

No.	Map Name	Description	Source Map	Reference
20	82P_SACO	25 m raster map of all types of salinity in all 3 mapped rural municipalities	Maps of Dryland Salinity for 3 Rural Municipalities prepared by AAFRD	Kwiatkowski et al., 1996, 1997
21	82P_SA10	10% random subset of 82P_SACO	Extracted from 82P_SACO	Kwiatkowski et al., 1996, 1997
22	82P_SA90	90% of total salinity remaining after removal of a 10% random subset	Extracted from 82P_SACO	Kwiatkowski et al., 1996, 1997
23	82P_allmask	Mask file of mapped MDs & Soil Zones with cells of the 10% random subset excluded (set to missing value)	Soil Group Map of Alberta, MD boundaries 1:250k digital base map	ArcView clip
24	82P_STPD	Simulated extent of surface water in streams and ponds within 82P	Computed from a combination of TM imagery and DEM derivatives	Custom method
25	82P_25m3m	25 m DEM surfaced from 1:20,000 x,y,z input data supplied by AAFRD	1:20,000 x,y,z elevation data produced by Alberta Env Protection	Hemenway, 1997
26	82P_25m3HS	Illuminated hillshade image based on 25 m DEM filtered with a 3x3 mean filter	25 m gridded DEM surfaced from 1:20,000 DEM x,y,z input data	Spatial Analyst

It is significant that the PSH procedures require only widely available environmental and topographical data sets

STEP 3.
Cross tabulate maps of visible salinity vs environmental & topographic input maps



STEP 4.
Compute factor scores for each type of salinity for each class of each map

$$FS_{k,i,j} = P\left(H_{k,i,j} \mid E_{i,j}\right) \ldots\ldots where$$

$H_{k,i,j}$ = the absolute extent (ha) of salinity of type k that occurs in areas mapped as map class j on map i.

$E_{i,j}$ = the absolute extent (ha) of areas on map i belonging to class j (e.g. shallow to bedrock)

In MCE the factor scores $FS_{k,i,j}$ are generally standardized by re-scaling the original absolute values for probability into the range of 0-100 or alternatively 0-255.

STEP 5.
Compute weighting factors for each type of salinity for each different input map

$$Wt_{k,i} = \sum_{j=1}^{1n} \left| P\left(E_{k,i,j} \mid H_{k,i}\right) - P\left(H_{k,i}\right) \mid E_i \right|$$

Where:

$E_{k,i,j}$ = the absolute extent (ha) of areas on map i belonging to class j (e.g. shallow to bedrock) that occur within areas mapped as salinity class k

$H_{k,i}$ = the total absolute extent (ha) of salinity of type k that occurs within map I

$E_{,i}$ = the total absolute extent (ha) of map i

STEP 6.
Compute potential salinity hazard (PSH) for each grid cell for 8 kinds of salinity

$$PSH_k = \sum_{i=1}^{n} FS_{k,i,j} * WT_{k,i}$$

Where:

PSH_k = The potential salinity hazard for the k^{th} type of visible soil salinity (where k = 1, 8)

$FS_{k,i,j}$ = A contrast stretched Factor Score for the j^{th} class of the i^{th} input map for the k^{th} type of visible soil salinity

$WT_{k,I}$ = A Weighting Factor representing the assumed relative importance of the i^{th} input map for predicting the k^{th} type of visible soil salinity

STEP 7.
Compare predicted PSH with actual occurrence of salinity in a 10% sample

- 10% of the data on actual mapped visible salinity was not used in the analysis used to estimate PSH
- The extent of this 10% sub-set of actual mapped salinity was analysed with respect to each of 10 classes of PSH
- The proportion of the 10% sub-set of mapped salinity that occurred in each of 10 classes of predicted PSH provided a measure of the accuracy of the PSH prediction

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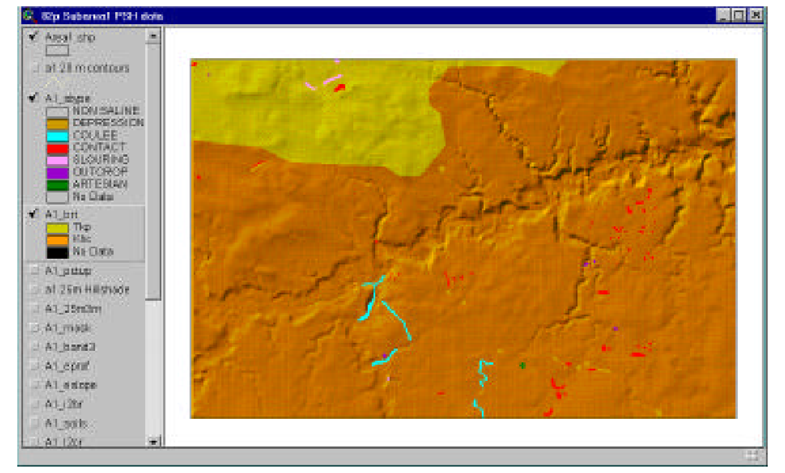
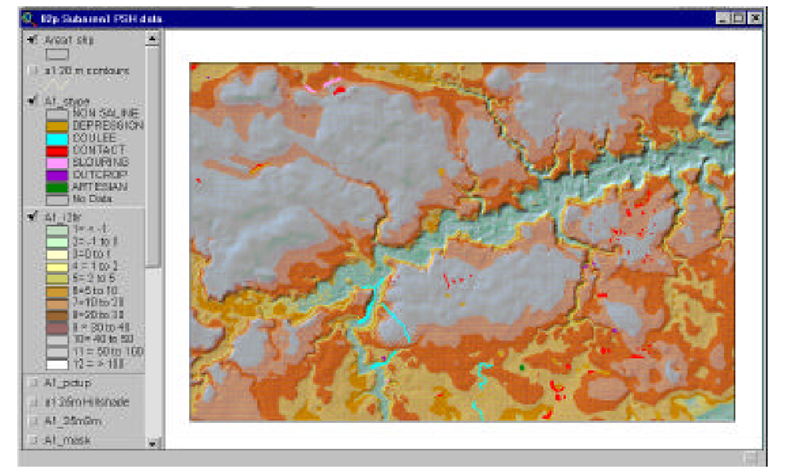
RESULTS

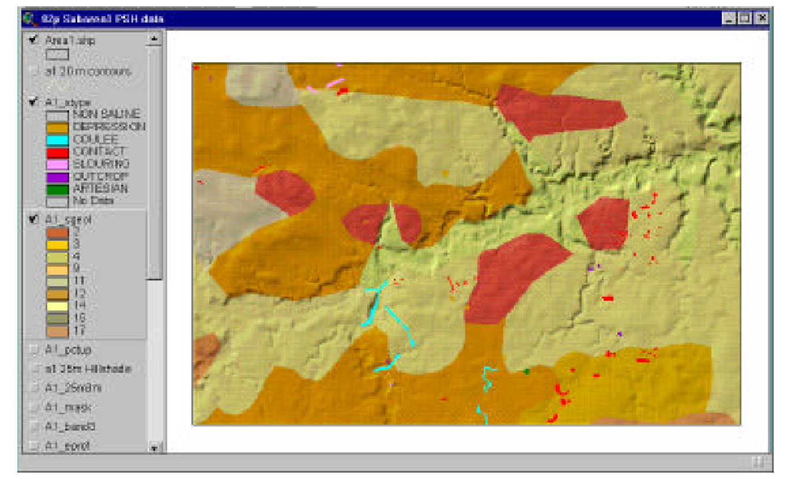
STEP 3.
Maps of visible salinity cross tabulated vs environmental & topographic input maps



Bedrock Type Map overlaid with mapped salinity



Depth to bedrock map overlaid with mapped salinity



Surficial geology map overlaid with mapped salinity

STEP 5.
Example illustrating the procedure for computing absolute weighting factor for type of bedrock map

Table 8. Distribution of each of the 8 kinds of visible salinity by bedrock formation in 82P

Map Class	Non saline	Depress	Coulee Bottom	Contact	Slough Ring	Outcrop	Artesian	Natural	Canal Seep	Map Total
TKp	414369.375	5937.875	598.875	2894.063	212.625	208.375	49.625	610.813	2133.938	427015.563
Khc	331134.750	1796.563	1581.875	620.813	405.563	49.938	18.938	340.438	188.563	336137.438
Kbp	1574.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1574.000
Total	747078.125	7734.438	2180.750	3514.875	618.188	258.313	68.563	951.250	2322.500	764727.000
TKp	55.465	76.772	27.462	82.338	34.395	80.668	72.379	64.212	91.881	55.839
Khc	44.324	23.228	72.538	17.662	65.605	19.332	27.621	35.788	8.119	43.955
Kbp	0.211	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.206
Col %	97.692	1.011	0.285	0.460	0.081	0.034	0.009	0.124	0.304	100.000
TKp	0.374	20.933	28.377	26.499	21.444	24.829	16.540	8.373	36.042	55.839
Khc	0.369	20.727	28.583	26.293	21.650	24.623	16.334	8.167	35.836	43.955
Kbp	0.005	0.206	0.206	0.206	0.206	0.206	0.206	0.206	0.206	0.206
Total Wt	0.747	41.866	57.166	52.997	43.300	49.658	33.081	16.745	72.084	

The first four lines of data (Table 8) give the absolute extent in hectares of each of the 8 different kinds of visible salinity (and of non-saline areas) within each of the 3 bedrock formations. In the next 3 lines, the absolute values are expressed as percent extent of total salinity of a given type within each of the 3 bedrock type classes. The column Map Total indicates the percent of the total map area occupied by each of the 3 bedrock formations. The degree to which each kind of visible salinity is over or under represented within each class of bedrock formation is evaluated by computing the absolute value of the difference between the percent extent of the bedrock formation map class within the area of interest (Map Total column) and the percent of the total salinity of each type in each of the bedrock formation map classes (e.g. |76-55| = 21). These absolute differences are reported in the next to last 3 rows of data for each of the 3 classes of bedrock type. The absolute difference values for each of the 3 bedrock classes are summed to compute an overall total (Total Wt) which is considered to provide a quantitative measure of the overall information content, or utility, of the bedrock type map for predicting the occurrence of each of the 8 kinds of salinity.

STEP 4.
Examples of factor scores as measures of probability of occurrence of visible salinity.

Table 5. Calculation of contrast stretched factor scores for the 3 bedrock formations

Map Class	Non saline	Depress	Coulee Bottom	Contact	Slough Ring	Outcrop	Artesian	Natural	Canal Seep	Map Total
TKp	414369.375	5937.875	598.875	2894.063	212.625	208.375	49.625	610.813	2133.938	427015.563
Khc	331134.750	1796.563	1581.875	620.813	405.563	49.938	18.938	340.438	188.563	336137.438
Kbp	1574.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1574.000
Total	747078.125	7734.438	2180.750	3514.875	618.188	258.313	68.563	951.250	2322.500	764727.000
TKp	97.038	1.391	0.140	0.678	0.050	0.049	0.012	0.143	0.500	55.839
Khc	98.512	0.534	0.471	0.185	0.121	0.015	0.006	0.101	0.056	43.955
Kbp	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.206
Map Tot	97.692	1.011	0.285	0.460	0.081	0.034	0.009	0.124	0.304	100.000
TKp	0.000	100.000	29.801	100.000	41.270	100.000	100.000	100.000	100.000	0.000
Khc	49.746	38.436	100.000	27.251	100.000	30.444	48.478	70.804	11.225	0.000
Kbp	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 6. Raw (not stretched) factor scores relating visible salinity and depth to bedrock

Map No.	Class No.	Class Def.	Depress	Coulee	Contact	Slough Ring	Outcrop	Artesian	Natural	Canal Seep	% Extent by Class
2	1	Outcrop	2.343	1.448	0.497	0.071	0.058	0.002	0.061	0.444	6.906
2	2	Very Shallow	3.536	1.208	1.410	0.049	0.103	0.017	0.062	0.657	1.026
2	3	0.5 to 1 m	2.770	1.086	1.389	0.064	0.148	0.015	0.124	0.827	1.207
2	4	1 to 2 m	2.341	0.923	0.985	0.062	0.134	0.025	0.168	0.911	1.441
2	5	2 to 5 m	2.202	0.496	0.904	0.059	0.113	0.009	0.158	0.882	5.899
2	6	5 to 10 m	1.549	0.251	0.727	0.091	0.059	0.019	0.156	0.691	14.986
2	7	10 to 20 m	0.703	0.120	0.478	0.080	0.021	0.009	0.083	0.230	31.912
2	8	20 to 30 m	0.282	0.056	0.213	0.132	0.013	0.003	0.098	0.034	20.818
2	9	30 to 40 m	0.156	0.016	0.085	0.011	0.017	0.014	0.133	0.022	9.971
2	10	40 to 50 m	0.041	0.016	0.048	0.005	0.001	0.004	0.104	0.000	4.060
2	11	50 to 100 m	0.005	0.011	0.092	0.000	0.000	0.000	0.028	0.012	1.772
2	12	> 100 m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		Extent of Map(%)	1.011	0.285	0.460	0.081	0.034	0.009	0.124	0.304	100.000

Table 7. Raw (not stretched) factor scores relating visible salinity to surficial materials

Map No.	Class No.	Class Def.	Depress	Coulee	Contact	Slough Ring	Outcrop	Artesian	Natural	Canal Seep	% Extent by Class
3	1	10 d	0.236	0.000	0.004	0.000	0.008	0.000	0.000	0.000	2.016
3	2	12	0.872	0.000	0.146	0.004	0.027	0.000	0.000	0.000	1.166
3	3	10 a	1.580	0.140	0.436	0.012	0.029	0.005	0.000	0.055	11.371
3	4	10 b	0.596	0.104	0.177	0.069	0.017	0.001	0.004	0.005	16.863
3	5	7 a	0.000	0.000	0.038	0.000	0.000	0.000	0.000	0.045	0.210
3	7	10 c	0.302	0.040	0.080	0.031	0.010	0.000	0.000	0.000	8.314
3	8	8	6.188	1.706	0.806	0.028	0.001	0.000	0.018	2.555	1.919
3	9	2 a	1.139	0.241	0.597	0.212	0.113	0.014	0.323	0.828	11.206
3	10	1	3.084	0.114	0.416	0.000	0.065	0.128	1.512	0.780	2.153
3	11	9	1.225	0.315	0.907	0.023	0.038	0.004	0.110	0.481	23.613
3	12	2 b	0.305	0.685	0.328	0.317	0.021	0.004	0.255	0.086	10.605
3	13	3 a	1.028	2.241	0.000	0.116	0.000	0.000	0.000	0.000	0.527
3	14	3 b	1.211	1.134	0.791	0.003	0.000	0.012	0.003	0.388	3.108
3	15	4 a	0.000	0.030	0.004	0.000	0.000	0.000	0.000	0.000	2.151
3	16	6 a	1.457	0.072	0.029	0.000	0.022	0.000	0.000	0.000	0.110
3	17	14 a	0.278	0.134	0.024	0.001	0.022	0.046	0.002	0.128	4.140
3	18	6 b	0.069	1.670	0.083	0.112	0.040	0.000	0.000	0.000	0.438
3	19	7 b	2.236	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.068
3	21	15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022
		Overall Extent (%)	1.011	0.285	0.460	0.081	0.034	0.009	0.124	0.304	100.000

STEP 5.
Overall weighting factors for each of the 19 input maps for each of the 8 kinds of visible salinity.

Table 9. Absolute values for total weight computed for each of the 19 input maps

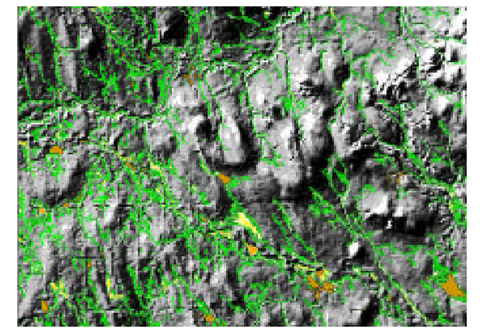
Map No.	Map name	Depress	Coulee	Contact	Slough Ring	Outcrop	Artesian	Natural	Canal Seep	Map Average
4	82P_salc	77.3	100.2	57.4	120.3	66.6	97.2	111.2	101.2	91.4
3	82P_sg	55.4	72.3	61.7	100.2	62.8	109.4	107.7	101.8	83.9
5	82P_lu25	72.0	103.2	19.4	86.8	52.6	73.6	81.1	89.3	72.3
19	82P_z2wt	99.7	82.8	53.0	98.2	16.0	62.4	58.4	70.8	67.7
2	82P_z2br	72.3	97.3	48.2	34.3	74.7	46.8	26.8	81.6	60.3
9	82P_flow	13.9	95.3	11.9	66.3	75.4	66.9	94.6	28.5	56.6
16	82P_pctu	69.6	75.4	39.4	92.4	39.0	15.0	34.1	41.8	50.8
17	82P_l2st	55.2	98.5	31.1	49.3	30.3	44.9	33.9	47.1	48.8
10	82P_tds	20.3	40.0	37.0	28.5	24.1	61.3	84.8	71.5	45.9
1	82P_brt	41.9	57.2	53.0	43.3	49.7	33.1	16.7	72.1	45.9
18	82P_filz	89.4	39.8	16.3	125.7	3.9	7.1	29.2	26.1	42.2
14	82p_prof	34.0	51.8	38.1	35.8	51.2	28.7	28.1	33.3	37.6
8	82P_b516	29.5	34.6	29.3	27.9	31.6	44.1	40.5	42.7	35.0
6	82P_b316	37.9	27.7	29.6	43.4	27.4	38.0	32.8	35.8	34.1
12	82P_slpc	38.3	27.2	35.6	36.2	40.9	20.1	35.2	35.1	33.6
11	82P_dcrc	39.3	40.8	34.1	1.0	32.6	30.2	49.0	38.1	33.2
15	82P_plan	31.3	31.8	32.9	28.3	32.7	25.2	30.2	29.6	30.3
7	82P_b416	36.6	41.4	25.5	30.4	17.5	21.4	15.8	31.0	27.5
13	82p_aspc	8.4	6.3	23.4	14.2	28.5	19.3	30.5	26.8	19.7
	Indiv PSH maps	113.8	140.8	96.1	128.1	118.2	126.1	150.9	135.5	126.2
	Max PSH	94.7	78.8	94.1	83.9	74.6	66.5	87.7	120.9	87.7

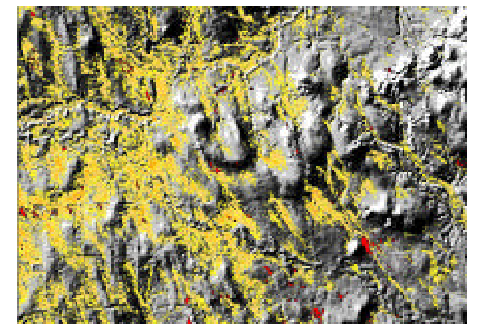
Table 10. Relative Weighting Factors computed for each of the 19 input maps

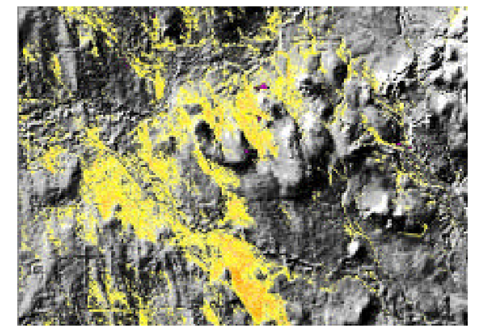
Map No.	Map name	Depress	Coulee	Contact	Slough Ring	Outcrop	Artesian	Natural	Canal Seep	Map Total
4	82P_salc	0.084	0.089	0.086	0.113	0.088	0.115	0.118	0.101	0.099
3	82P_sg	0.060	0.064	0.092	0.094	0.083	0.129	0.114	0.101	0.092
5	82P_lu25	0.078	0.092	0.029	0.082	0.069	0.087	0.086	0.089	0.077
19	82P_z2wt	0.108	0.074	0.079	0.092	0.021	0.074	0.062	0.070	0.073
2	82P_z2br	0.078	0.087	0.072	0.032	0.099	0.055	0.029	0.081	0.067
9	82P_flow	0.015	0.085	0.018	0.062	0.100	0.079	0.101	0.028	0.061
16	82P_pctu	0.075	0.067	0.059	0.087	0.051	0.018	0.036	0.042	0.054
17	82P_l2st	0.060	0.088	0.047	0.046	0.040	0.053	0.036	0.047	0.052
10	82P_tds	0.022	0.036	0.056	0.027	0.032	0.073	0.090	0.071	0.051
1	82P_brt	0.045	0.051	0.079	0.041	0.066	0.039	0.018	0.072	0.051
18	82P_filz	0.097	0.035	0.024	0.118	0.005	0.008	0.031	0.026	0.043
14	82p_prof	0.037	0.046	0.057	0.034	0.068	0.034	0.030	0.033	0.042
8	82P_b516	0.032	0.031	0.044	0.026	0.042	0.052	0.043	0.043	0.039
6	82P_b316	0.041	0.025	0.044	0.041	0.036	0.045	0.035	0.036	0.038
12	82P_slpc	0.042	0.024	0.053	0.034	0.054	0.024	0.037	0.035	0.038
11	82P_dcrc	0.043	0.036	0.051	0.001	0.043	0.036	0.052	0.038	0.037
15	82P_plan	0.034	0.028	0.049	0.027	0.043	0.030	0.032	0.030	0.034
7	82P_b416	0.040	0.037	0.038	0.029	0.023	0.025	0.017	0.031	0.030
13	82p_aspc	0.009	0.006	0.035	0.013	0.038	0.023	0.032	0.027	0.023

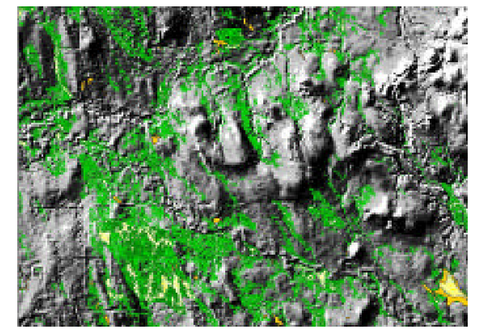
RESULTS

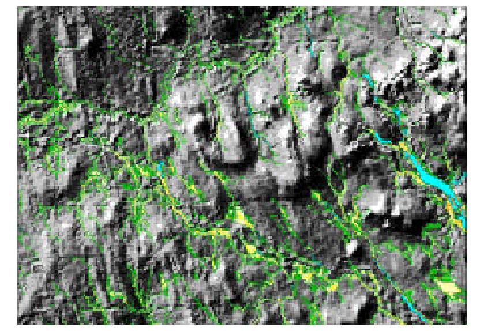
STEP 6.
Mapped distribution of the 8 kinds of visible salinity compared to areas of high predicted PSH

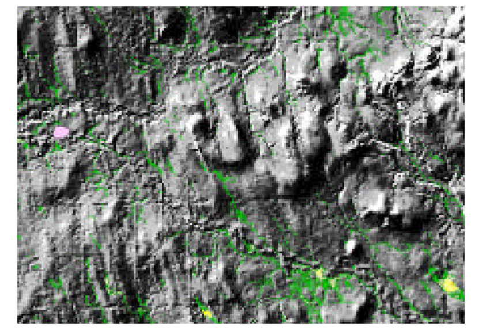

Depression Bottom Salinity (high PSH vs Mapped salinity)


Contact Salinity (high PSH vs Mapped salinity)

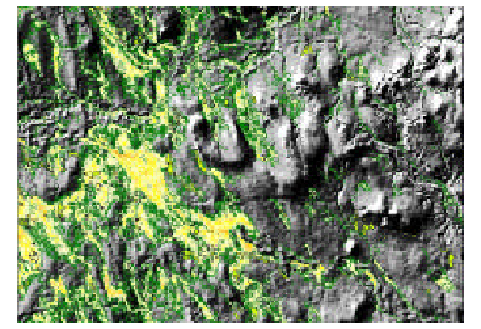

Outcrop Salinity (high PSH vs Mapped salinity)


Natural Salinity (high PSH vs Mapped salinity)


Coulee Bottom Salinity (high PSH vs Mapped salinity)


Slough Ring Salinity (high PSH vs Mapped salinity)


Artesian Salinity (high PSH vs Mapped salinity)


Canal Seep Salinity (high PSH vs Mapped salinity)

CONCLUSIONS

- The PSH methodology was demonstrated to be scalable from its initial scale of application at a local watershed level:
  - It was shown that the PSH methodology was feasible to apply to a large and environmentally diverse area (1 1:250,000 map sheet)
- Application of the PSH procedure resulted in identification of sites (cells) with environmental and topographical conditions similar to those at sites of known visible salinity.
  - The procedures may be applied to presently un-mapped areas to predict the most likely sites of visible salinity prior to field mapping.
  - Alternately they may be re-applied to the areas used to develop the rules to identify mis-classified sites or outliers.
- The PSH procedure represents a systematic, re-produceable and effective way of testing and validating hypotheses regarding spatial relationships between observed salinity & environmental or topographic factors thought to influence this distribution.
  - Weighting factors provide a quantitative indication of the degree to which any given environmental or topographical factor influences the spatial distribution of observed salinity.
  - Factor scores provide a quantitative indication of the manner, direction and magnitude in which a given class on any map of interest influences the spatial distribution of visible salinity.
- Use of evidential reasoning in the PSH procedures represents a formal, systematic method of producing knowledge basis from quantitative analysis of widely available environmental data sets.
  - The PSH procedures helps turn data into knowledge and knowledge into understanding
- Evaluation of the statistical distribution of the 10% sub-set of salinity data not used to construct the PSH rules (not shown) lead to the following conclusions:
  - The PSH maps were able to predict the likelihood of occurrence of visible salinity more accurately and consistently than any of the individual input maps.
  - The digital soil survey map had the highest predictive power of any of the individual input maps used in this project.

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