



5HVHDFK \$UWLFOH

20, & 6 , QWH

# %ZOBNJDT PG \$IFNJDBM BOE #JPMPHJDBM 1SP 1FUSPMFVN )ZESPDBSCPO 1PMMVUFE 4PJM BT

\$JHOH 6ZGH\HPR \$- DQG %DPLGXUR ,

'HSDUWPHQW RI &URS 6RLO DQG 3HVW ODQRQRQRQRW )NKHUWHG L&GHLUHLDU VLW\ RI 7

&RUUHVSRRQLQJ DXWKRU

QcDT &r`P`°`ò`\*`R f`MP`PR g`U AVpl Qc  
 DPHQGPHQWV XVHG ZHUH SRXOWU\ PDQXUH DQG P\FRUUKL]DO IXQJL \*ORPXV PRVVDH VS  
 K\GURFDUERQ FRPSRXQGV VSHQW HQJLQH RLO 6(2 ELWXP HQ %,7 DQG FUXGH RLO &52 Z  
 PO SHU SRW DQG OHYHOV RI RUJDQLF DPHQGPHQWV IROORZHG E\ LQFXEDWLRQ IRU  
 FROOHFWHG IURP HDFK WUHDWPHQW DW DQG PRQWK DIWHU WUHDWPHQW DSSO  
 FKHPDFDO SURSHUWLHV S+ RUJDQLF FDUERQ 1 3 . &D DQG 0J 7KH WLPH FKDQJHV LQ  
 FRQWDPLQDWLRQ ZLWK SHWUROHXP K\GURFDUERQ FRPSRXQGV 6(2 %,7 DQG &52 VKRZHG  
 RI S+ RUJDQLF FDUERQ DQG 0J ZKLOH 1 7RWDO &D DQG DYDLODEOH 3 DQG . URVH ZLWK  
 WUHQGV SRO\QRPLDO IXQFWLRQ DV EHVW ILW LQGLFDWHG WKDW WKH REVHUYHG UHVS  
 VXJJHVW LQWUHDWLRQ DPRQJ IDFWRUV UHVSQRVLEOH IRU WKH EUHDNGRZQ RI SHWUROH  
 LWV WR[LFLW\ WR VRLO FKHPDFDO SURSHUWLHV 7KH WLPH FRXUVH RI FKDQJHV LQ VR  
 SHWUROHXP K\GURFDUERQ FRPSRXQGV 3+&V FRQWDPLQDWLRQ LQ VRLO GLIIHUG DPRQJ  
 WKH PHDVXUHG VRLO SDUDPHWHUV UHFRUGHG DW WKH FRPPHQFHQW RI WKH H[SHULPH  
 DSSOLFDWLRQ RI WKH SHWUROHXP K\GURFDUERQ FRPSRXQGV VKRZHG GHFOLQLQJ WUHQG  
 DQG 0J ZHUH REWDLQHG ,QFUHDVLRQ WUHQGV LQ 1 7RWDO DQG DYDLODEOH 3 ZLWK WLP  
 6(2 UHFRUGLQJ WKH KLJKHVW YDOXH DW PRQWK RI LQFXEDWLRQ 7UHQGV RI WKH PHD  
 ZLWK UHVSHFW WR WUHDWPHQW VKRZHG WKDW &52 KDG WKH KLJKHVW VRLO S+ DW DQG  
 LQFUHDVHG DFURVV WUHDWPHQWV ZLWK 6(2 UHFRUGLQJ WKH KLJKHVW YDOXH DW PRQW  
 JHQHUDO GHFOLQH LQ YDOXH ZLWK WLPH DFURVV WKH 3+&V 7KH UHVXOWV LQGLFDWHG  
 SURSHUWLHV DQG WKDW DGGLWLRQ RI RUJDQLF VXEVWDQFHV LPSURYHG FKHPDFDO SURS  
 XP`°`P`°`EP`AVX`L [H`U`@

LPSDFW RQ WKH HFRV\WHP /DUJH WUDF  
DU

.H\ZRUG\SHWUROHXP K\GURFDUERQ FRPSRXQGV (QYLURQPHQW  
7R[LFL 5PHHGLDWLRQ H HVSHFLDOO\ VXFVHSWLEOH WR RLO W  
WKH VRLO DQG UH UHOHDVHG DQXDOO

,QWURGXFWRQ

&RQWDPLQDWLRQ RI VRLO HQYLURQPHQW D\RK\GURFDUERQ ERWZ\HQ VRLO  
 SHWUROHXP K\GURFDUERQV LV D ZLGH SURSHUHQYSLURQFHV\WUHDWPHQW SUREOHP @ `U  
 ZRUOGZLGH SUREDEO\ GXH WR KHDY\ GHFOLQH\PHQW\SHWUROHXP\WUHDWPHQW\WUHDWPHQW  
 DPDMRU VRXUFH RI HGHUJ\ WKURXJKRXV\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 SRXODWLRQ JURZWK DQG FRPSOHWHK\GURFDUERQV\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 KHDOWK 5HOHDVH RI K\GURFDUERQV\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 DFFLGHQWDOO\ RU GXH WR KXPDQ DQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 HQYLURQPHQW WKURXJK YDULRXV DQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 HGHUJ\ DQG FUXGH RLO SURGXFWLRQ\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 ZDVWHZDWHU VOXGJH WUHDWPHQW DQG\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 HQYLURQPHQWDO SUREOHP KIKO\ UHGXFHG ZLWK DQ LQFUHDVHG LQ FU

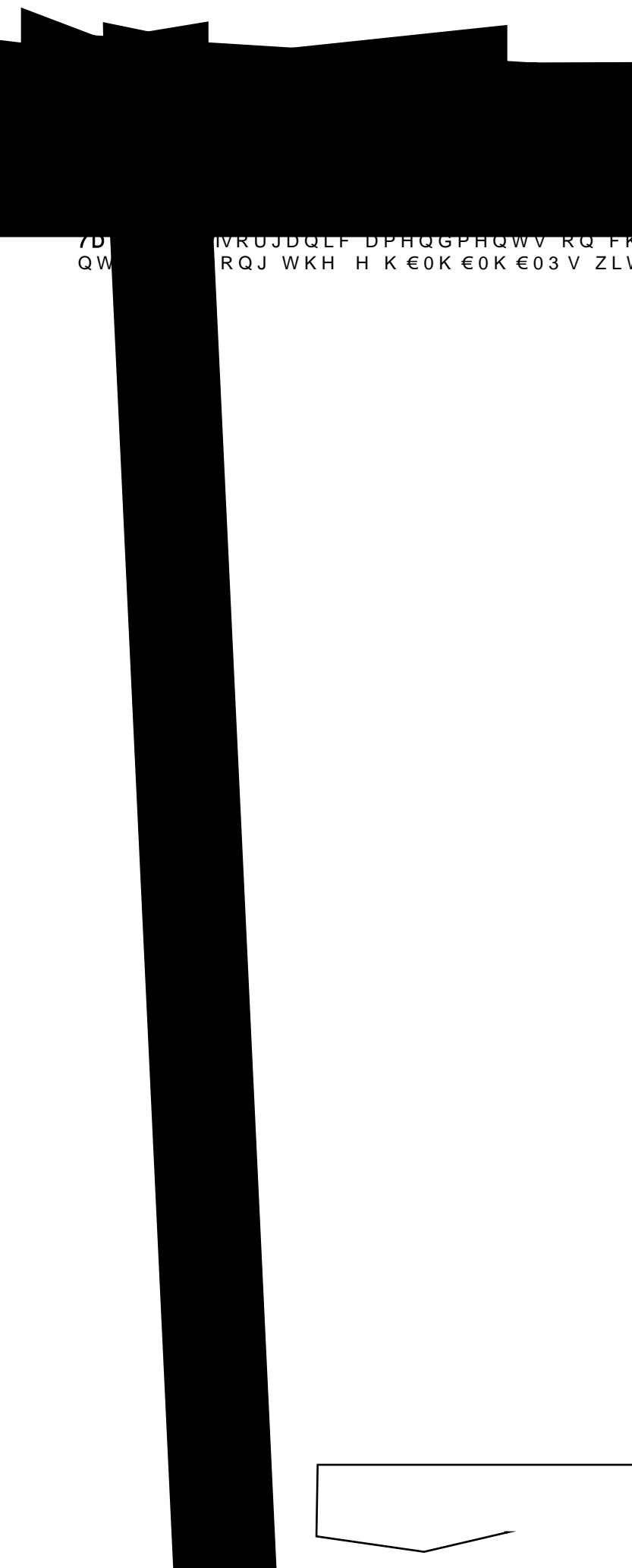
2LO 6SLOODJH LV WKH UHOHDVH RI D\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 GHULYDWLYHV LQWR WKH HQYLURQPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 WR KXPDQ DFWLYLWLHV DQG LV D IRUP\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW\WUHDWPHQW  
 OHDYHV ,Q ERWK FRQGLWLRQV WRWDO F  
 FUXGH RLO PD\ UHPDLQ XQVXLWDEOH IRU

\H DUV GHSHQGLQJ RQ WKH OHYHO RI SROOXWLRQ XQWLO WKH RLO LV GHJUDGHG  
WROHUDEOH OHYHO > @

(DUOLHU VWXGLHV FDUULHG RXW E\ 2ODMLUH HW DO RQ TXDOLWDWLYH DQG  
TXDQWLWDWLYH DQDO\VHV RI 3RO\F\FOLF \$URPDWLF +\GURFDUERQV 3\$+V LQ  
WKH ULYHU DQG VRLO LQ \$JEDEX VKRZHG DQ HOHYDWHG \$OLSKDWLF DQG 3\$+V  
OHYHOV LQ WKH ZDWHU DQG VRLOV ,Q 1LJHULD DOWKRXXJK WKH IXOO H[SORUDW  
WKH ELWXPHQ LV \HW WR WDNH

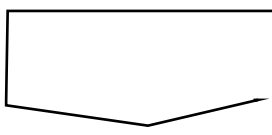
73\$ PRQWK PO &52 W KD 30  
73\$ PRQWK PO &52 W KD 0,  
73\$ PRQWK PO &52 W KD 30  
73\$ PRQWK PO &52 W KD 30  
73\$ PRQWK PO &52 W KD 0,  
73\$ PRQWK PO &52 W KD 30  
73\$ PRQWK PO &52 W KD 30  
73\$ PRQWK PO &52 W KD 0,

ZKHUH 3 3+& 6SHQW HQJLQH RLO 6(2 %LWXPHQ %,7 DQG FUXGH RLO  
&52 7 DQG SHULRGV PRQWKV RI LQFXEDWLRQ \$



Ελ. c. α° 15. b. Ed μ j ( - ( t . ) ε . ) Λ Σ Η α° μ i c M H b α° 1 M b . — D X ε Ε . Φ Δ

7D IVRUJDQLF DPHQGPHQWV RQ FKHPLEDO SURSHUWLHV RI VRLO FRQWDPLQ  
QW RQJ WKH H K € 0 K € 0 K € 0 3 V ZLWK ÁWK ÁWK P c 3 V W LHV RU9h @ ð 0 SU uS—€ H



LQFXEDWYDQXHV LQFUHDVHG DW DQG PRQWKV ZLWK DQG  
LQFUHPPHQW UHVSHFWLYHO\ \$W PO UDWH RI DSSOLFDWLRQ WKH YDOXH RI 628  
ZDV VLPLODUVZLPRQWKWRH LQFXEDWLRQ IROORZHG E\ D  
DQG UHGXFWRQ EHWZHHQ DQG PRQWKV RI LQFXEDWLRQ 1 7RWDO 3  
. &D DQG 0J LQFUHDVHG ZLWK LQFXEDWLRQ SHULRGV DW ERWK OHYHOV RI  
DSSOLFDWLRQ UDWHV

Effect RI 6(2 %,7 DQG &52 FRQWDPLQDWLRQ DQG RUJDQLF

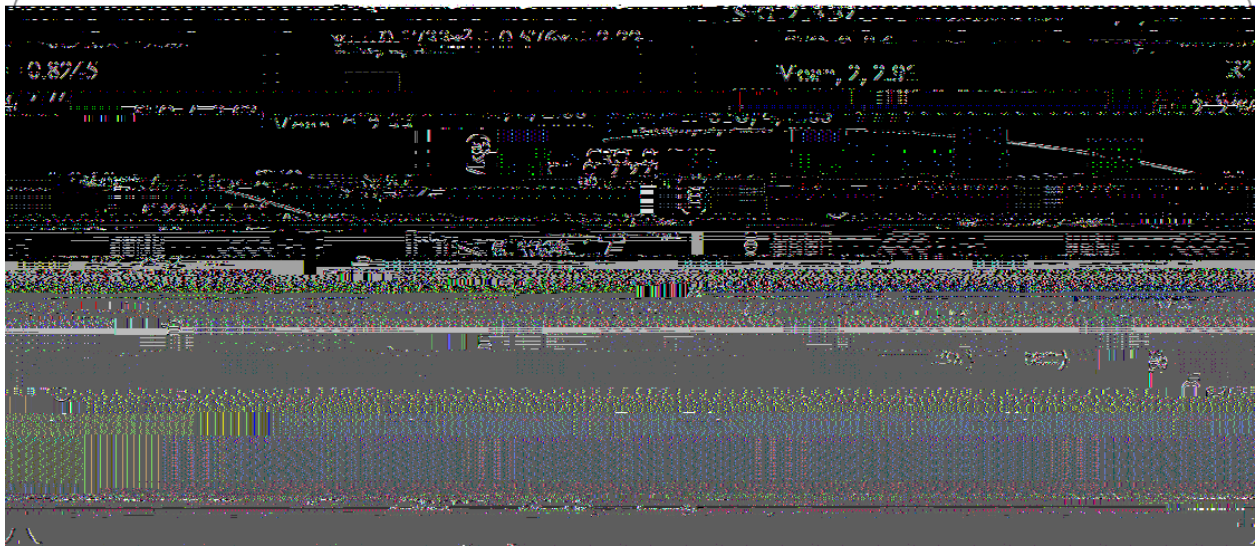
|  |  |   |   |   |   |   |   |   |
|--|--|---|---|---|---|---|---|---|
|  |  | D | F | D | D | D | D | D |
|--|--|---|---|---|---|---|---|---|

|      |      |   |   |   |   |   |   |   |
|------|------|---|---|---|---|---|---|---|
|      | 30   | D | E | E | D | D | D | D |
|      | \$0) | D | F | E | D | D | D | D |
| & 52 |      | D | F | E | E | E | E | D |
|      | 30   | D | F | D | D |   |   |   |

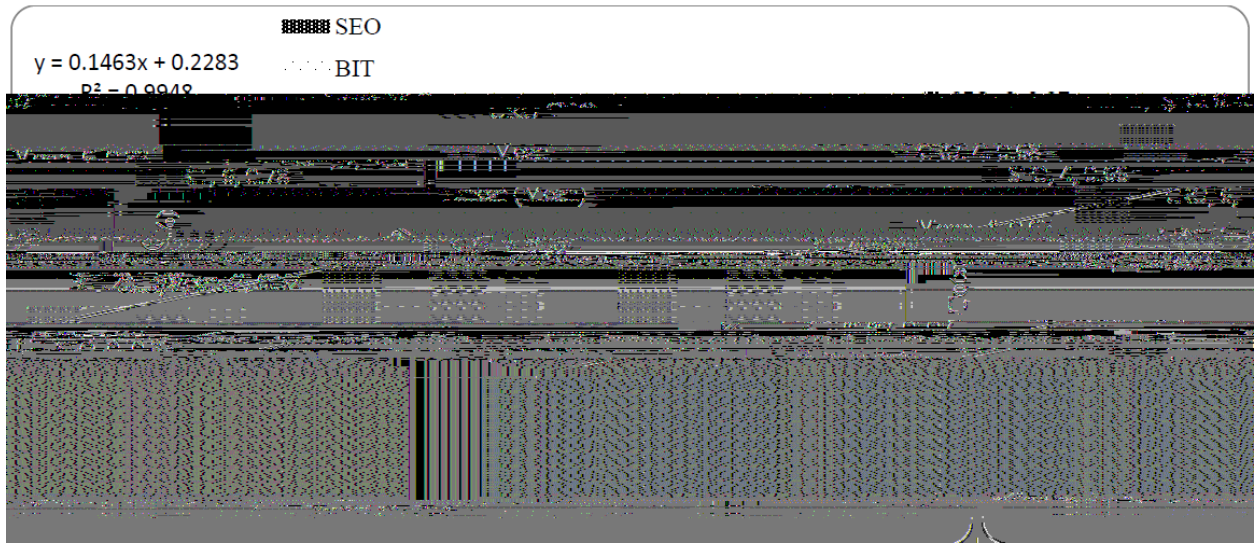
62& DFURVV WKH 3+& FRCWZPVE DQW HFDW H O MDOV IWDO%RUJDQLF  
LQFUHDVHV LQ WKH YDOXHV RI 1 7RWDO 3 . &D DQG 0J ZKHQ WKH RUJDQLF



|  |  |  |      |   |   |   |   |   |   |   |
|--|--|--|------|---|---|---|---|---|---|---|
|  |  |  |      | D | E | E | F | E | F | D |
|  |  |  | 30   | D | E | D | D | D | D | D |
|  |  |  | \$0) | D | G | D | D | E | D | D |



)LJXUHLPH FRXUWHHRW S\W\WUROHXP K\GURFDUERQ FRPSRXQGV DQG RUJDQLF DPHQQ

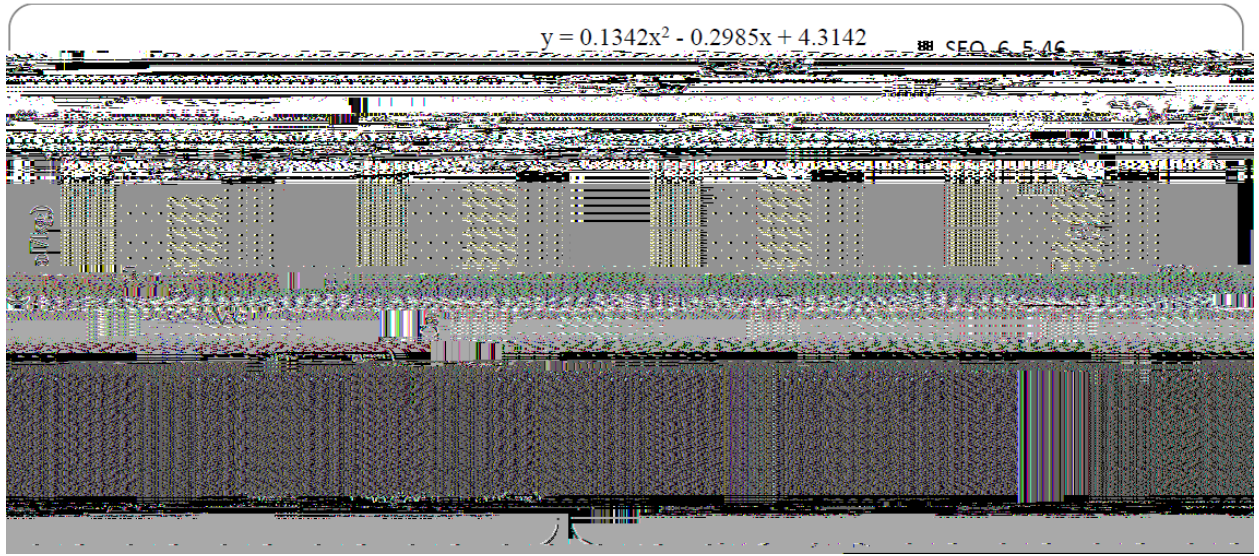


)LJXUHLPH FRXUWHHRW S\W\WUROHXP K\GURFDUERQ FRPSRXQGV DQG RUJDQLF DPHQQ



$$y = 0.1342x^2 - 0.2985x + 4.3142$$

SE0\_6\_5\_16



FRPSRXQGV ZKLFK FRQWUDGLFWHG W K H S H S R R W O R I O Q R X K 9 H W O Y O \$ J H O Z I O R G H V  
REVHUYHG GHFUHDVHV DV WKH OHYHO R L F U X P H L W R Q S R O O X W H G P R W R U H D O H S  
([FKDQJHDEOH EDVHV &D . DQG OJ ZHUH REVFHUYHG WR L Q F U H D V H G Q W K R I W K H  
LQFUHDVHV LQ UDWHV RI 3+&KLSK21 %DQG D G G R U O L D 86\$  
FRQWHQWV P D \ E H D W U L E X W H G W R W K H 2 X V H R I W K H Y H H I F K D Q J H D E O H E D V H V E  
WKH P L F U R E H V S U H V H Q W L Q W K H V R L O V D P S O H V \$ G L W R Q P I S R X O W U \ P D Q X U H  
D Q G P \ F R U U K L \ D O L Q R F X O X P W R W K H 3 + & V Z D V D P H Q G H G Z L W K S R X O W U \ P D Q X U H  
WKH V R L O S + W K R Q L K L D W W K R F W H Y S G V D Y H U S L W W L Q Y L J H U L D A O - D P A W V L P P P H A  
Y D O X H V R I W K H V R L O V D P H Q G H G Z L W K W K D 30 D Q G W K D 0, Z H U H  
K L J K H U W K D Q X Q D F H C H K G W R C R E W R D Q H G D U H L Q D J U H H P H Q W  
Z L W K W K R V H R E W D L Q H G E \ Q \ M D R I H W D B O D G G @ D Q G W K H  
\$ Q W D L > @ W K D W R U J D Q L F P D Q X U H M L Q R X O W U \ G U R S S L Q J V K D Y H  
H v H R V F U X G H R L O L S R O O X W H G W R L S + R I W K H D P H Q G H G  
V R L O V P D \ I D Y R X U R L O G H J U D G D W L R Q E \ P L F U R R U J D Q L V P V D V R E V H U Y H G L Q  
V L P L O D U V W X G L H V W K D W K L J K H U S + U D Q J H W R S U R Y L G H V E H W W H U F R Q G L W L  
I R U P L Q H U D O L \ D W L R Q R I K \ G U R F D U E R Q V V L Q F H P R V W E D F W H U L D F D S D E O H R I  
P H W D E R O L \ L Q J K \ G U R F D U E R Q V G H Y H O R S E H V W D W S + F R Q G L W L R Q V F O R V H W R  
Q H X W U D O L W H Y X O W V D O V R V K R Z H G W K D W S H U F H Q W D J H R U J D Q L F F D U E R Q  
L Q F U H D V H V D V W K H 3 + & V Z D V D P H Q G H G Z L W K S R X O W U \ P D Q X U H D Q G  
P \ F K R U U K \ \ D O L Q R F X O X P O F \* L O O > @ U H S R U W H G W K D W R U J D Q L F F D U E R Q  
Z K H Q S U H V H Q W L F I C O V O L W E H Q B Y H L D B R Q V R L O  
F K H P L F D O D Q G S K \ V L F D O S U R S H U W L H V 7 R W D O Q L W U R J H Q D Q G S K R V S K R U X V  
F R Q W H Q W R I W K H D P H Q G H G X Q S R O O X W H G D Q G 3 + & V S R O O X W H G V R L O V Z H U H  
K L J K H U E X W Q Q F O L Q W O N Q P W K R V H R I W K H X Q D P H Q G H G  
V R L O V L Q F U H D V H L Q W K H S H U F H Q W D J H Q L W U R J H Q D Q G S K R V S K R U X V P D \ E H  
D V D U H V X O W R I D Q W K U R S R J H Q L F L Q S X W V R I W K H V H Q X W U L H Q W V I U R P W K H R U J D  
P D Q X U H V E H F D X V H R U J D Q L F P D Q X U H V K D Y H E H H Q U H S R U W H G D V E H L Q J F D S D E O H  
R I L Q F U H D V L Q J V R L O Q X W U L H Q W V E \ V X S S O H P H Q W L Q J W K H O L P L W L Q J Q X W U L H Q  
> @ R U J D Q L F P D W H U L Q L F O D G W D G K H U H P H G L D W L R Q  
S U R F H V V I R U 3 + & F R Q W D P L Q D F W P I G W H U L D O V D G G H G W R W K H  
3 + & S R O O X W H G V R L O V Z R X O G K D Y H H Q K D Q F H G W K H D X W R F K W K R Q R X V  
P L F U R E L R W D Z K L F K Q D W X U D O O \ D W W H Q X D W H V S H W U R O H X P K \ G U R F D U E R Q > @

**&RQFOXVLRQV DQG 5HFRPPHQGDWLRQV**

,W FDQ DOVR EH DVVHUWHG WKDW WKH H[WHQW RI WR[LFLW\ DQG GXUDWLRQ  
3+& SROOXWDQWV ZLOO GHSHQG RQ WKH QDWXUH RI WKH K\GURFDUERQ  
FRQWDPLQDQW DQG WKH V R I X O F K D U F F W K U V V W L X G \  
VKRZHG WKDW 3+& FRQWUDPHQDWRGRKPLW R O V R L O  
SURSHUWLHV +RZHYHU WKH DGGLWLRQ RI RUJDQLF VXEVWDQFHV SRXOWU\  
PDQXUH DQG \$0) DPHOLRUDWHG VRHO WR[LFLW\ DQG RQ DDPDUDQWXXV  
> }GGLQDQVR VKRZHG WKDW DDPDUDQWXXV SHUIRUPDQFH ZDV QRW  
VLJQL}DEAFWZHGG JURZQ LQ 3+& VSHQW HQJLQH RLO SROOXWHG  
VRLO ZKLOH DPHQGPHQW RI VXFK VRLO ZLWK RUJDQLF PDWHULDOV HVSHFLDOO\  
SRXOWU\ PDQXUH DQG P\FRUUKL]DO LQRFXOXP IXUWKHU LPSURYHG VRLO  
IXQFWLRQDO SURSHUWLHV DGHUDDQWFKXRI SHUIRUPDQFH  
RUJDQLF VXEVWDQFHV HYDOX}DGHGJLWKLWYHQ FUHGHQFH E\ WKH  
VWXE\RUJDQLF PDWHULDOQDQDQGVKH UHPHGLDWLRQ  
SURFHVV IRU 3+& FRQWUDPHXODWYHGQGREOWHG WKDW 3+&V  
DGYHDDVHDOV FKHPLFDO SURSHUWLHV DQG WKDW DGGLWLRQ RI RUJDQLF  
VXEVWDQFHV LPSURYHG FKHPLFDO SURSHUWLHV RI WKH VRLO IROORZLQJ  
SROOXWLRQ ZLWK SHWUROHXP K\GURFDUERQ FRPSRXQV FRPSDUHG ZLWK WKH  
XQ DPHQGPHG VRLOV 3RXOWU\ PDQXUH LQ SDUWLFXODU SHUIRUPHG EHWWHU  
FRPSDUHG ZLWK P\FRUUKL]DO LQRFXOXP ZLWK UHVSHFW WR LPSURYHPPHQW RI  
VRLO FKHPLFDO SURSHUWLHV

**5HIHUHQFHV**

+ROO&JHDDVSDUG 6 \*ORG \* +HLMPDQ & 6FKXPDFKHU : HW DO  
&RQWDPLQDWHG HQYLURQPHQW LQ WKH VXEVXUIDFH DQG ELRUHPHGLDWLRQ  
2UJDQLF FRQWDPLQDQWV )(06 0LFURELRO 5HY

0F\*LOO :%

\$Q LQWURGXFWRQ IRU